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Petroleum system modeling along a dip section of Bengal Basin, India

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Summary

Petroleum system modeling has become a vital part of the petroleum exploration. The petroleum industry now ranks multidimensional petroleum system modeling as the top leadership technology that enhances exploration success and reduces finding costs. The multidimensional petroleum system modeling software incorporates the simulation of basin geometry to assess charge risk associated with each of the various elements of petroleum system by integrating diverse geological, geochemical and engineering data.

More than fifty years of exploration for hydrocarbons in the Bengal Basin has not yet led to a commercial success. Oil and gas indications in a number of drilled wells and seepages have confirmed hydrocarbon generation in the basin. 1-D modeling for the numerical simulation of the burial, temperature and maturity history of source rocks has been carried out at different well locations of Bengal Basin. One dimensional modeling does not, however, handle mass transfer other than in a vertical direction. Therefore, there is a need to use 2-D modeling to model flow of hydrocarbon and petroleum systems analysis for sections within the basin. In this paper, a 2-D petroleum system modeling along a dip section of Bengal Basin has been attempted for the first time to assess hydrocarbon charges and its migration for evaluation of possible hydrocarbon prospectivity in the Permo-Mesozoic and Tertiary realm.

Re look on the source rock confirms excellent source rocks charecteristics in Gondwana sequence. Fair to good source rocks are present in Createaceous and Tertiary sections with mostly type-III kerogen. In the study section, main oil window extends from Gondawana sequence at western edge of Bengal shelf to bottom part of Matla sequence (Miocene) at eastern shelf edge and Hinge zone. The Cretaceous-Tertiary source rocks at eastern shelf edge, slope and hinge zone are within main oil to dry gas window at present-day (0.7 – 4.0 %VRo). Gondwana and Cretaceous prospects may contain hydrocarbon generated (~ 22.5 MMT) during 136 to 30 Ma from terrestrial Gondwana source rocks. Hydrocarbon charge (~ 2.5 MMT maximum) from the Cretaceous and Tertiary sediments during 30 Ma to recent is not sufficient enough for existence of sizable volumes of hydrocarbon reservoir. Study shows that the inadequate hydrocarbon charges are responsible for poor accumulation rather than the leakage and migration losses of hydrocarbon in migration path within Cretaceous and Tertiary sediments.

Introduction

The Bengal Basin, a divergent margin sedimentary basin in the eastern part of Indian shield, appears to have most of the elements required to become an important hydrocarbon province. The basin extends to offshore where the sediment thickness increases as the basin grows deeper with a total sedimentary area of about 90,000 sq. km (up to 200m bathymetry) and includes four tectonic zones: basin margin, stable shelf, hinge zone and deep basin, separated by NE-SW bound step-faults (Fig. 1). More than fifty years of exploration for hydrocarbons in the Bengal Basin has not yet led to a commercial success. Oil and gas indications in a number of drilled wells and seepages have confirmed hydrocarbon generation in the basin. In this paper, we present results of basin simulation and 2-D modeling studies of Bengal Basin in order to understand subsurface generation/expulsion, migration and accumulation/loss of hydrocarbon through geologic time, to predict the timing of

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petroleum generation/expulsion, and for identifying the hydrocarbon charge and accumulation locales

Geology and tectonics

The depositional history of the Bengal Basin is related to the break-up of Gondwana. The tectonic evolution of the margin can be subdivided into four stages: Pre-rift stage (Permo-Carboniferous and Lower Mesozoic time) associated with deposition of continental Gondwana sediments in block faulted troughs. Rift-drift stage (late Jurassic-early Cretaceous time) associated with Rajmahal volcanism and break up of Gondwanaland. Post-rift stage (mid Cretaceous-Paleocene time) witnessed clear differentiation of the basin into shelf, slope and rise. After the regressive phase during Oligocene, the basin experienced a late Tertiary deltaic deposition during lower Miocene-Pliocene times, showing enormous thickening of clastics towards the basin deep.The geology, tectonics and stratigraphy of the basin are discussed by Roy-barman, 1983.

