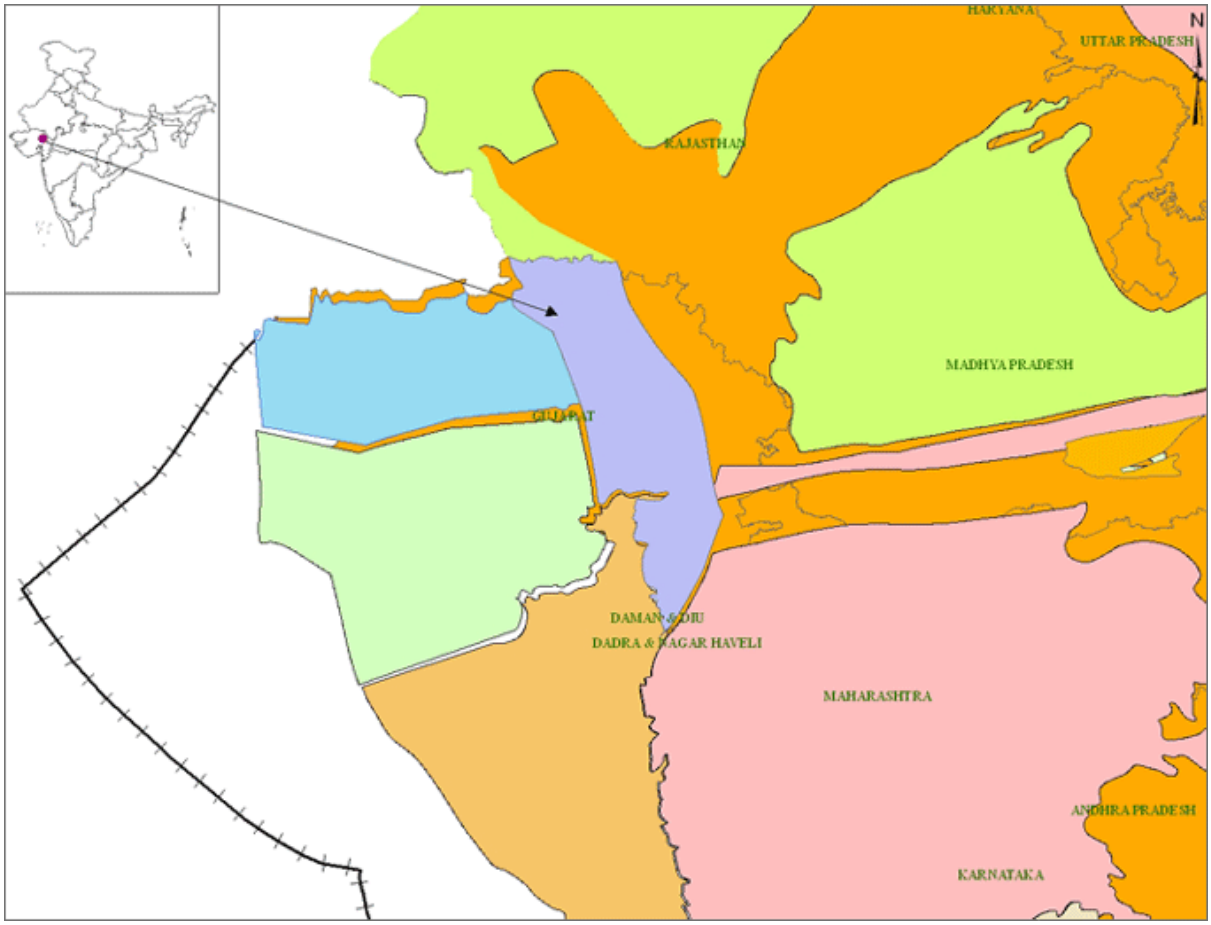
Basin Introduction:



Geographic Location of the basin
The Cambay rift Basin, a rich Petroleum Province of India, is a narrow, elongated rift graben, extending from Surat in the south to Sanchor in the north. In the north, the basin narrows, but tectonically continues beyond Sanchor to pass into the Barmer Basin of Rajasthan. On the southern side, the basin merges with the Bombay Offshore Basin in the Arabian Sea. The basin is roughly limited by latitudes 21° 00' and 25° 00' N and longitudes 71° 30' and 73° 30' E. (FIG: 1, Index Map)

Category of the basin
Proved

Area
The total area of the basin is about 53,500 sq. km.

