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Advances in Seismic API Techniques in Kerala Konkan Basin-Historical Prospective.

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Abstract

The Kerala-Konkan Basin covers an area of approximately 390,000 sq. km. Water depths in this offshore area varied from shallow water to greater than 3000m.The tectonic structural style of Kerala-Konkan Basin is similar to Bombay Offshore Basin up to tertiary section, however the horst and graben features on continental shelf are comparatively less pronounced.

The journey of geophysical surveys in Kerala –Konkan Basin commenced in the year 1979 onwards, with initially 24-48 fold seismic data. During that period the focus was Tertiary sediments due to limitation of cable length, acquisition parameters and processing techniques. Initial seismic data had poor imaging and appear to be masked with multiples, poor S/N ratios and low frequency. Gradually cable length (offsets) was increased and data foldage and frequency were increased but mostly limited to 48 fold data till the year 2000 mainly because of acquisition limitations. Analysing sub-basalt sediments by seismic surveys has always been a challenge due to the massive thick section of basalt. Only a few wells have penetrated sub- basalt section. Few wells, CSP-1 and KK-OS-II/B-1, in Kerala-Konkan have shown the presence of hydrocarbons during drilling. This study aims at historical prospective of API of seismic data vis-à-vis evolution of various techniques for better deciphering of seismic imaging of the Basin. Seismic data series KK-DWN series (2002) appears to have the least multiple interference compared to earlier vintages and enhanced S/N ratio over the recorded length of the section. Here final velocity analysis was applied every 500 meters, resulting in better velocity control and improved stack response and the combination of better acquisition parameters and processing sequence has resulted in better data quality for shallow and also for deeper events. Again during 2002-2006 seismic data acquired by DGH, in water depths ranging from 100m-4600m is of very high quality, (cable length 8-10 km.). These data sets, WC-line series and GXT lines using the modern seismic techniques (Radon Demultiple, PSTM and PSDM) has wideband spectrum with adequate high frequency content in the reflection spectra and good S/N ratio and has improved seismic imaging at both within the Tertiary and deeper Mesozoic sections. In the year 2008-09, 2D long offset data were acquired and processed for NELP-IV, VI &VII areas. The imaging of 2D long offset was very useful as seismic sections show good correlatable sub- basalt seismic reflections. In the year 2012-13, 2D long offset data (12 Km. offset) coupled with SBN WARRP profiling data of 40-160 km. offset, was acquired and processed with beam PSDM model based imaging. The beams PSDM imaging has shown excellent improvement of S/N ratios, preservation of amplitudes and continuity of seismic reflection events. The SBN tomography and velocity model indicated existence of Mesozoic basin with velocities in higher ranges corroborating to sparse drilled well data and geological model.

Seismic survey History in KK Basin

Seismic survey in Kerala –Konkan Basin has accounted for over 1600 2D seismic lines, totalling over 123, 000 line km., and 3D seismic survey areas which are covered to investigate particular prospects. The seismic data base (Fig-1) consisted of over 123,000 line kilometres of 2D digital data and 3D surveys. The regional survey grids are parallel to western shoreline, with strike lines trending NNW-SSE and dip lines trending ENE-WSW. In addition to this various 3D surveys were conducted to better define prospect areas prior to exploration drilling. These lines within the basin were acquired during many seismic survey programs of reconnaissance, regional, infill and detail 2D data, from 1979 to 2013. The subsurface coverage varies from 2*5 km grid spacing or less, along the present day continental self slope, to up to 20*30km grid spacing in the deepwater parts of the basin area. (Fig-1). As the seismic data pertains to different vintages, acquired with different parameters, at times problems related to mismatch/misties were encountered. Some of the examples are shown below.

