CHAPTER V

LIMESTONES OF GUJARAT

This chapter deals with various occurrences of limestone deposits in different stratigraphical horizons, wherein a brief account of their geology, chemical and mineralogical characters, extent and uses have been given. In the table No.12, the stratigraphical horizons in which limestones occur in the Gujarat State are shown. **Fig.2 to 6.**

The author visited most of the occurrences of limestones and examined them from the point of view of their utility.

ARAVALLI SYSTEM

(a) Limestones of Champaner Series:

Crystalline limestones belonging to the Champaner Series, are recorded in the following areas:

(1) Dolomitic limestone of Chhota Udepur (District:Baroda)

(2) Variegated limestones of Sandara in Sankheda Taluka (District:Baroda).

TABLE NO.12

Limestones in Different Geological formations in Gujarat State in Stratigraphical Order

Age	K U T C H			S A U R A S H T R A			G U J A R A T		
	Formation & Thickness	Locality	Lithology	Formation & Thickness	Locality	Lithology	Formation & Thickness	Locality	Lithology
1	2	3	4	5	6	7	8	9	10
Recent	Kankar	Scattered	Kankar nodules	(i)Calcareous sand dunes	(i) Along sea coast from Gopnath to Porbandar & beyond	Wind blown sand	Kankar	Scattered	Kankar nodules
				(ii)Kankar	(ii) Scattered	Kankar nodules	Calc-tufa	Gora (Near Rajpipla) Dist.Broach.	Spring deposits
Pleisto-cene	Miliolite 15 m	(i)Katrol hills	Foraminifers of Miliolidae family	Miliolite 30 m ft. thining eastwards	Along coast from Gopnath to Miani (N W of Porbandar -240 km long & 16 km wide - discontinuous belt).(3 cement factories at Porbandar)	Marine limestone composed of the remains of the foraminifer Miliolite around which calcite grains have been formed.		Absent	
		(ii)Wagod region			Porbandar to Upleta-E-W strip-10 to 13 km wide & 80 km long.				
		(iii)Baladia			Upleta to Junagadh. 40 km long and 5 km wide.				
		(iv)Jhumka							
Pliocene		Absent		Dwarka beds 45 m(?)	Near Dwarka & extend northwards.	Light to dark buff and yellowish limestones fringing the coast. Marly yellowish limestones. Some are entirely of small organisms(foraminifera) interspaces filled with calcite. Fossils,Pecten, Balanus,Coral,Bryozoan.		Absent	

Age	KUTCH			SAURASHTRA			GUJARAT		
	Formation & Thickness	Locality	Lithology	Formation & Thickness	Locality	Lithology	Formation & Thickness	Locality	Lithology
1	2	3	4	5	6	7	8	9	10
Miocene	Argillaceous and Arenaceous groups- 350 m. Khari & Waior stage.	Khari river section	Fossiliferous	Gaj beds	1. 20 km NW of Veraval. 2. Khorasa- cast of Chorwar 3. Bharwara- 15 km north of Porbandar 4. Bhogat 5. Between Nandana & Ban	Yellow limestone argillaceous composed largely of fragmentary organisms. Hard, tough marly limestones with fragmentary fossils of Bryozoa, corals, etc.	Kand	Kondh(Kandh)	Yellowish limestones marly bands with conglomerates with clay matrix sandstones and grey clays, yellowish bentonitic clays.
Oligocene	Lakhpat series	Lakhpat area	Dirty white, yellow and greenish grey marls and argillaceous limestones- Epineritic regressing sea. Oligocene reticulata Nummulites.	-	-	-	-	-	-
Middle & Upper Eocene (Kirthar)	Nummulitic limestones Berwali series- Bania stage upper.	Lakhpat area 5 to 10 km broad belt. Godhatad dam site.	A cream & buff coloured, massive limestone packed with fossils. 150 m of well bedded white limestone and those are overlain by 16 m of Nari limestone.	-	-	-	Nummulitic limestones	1. Broach Dist. Dinod, Kanerao, Phalkau, Ghoda, Dungri, Siludi, Sengpur, etc. 2. Surat Dist. Tarkeshwar Nogama.	Yellow limestones with clays mixed with Nummulites.

... contd.

Contd..

Age	K U T C H			S A U R A S H T R A			G U J A R A T		
	Formation & Thickness	Locality	Lithology	Formation & Thickness	Locality	Lithology	Formation & Thickness	Locality	Lithology
1	2	3	4	5	6	7	8	9	10
Cretaceous							Lameta beds	1)Sabarkantha Dist. Gabat 2)Kaira Dist. Balasinor Parbia 3)Panchmahals Dist. Dohad, Jhalod Devgadh Baria.	Light grey to pinkish limestones with cherty and chalcedomic stringers.
				Umia	1)NW of Bhuduka 2)Bhogawo river section 3)Chotila		Bagh beds	1)Broach Dist. Gora, Limdi Mokhadi Vandri Vanji Bhadrva 2)Baroda Dist. Mohan fort.	Fine grained, grey, pinkish to black in colour limestone. Fossils obtained.
Jurassic	Chari series-Dhosa Oolites. (Green & brown Oolites). Athleta beds. Patcham series -Kuar bet beds-yellow limestones, Patcham beds - Shell & Coral limestone	Patcham, Khadir Bela, Wagur islands. Jarra, Kira hills near Chari, Jura & Halaman hill near Lodai.	Light grey or yellowish limestones & marls, corals, etc.						
Pre-Cambrian Purana (Delhi System)							Ajabgarh series	Pasuval, Rampur Atal, Mahudi Bhakudar Diwania Posina, Ambaji	Calc-gneiss and calc-schists grading into limestones & marbles.

Contd...

Age	KUTCH			SAURASHTRA			GUJARAT		
	Formation & Thickness	Locality	Lithology	Formation & Thickness	Locality	Lithology	Formation & Thickness	Locality	Lithology
1	2	3	4	5	6	7	8	9	10
Archeans							Champaner series	i) Chhota Udepur	Dolomite & dolomitic limestones.
								ii) Chhuchhapura	Green marble
							Aravalli system	Bhetali (Sabarkantha District)	Magnesian limestone

(3) Serpentinous limestones of Chhuchhapura, Sankheda Taluka (District:Baroda).

(4) Tremolitic limestones of Jambughoda (District:Panchmahals).

1. Dolomitic limestones of Chhota Udepur:-

Crystalline dolomitic marble-like limestone commercially known as 'Dolomite' are being extensively quarried at Kanawant, Jhair, Wanar, Dhamori, Padlia, Bervi, Chatawada, Dadigam, Ambala, etc., from the area 10-15 km north of Chhota Udepur town. These are seen resting unconformably over the gneissic basement and constitute the lowermost portion of the Champaner series. These dolomitic beds show intense folding on large scale, strata dipping steeply, and the regional strike of the folds being NNW-SSE. The folds are seen plunging due NW.

These crystalline limestones are medium to coarse grained, and show saccharoidal texture, and white to light grey in colour.

The chemical composition of this dolomitic limestone is as follows:

TABLE NO.13

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CO_2	P_2O_5	Total	
3.03	0.13	0.29	30.26	20.90	45.38	0.01	100.0	Private
1.18	1.00	0.28	35.06	24.02	37.76	-	100.0	

From the composition point of view, these limestones belong to Grades-Super(Mg), and I(Mg) and can be utilised in a number of industries. However, at present, these crystalline limestones are crushed to small chips and used in the manufacture of mosaic tiles. These also find use in glass manufacture, as well as in metallurgical and chemical industries.

The present annual production is reported to be around 0.1 m. tonnes. The total estimated reserves of these limestones are about 1,000 m.tonnes.

2. Variegated Limestones of Sandara:-

Near the village Sandara, a group of hard crystalline limestones of various colours are exposed in the Heran river bed. These belong to the Champaner Series, and appear to be affected by the intrusive

granite. As usual these rocks are highly folded, but the folding here is rather open. These limestones are described as follows:

" _____ The different colours noticed are pinkish drab, medium ash grey, deep bluish black streaked and spotted with white, and pale yellow _____. The outcrop of the pinkish variety is made up of several thin beds, which split readily into slabs with a thickness of half an inch and upwards slabs 2 ft. square and one inch in thickness can be easily had from this exposure. The other marbles are not of any commercial value" (Iyer, 1910, P.109).