Hydrocarbon occurences

Hydrocarbon indications in the drilled locations ICH and GG (Fig.1) from Eocene to Oligocene section and hydrocarbon show in CH and BOD drilled locations (Fig.1) from Cretaceous/Gondwana and Miocene sequences respectively, have been noticed in Bengal Basin.

Samples and method

Source rock evaluation has been done based on the geochemical data obtained from 29 wells (Fig. 1) comprising total organic carbon, Rock-Eval pyrolysis, vitrinite reflectance, (Peters, 1986; Stach et al., 1982). The study has used IES Petromod software for 2-D Basin modeling. Temperature and vitrinite reflectance data from wells available (GAL, PAL and JAG) were used to calibrate the 2-D model.

Source rocks

Excellent source rocks are present in Gondwana sequence (Pahari et al., 2001). Createaceous and Tertiary sections possess fair to good source rock characteristics (Table-1). Bengal sediments from various formations are mostly Type-III kerogen except some Oligocene to Middle Miocene sediments of GG and DOM (Fig. 2).

Simulations

The model is simulated with efficient hybrid petroleum migration path which is an integration of the Darcy and the flow-path migration methods. Both have used pressure, volume and temperature controlled migration equations. Nature of faults is closed fault throughout the basin evolution and open faults during rifting. Basin history is subdivided into sequences of depositional, non-depositional and erosional events which are specific with respect to time and space. Similarly, structural and tectonic events such as faulting, rifting and volcanic eruptions have been included. Information available on geometry, lithology, stratigraphy and source rock was used as input data for the conceptual model of the basin. The available cross-section was digitized in the modeling software in order to define the coordinates of every layer and structures like faults and basement highs. Each formation/layer is assigned with its pertinent lithology and facies. The lateral variation in the facies, within individual layer is also taken into account (Fig. 3). Heat flow (between 55 to 90 mW/m2) and Paleo water depths of the basin are defined according to tectonic events and change in sea level. The sediment water interface temperatures are based on Wygrala (1989). The kerogen-hydrocarbon kinetics used in the model for tertiary source rocks is based upon Burnham (1989) _T3 where activation energy range is between 48-68Kcal/mol with maxima at 52Kcal/mol and HI is 160, Behar_et_al (1997) _T3-(Mahak) where activation energy range is between 50-72Kcal/mol with maxima at 60Kcal/mol and HI is 100. The kinetics of Ungerer(1990)_T3- (Are) where activation energy range is between 54-74Kcal/mol with maxima at 58Kcal/mol and HI is 265 are used for Gondwana source rocks.

Layer (Fig.4)	Formations/Facies	Age at bottom (Ma)	Petroleum System Elements	Lithology	TOC%	HI	Kerogen Kinetics
A	Bengal Allu	1.59	Overburden Rock	SAND&SILT	0	0	none
B	Debgram	5.3	Seal Rock	Debgram	0	0	none
	Ranaghat		Reservoir Rock	Ranaghat	0	0	none
C	Bodra	15.97	Reservoir Rock	Pandua	0	0	none
	Joynagar		Source Rock	Pandua shaly	1	100	Behar_et_al(1997)_T3-(Mahak)
	Debipur		Reservoir Rock	Pandua	0	0	none
	Matla top		Source Rock	Matla	1	100	Behar_et_al(1997)_T3-(Mahak)
D	Diamond harbour	25	Source Rock	Diamond hbr	1	100	Behar_et_al(1997)_T3-(Mahak)
	Matla mid		Source Rock	Matla mid	2	160	Burnham(1989)_T3
E	Burdwan	33.9	Reservoir Rock	Burdwan	0	0	none
	Memari top		Reservoir Rock	Memari top	0	0	none
	Memari		Source Rock	Memari	1	100	Behar_et_al(1997)_T3-(Mahak)
	Golf green		Reservoir Rock	Golf green	0	0	none
	Matla bot		Source Rock	Matla shaly	2	160	Burnham(1989)_T3
F	Hooghly	40.4	Source Rock	Kopili	2	117	Behar_et_al(1997)_T3-(Mahak)
G	Up Kalighat	52.1	Reservoir Rock	Up Sylhet	0	0	none
	Mid Kalighat		Source Rock	Mid sylhet	1	125	Behar_et_al(1997)_T3-(Mahak)
	Low Kalighat		Reservoir Rock	Low Sylhet	0	0	none
	Kalighat basinside		Source Rock	Sylhet Shaly	2	125	Behar_et_al(1997)_T3-(Mahak)
H	Up Jalanghi	58.7	Reservoir Rock	Up Jalanghi	0	0	none
	Mid. Jalanghi		Source Rock	Mid. Jalanghi	2.0	144	Burnham(1989)_T3
	Low Jalanghi		Reservoir Rock	Low Jalanghi	0	0	none
	Jalanghi basinside		Source Rock	Jalanghi shaly	2.5	150	Burnham(1989)_T3
	Ghatal	63	Source Rock	Ghatal	1.5	100	Behar_et_al(1997)_T3-(Mahak)
I	Bolpur	83.5	Reservoir Rock	Bolpur	0	0	none
	Dhananjaypur		Source Rock	Dhananjaypur	1.5	100	Behar_et_al(1997)_T3-(Mahak)
J	Rajmahal	145.5	none	Basalt (normal)	0	0	none
K	Panchet	239	Reservoir Rock	SANDshaly	0.4	0	none
	Ranigang	273	Source Rock	COALshaly	17.3	288	Ungerer(1990)_T3-(Are)
	Barakar	288	Source Rock	COALshaly	5.3	316	Ungerer(1990)_T3-(Are)
	Talchir	299	None	SANDshaly	0.52	0	none