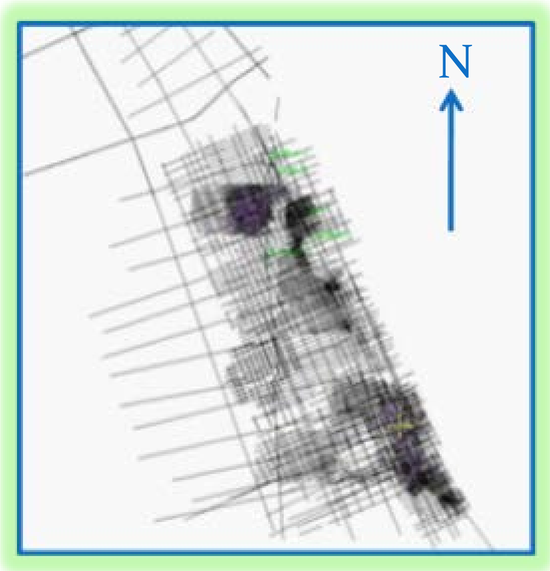
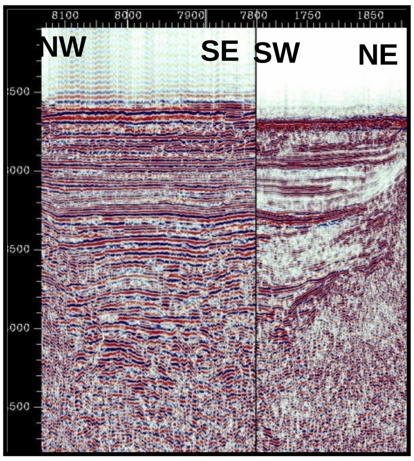


Fig-01, Seismic line coverage in Kerala Konkan Basin



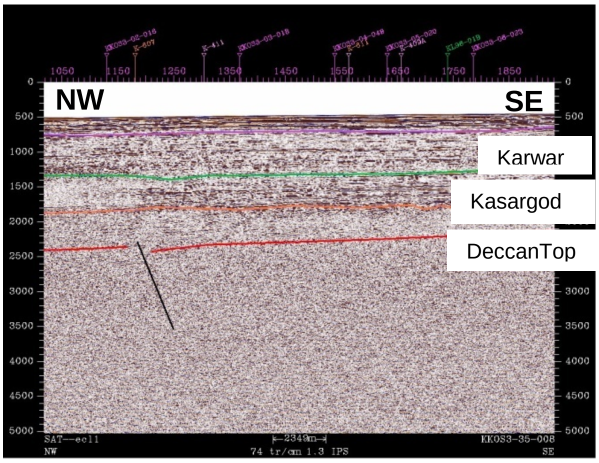


Fig- 2 Line KAN-316A & KKDWN-19-03 **Fig- 3 Seismic line KKOS3-34-008**

Fig-2 shows misties at the top at sea bottom as well as at different levels of intersecting lines KAN-316A and KKDWN-19-03, also data quality of KAN-316A is masked with noise and multiples and reflectors are not matching with KKDWN-19-03 section which has superior data quality compared to KAN-316A line. In fig-3, line no-KKOS3-34-008 has poor data quality and reflectors are not properly imaged.

Acquisition and processing of seismic data in the study area were carried out over a period of more than three decades. Most of the 123,000 km of 2D seismic line kilometres were acquired by ONGC. During eighties and nineties no survey was specifically designed for imaging the Mesozoic sequences (pre-Deccan) as this was not a defined play at that time.

Seismic data acquisition in KK Basin began in late 1979 with the RE-series of reconnaissance lines. In early 1981, the regional L-series was acquired in the deeper waters surrounding the remote offshore Laksha Dweep islands. The 88SI- and early K-regional series followed (from 1989), but were mostly limited to the continental shelf of the basin (within 200 m water depths). Later, as technology improved and increased oil prices made deep water drilling more economically feasible, the seismic surveys were consistently extended well beyond the continental shelf.