These limestones have not been investigated in detail.

3. Serpentinous limestones of Chhuchhapura:

Well known as "Motipura Marble", this limestone - very rich in serpentine, forms a small but conspicuous band near the Railway Station Chhuchhapura (Western Railway - Narrow Gauge - Baroda -Chhota Udepur Section). The rock can better be called a serpentine marble, and because of its variegated green and white

appearance, it is extensively quarried and used as ornamental stone.

Total reserves of this marble as assessed by Directorate of Geology & Mining are approximately 170 m.cft., i.e. 10 m.tonnes.

4. Tremolitic limestones of Jambughoda:

In the neighbourhood of villages Gandhara, Poyelli and Jharau in the Jambughoda taluka of Panchmahals, crystalline limestones with tremolite form good exposures. Perhaps these are stratigraphically equivalent to those of Chhota Udepur.

On account of the contact metamorphism due to the neighbouring granite, these limestones have quite often developed interesting calc-silicate minerals. In fact, one such limestone band, involved in granite has given rise to the interesting calc-silicate mineral assemblage of Goldungri, well known for minerals like blanfordite, winchite, wollastonite, garnet, diopside, scapolite and epidote.

The chemical composition of these limestones

are as follows:

TABLE NO.14

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	FeO	MnO	TiO_2	Na_2O	K_2O	H_2O	Total	
50.06	0.34	1.03	41.11	1.28	2.16	1.30	Tr	0.33	1.20	1.25	100.07	Private

The Directorate of Geology and Mining (Gujarat) has reported 96 m.tonnes of these limestones in Halol and Jambughoda talukas. At present these limestones have little importance from the economical point of view.

(b) Limestones in the Aravallis of Sabarkantha:

Aravalli rocks of north Gujarat are rather poor in limestones and no major limestone exposures are recorded. The author has come across only a small band of crystalline limestone in phyllites at a place Bhetali near Bhiloda, the chemical composition of these limestones is as follows:

TABLE NO.15

Percent

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign	Total	
3.87	3.04	0.96	25.83	16.40	0.36	45.56	97.04	ERI

The author's investigations have revealed that these limestones of Grade-IV (Mg) could be usefully explored for making 'Natural Cement'on a small scale.

The reserves of these limestones are over 1 m, tonnes.

DELHI SYSTEM

Marbles occur in the Ajabgarh series of Delhi System. Considerably large reserves of marbles are recorded from Ambaji. Medium sized deposits occur at Diwania, Pasuwal, Rampura, Atal, Mahudi, Ganguwada and Bhakudar in Banaskantha. The limestones at Posina lie in Sabarkantha, while those of Jitpur come under Mehsana District.

These are in fact, calc-gneisses - metamorphosed calcareous sediments. Various impurities in the

sediments have given rise to the development of a number of calc-silicate minerals in these limestones, and wherever these calc-silicates are less developed, the rock is seen to be more or less pure crystalline limestone - a stone of considerable beauty. All gradations from coarse saccharoidal variety to fine uniform marbles are present. These limestones show conspicuous folding in NE-SW direction, the dip being steep or vertical. **Plate I.**

The minerals present in these limestones in different proportion are calcite, quartz, biotite, diopside, felspar, epidote, zoisite, etc.

In the following paragraphs the account of various deposits of limestones in different districts is given.

Banaskantha District:

The limestone occurs and is obtained from the following places:

PLATE I

Folded calc-gneisses (Delhi)

TABLE NO.16

Area	Limestones		Reserves assessed by
	Grade	Reserves (million tonnes)	
1) Ambaji			
(a) Marble	I	50	Author
(b) Limestone	(could be III & IV)	100	G.M.*
2) Diwania	II	9	G.M.*
3) Karamundi	IV	15	G.S.I.
4) Pasuwal	I	3-4	G.S.I.
5) Khunia	II	0.2	G.S.I.
6) Ganguwada	I	2	Author
7) Atal-Mahudi	III	0.2	Author

* (G.M.= Directorate of Geology & Mining, Gujarat State).

Marbles from Ambaji area are well known as ornamental stones for temples, mosques and public buildings of architectural importance. Their waste chips are used in the manufacture of mosaic tiles, and powder in manufacture of fat lime, in chemical

industries, etc.

The chemical composition of these marbles as given below indicates that those are of Grade-I.

TABLE NO.17

Percent

Location	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	
Chikhla	2.5	--	0.7	--	52.5	2.8	41.9	103.6	*ERI
Kumbharia	1.3	--	0.6	--	51.9	3.2	43.2	100.2	ERI
Zarivav	3.6	--	0.3	--	53.0	1.0	42.5	100.4	ERI

(*ERI = Engineering Research Institute, P.W.D. Gujarat State).

The physical properties of these marbles are given below which are comparable with those of Makrana marble.

TABLE NO.18

Av.of No. of samples.	Sp.gravity		Percentage water absorption in 24 hours (by weight)
	True	Apparent	
5	2.74	2.81	0.18

The annual production of marble from this area is

about 400 tonnes. Extensive deposits of marbles still await proper exploitation. The rough estimate indicates reserves of the order of 50 m.tonnes.

Diwania forms three hill ranges SE of Amirgadh railway station on Ahmedabad-Delhi Metre Gauge line. These crystalline limestone beds have a strike along NE-SW.

The representative chemical composition of these limestones as given below indicates that these are of Grade-I.

TABLE NO.19

Percent

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	
1.45	0.50	0.40	51.08	3.29	42.64	99.36	G.S.I.

The assessment by the Directorate of Geology and Mining by six boreholes aggregating to 655 m drilling indicates the reserves of 9 m. tonnes.

Karamundi limestone is rather siliceous and unsuitable for utilisation in cement manufacture. It is, however, good for lime manufacture. Its chemical composition as given below indicates that it is of Grade-IV.

TABLE NO.20

Percent

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	
21.56	6.77	1.93	37.49	2.85	26.42	97.02	G.S.I.

According to the G.S.I., the reserves of this deposit are 15 m.tonnes.

The limestones at Khunia are of Grade-II and Pasuval and Ganguvada are of Grade-I as can be seen from their chemical composition given below:

TABLE NO.21

Percent

Location	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	
Khunia	6.24	0.89	0.59	50.37	3.02	38.94	99.97	G.S.I
Pasuval	0.60	2.62	0.88	51.09	1.27	42.28	99.38	G. S.I
Ganguvada	0.70	0.50	0.10	51.20	5.4	42.20	100.10	G.M.

The reserves as given by the Geological Survey of India at Khunia and Pasuval are 0.2 and 3 to 4 m. tonnes respectively, while the author puts reserves of 2 m.tonnes at Ganguvada from where the Associated Cement Companies Ltd., get the limestone for their Sevalia Cement Factory for blending with low grade limestone of Balasinor.

Atal-Mahudi area covers other villages, viz. Rampura, Bhakudar, Ganodra, Kotada, Bhilachal, Hadmatia, Bhaldev, etc. Here small patches of pure limestones occur among calc-gneisses, NW of Palanpur. Here too, the strike of formations is NE-SW with a dip of 50^{o}- 60^{o} to SE. Limestones from Atal and Mahudi were used in the manufacture of lime for the construction work of the Dantiwada dam across the Banas river nearby. The chemical composition of these limestones as given below indicates that those are of Grades-III and IV.

TABLE No.22

Percent

Av.of No. of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol.	Loss Ign.	Total	
4	6.87	1.66	1.20	46.32	2.15	5.64	37.05	100.89	Private
1	18.44	6.44	3.37	41.52	2.39	-	27.74	99.90	Private

The reserves of these limestones in these localities are approximately 0.2 m.tonnes, and could thus be used only locally for lime manufacture.