Table 1: Input data for modelling

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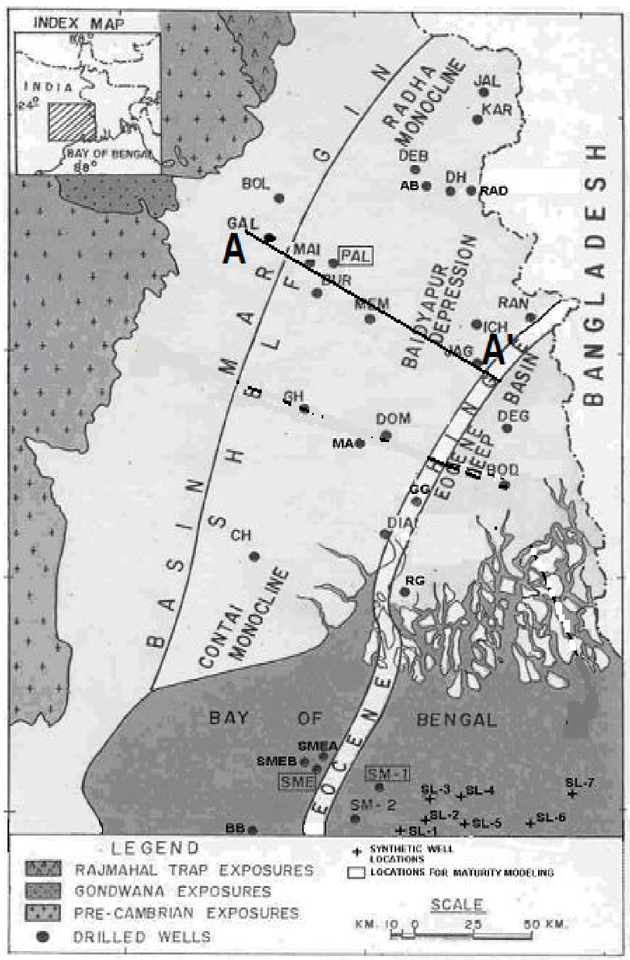

Fig. 1: Map of Bengal Basin showing cross section AA'