Age of the Basin & Sediment-thickness
The evolution of the Cambay basin began following the extensive outpour of Deccan Basalts (Deccan Trap) during late cretaceous covering large tracts of western and central India. It's a narrow half graben trending roughly NNW-SSE filled with Tertiary sedimentswithrifting due to extensional tectonics. Seismic and drilled well data indicate a thickness of about 8 km of Tertiary sediments resting over the Deccan volcanics.

Major Discoveries, Total Seismic coverage, 2D/3D and exploratory wells drilled
A total of 12,937 gravity and magnetic stations were measured by the ONGC in the entire Cambay Basin. The Bouguer anomaly map has helped in identification of the major structural highs and lows in the basin. The magnetic anomaly map also depicts the broad structural configuration of the basin. A total of more than 30,688 LKM of conventional data has been acquired.

The total volume of seismic reflection data acquired from the Cambay Basin is of the order of 104113 LKM (2D) and 7895 sq. km (3D). (Fig: 2, Showing Density of Seismic coverage)

In 1958, ONGC drilled its first exploratory well on Lunej structure near Cambay. This turned out to be a discovery well, which produced oil and gas. The discovery of oil in Ankleshwar structure in 1960 gave boost to the exploration in the Cambay Basin. More than 2318 exploratory wells have been drilled in Cambay Basin. Out of 244 prospects drilled, 97 are oil and gas bearing.

Exploration Status
(Fig: 2 & 3 showing exploration status of N.Cambay & S.Cambay)

PEL AREAS 'P'	ML AREA 'M'	TOTAL AREAS 'T'	UNEXPLORED AREAS 'U' = T – (P+M)
15,838.04 Sq. KM	5,083.62 Sq. KM	53,500 Sq. KM	32578.34 Sq. KM

Fields of Cambay Basin

Field	Date of Signing contract	Area(Sq Km)	Field Size
Lohar-ONGC		8.29	
Cambay-ONGC		161	
Umra Ext. - II		34.43	
Kosamba Ext. - I		39	
Kim Ext. - I		56.11	
Pakhajan Ext. - II		38.50	
Olpad - Dandi Ext. - I		94.40	
Gandhar Ext. - IX		40.91	
Kural (Ml)		83.49	
Gandhar Ext. - VIII		7.23	
Gandhar Ext. - VII (G#155)		25.82	
Dabka Ext. - V (D#38)		2	
Nada Ext. - I		6.12	
Gandhar Ext. - VI (G#388)		644.47	
Kim (Ml)		18.33	
Dabka Ext. - IV (D#6)		1	
Olpad (A)		2.75	
Kosamba		19.07	
Kharach		0.70	
Elav		10.37	
Kudara		2.60	
Sanaokhurd		23.29	
Motwana		42.21	
Ankleshwar (Main)		38.98	
Ankleshwar Ext. - I		17.43	
Kasiyabet		5.06	
Pakhajan Ext. - I		18	
Pakhajan (Ml)		6.25	

Dahej		18.52	
Dahej Ext. - I		90.90	
Gandhar Ext. - V		29.43	
Gandhar Ext. - III		235.38	
Gandhar Ext. - II (Denwa)		54.30	
Gandhar		11.78	
Gandhar Ext. - I		32.75	
Gandhar Ext. - IV		36.75	
Nada		9.85	
Malpur (Ml)		1	
Umera Ext. - I		9.93	
Umera		8.44	
Dabka Ext. - III		1.15	
Dabka		21.67	
Dabka Ext. - II		0.56	
Dabka Ext. - I		12.85	
Kathana Ext. - I		16.99	
Anklav Ext. - I		61	
Akholjuni		81.25	
Padra Ext. - IX		21	
Padra Ext. - VIII		15.68	
Padra Ext. - VII		7.11	
Padra Ext. - VI		83.95	
Padra Ext. - V		3.58	
Padra Ext. - IV		6.37	
Padra Ext. - III		0.38	
Padra		1.25	
Padra Ext. - I		8.42	
Padra Ext. - II		14.50	
Kathana		16.95	
Siswa		37.78	
Nawagam South Ext. - III		53.71	
Kadi Ext. - IV		5.28	
Rupal		14.06	
Nawagam South Ext. - II		43.94	
Nawagam South Ext. - I		30.88	
Kalol West Ml		14.53	
Kalol West Ext. - I		54.25	
Nawagam Ext. - III		56	
South Wamaj ML		18.29	
Gamij Ext. - II		116.22	
Nadej Ext. - I		56.18	