The early seismic acquisition campaigns were carried out largely by the ONGC vessels M/V Anweshak & M/V Sagar Sandhani and partly by contractual vessels (G.S.I.'s M/V R.C.Dunlap & Western Geophysical's M/V Western Horizon). Some of the early seismic acquisition surveys and data acquisition parameters are shown in Table 1.

Table 1.: Seismic Acquisition Survey Parameters

Investigation	Acquisition Year	Vessel (M/V)	No of channels	Group Int. (m)	SP Int. (m)	Fold	Filters Lc - Hc	Sample Rate (ms)	Source Volume (cu. In)	Source Pressure (psi)	Near Offset (m)	Far Offset (m)	Record Length (sec)	Recording Instrument	Format
RE -	Dec-79	Anweshak	48	50	50	24	3.5-128	4			265	2615	8	DFS - V	
L -	Mar-81	GSI-RC Dunlop	48	50	25	48	3.5-128	2	2000	1800	230	2630	6	DFS - V	
88 SI -	1988 - 89	Western Horizon	240	13.33	26.66	60	3.5-128	4	2670	1950	81.5	3185.87	7	DFS - V	
K - Series	Dec-89	Sagar Sandhani	120	25	50	48	3.5-128	2	1330/1665	2000	188	2751	6	DFS - V	
K -142 to	Sep-89	Anweshak	96	25	25	48	3.5-128	2	--	--	222	2597	6	DFS - V	SEG-B
K - to 611	Mar-90	Anweshak	96	25	25	48	3.5-128	2	1382	1900	222	2597	6	DFS - V	SEG-B
K - 282 to	Jun-90	Anweshak	96	25	25	48	3.5-128	2	--	--	222	2597	6	DFS - V	SEG-B
K - to 300	Mar-91	Anweshak	96	25	25	48	3.5-128	2	--	--	222	2597	6	DFS - V	SEG-B
K -	Nov-93	Sagar Sandhani	96	25	25	48	3.5-128	2	--	--	198	2573	7	DFS - V	SEG-B
RM-	Feb-93	Anweshak	96	25	25	48	3.5-128	2	1250/1382	1900	222	2597	6	DFS - V	SEG-B
KSS -	Oct-93	Sagar Sandhani	96	25	25	48	3.5-128	2	1250/1382	1900	198	2573	7	DFS - V	SEG-B
KAN -	Nov-93	Anweshak	96	25	25	48	3.5-128	2	1250/1383	1900	222	2597	7	DFS - V	SEG-B
K - 94 -	May-94	Anweshak	96	25	25	48	3.5-128	2	1250/1384	1900	222	2597	6	DFS - V	SEG-B
K - 95 -	Jun-95	Anweshak	96	25	25	48	3.5-128	2	1250/1385	1900	222	2597	6	DFS - V	SEG-B
K-	Jan-96	Anweshak	96	25	25	48	3.5-128	2	1250/1386	1900	222	2597	6	DFS - V	SEG-B
KL - 95 -	Oct-95	Anweshak	96	25	25	48	3.5-128	2	---	---	222	2597	6	DFS - V	SEG-B
KL - 96 -	Jan-96	Anweshak	96	25	25	48	3.5-128	2	---	---	222	2597	6	DFS - V	SEG-B
RKK - 98 -	Oct-96	Sagar Sandhani	96	25	50	24	3.5-128	2	---	---	197.5	2572.5	7	DFS - V	SEG-B
KK-DWN-	Mar-02	C-Explorer	184	25	25	92	3.5-128	2	4200	2000	150	4750	7	I/O MSX	SEG-D