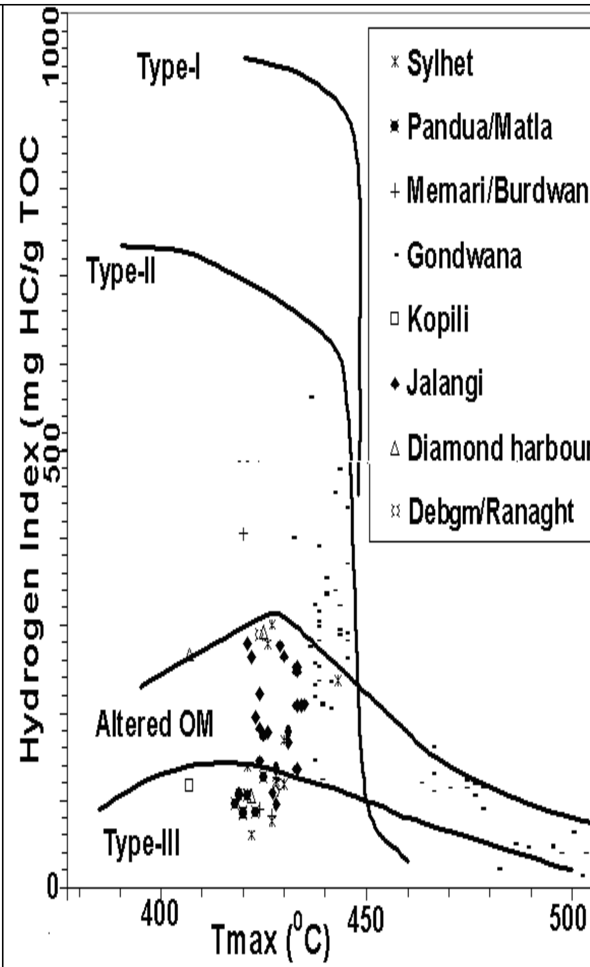

Fig. 2: Kerogen type for sediments of Bengal Basin

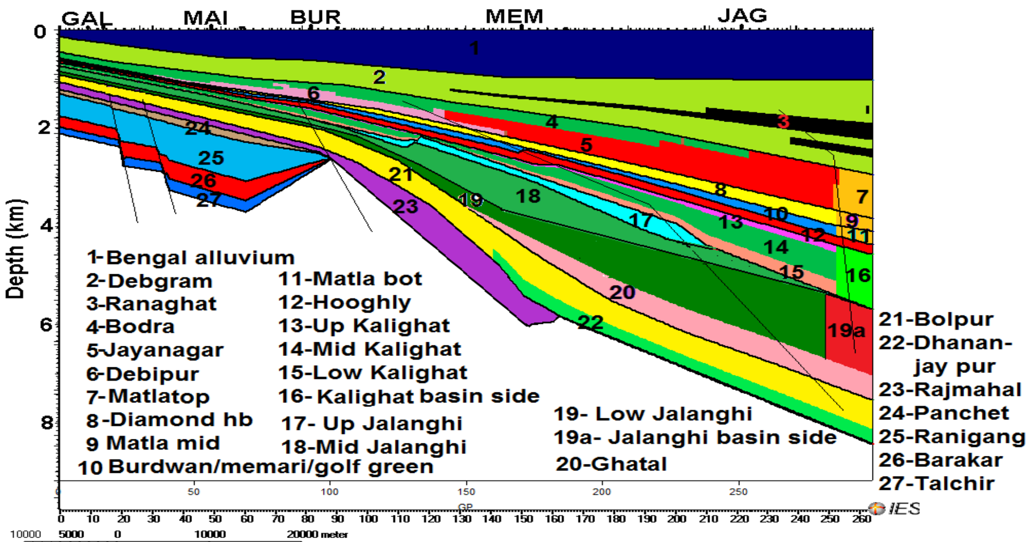

Fig. 3: Facies map along cross section AA' (Fig. 1)