Sabarkantha District:

The limestone band extends from Posina in Sabarkantha to Ranpur, Birpur,Magwas, Janera, Sandoshi etc., in the Banaskantha District, covering roughly 26 sq.km. (10 sq. miles).

The chemical composition of these limestones as given below indicates that those are of Grade-II and III.

TABLE NO.23

Percent

Locality	Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	
Posina	20	12.36	---1.02---		47.45	0.91	38.96	100.70	G.M.
Ranpur	50	5.9	---1.1 ---		50.8	1.4	37.40	96.60	"
Birpur	48	10.6	---3.2 ---		46.5	2.3	37.40	100.00	"

The reserves as estimated by the Directorate of Geology and Mining are about 71 m.tonnes upto 15 m.depth.

The limestones in this district around Vadali area are only impure calc-gneisses. The strike of formations near Vadali is ENE-WSW with dips from 60^{o} to 80^{o} towards SSE.

The chemical composition as given below indicates that these limestones are of Grades-IV to VI.

TABLE NO.24

Percent

Locality	Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol.	Loss Ign.	Total	
Vadali) Area)	6	28.14	6.78	4.92	36.37	2.29	1.87	20.10	100.47	ERI
	2	38.82	8.88	12.62	24.81	2.53	1.85	9.06	98.57	ERI
Note: Samples grouped into two, viz.one of Grade IV and V, and other of Grade VI.										
Babsar	1	24.50	7.91	4.59	38.13	2.71	1.00	23.00	101.84	ERI

It is seen that the CaO does not occur only in calcite, but also occurs in the form of silicates like diopside, epidote, zoisite, etc. The variation in composition being very large, these formations as a whole are not useful even for the manufacture of lime. However, a selective quarrying may facilitate lime manufacture on a small scale.

Mehsana District:

The only promising deposit of crystalline lime-

stone is near Jitpur village. The P.W.D. drilled seven boreholes and got samples analysed; the average chemical analyses are as follows:

TABLE NO.25

Percent

B.H. No.	Total depth in ft.	Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign.	Total
1	30'	6	10.10	2.09	2.44	46.45	3.50	1.31	34.15	100.07
2	30'	6	2.67	1.22	1.25	51.37	2.29	0.71	40.57	100.29
3	30'	6	3.59	1.64	1.11	51.57	1.62	1.11	39.75	100.10
4	0'-30'	6	7.02	3.58	2.44	47.08	3.11	2.42	34.17	99.82
	30'-50'	3	30.58	9.48	3.57	30.08	2.52	3.22	16.70	96.15
5	0'-55'	10	10.25	3.44	2.16	45.70	2.84	1.83	33.09	99.31
	55'-60'	1	---------- Siliceous ----------							
6	60'	12	7.82	2.08	1.76	48.44	1.89	1.32	37.04	100.35
7	30'	6	14.28	4.39	1.70	44.14	1.87	1.28	31.94	99.62

The limestones in general are of Grades-I to III and their reserves are of the order of 2 m.tonnes only, and thus insufficient for any large scale utilisation. As these limestones will yield fat lime, the P.W.D. has

proposed to use it after adding pozzolan (Surkhi) in the construction of dam on Sabarmati river near Dharoi, a place closeby.

JURASSIC SYSTEM

The jurassic rocks occuring in the Kutch region contain considerable limestone. Light grey or yellowish silty, oolitic and coralline limestones occur in the islands of Patcham, Khadir, Bela, in Wagur area, in Jarra, Kira hills near Chari, and in Jura and Halaman hills. These occurrences have not been investigated in detail; they do not seem to be very important. Because of their locations, no facilities including communication are available.

The grey limestones are locally used as crushed aggregates in the construction work of the bridge near Khavda.

Mainly these are allochthonous limestones, and their field identification indicates that they vary from calcarenite to calcilutite. However, there are also autochthonous limestones, deposits of which are

biostromal; they are associated with shales, and those are grading into calcareous shales and mudstones.

CRETACEOUS SYSTEM

The Cretaceous rocks contain important limestone deposits. Broadly, the Cretaceous rocks have following three groups:

(1) Lametas of Panchmahals, Kaira & Sabarkantha,
(2) Bagh beds of Narmada Valley,
and (3) Umias of Saurashtra.

All these limestones fall under the allochthonous group of Pettijohn as indicated by their association with sandstones. Umia and Lameta limestones are calcarenite to calcirudite, while Bagh limestones are calcilutites; fossiliferous horizons are thin with fossils of fragmentary nature, indicating that those are transported.

UMIA SERIES

Umia series contains cherty limestone beds NW of Bhuduka, Bhogao river section and Chotila in the NE

corner of the Saurashtra region. These are not important because of their small extent and as such no investigation was considered necessary.

BAGH BEDS

The Bagh beds contain quite big deposits of limestones. In the lower part of the Narmada valley, inliers of this sedimentary group in the Deccan trap occur in the vicinity of Gora, Limdi, Mokhadi, Vandri, Vanji in Broach District. In addition to these, there are smaller deposits of similar limestones occurring at Shir, Thavadia, Bhadarwa, Mota Amba, Bhilwasi, Jantar, etc. In Baroda district those are there at Mohan Fort, Amba Dungar, etc.

At present, these Cretaceous rocks form inliers in the basalts, and it is obvious that the trap has come up through east-west fractures and spread all over isolating sedimentary patches which were once forming a somewhat continuous mantle over the steeply dipping Champaners. The author has extensively investigated the different exposures of the formation, and it is very evident that the nature of sediments from north

to south clearly indicates increasing depth of the basin of deposition. Near Ghantoli (Songir in Baroda District), the basal conglomerates are seen resting over the Champaner quartzites. On proceeding southwards the inliers gradually become dominant in argillaceous layers and ultimately near Gora and Vandri in the south, the calcareous sediments almost dominate over the shales and sandstones.

The broad succession from north to south is as under -

Deccan Traps	Cretaceo-Eocene.
Limestones, Shales and sandstones	Bagh Beds - Cretaceous
Shales, marls and sandstones.	
Sandstone and shales	
Conglomerates and sandstones.	
Quartzite and phyllites	Champaner Series.

22

As stated above, thick beds of limestones are seen developed in the southern inliers in the vicinity of Gora,Mokhadi, and Vandri. The nature of limestone and its fossil content is indicative of a distant coast line. The limestones are generally fine grained, very often shaly, massive or flaggy, with numerous fossiliferous layers containing shells of Ostrea, Hemiaster and few Ammonites.

Limestone beds occur interstratified with black and purple shales and gritty sandstones. These limestones are grey, dark grey, ash grey, greenish, black and pink in colour. On account of the argillaceous nature and presence of laminations, some workers called them as calcareous shales. Specks and sometimes small size nodules of pyrites are present, and microscopic examination of thin sections indicates calcite in cryptocrystalline state with other minerals like quartz, iron oxide and flakes of mica.

Gora-Limdi deposit:

A limestone bed about 4 km (2½ miles) long runs across the Narmada river from the village Gora to the

village Limdi. The strike is ESE-WNW to E-W with dips varying from 28° to 67° towards SSW to south. The width of the limestone bed on the southern side varies from 45 to 150 m, the average being 60 m, while on the northern side, i.e. Limdi side, it is as wide as 300 m, the average being 120 to 150 m. Plate II.

This limestone has been investigated in detail for its utilization in the manufacture of Portland cement. Sampling was done by putting grooves, trenches, and boreholes. Fifteen boreholes were drilled. Sections of boreholes indicate only a few small bands, 5 to 7 m in thickness which have carbonate content higher than 70 percent. Fig.8.

Limestones from Gora were once examined by Associated Cement Companies Limited around 1950, and re-examined in 1962 on behalf of other private parties. After carrying out experiments, these limestones were considered low in CaO and not amenable to floation. Results of experiments are discussed later.

The chemical composition of limestone samples are given in the table No.26; the carbonate contents

PLATE II

View of Bagh Limestone near Gora

of several samples were determined by titration as a check.