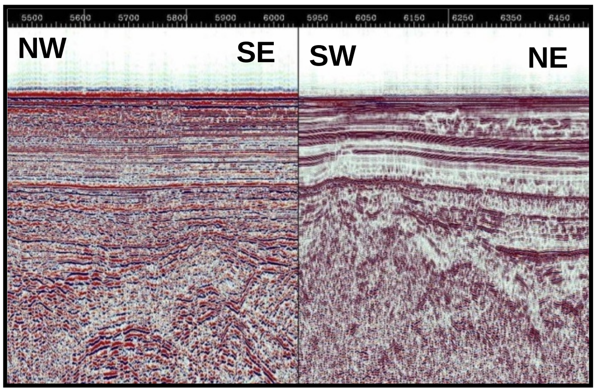
The acquisition parameters for the ONGC vessels were suitable for initial regional exploration had relatively low fold and short cables. In comparison, subsequently other explorers (e.g. Shell India, SI-series) generally shot with longer cables, more receiver channels, and improved source parameters (higher gun pressure and volume) which provided a better data quality.

However, during some surveys acquisition, problems resulted from either technical difficulties (e.g. equipment failure) or operational difficulties (such as interference from fishing boats or nets). This resulted in insufficient overlapping on broken lines which resulted in low subsurface coverage and in some cases data gaps. Seismic surveys prior to 2002 were targeted for tertiary sediments and have limited far offsets (cable lengths). These data sets were either of 24 or 48 fold data and after processing the output were either masked with noise or poor resolution of reflectors and imaging below trap were very poor. These regional seismic surveys acquired by the Departmental vessels (M/V Anweshak & Sagar Sandhani) were processed at GEOPIC (Dehradun) over the period 1980-2002. There is a wide variation seen in the processing parameters adopted, which has resulted in differences in data quality between surveys. In perticular the data quality of sets KSS-, KAN-, and K-94, series are very poor and contain very low frequency data and are saturated with multiples. In these sets, DBS filter is applied and no DAS filter. The time variant filter (TVF) after stack appears not to be optimal. Acquisition limitations are thought to also be responsible for the relatively poor quality of these surveys (Table-2).

In order to reduce noise level and enhance signal to noise ratio and map deeper reflectors, a new data set was acquired in March 2002, KK-DWN series appears to have the least mutiple interference and enhanced S/N over the recorded length of the section. A recorded source wavelet was utilised to define the deconvolution parameters (using predictive deconvolution) followed by velocity analysis at 2 km intervals. Then a dip move out (DMO) correction was applied, followed by a multiple supression filter (z Mult –velocity filter). Final velocity analysis was applied every 500 meters, resulting in better velocity control and improved stack response. An F-K finite difference migration was then applied to the stack, followed by DAS (24 ms gap, with 320 ms operator length). Finally, a carefully selective series of TVF filters were applied to enhance the S/N ratio, followed by multi-window display gain (13 numbers, 1000 ms gate length, and 500 ms step window). In combination with better acquisition parameters this processing sequence has resulted in better data quality for shallow to deeper events. However, the pre-Deccan sequences are still poorly imaged. The seismic data processing parameters details are shown in Table-2