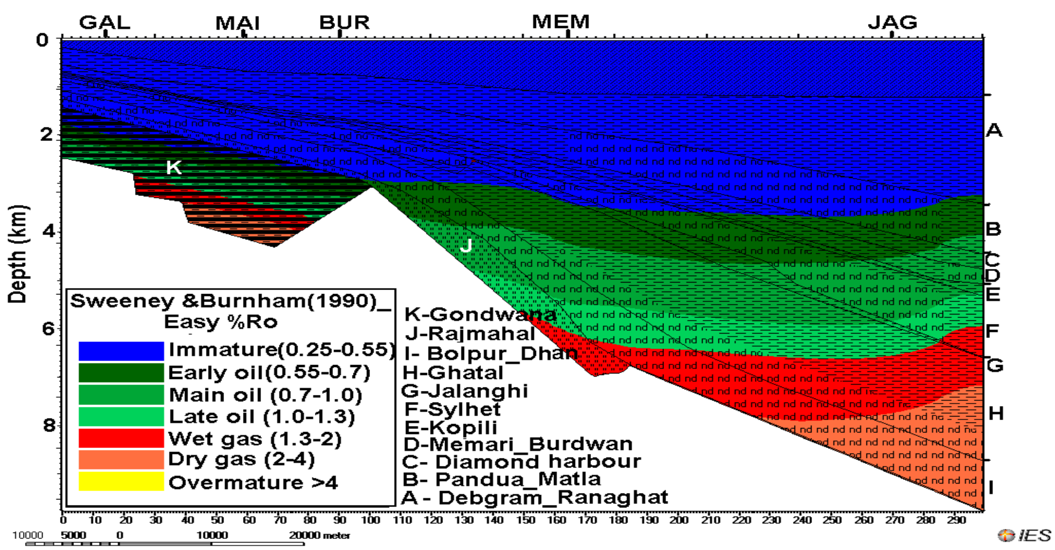

Fig. 4: Progression of maturity along cross section AA' (Fig. 1)

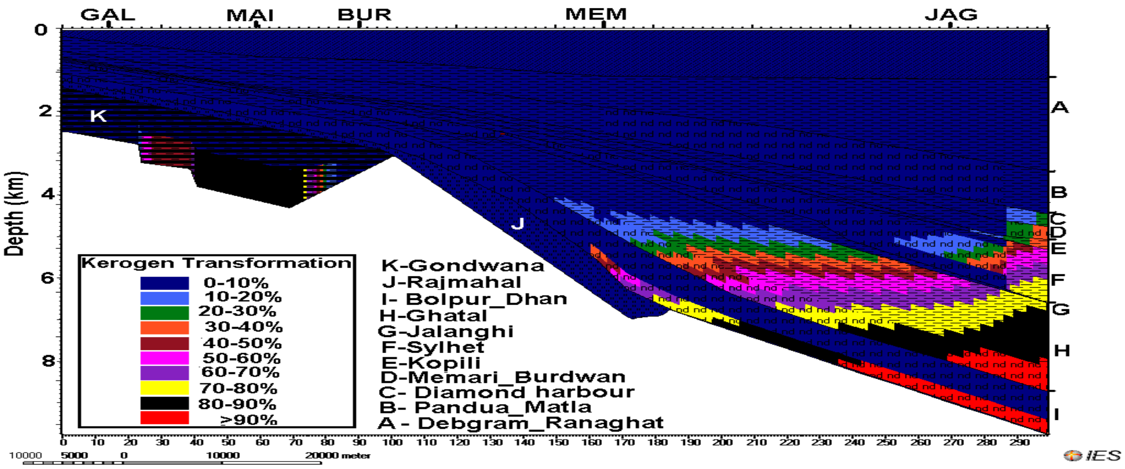

Fig. 5: Kerogen transformation along cross section AA' (Fig. 1)