Gamij Ext. - III Ml		15.41	
Ahemdabad Ext. - V		17.75	
Nawagam Ext. - II		14.66	
Kadi Ext. - III		16.07	
Asmali Ml		43.26	
Raipur Ext. - I		8.70	
Ahemdabad Ext. - IV		10.21	
Wadu Ext. - I		55.17	
Mawagam Ext. I		2077.77	
Nawagam Main		72.23	
Nadej		90.18	
Nadej East		20.92	
Ahmedabad Ext. -III		34.75	
Ahmedabad Ext. -II		5.98	
Ahmedabad Ext. -I		17.29	
Ahmedabad - Bakrol		30.16	
Hirapur		87.92	
Gamij Ext. -I		81.22	
Gamij		39.16	
Sanand Ext. -III		19.30	
Sanand Ext. -II		10.37	
Sanand Ext. -I		18.51	
Sanand		81.36	
Viraj		17.49	
Wamaj		19.44	
Motera Ext. -I		23.64	
Motera		15.86	
Motera Ext. -II		26.02	
Kalol Ext. -II		15.50	
Kalol Ext. -I		159.82	
Kalol Main		35.84	
Halisa		143.44	
Limbodra Ext. -I		14.96	
Limbodra		15.75	
Paliyad-Kalol-Limbodra		161.48	
Kalol North East		9.44	
Wadu		15.41	
Rajpur		6.76	
Jotana - Warosan		38.05	
Kadi Asjol		0.72	
Chandrora		1.39	
Langhnaj ML		17.90	

Sanganpur ML		6.97	
Langnaj - Wadasma		13.84	
West Mewad (ML)		13.02	
North Sobhasan Ext. -II		23	
East Sobhasan		22.42	
N. Sobhasan Pt. A+B		12.05	
South Patan		6.99	
Joksana (ML)		9.80	
Jotana Ext. -II		0.87	
Lanwa Ext. -I		2.15	
Dedana (ML)		5.44	
Chansama		2.81	
Nandasan - Langnaj		61.90	
Mansa		58.72	
Nandasan Ext. -I		26.39	
Linch		43.73	
Linch Ext. -I		34.25	
North Kadi		64.49	
N. Kadi Ext. -I		20.42	
Kadi Ext. -II		41.01	
Bechraji Ext. -I		3.06	
Bechraji		37.11	
Santhal		19.46	
Jotana		39.50	
North Sobhasan Ext. -I		56.85	
Linch Ext.- II		13.35	
Geratpur		18.31	
Sobhasan		35.89	
Mehsana City Ext. -II		7.58	
Mehsana City		8.85	
West Sobhasan		9.60	
Jotana Extn. - I		57.70	
Balol		24	
Lanwa		30	
CB-OS/2		201.76	4
Cb-On/3		7.81	4
Cb-Onn-2000/2_Nsa/Bheema		24.25	4
CB-ONN-2000/1	01/01/1900	14.10	4
Palej-Pramoda(CB-ON/7)	01/01/1900	3.54	4
Bheema(CB-ONN-2002/2)	01/01/1900	4.03	3
NS-A(CB-ONN-2002/2)	01/01/1900	20.22	4
CB-X	01/01/1900	33.30	3