Table-2, Seismic data processing parameters

Investigation / Year of Processing	Demult + Resample (ms)	TAR + Gain rec. Sprical div. correction	Bulk Statics	D E C O N Before Stack Prediction distance (ms)	Operator length (ms)	Pre-white noise %	Pre-FILTERS Lc - Hc (Hzs)	Mute	Velocity Analysis (Distance) (Kms)	STACK	D E C O N After Stack GAP (ms)	Operator length (ms)	Pre-white noise %	F I L T E R S T V F ms - Lc - Hc	Balance/ Equilization	Migration	Remarks
RE - 1980	4	Applied	11	16	120	---	10 - 80	As perWD	6	12	---	---	----	3/5 - 35/40	AGC-500 ms	----	2 × 12 processed
L - 1981	4	Applied	11	Spike	320	1	10 - 80	-do-	2	24	28	500	1	WB+1.2 - 5-40	AGC-1000ms	----	1 × 24 Alternate pop processed
					(2 Filter)									6.0 - 5-30			
88 SI - 1989	4	-do-	9		Adjacent Receiver sum		K-F filter	-do-	2	60	DAS not applied			0-1200 --7/12 - 60/75	Trace		
				Simulate 26.66M Rec.spacing							Adjacent CMP sum			1200-2500-6/10-50/65	normalization		
														2500-7000-5/8-40/55	to level 1900		
K- 1988	4	-do-	14	4	240	---	-----	-do-	1	48	16	360	--	700 - 15/48-60/72	Time varient		
				1500 - 2500 window										1500 - 15/48-50/72	R M S		
														2000 - 10/48-40/72	128 -512 ms		
														3000 - 8/48 - 30/48			
K - Mar-1990	4	-do-	12	4	240	1	5/10-65/75	-do-	2	48	20	360	1	0-200014/18-55/60	Balance		
														2300-36010/14-40/72	window 600 ms		
															overlap 300ms		
K- June-1990	4	-do-	12	8	200	---	6/60- open	-do-	2	48	32	300	--	0-1300 - 12/18-36/45	RMS gain		
														2700 - 10/18-36/40	64- 512 ms		
														6000 - 8/18 -35/36			
K- Aug -1990	4	-do-	12	spiking	240	0.1	5/10-45/50	-do-	2	48	32	360	1	0-2000 -1 4/18-40/45	1000 MS		
														2300-3600-10/14-35/40	window over-		
														2900-6000- 6/10-30/35	lap 500 MS		
K- Nov - 1992	4	-do-	12	spiking	240	0.1	4/8-68/72	-do-	2	48	28	360	0.1	0-2000 - 14/18-55/60	window 600 ms		
														2300-4000-10/14-45/50	overlap 300ms		
RM- Nov - 1993	2	-do-	12	spiking	240	1	6/10-68/72	-do-	2	48	40	320	0.1	0-1600- 8/12-48/52	Balance 600ms		
														1800-4000- 4/8-38/42	with 200ms		
														4300-6000- 4/8-28/32	overlap		
K- Mar - 1994	2	-do-	12	No	D B S		4/8-70/80	-do-	2	48	16		0.1	0-800 - 6/10-53/57	Full window		
														1000-2000- 4/8-43/47	6000 MS		
														2200-6000- 4/-33/37			
KSS Aug - 1994	2	-do-	12	No	D B S		4/8-70/80	-do-	2	48	16	320	0.1	0 - 800 - 6/10-53/57	Full window		
														1000-2000- 4/8-43/47	6000 ms		
														2200-6000- 4/8-33/37			
KAN May - 1994	2	-do-	12	No	D B S		6 - 75	-do-	2	48	16	320	--	10/18-53/48	Single		
														8/18 - 43/48	window		
														8/18 - 33/48			
k-95 July - 1996	2	-do-	12	Spiking	180	1	6 - 70	-do-	2	48	24	160	0.1	0 - 1300 - 10-60	Balance ?		
														1500-3000 - 6-50			
														3300-6000 - 6-35			
KL-95- July - 1997	2	-do-	12	Spiking	180		6 - 70	-do-	2	48	24	160	0.1	0 - 1300 - 10-60	Balance ?		
														1500-3000 6-50			
														3300 - 6000- 6-35			
KL- 96 - 1996	4	-do-	12	spiking	180	0.1	6 - 70	-do-	2	48	24	320	0.1	100-1000 - 15-60		RCC-Calcutta	
														1500-3000 - 10-60			
														3300-5000 - 6-30			
RKK-98 - Jan-1998	2	-do-	12	12	200	0.1	10 -80	-do-	2	24	24	240	0.1	100-1500 - 10-60	Balance ?		
														2000-3500 - 5-45			
														4000-7000 - 4-35			
KK-DWN- Mar-2002	2	-do-	10	16	180	1	4/24-out	-do-	Pre - 2	92	24	320	1	1000 - 12 - 85	Bal.gates=13		
									Final- 0.5					2000 - 10 -65	gate = 1000ms		
														3000 - 8-50	step window:500ms		
														4000 - 6-35			