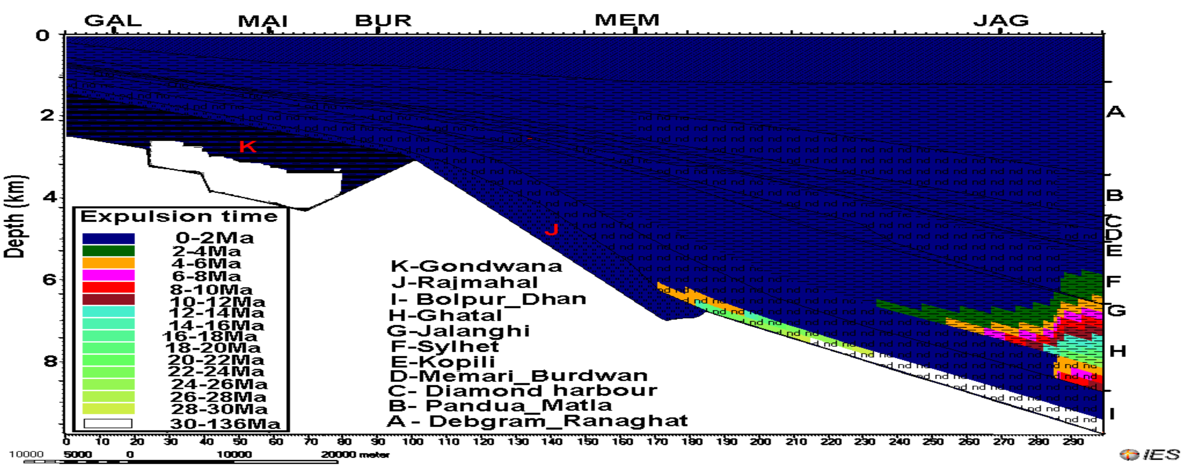

Fig. 6: Expulsion time along cross section AA' (Fig. 1)

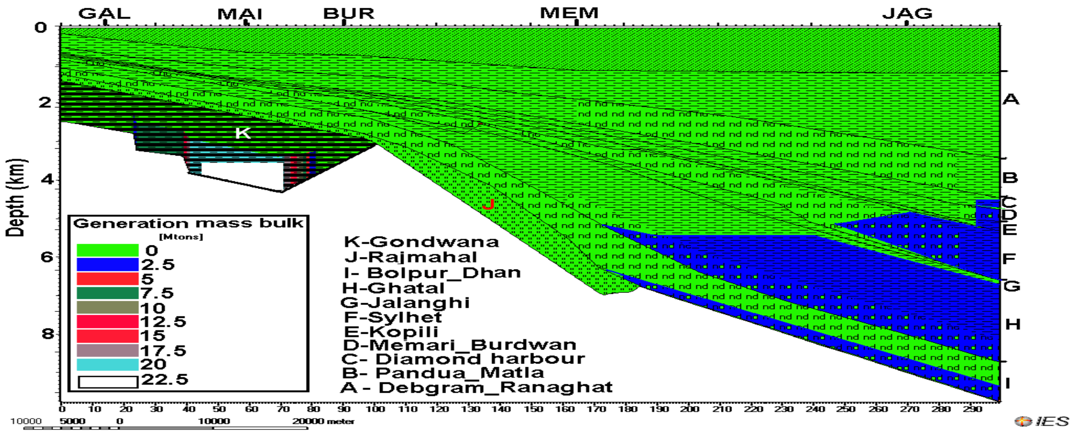

Fig. 7: Hydrocarbon generation mass bulk along cross section AA' (Fig. 1)

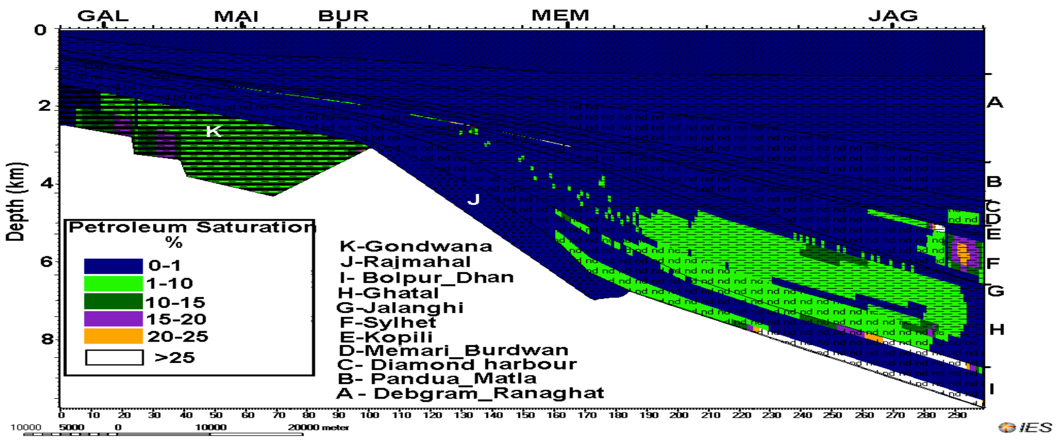

Fig. 8: Petroleum saturation along cross section AA' (Fig. 1)