Gauri(CB-OS/2)	01/01/1900	80.70	3
lakshmi(CB-OS/2)	01/01/1900	121.06	3
Modhera	23/02/2001	12.70	1
Ognaj	16/02/2004	13.65	1
Karjisan	16/02/2004	5	1
N.Balol	23/02/2001	27.30	1
Baola	05/04/1995	4	1
Lohar	13/03/1995	5	1
Bakrol	13/03/1995	36	1
Indrora	13/03/1995	130	1
Wavel	20/02/1995	9	1
Dholka	20/02/1995	48	1
Sabarmati	23/09/1994	6	1
Matar	01/01/1900	0	1
Cambay	23/09/1994	161	1
Bhandut	23/09/1994	6	1
Hazira	23/09/1994	50	1
Asjol	03/02/1995	15	1
Sanganpur	23/02/2001	4	1
Unawa	23/02/2001	6	1
Kanawara	23/02/2001	6.30	1
Allora	23/02/2001	6.85	1
North Kathana	23/02/2001	12.20	1
Dholasan	23/02/2001	8.80	1

Tectonic History :.

Type of Basin
Intracratonic rift graben.

Different Tectonic Zones with in the Basin
The Cambay rift valley is bounded by well demarcated basin margin step faults. Based on the cross trends the basin has been divided into five tectonic blocks. From north to south, the blocks are:

- Sanchor – Tharad
- Mehsana – Ahmedabad
- Cambay – Tarapur
- Jambusar – Broach

and

- Narmada Block.(FIG 4: Tectonic Map of the Basin)

Basin Evolution :.

The Early Tertiary sediments ranging in age from Paleocene to Early Eocene represent syn-rift stage of deposition that was controlled by faults and basement highs in an expanding rift system. These sediments are characterised by an assortment of illsorted, high energy trap derived materials. Subsidence of the basin resulted in the accumulation of a thick sequence of euxinic black shales with subordinate coarser clastics. The Middle Eocene witnessed a regressive phase with oscillating conditions of deposition and development of deltaic sequences in the entire basin. There was a regional southward tilt of the entire rift basin during Late Eocene and it is marked by a regional marine transgression extending far to the north upto Sanchor basin. Oligocene – Lower Miocene marks another phase of tectonic activity with extensive deposition of coarser clastic sediments in the central and southern blocks.

Generalized Statrigraphy :.

- Standard stratigraphic table. (Fig 5: Generalized Stratigraphy of Cambay Basin)
- Sedimentation survey and Depositional environment in different location zones

The formation of the Cambay Basin began following the extensive outpour of Deccan basalts (Deccan Trap) during late Cretaceous covering large tracts of western and central India. The NW-SE Dharwarian tectonic trends got rejuvenated creating a narrow rift graben extending from the Arabian sea south of Hazira to beyond Tharad in the north. Gradually, the rift valley expanded with time.

During **Paleocene**, the basin continued to remain as a shallow depression, receiving deposition of fanglomerate, trap conglomerate, trapwacke and claystone facies, especially, at the basin margin under a fluvio–swampy regime. The end of deposition of the Olpad Formation is marked by a prominent unconformity. At places a gradational contact with the overlying Cambay Shale has also been noticed.

During **Early Eocene**, a conspicuous and widespread transgression resulted in the deposition of a thick, dark grey, fissile pyritiferous shale sequence, known as the Cambay Shale. This shale sequence has been divided into Older and Younger Cambay Shale with an unconformity in between. In the following period, relative subsidence of the basin continued leading to the accumulation of the Younger Cambay Shale. The end of Cambay Shale deposition is again marked by the development of a widespread unconformity that is present throughout the basin.

Subsequently, there was a strong tectonic activity that resulted in the development of the Mehsana Horst and other structural highs associated with basement faults.

Middle Eocene is marked by a regressive phase in the basin and this led to the development of the Kalol/ Vaso delta system in the north and the Hazad delta system in the south. Hazad and Kalol/ Vaso deltaic sands are holding large accumulations of oil.

Major transgression during **Late Eocene-Early Oligocene** was responsible for the deposition of the Tarapur Shale over large area in the North Cambay Basin. The end of this sequence is marked by a regressive phase leading to deposition of claystone, sandstone, and shale alternations and a limestone unit of the Dadhar Formation.