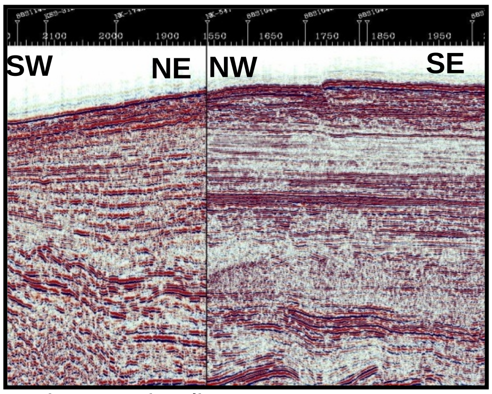
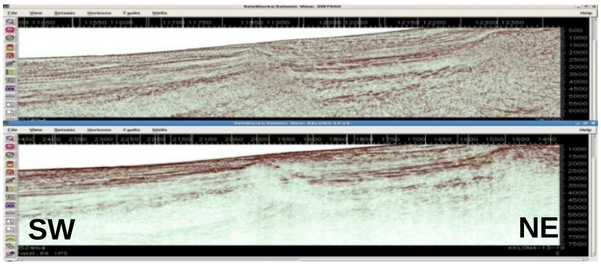


Fig- 4, intersecting lines KAN-32-&KKDWN-11-17 Fig-5, intersecting lines NK-547&DWN-40

Again during 2002-2006 seismic data acquired by DGH, in water depths from 100m-4600m is essentially of a very high quality, (offset 8-10 km.). These data sets WC-line series and GXT lines using the modern seismic techniques (Radon Demultiple, PSTM and PSDM) has wideband spectrum with adequate high frequency content in the reflection spectra and good signal to noise ratio and has upgraded seismic imaging at both in the tertiary and deeper Mesozoic section, representative section shown in fig-6 & fig-7

The use of GXT Technology reduced the risk and cost of hydrocarbon exploration and development by delivering the highest quality seismic data processing techniques. This technology is very useful in prestack time and depth migration.

But all these seismic technology could not give out solution for mapping sub-basalt sequences of Kerala Konkan-Basin because of heavy thickness of Basalt at Paleocene level and below. Therefore in 2009-10 around



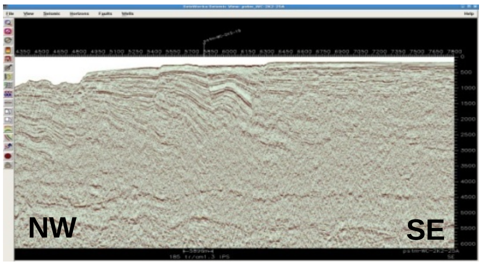


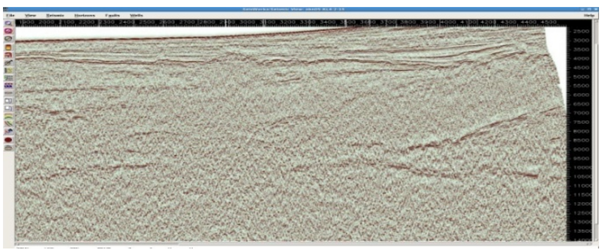
Fig-6, parallel lines, SW7000 & KK-Long-13-19 **Fig-7, pstm_WC-2k2-25A**

In fig-6 a comparison between close parallel lines GXT line SW7000 and long offset line KK-Long-13-19 has been shown, which gives better clarity and continuity of reflectors at deeper level in SW7000 compared to KK-Long-13-19. Fig-7, is WC series lines acquired by DGH in western offshore basin targeting deeper reflectors and imaging is of very good quality.