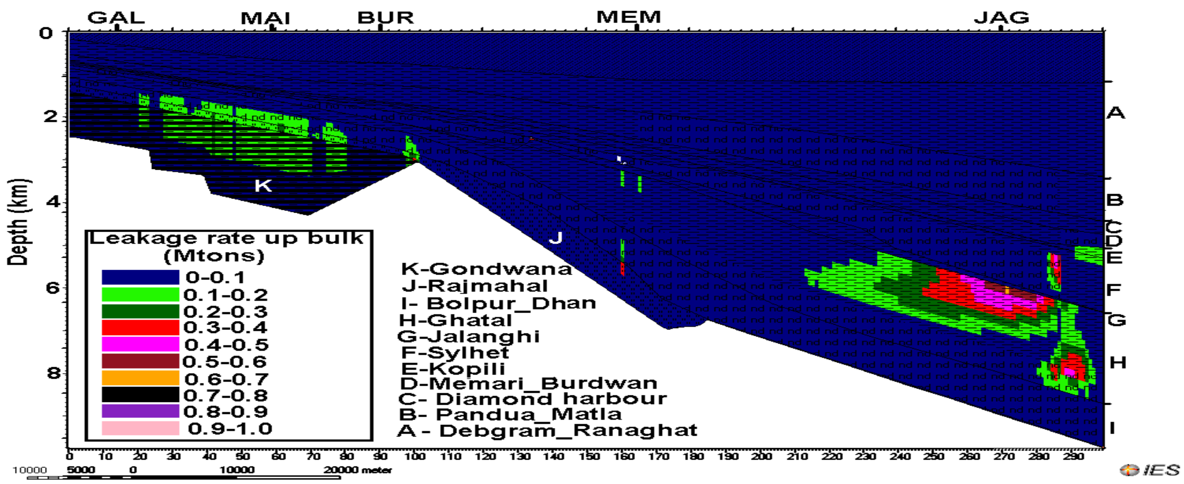

Fig. 9: Leakage bulk along cross section AA' (Fig. 1)

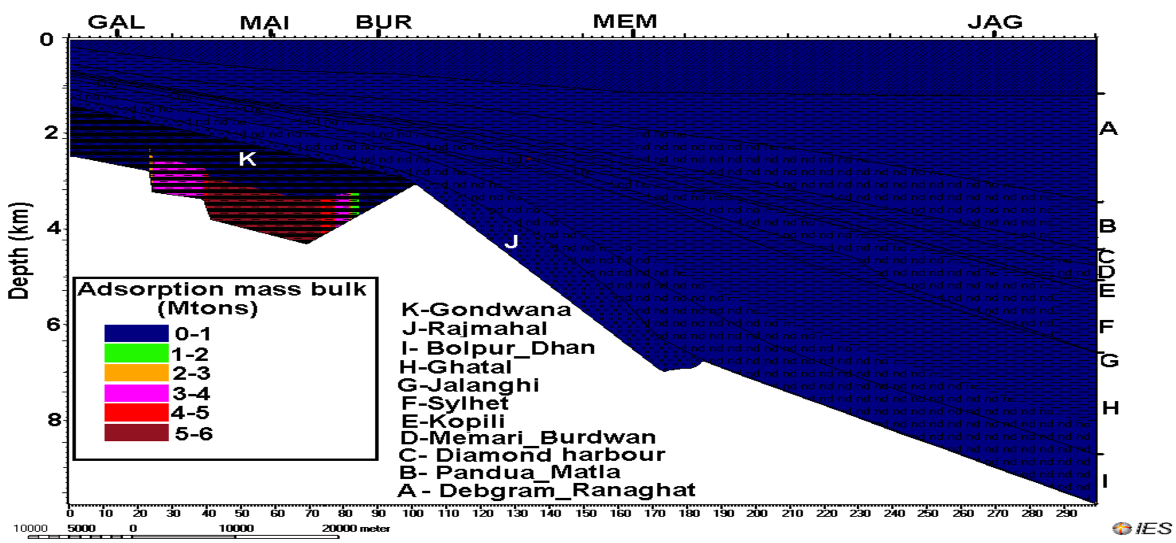

Fig. 10: Adsorption bulk along cross section AA' (Fig. 1)