The end of the **Paleogene** witnessed a major tectonic activity in the basin resulting in the development of a widespread unconformity.

During **Miocene** The depocenters continued to subside resulting in the deposition of enormous thickness of Miocene sediments as the Babaguru, Kand and Jhagadia formations.

Pliocene was a period of both low and high strands of the sea level, allowing the deposition of sand and shale.

During Pleistocene to Recent, the sedimentation was mainly of fluvial type represented by

characteristic deposits of coarse sands, gravel, clays and kankar followed by finer sands and clays, comprising Gujarat Alluvium.

Throughout the geological history, except during early syn– rift stage , the North Cambay Basin received major clastic inputs from north and northeast, fed by the Proto–Sabarmati and Proto–Mahi rivers. Similarly, the Proto–Narmada river system was active in the south, supplying sediments from provenance, lying to the east.

Petroleum System :.

Source Rock
Thick Cambay Shale has been the main hydrocarbon source rock in the Cambay Basin. In the northern part of the Ahmedabad-Mehsana Block, coal, which is well developed within the deltaic sequence in Kalol, Sobhasan and Mehsana fields, is also inferred to be an important hydrocarbon source rock. The total organic carbon and maturation studies suggest that shales of the Ankleshwar/Kalol formations also are organically rich, thermally mature and have generated oil and gas in commercial quantities. The same is true for the Tarapur Shale. Shales within the Miocene section in the Broach depression might have also acted as source rocks.

Reservoir Rock
There are a number of the reservoirs within the trapwacke sequence of the Olpad Formation. These consist of sand size basalt fragments. Besides this, localized sandstone reservoirs within the Cambay Shale as in the Unawa, Linch, Mandhali, Mehsana, Sobhasan, fields, etc are also present.

Trap Rock
The most significant factor that controlled the accumulation of hydrocarbons in the Olpad Formation is the favorable lithological change with structural support and short distance migration. The lithological heterogeneity gave rise to permeability barriers, which facilitated entrapment of hydrocarbons. The associated unconformity also helped in the development of secondary porosity.

Transgressive shales within deltaic sequences provided a good cap rock. (Fig 6: Generalized Tectono Stratigraphy Map Showing Source rock, Reservoir Rock, and Oil and Gas Occurrences.)

- **Timing of migration & Trap formation:** The peak of oil generation and migration is understood to have taken place during Early to Middle Miocene.

Petroleum Plays :.

Structural Highs and fault closures & Stratigraphic traps (pinchouts / wedgeouts, lenticular sands, oolitic sands, weathered trap) in Paleocene to Miocene sequences have been proved as important plays of Cambay Basin.

Paleocene – Early Eocene Play :

- **Formations :** Olpad Formation/ Lower Cambay Shale.
- **Reservoir Rocks :** Sand size basalt fragments & localized sandstone. Unconformities within the Cambay Shale and between the Olpad Formation and the Cambay Shale have played a positive role in the generation of secondary porosities. The Olpad Formation is characterised by the development of piedmont deposits against fault scarps and fan delta complexes.

Middle Eocene Play :

- **Formations :** Upper Tharad Formation

- **Reservoir Rocks :** In Southern part, Hazad delta sands of Mid to Late Eocene & in the Northern part the deltaic sequence is made up of alternations of sandstone and shale associated with coal. Plays are also developed in many paleo-delta sequences of Middle Eocene both in northern and southern Cambay In the Northern Cambay Basin, two delta systems have been recognised.

Late Eocene – Oligocene Play :

- **Formations :** Trapur Shale, Dadhar Formation.
- **Reservoir Rocks :** This sequence is observed to possess good reservoir facies in the entire Gulf of Cambay. North of the Mahi river, a thick deltaic sequence, developed during Oligo–Miocene, has prograded upto south Tapti area.

Miocene Play :

- **Formations : Deodar :** Formation (LR. Miocene), Dhima Formation (Mid Miocene), Antrol Formation (UP. Miocene) The Mahi River delta sequence extends further westward to Cambay area where Miocene rocks are hydrocarbon bearing.