10000 LKM, 2D long offset data was acquired for NELP-IV, VI &VII and processed using the latest available seismic acquisition and processing techniques to image deeper reflection of Mesozoic sequences. The definition of long-offsets is relative to the depth of the target and can be defined as seismic data recorded at distances as great as three times the predicted depth of the target. By doing this, a wide range of seismic phases are collected, all carrying information about structures and velocities at depth. In conventional processing, most of the seismic phases other than near-vertical reflections are disregarded, whilst in the wide-offset workflow they are used to derive robust 3D velocity models and enhanced seismic images in the time and depth domain. The imaging of 2D long offset was very useful as seismic sections shows good correlatable reflections below basalt.

Seismic energy transmission below the Deccan Trap is constrained by the past acquisition parameters, but recently acquired 2D long-offset data couple with SBN WRRAP has improved the resolution of this deeper sub-basalt section. Since the stacked basalt flows of the Deccan act as an energy transmission barrier, different acquisition techniques need to be implemented for improved resolution within the sub-basalt (Mesozoic) section.

The newly acquired data in the Basin by Long offset (offset 12 km.) and long offset data coupled with SBN WARRP profiling 40-160 km. has shown that these data sets can significantly improve the resolution of the pre-Deccan section. More extreme long offset acquisition techniques (offsets of up to 40-160 kms. – using dual boats), utilising refraction and reflection methods, were used successfully in the NELP-IV area of the Basin to image data below a stacked series of basalt flows.



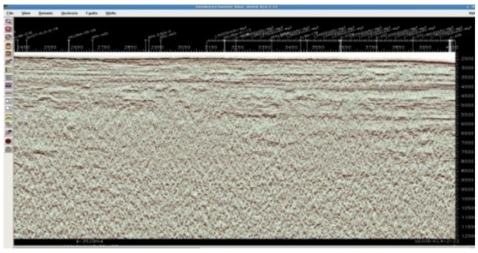


Fig- 8, Long offset line sbn05-KK4-2-15 **Fig-9, Long offset line sbn06-KK4-2-22**

In fig-8 & 9 sections (E-W lines), reflection seismic data acquired through long offset (12 KM) is sufficient enough to provide subsurface imaging even up to Moho through robust multiple attenuation packages and PreSDM through Beam Migration in the Kerala basin. These Beam migrated sections show very much improvement in sub basalt mesozoic section imaging. The crust-mantle boundary “Moho” is clearly seen along the imaged profiles. The lower and upper crust boundary i.e Conrad is distinct towards eastern shelf part in Fig-8. The top part upper crust is the inferred granitic basement. The rift grabens, syn-rift, post-rift sections and anticlinal structural features are seen in the seismic profiles, which demonstrate existence of Mesozoic basin extending to deep basinal part of basin.

Conclusion:

In the Kerala-Konkan Basin, seismic data quality is variable and at some places poor and patchy throughout the basin and the basin is under-explored. Total 18 wells have been drilled and except few most of the wells are on or just off the shelf have encountered only sporadic hydrocarbon shows, and no hydrocarbon accumulations have been proved.

In the Kerala-Konkan Basin the common reflectivity issues are related to reflection ray bending in comparatively hard rock sequences. High velocity (Vp) contrast between lithological boundaries causes the seismic incident energy to move away from normal incidence. As a result, within shallow depths the critical angle is achieved, and therefore, in order to pick and receive transmitted energy from deeper reflectors long steamer cable (long offset data) are a requirement. It is the differing seismic velocities (more than 5000m/s) in basalt, which are usually higher than those of the surrounding sediments, which can result in ray tuning, wave-mode conversion and scattering of seismic waves (Kumar et al, 2004). Whereas most processing is focused on reducing the effect of multiples within the dataset, it is both the effect of scattering and attenuation due to heterogeneity and the presence of multiples which has made sub-basalt imaging difficult. Whereas the long streamer seismic data coupled with WARRP profiling as done in NELP IV area, shown in fig-8 & 9 can penetrate and image pre Deccan sequences, therefore, it is often necessary to use long offset pre-stack multi-component seismic data to improve the image. Deeper events continuity in pre-Deccan section will give more confidence to the interpreters in mapping Mesozoic sediments.

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