Results & conclusions

Excellent source rocks are present in Gondwana sequence. Cretaceous and Tertiary sections possess fair to good source rock characteristics in study section. Bengal sediments from various formations are mostly Type-III kerogen except some Oligocene to Middle Miocene sediments of GG and DOM. The Mio-Pliocene deposits seem to become less prolific with depth, and a gradual facies change to basinwards can be observed through the succession. Hence, the deeper parts of the succession are less rich in organic carbon and seem to contain a greater proportion of terrigeneous type III kerogen. However, better source characteristics of Paleogene sediments towards basinal side could not be ruled out.

In the study section, main oil window extends from Gondawana sequence at western margin of Bengal shelf to bottom part of Matla sequence (Miocene) at eastern shelf edge and Hinge zone (Fig. 4). The Cretaceous-Tertiary source rocks at eastern shelf edge, slope and hinge zone are within the main oil to dry gas window at present-day (0.7 – 4.0%VRo). Further basinwards, these source rocks may have already generated its full potential and could be over mature at present. Kerogen transformation has crossed 10% at eastern shelf edge and gone up to about 100% at hinge zone (Fig. 5) for Cretaceous-Tertiary source rocks.

Gondwana and Cretaceous prospects may contain some hydrocarbon generated (~ 22.5 MMT) during 136 to 30 Ma from terrestrial Gondwana source rocks. Whereas, Cretaceous and Tertiary prospects may hold hydrocarbon charge (~ 2.5 MMT) generated during 30 Ma to recent (Fig. 6 & Fig. 7)). Petroleum saturation in Cretaceous-Tertiary source rocks are only 10% at eastern shelf edge and gone up to about 30% at deeper sediments in hinge zone (Fig. 8).

The end-results of the simulation studies reflect the possibility of the nonexistence of sizable volumes of liquid and gaseous hydrocarbon that could be trapped against the structural and stratigraphic traps. As the likely better source rock is around 100 km from the shelf margin, the charge has to occur via long distance migration, one can only speculate migration losses could be enormous. Hence valid traps and top/lateral seals seem to be the critical factors to keep hydrocarbons from leaking out of the system. But study shows inadequate hydrocarbon charges are responsible rather than leakage and adsorption of hydrocarbon in migration path within Cretaceous and Tertiary sediments for poor accumulation (Fig.9 & Fig.10).

References

Behar, and PG Hatcher, 1997, Experimental determination of the reaction kinetics and product ... eds., Advances in Petroleum Geochemistry 1981: p. 775-787

Burnham, A. K., 1989. A simple model of petroleum formation and cracking. Lawrence Liverpool Lab. Report. UCID 21665, March,1989

Pahari, S., Varshney, M., Banerjee, A., 2001.Geochemical data book and geochemistry of Bengal Basin, KDMIPE report.

Peters, K.E. 1986. Guidelines for evaluating petroleum source rocks using programmed pyrolysis. American association of petroleum geologists bulletin, 70,319-329.

Roybarman, A. 1983.Geology and hydrocarbon prospects of west Bengal, , Petroleum Asia Journal, p.51-56.

Stach, E., Machowsky, M., Teichmuller, M., Taylor, G.H., Chandra, D., &Teichmuller,R. 1982. Coal petrology, (3rd ed.) Berlin: Borntraeger

Sweeny, J.J. and Burnham, A.K. 1990. Evaluation of a simple model of vitrinite reflectance based on chemical kinetics: AAPG Bulletin, v. 74, p.1559-1570.

Ungerer, P.M.1990. Basin evaluation by integrated two-dimensional modeling of heat transfer, fluid flow, hydrocarbon generation and migration. Bulletin of AAPG. v74 i3. 309-335

Wygrala B. P., 1989. Integrated study of an oil field in the southern Po basin, northern Italy. Berichte kernforschungsanlage julich 2313:p.217

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