Limestone samples are grouped into 3 categories for presenting their chemical analyses with CaO as basis; it is as follows:-

(a) CaO upto 40 percent

(b) CaO between 40 to 45 percent

and (c) CaO above 45 percent

TABLE NO.26

Percent

Sr. No.	No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol.	Loss Ign.	Total	Remarks
					Locality:Gora					
1		20.54	--	6.70	--	37.37	2.88	32.22	99.61	G.S.I.
2		30.62	--	4.80	--	32.81	3.17	28.80	100.20	G.S.I.
3	3	18.76	5.53	2.80	37.53	1.69	0.77	32.50	99.58	Guj. Cement
4	5	14.43	4.34	2.33	42.36	1.67	0.46	34.48	100.07	Guj. Cement
5	14	20.59	6.14	3.76	35.05	1.85	1.73	30.08	99.20	
6	2	9.50	2.46	1.48	46.36	1.18	1.70	37.73	100.41	E.R.I.
7	1	13.73	6.16	2.74	41.69	1.02		33.96	99.30	E.R.I.

Contd...

Sr. No.	No. of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol.	Loss Ign.	Total	Remarks
				Locality: Limdi						
1	13	10.18	7.33	2.69	42.75	1.33		35.11	99.39	Guj. Cement
2	6	20.27	9.41	3.64	35.31	1.15		29.05	98.83	
3	2	10.35	2.7	2.1	46.34	1.42	2.7	36.47	102.08	E.R.I.
4	5	13.10	2.35	2.44	43.31	1.78	2.35	34.38	99.71	
5	7	23.34	4.10	1.62	36.63	2.07	3.47	28.12	99.35	

The above results indicate that in the case of Gora limestones only 8 percent samples have CaO more than 45 percent, while 24 percent samples have CaO between 40 and 45 percent. In the case of Limdi deposit, 54 percent samples have CaO between 40 and 45 percent, and 7 percent have above 45 percent.

These limestones in general are of Grade-IV, and the estimated reserves of this Gora-Limdi deposit come to about 20 m. tonnes.

Mokhadi:

This deposit is 9 km (5¼ miles) SE of Gora, and occurs in the Narmada river bed at Mokhadi falls.

Limestones are seen in the left bank section extending upto Sekhbar village on the east. These beds form a gentle anticlinal fold with ENE - WSW axis. The thickness of limestones is 30 m above the river bed, while 27 m below the bed as proved by a borehole.

The chemical composition of these limestones is as follows:

TABLE NO.27

Percent

Sr. No.	Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol.	Loss Ign	Total	Remarks
1	7	12.89	5.81	2.69	41.99	1.37		34.63	99.38	Guj. Cement
2	9	19.80	7.92	3.98	35.77	1.71	-	30.35	99.53	
3	1	9.50	4.65	1.63	45.32	1.26	0.25	37.09	99.70	E.R.I.
4	5	15.24	4.82	2.66	42.46	1.39	0.40	33.29	100.07	
5	3	23.99	5.70	5.88	33.80	2.20	1.07	29.43	102.07	

It is seen that only one sample is with CaO above 45 percent. These limestones too are of Grade-IV and are similar to that of Gora.

The estimated reserves of these limestone are about 10.5 m.tonnes.

Vandri:

This limestone deposit is the largest one in this area. The village Vandri is about 15 km (9¼ miles) SE of Gora, and 7 km (4 miles) of Surpan. These deposits are situated in the interior in the Devganga valley, a tributory of the Narmada river, and not easily accessible.

Limestones cover the area partly in Mathasar and partly in Vandri villages. An exposed section of limestones in the Vandri valley is over 200 m; the thickness of limestones below the surface is not determined; but as a whole the thickness could be 300 m (1000 ft.). Limestones are more or less horizontal, thinly bedded, and fossiliferous; fossils of Echinoids also are recorded.

These limestones too are similar to that of Gora; chemical composition of the same is given in the table No.28, below:

TABLE NO.28

Percent

Sr. No.	Av.of No.of Samp-les.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign.	Total	Remarks
1	1	7.75	2.25	2.48	45.03	3.26		38.94	99.71	Guj. Cement
2	3	11.43	5.52	2.97	43.02	1.29		35.15	99.38	Guj. Cement
3	13	19.48	7.70	3.93	34.88	2.82		30.45	99.26	Guj. Cement
4	3	14.29	4.47	3.04	41.56	1.88	0.68	34.04	99.96	E.R.I.
5	9	21.91	5.94	4.43	34.63	1.66	1.13	30.48	100.58	E.R.I.

There is only one sample having CaO 45 percent; rest are with low CaO. These limestones are of Grades-IV and V.

The estimated reserves of these limestones are over 50 m.tonnes.

Vanji:

About 14 km (6½ miles) NE of Gora, limestones occur on the west as well as north of village Vanji. The limestone formation strikes ENE-WSE and extends from Vanji to the ENE towards Shir and Panchala villages; the

dip is about 30°-70° towards SE to SSE.

These Vanji limestones similar to those of Gora were examined by the Officers of the former Baroda State for their suitability for the cement manufacture.

The chemical composition of these limestones is as follows:

TABLE NO.29

Percent

Sr. No.	Av.of No.of samples.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign	Total	Remarks
1		54.25	---	2.70	-- 21.95	1.15		20.00	100.04	G.S.I.
2		21.98	--	4.50	-- 38.29	1.98		32.89	99.64	
3		28.26	--	2.20	-- 37.79	0.58		30.64	99.47	
4	1	11.48	4.84	3.07	45.93	2.31		32.31	99.94	Guj. cement
5	2	13.70	4.21	2.61	42.43	1.60		35.37	99.92	
6	6	22.91	6.90	3.86	35.74	1.91		28.35	99.67	
7	6	15.01	3.99	2.60	41.51	1.23	2.30	33.77	100.41	E.R.I.
8	10	23.45	10.40	5.07	31.78	1.33	2.05	26.50	100.58	

Among all, only one sample has got CaO above 45 percent, rest are low in CaO. These limestones are

of Grade-IV.

The reserves of these limestones as estimated by Geological Survey of India are about 5 m.tonnes.

Floatation Experiments:

The above named deposits of limestones, of late have been very critically re-examined in order to assess their economic potentialities. The chemical characters have already been described above. In order to utilize this limestone for cement manufacture, experiments on beneficiation were also conducted. The results of these investigations have been briefly discussed below. The Government of Gujarat referred the problem of beneficiation to the following consultants:

(1) M/s F.L.Smidth & Co.,Bombay

(2) M/s M.J.Seguin & Associates,Canada,

and (3) National Metallurgical Laboratory, (Government of India), Jamshedpur.

Samples from Gora and Limdi were examined in the laboratory of F.L.Smidth & Co. at Copenhegon (Denmark). The rock samples were subjected to floatation experiments

after suitable grinding.

The analyses of samples taken for experiments and results obtained are given in the table No.30 below:

TABLE NO.30

Percent

	Before floatation				After floatation			
	Gora		Limdi		Gora		Limdi	
	I	II	I	II	I	II	I	II
Titration Total	62.9	62.5	81.1	74.1	66.1	72.1	85.5	80.3
$CaCO_3$	59.4	62.3	80.3	71.1	68.5			77.3
$MgCO_3$	2.9	2.5	0.7	2.5	3.09			2.49
SiO_2	21.70	20.0	11.0	13.9	15.8			10.4
Al_2O_3	7.31	6.37	3.80	4.53	4.73			3.41
Fe_2O_3	3.49	3.97	1.81	2.64	3.17			2.11
CaO	34.2	35.8	45.3	42.7	39.3			45.5
MgO	2.3	2.18	1.2	1.7	1.73			1.03
Loss Ign.	29.8	30.7	36.4	33.8	33.9			36.5
SiO_2/Al_2O_3	2.0	1.9	2.0	1.9	2.0			1.9
Al_2O_3/Fe_2O_3	1.24	1.60	2.1	1.7	1.5			1.6
L.S.F.	0.48	0.54	2.1	0.93	0.76			1.32

It is seen that even with a low weight recovery (60 - 70 percent), the floatation could raise the CaO

only by 2 to 5 percent. Even after the samples were thoroughly cleaned, and then subjected to floatation, it was found that the percentage did not appreciably improve. On the other hand, the consumption of floatation reagents was found very high. The above firm reported that " ..... the size of the grains in the limestone samples would make it extremely difficult to obtain effective cleaning by floatation. The very fine grinding required would yield a material difficult to clean by floatation, and the cleaning expenses would become high, partly on account of the high power consumption for the grinding process, and partly on account of the large consumption of floatation reagents."

As the methods adopted by M/s F.L.Smidth & Co., did not give encouraging results, these limestones were subjected to experiments with entirely a new approach by M/s M.J.Seguin & Associates, Canada. They tried cationic floatation method, but this also did not prove successful. The mechanical separation was also considered unsuitable for raising $CaCO_3$ content by floatation in the case of Gora limestone on the basis

of its overall mineralogy and texture. On the whole, the report of these consultants was not favourable.

According to National Metallurgical Laboratory, this limestone can be upgraded by froth floatation. Their floatation experiments indicated that optimum grinding to finer than - 325 mesh for 50-60 minutes was required for the effective useful concentration. Thus the cost involved is quite high.

The author, however, is not very enthusiastic about the possibilities of beneficiation for these limestones. Theoretically, it may be possible, but in practice, the cost may work out uneconomical. In this connection the experience of Associated Cement Companies Limited in their Sevalia Cement Factory (Gujarat State) is rather unhappy. Though the siliceous limestone from Balasinor is much easily amenable to floatation process, as compared to Gora-Limdi limestones; and in their factory, the carbonate content could be raised from 70 to 85 percent by floatation, they prefer to transport the high grade limestone from Ganguvada deposits near Palanpur, Dist. Banaskantha over a

distance of 300 km to blende it with limestones from Balasinor. The transport cost works out lower than the floatation cost. On comparing this with Gora-Limdi limestones, the possibility of improving the quality of limestone for making use in the manufacture of cement does not appear to be promising.

However, with the starting of Gujarat State Fertilizer Corporation near Baroda, chalk with CaO around 50 percent is available as a by-product to the extent of about 350 tonnes a day. This, if blended with these limestones, Portland cement can be economically manufactured provided the higher SO_3 between 5 and 6 percent is taken care of.

LAMETA BEDS:

Limestones under this group are almost as extensive as those of Bagh Beds; and occur at following places:

Kaira district: Balasinor, Parbia.
Panchmahals district: Dohad, Jhalod, Devgad Baria.
Sabarkantha district: Gabat.

These limestones are supposed to be fresh water deposits occurring below traps at about the same horizon or slightly above that of the Bagh beds of the Narmada Valley. They are underlain by Aravallis and Erinpura granites. Conglomeratic at the base, these grade into massive limestones upwards. Cherty and chalcedonic stringers are common in these limestones, and those could be derived by solutions from the overlying Deccan traps (Fox 1913). The limestone is mottled with limonitic spots and blotches. In thickness, these vary from few metres to 15 metres.

The limestones are earthy to massive, fine grained, and whitish with spots of brownish colour or tinge. Under the microscope, grains of quartz, round or sub-angular in shape in calcareous groundmass are seen.

Kaira District:-

A number of limestone samples from Balasinor have been analysed by various agencies; the results available are as follows:

TABLE NO.31

Percent

Sr. No.	Av.of No.of Samp-les.	Insol.	R_2O_3	CaO	MgO	Remarks
1	10	5.73	0.87	50.67	0.71	G.S.I.
2	2	25.00	4.87	31.17	6.69	

		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	
3	1	5.40	3.10	1.40	51.03	0.54	38.0	100.37	E.R.I.
4	4	19.45	1.61	2.14	42.51	1.88	32.60	100.19	
5	2	37.05	1.96	4.29	32.38	1.99	22.82	101.12	

Limestones of Grade-II & III are very limited; Grades-IV to VI are in abundance.

The Associated Cement Companies Limited for their Sevalia factory draw their requirement of limestones from quarries near Balasinor. The top 1 m thick limestone is of Grade-I, while the lower one is rather siliceous. Plate III.

The area covered by limestone is approximately 25 x 3 km; the reserves as a whole as estimated by the Directorate of Geology and Mining are over 800 m.tonnes;

PLATE III

Quarry face in Lameta Limestone
near Balasinor

however, good quality limestones are very much less, say 20 to 30 m.tonnes or so.

Parabia is on way to Virpur, and about 20 km. from Balasinor. The chemical composition of samples from this area is as follows:

TABLE NO.32

Percent

Sr. No.	Av.of No.of samp-les.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign	Total	Remarks
1	7	9.30	3.64	0.86	47.56	1.80	0.86	37.34	101.30	E.R.I.
2	2	11.26	2.85	1.43	41.68	3.46	2.50	35.91	99.09	

Results of chemical analyses indicate that the limestones are of Grade-II; however the Grades-III and IV limestones also are in plenty. This is a promising area, and it deserves further attention. In fact, the Associated Cement Companies Limited, can supplement their requirement from this deposit.

The reserves of these limestones are over 5 m. tonnes.

Panchmahals District:

Large area around Dohad is occupied by these limestones covering the villages Usarwan, Kharod, Doki, Chhapri, Mivkhadi, etc. The chemical composition of these limestones is as follows:

TABLE NO.33

Percent

Sr. No.	Av.of No.of samp-les.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	Remarks
1	5	11.07	0.74	0.51	48.38	0.70	37.83	99.23	Private
2	2	19.08	1.73	0.15	42.87	0.53	34.48	98.84	
3	2	30.54	1.38	0.65	35.87	0.91	29.76	99.11	

In general limestones are of Grades-II to IV. Lime from these limestone is found to be good in engineering works for white wash, paints and in construction works. However, this limestone occurs in patches and lenses, and thus requires selective quarrying.

In Panchmahals, another identical occurrence of

limestones is at Devgad Baria; these limestones are of Grade-IV, the chemical composition of which is as follows:

TABLE NO.34

Percent

Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	Remarks
3	25.87	3.48	2.00	35.03	0.63	30.50	97.51	) Masonry) Sagol
1	15.3	4.6	2.3	43.7	0.4	33.50	99.80	) Project.

The Dohad area holds about 17.5 m.tonnes of good quality limestones as indicated by Directorate of Geology & Mining, while Devgad Baria area have roughly 5 m.tonnes.

Sabarkantha district:

In the Sabarkantha district, a limestone deposit occurs near the village Gabat. This too is siliceous like other Lameta limestones forming irregular lenticular masses, with pebbles of quartz and red jaspar at the base. The chemical composition is as

follows:

TABLE NO.35

Percent

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol.	Loss Ign	Total
22.20	0.41	1.59	41.49	1.45	1.60	30.80	99.9

The reserves of these limestones of Grade-IV are about 2 m.tonnes. Limestones of Grades-V and VI also are there, and the total reserves come to over 4 m.tonnes.

TERTIARY

The various Tertiary formations are fairly rich in limestones.

Eocene:

Limestones of Eocene age occur in the south Gujarat and the Kutch district at following localities.

Broach district: Dinod, Kanerao, Phalkui, Ghoda, Dungri, Siludi, Sengpura, etc.

Surat district: Tarkeshwar near Kim.

Kutch district: Lakhpat area, Ramania village, Waghapadar, Sansora, Hasudi, Kharoda, Khari, Kuraini, Fulra, etc.

These are earthy limestones packed with fossils of Nummulites, Corals, Echinoids, Gastropods, etc. These are fine grained, and of varying colours from white to yellow with reddish tinge; the beds are more or less horizontal, and lense-shaped merging into clay beds. Innumrable fossil shells of Nummulites occur in a clayey matrix. The limestone is cavernous with cavities ranging from few cm to 30 cm all over the area, and many a times those are filled in by clays. Calcite veins are common.

These limestones come under the autochthonous group of Pettijohn. On the whole the deposits are biostromal, however in Tarkeshwar area borehole data indicate its limited extent and as such is biohermal.

Broach district: At Dinod, a thick section of limestones is exposed in quarries for road material; the deposit near Kanerao is also comparatively large.

12

The chemical composition of these limestones is given in the table No.36 below:

TABLE NO.36

Percent

Location	Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	Remarks
Dinod	4	7.85	4.62	13.20	37.09	5.78	32.55	101.09	G.M.
Kanerao	4	4.28	3.09	6. 34	46.93	0.59	37.71	98.94	Guj. Cement
Phalkui	4	6.21	4.19	3.64	45.51	2.50	34.14	96.19	
Ghoda	3	3.22	2.30	5.13	48.09	0.44	39.85	99.03	
Dungri	1	3.73	2.14	5.32	48.53	0.29	39.12	99.13	
Siludi	2	7.18	3.40	6.74	43.83	0.72	37.27	99.14	
Sengpur	1	9.01	1.33	4.29	46.29	1.27	37.02	99.21	

Except Dinod, the CaO content in this limestone samples is satisfactory, however, the high iron content renders it unsuitable for the cement manufacture. At Dinod, the limestone has low CaO and high Fe_2O_3 and MgO. It may be possible to use this limestone for lime burning with improved methods which need to be developed by deciding proper calcination temperature, some admixture

of chemical or material to be decided by experiments. The reserves of the Grades-II(Fe) to IV(Fe) limestones are approximately 5 m.tonnes.

Surat district: Nummulitic limestones are exposed around Tarkeshwar, 16 km (10 miles) east of Kim Railway Station (W.Rly.-Bombay-Delhi Line), and on the Hansot-Mandvi road.

These limestones crop out between Tarkeshwar and Nowgama in the alluvial area. Kim river section too, exposes thin bands of these limestones. The strike is about NE-SW, with a dip of about 25^{o} to SE.

These limestone deposits have attracted attention of few cement companies from time to time. Associated Cement Companies Ltd. also examined these deposits.

The composition of this limestone is as under:

TABLE NO.37

Percent

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign	Total	Remarks
Tarkeshwar								
(a) Massive	3.0	1.4	4.5	50.4	0.4	40.3	99.60	A.C.C.
(b) Shelly	4.9	2.7	7.4	46.9	0.3	37.7	99.90	Average
Av.of 5 samples	2.82	--	7.39 --	48.07	2.15	38.94	99.37	G.S.I.

The Associated Cement Company gave up the area on account of the high Fe_2O_3 content. Even a thorough washing of the rock did not effectively reduce the iron content.

Later the Public Works Department (Gujarat State) explored the Tarkeshwar limestone deposit during 1957-58 by drilling 44 boreholes of which 37 were in Tarkeshwar area, 5 in Nowgama, and 2 were in Lindiyad villages. The author logged all the cores, did the sampling and got them analysed.

The average chemical composition is given in the table No.38 below:

TABLE NO.38

Percent

Sr. No.	B.H. No.	Total depth in ft.	Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol.	Loss Ign	Total
1	1	50	10	20.33	6.80	12.47	28.15	1.75	6.39	24.71	100.60
2	3	20	5	6.06	2.41	4.54	47.89	1.53	1.12	37.09	100.81
3	5	20	5	6.02	1.19	3.67	48.16	1.99	1.96	37.78	100.77
4	6	20	4	31.35	4.43	11.85	25.68	2.48	3.75	20.42	99.96
5	7	20	4	14.88	3.44	2.68	41.59	2.12	3.58	33.03	101.32

Contd..

Sr. No.	B.H. No.	Total depth in ft.	Av. of No. of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol.	Loss Ign.	Total
6	8	20	6	7.59	2.72	3.10	46.16	2.23	2.18	36.31	100.29
7	9	20	7	7.80	1.58	4.84	45.87	2.71	2.71	35.89	101.40
8	10	20	4	9.87	4.52	6.81	41.75	1.99	3.02	32.61	100.57
9	11	20	6	6.32	3.96	7.69	44.28	1.31	2.95	34.71	101.22
10	12	20	4	13.95	4.35	8.02	40.02	1.65	1.76	31.36	101.11
11	13	20	4	18.07	4.03	9.72	35.38	2.25	2.70	27.68	99.83
12	14	20	5	12.34	3.85	5.81	41.68	1.20	2.30	33.62	100.80
13	15	20	7	8.47	3.41	5.38	44.73	1.68	2.27	35.19	101.13
14	16	20	7	13.33	5.39	7.25	39.56	1.59	3.00	31.07	101.19
15	17	20	8	12.81	2.13	4.65	43.13	1.50	2.62	33.99	100.83
16	19	20	1	33.90	7.0	12.50	21.50	1.81	6.10	16.65	96.46
17	20	20	3	19.90	2.91	6.89	38.10	1.81	2.03	30.03	101.64
18	21	50	11	5.73	2.96	4.45	47.55	1.11	1.99	37.46	101.25
19	23	100	31	5.88	3.22	6.79	45.37	1.34	2.07	36.26	100.93
20	24	50	6	18.45	3.72	14.28	32.80	1.90	3.30	28.12	102.57
21	27	20	3	14.65	3.41	13.09	35.41	2.02	3.92	28.16	100.66
22	28	20	3	13.10	6.30	14.37	34.14	2.10	3.50	27.53	101.04
23	29	20	4	7.95	2.91	19.59	34.46	1.90	4.97	28.41	100.19
24	33	20	3	8.97	2.62	8.71	38.83	2.11	1.77	33.05	96.06
25	34	20	4	7.02	4.29	7.58	43.01	1.92	3.05	33.74	100.62

Contd..

Sr. No.	B.H. No.	Total depth in ft.	Av.of No.of samp-les	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign	Total
26.	38	50	9	20.23	3.54	10.45	34.79	0.89	3.70	27.31	100.91
27.	39	20	4	7.60	11.90	8.48	42.18	0.51	1.52	28.95	101.14
28.	40	31	8	20.68	7.02	21.04	26.16	0.81	3.72	20.35	99.78
29.	41	30	13	14.21	6.03	9.67	38.85	0.95	1.74	30.62	102.07

It will be seen from above that the areas of limestone with satisfactory CaO content can be located; but the higher Fe_2O_3 comes in the way of its utilisation in the cement manufacture.

The reserves of these limestones of Grades-III(Fe) to VI(Fe) as estimated by Geological Survey of India are about 3.0 m.tonnes; however, the assessment appears to be on a lower side; these could be over 5 m.tonnes.

This limestone was found unsuitable for the manufacture of Ferrari cement also, which contains 6 percent Fe_2O_3.

Thus, these large limestone deposits, as they stand today, on account of high iron content are

unsuitable for the manufacture of cement. These limestones should, however, give good hydraulic lime on proper calcination at the correct controlled temperature to be determined by experiments.

Kutch district: Eocene limestones of Kutch are somewhat different in nature from their counterpart in the south Gujarat; those are white, cream, buff to light grey in colour and earthy. Their chemical composition given below indicates high CaO content and low iron oxide, making them suitable for industrial and chemical uses. But these limestones have failed to attract business community because the region is not well communicated, suffers from water shortage and is thus under-developed. With such a rich potential of mineral wealth and its strategic importance, the Kutch region deserves rapid development by the establishment of industries. This can happen only if the water-supply and communication position is immediately improved.

The Directorate of Geology and Mining (Gujarat State) has already begun the surveys and exploration of minerals; which include limestones also. Limestones of

Kutch give the following composition:

TABLE NO.39

Percent

Location	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign	Total	Remarks
Ramania area	4.0	1.5	1.0	48.3	2.1		43.1	100.0	
	2.7	0.2	1.8	49.1	2.7		42.3	98.8	
	5.5	1.0	1.5	49.6	1.4		41.5	100.5	G.M.
Waghpadar	1.13	1.19		49.56	1.92		43.72	97.52	
Fulra	1.82	1.87		52.31	0.67		42.44	99.11	
Ghodatad	6.3	1.9	1.2	47.9	1.0	3.8	38.3	100.4	
	3.6	0.8	0.8	51.1	1.2	1.5	41.0	100.0	ERI

The reserves of these limestones of Grades-I and II as assessed by the Directorate are as follows:

(a) Ramania area — 124.66 m.tonnes

(b) Waghpadar, Sanosara, Kharoda, Khari and Harudi. — 937.00 m.tonnes

(c) Fulra, Kuriyani, Lakhpat and Ratipur — 6703.49 m.tonnes.

The total reserves worked out to be 7765 m.tonnes.

Miocene:

These limestones too fall under the autochthonous group and are biohermal in nature.

Broach district: Limestones of this age occur around Kand (Kondh) near Ankleshwar. These horizontally bedded, flaggy, and fossiliferous limestones vary in thickness, and at many places covered under the black soils.

The chemical composition of these limestones is as follows:

TABLE NO.40

Percent

Location	Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign.	Total	Remarks
Kondh	5	5.46	1.75	4.28	47.42	1.21	38.61	98.73	Guj. Cement.
"	3	6.14	3.68	6.81	45.27	2.93	35.90	100.73	G.M.

Though CaO content is satisfactory in these limestones of Grade-III (Fe), the high iron oxide content renders them unsuitable for cement. Approximate reserves as calculated by the Directorate of Geology and Mining, are 18 m.tonnes.

Saurashtra: Scattered patches of yellow limestones, somewhat argillaceous and composed largely of fragmentary fossil shells equivalent to the Gaj Beds, occur all along the coast.

Kutch district: Miocene of Kutch contains some beds of fossiliferous marls, but they are of little importance.

Pliocene:

Pliocene rocks, as stated earlier are not recorded in Gujarat mainland. However, in Saurashtra, light or dark buff and yellowish limestones belonging to Dwarka Beds occur along the coast in scattered patches. There are also marly yellowish limestones, and some are made up entirely of remains of small organisms.

These are autochthonous limestones and are biostromes in nature. These are associated with gypsiferous shales.

In Jamnagar district, a pale buff coralline limestone, more or less marly, or arenaceous, is seen at Positra in the north west corner of Okhamandal passing down into soft earthy marls. It is also seen southwards

beyond Mulwasar. This limestone extends from Okhamandal to Mithapur. The cliffs at Dwarka show 5 to 10 m. of beds varying from impure to pure limestone.

These limestones are utilised on an extensive scale in Mithapur chemical works and in the cement factory of Associated Cement Companies Limited at Dwarka. The chemical composition of these limestones is as follows:

TABLE NO.41

Percent

Locality	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign.	Total	Remarks
Mithapur	2.22	0.12	0.60	53.73	1.50	41.83	100.00	Tata Chemicals.
Dwarka	2.50	0.70	0.60	51.30	1.40	42.50	99.00	A.C.C.

The analysis of some sand from the beach at Dwarka and Aramda are given below as reported in Geology of Baroda by Foote (1898).

Locality	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	Total
Dwarka	17.21	1.12	0.40	76.82	95.55
Aramda	6.65	1.24	0.46	87.43	95.78

The reserves of these limestones of Grades-Super and I are approximately 50 m.tonnes.

QUATERNARY:

Pleistocene:

The miliolite limestone along Saurashtra Sea-board is the largest nature's gift of limestone to this region. It occurs in long, but discontinuous belts from Gopnath, south of Talaja to Miani near the mouth of Sani river, NW of Porbandar. Because of its popularity as building stone, its trade name is 'Porbandar stone'.

These are marine deposits composed of oolites of calcite and the remains of the foraminifer of Miliolidae family. It is dirty white, yellowish to buff in colour. The foraminifera are Rotalids and Miliolids. Sastri and Pant (1960) have assigned a Pliostocene to Sub-Recent age group. These are autochthonous limestones, and are calcarenite.

Miliolites, in many places, overlap Tertiary rocks, and also rest upon laterite and trap. Their thickness varies from few metres to over 50 m. They are practically horizontal, however, sometimes have

dips varying upto 20^{o}-30^{o} towards S, SE or NE. Plate IV.

Physical qualities of Miliolite limestones are as follows:

TABLE NO.42

Percent

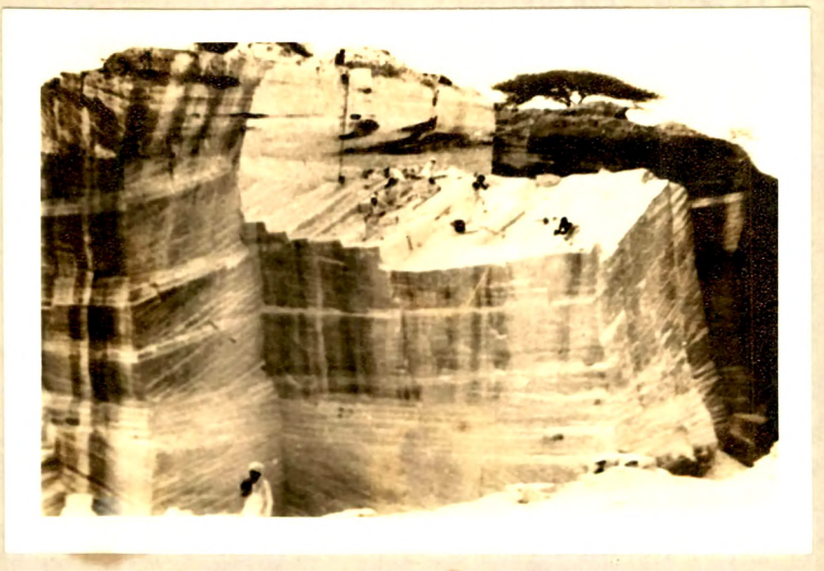
Av.of No.of samples	Specific Gravity True	Specific Gravity Apparent	Percentage water absorption	Compression strength Kg/cm^2	Transverse Kg/cm^2	Shear Kg/cm^2	Percentage loss by weight after 80 hours
11	1.80	2.03	11.16	94.28	24	29	8.72

Artificial weathering tests on these rocks have shown that the loss of weight was negligible.

As stated earlier, these Miliolite limestones are exposed practically all along the Saurashtra coast and constitute a rich and extensive limestone deposits. It is noteworthy that throughout its extent, this rock maintains a fairly good uniformity in its composition and texture. The author selected a typical area in Bhavnagar district for detailed investigation of this rock type.

Bhavnagar district: The area covered in detail lies

PLATE IV



A quarry in Miliolite Limestone
at Porbandar

between Gopnath and Methla villages, and a quick reconnaissance was made upto Jafrabad. Groove samples from quarry faces were collected and analysed.

Some private parties carried out prospecting in the Gopnath area comprising Rajpura-Juna, Jhanjhmer, Madhuvan and Methla. Six boreholes aggregating to 81 m (265 rft.) ranging in depth from 8.5 to 21 m were drilled. An open section upto 21 m is also available in Jhanjhmer quarries.

The chemical composition of limestones from this area is as follows:

TABLE NO.43

Percent

Sr. No.	Location	Av.of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign.	Total	Remark
1	Gopnath	2	12.50	2.51	2.49	43.01	0.96	0.95	36.70	99.12	ERI
2	"(Bores)	82	9.07	2.94	3.97	46.22	1.65	-	34.70	97.94	Private
3	Rajpura-Juna	3	6.03	0.98	2.52	49.17	0.57	0.57	39.33	33.17	ERI
4	Jhanjhmer 0-21 m	5	8.22	2.85	2.95	46.61	0.88	1.06	37.84	100.40	ERI
5	Madhuvan 0-11 m	3	6.80	2.84	2.99	47.77	1.20	0.80	38.36	100.78	ERI
6	Methla	1	5.30	0.71	1.79	51.87	1.09	0.50	40.50	101.76	ERI

The reserves of these limestones of Grades-II and III easily quarryable around Jhanjhmer were calculated by author to be about 25 m.tonnes, while the whole area calculated by Directorate of Geology & Mining holds 256 m.tonnes. In the Bhavnagar district alone, the total reserves are reported to be 525 m.tonnes. There are, in addition, large deposits of calcareous sand-dunes over these rocks; and these also consitute a good material for blending the Miliolite to raise the required silica content; the chemical composition of a sand-dune sample from Madhuvan is as follows:

TABLE NO.44

Percent

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign.	Total	Remarks
33.5	3.82	7.18	28.04	2.53	2.2	21.5	99.71	E.R.I.

The area further southwards from Kotada to Jafrabad was reconnitred; the chemical composition of limestone samples in Bhavnagar district is given in

the table No.45 below:

TABLE NO.45

Percent

Sr. No.	Location	Av. of No. of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign.	Total	Remarks
1.	Kotada	2	2.25	0.96	2.79	51.50	1.26	0.60	40.90	100.26	E.R.I.
2.	Kalsar	2	14.25	1.81	2.19	46.51	1.17	1.35	37.10	104.38	
3.	Naip	3	10.50	3.08	5.25	42.28	1.87	1.67	36.50	101.15	
4.	Umniara-dar	3	9.77	2.08	1.89	46.09	1.55	1.63	37.37	100.38	
5.	Jadra-Pancho-lina	1	9.20	2.21	1.79	48.51	1.09	0.60	38.10	101.50	
6.	Gujarada (Aklaria)	1	8.00	3.91	1.59	43.60	1.81	1.50	37.70	98.81	

It can be seen that limestones of all these areas are of Grades-II and III.

Amreli district: The important areas in this district holding limestones are - (a) Jafrabad area, and (b) Kodinar area. Limestones in this district have been well investigated by several agencies.

The chemical composition of these limestone deposits is as follows:

TABLE NO.46

Percent

Sr No.	Location	Av.of No.of samp-les	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss	Total	Remarks
1.	Visalia	1	4.40	3.21	3.79	45.97	1.45	38.90	100.72	E.R.I.
2.	Varashrup		13.51	2.87	1.82	44.27	0.96	35.57	99.00	G.S.I.
3.	"	3	2.62	0.67	1.37	52.66	0.90	41.40	99.62	Private
4.	Bhakodar	4	4.49	0.64	1.27	52.17	0.89	40.93	100.39	"
5.	Babarkot	9	4.76	1.42	1.50	51.11	0.78	40.25	99.82	"
6.	"		4.48	0.66	1.94	51.15	0.51	40.72	99.46	G.S.I.
7.	Charni (Jafrabad west)	11	4.09	1.83	1.89	49.72	0.89	39.76	98.18	Private
8.	Jafrabad west		13.72	4.55	4.05	39.54	1.68	36.52	100.06	G.S.I.
9.	" 2 miles west		3.02	1.49	0.89	51.76	0.62	41.84	99.62	"
10.	Jafrabad	2	9.65	3.36	4.38	41.94	2.26	36.35 1.4 Ins.	99.34	E.R.I.
11.	Mitiala		5.16	1.83	1.26	48.77	1.78	40.10 1.9 Ins.	100.80	E.R.I.

The limestones of Grades-II & III in particular and IV in general have estimated reserves around Jafrabad by the Directorate of Geology and Mining as 169 m.tonnes. Also there are small deposits around Chanch island and Danterdi in Rajula taluka and in Una. At Una, the limestones of Grade-I are about 1 m thick, the composition of Una limestone is as follows:

TABLE NO.47

Percent

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign.	Total	Remarks
Una	2.54	0.32	0.32	52.16	0.93	41.72	97.99	G.S.I.

All the above limestones can be used in metallurgical, chemical and cement industries.

In Kodinar area also, large deposits of Miliolite limestones of Grade-I are recorded. The river Shingoda exposes good sections of these limestones along its course where quarries are established.

The chemical composition of these limestones as given by Foote (1898) is as follows:

TABLE NO.48

Percent

Location	$CaCO_3$	$MgCO_3$	R_2O_3	Insol.	Combined water
Adivi	94.25	1.14	1.45	3.0	0.16
Dholassa	92.05	1.59	1.91	4.05	0.40
Harmaria	94.63	1.05	1.52	2.62	0.17

The reserves of these limestones are about 200 m.tonnes.

Junagadh district: Miliolites form the largest deposits in Junagadh district and are extensively exploited for chemical industries, cement manufacture, and as a building stone. Private parties interested in setting up cement plants have done extensive prospecting of limestones in this area.

The chemical composition given below indicates that these limestones are of high grade. The total number of samples analysed by various agencies is 146 from 50 localities and the average points out that the composition is consistantly uniform.

TABLE NO.49

Percent

Average of No.of samples	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign.	Total
146	2.56	1.25	0.78	53.13	0.78	40.33	98.83

Being of Grade-Super limestones in particular and Grade-I in general, these can be utilised conveniently for almost all purposes including metallurgical, chemical and, industrial, cement, etc.

The reserves of Miliolite limestones in this district may run into 100 m.tonnes and over. These are already being utilised in chemical industries in the manufacture of soda ash, calcium carbide, bleaching powder etc. Though it can be used for metallurgical industries as a flux, there is no possibility of having a steel plant here in absence of iron ore. The present large scale use of these limestones is in cement manufacture, and still there is a scope for more cement plants to come up. These are also used as building stones on very extensive scale.

Jamnagar district: Digvijay Cement Co. in this district draw their requirement of limestones from Gop area, and Narara islands.

The chemical composition of lime stone is as follows:

TABLE NO.50

Percent

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss Ign.	Total	
Gop	12.20	4.40	3.20	42.40	1.30	33.90		Digvijaya Cement Company.
	13.80	5.20	3.80	43.50	1.80	35.60		
	6.0	4.30	3.60	48.0	1.55	36.55		G.S.I.

These limestones are blended with calcareous sands (taken out from the sea) to raise their CaO content; these sands have as much as 90 percent $CaCO_3$.

The reserves of these limestones of Grade IV are roughly of the order of 50 m.tonnes. However, the calcareous sand is of Grade-II, and that makes up the difficiency of CaO.

Kutch district: Miliolite limestones occur in this region at the foot of Katrol hills, in Wagad region,

Baladia, and Jhumka.

At present these limestones are used locally as building stone. Unlike Saurashtra area, here these Miliolites do not occur in continuous long strip, but in scattered patches away from the coast. The rough estimate indicates the reserves over 15 m.tonnes. These also can be put to other uses such as lime burning, etc.

Recent:

The Recent limestone deposits are Calc-tufa and kankar met with at several places all over Gujarat State.

Calc Tufa

In Broach district, calc-tufa occurs at Umarwa, Bhilwasi, Thavadia, etc., near Rajpipla. This occurs in nala portions, and is sometimes mixed with trap sand and gravel.

Other occurrences recorded by Bose (1908) are at Ambakhadi, Rakhaskundi, Tejpur, etc. in Broach district. Ramarao (1931) too recorded calc-tufa and

travertine deposits in Devgad Baria area in Panchmahal district.

These rocks are of high purity, as seen from the following chemical composition:

TABLE NO.51

Percent

Location	Av.of No.of samples.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign.	Total	Remarks
Umarwa	2	1.30	1.10	0.39	54.30	0.36	0.10	43.09	100.64	
Bhilwasi	2	0.95	1.25	0.49	53.80	0.45	0.10	43.60	100.64	

These are of Grade-Super, but being of limited extent, are used to manufacture of fat lime or hydraulic lime by mixing surkhi - the artificial pozzolana.

Kankar

Kankar, a nodular limestone, is scattered all over, concentration of which is sometimes seen at few places only. It consists of 1 cm to 10 cm diameter uneven size nodules, composed of $CaCO_3$ with admixture of clay minerals.

Around Vasad, near Baroda, the kankar is collected from the ravines of Mahi river by hand picking, the cost of which comes to Rs.43/- per 100 cft. It is burnt and sold, under the trade name of 'SAGOL' a hydraulic lime, suitable for use in construction of building works.

The chemical composition of Sagol is as follows:

TABLE NO.52

Percent

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Insol	Loss Ign.	Total	Remarks
28.1	8.3	8.2	52.0	1.6	0.2	15.0	98.4	E.R.I.

This product is used as a mortar in building construction works where much strength is not required.