EVIDENCE OF SHALLOW LITHOSPHERE AND CRUST IN THE WESTERN CONTINENTAL MARGIN OF INDIA THROUGH MODELING OF GRAVITY DATA

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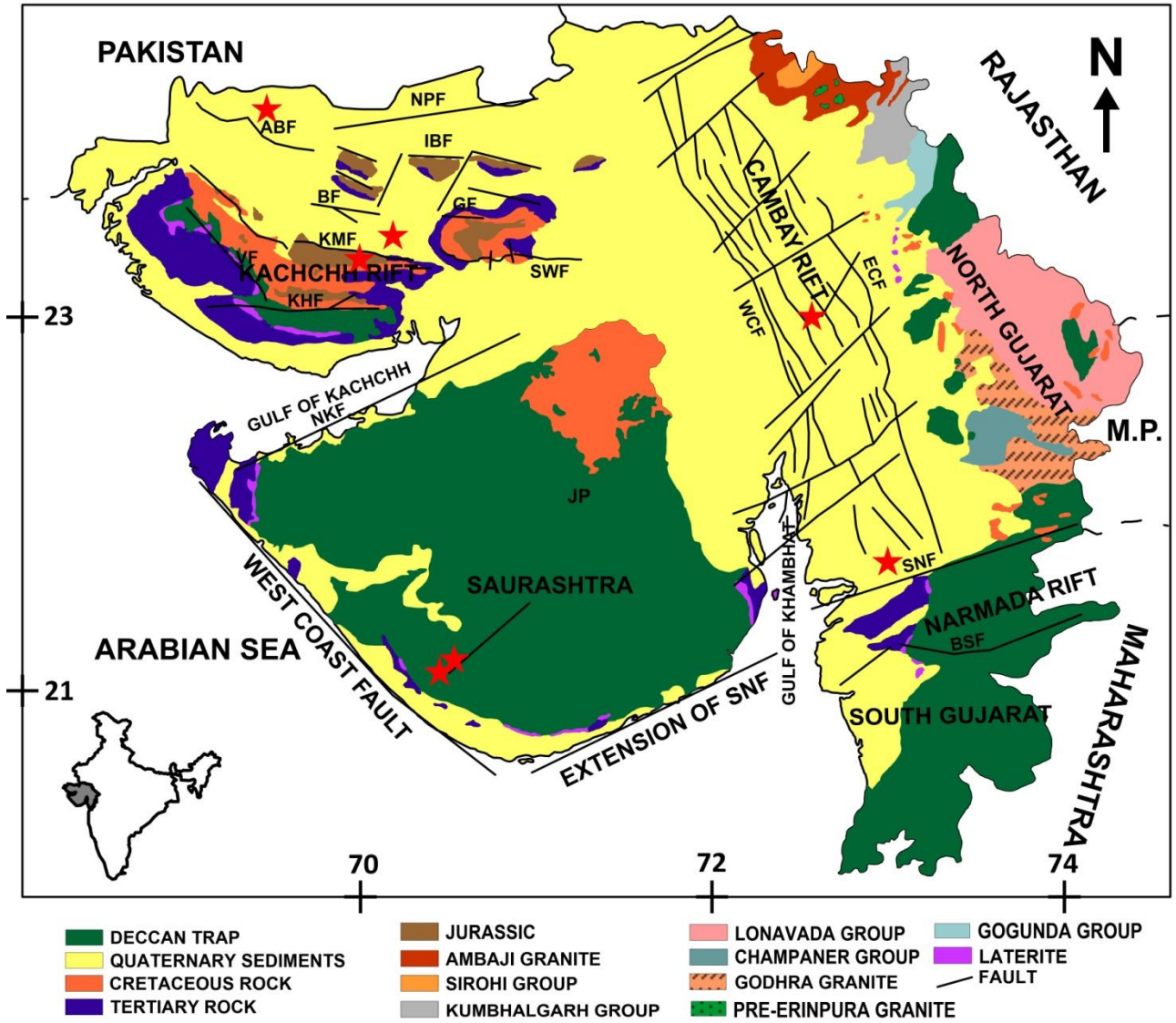
LOCATION, GEOLOGY AND TECTONICS OF THE STUDY AREA



1. Geological and tectonic map of the study area (after Biswas, 1987; Merh 1995)

- WCMI comprises of the **Saurashtra** peninsula along with the three pericratonic rift system **Kachchh**, **Cambay** and **Narmada**.
- Presence of a wide spectrum of rocks type of age ranging from the Precambrian, Mesozoic and Cenozoic era.
- Witnessed two of the deadliest earthquakes in the span of last two centuries of magnitude>7, the **Allah Bund (1819)** and the **Bhuj (2001)** earthquake.

PREVIOUS STUDIES

Various geophysical techniques have been used to study the lithospheric structure

Earth and Planetary Science Letters
Volume 165, Issue 1, 15 January 1999, Pages 145-155

A low seismic wavespeed anomaly beneath northwestern India: a seismic signature of the Deccan plume?

B.L.N Kennett a, S Widiyantoro b

Imprints of volcanism in the upper mantle beneath the NW Deccan volcanic province

G. Mohan ; M. Ravi Kumar ; Dipankar Saikia ; K.A. Praveen Kumar ; Pankaj Kumar Tiwari ; G. Surve

Lithosphere (2012) 4 (2): 150–159.

AGU100 ADVANCING EARTH AND SPACE SCIENCE
JGR
Journal of Geophysical Research: Solid Earth

RESEARCH ARTICLE
10.1029/2018JB015947

Seismic Imprints of Plume-Lithosphere Interaction Beneath the Northwestern Deccan Volcanic Province

Key Points:
- Crust and upper mantle shear wave structure beneath the northwestern Deccan Volcanic Province (DVP) from surface wave tomography

Jyoti Sharma[1,2], M. Ravi Kumar[1,3], Ketan Singha Roy[1], and P. N. S. Roy[2,4]

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Structure, mechanical properties and evolution of the lithosphere below the northwest continental margin of India

G. Srinivasa Rao, Manish Kumar & M. Radhakrishna

International Journal of Earth Sciences 107, 2191–2207(2018) | Cite this article

Lithospheric structure below the eastern Arabian Sea and adjoining West Coast of India based on integrated analysis of gravity and seismic data

M. Radha Krishna, R.K. Verma & Arts K. Purushotham

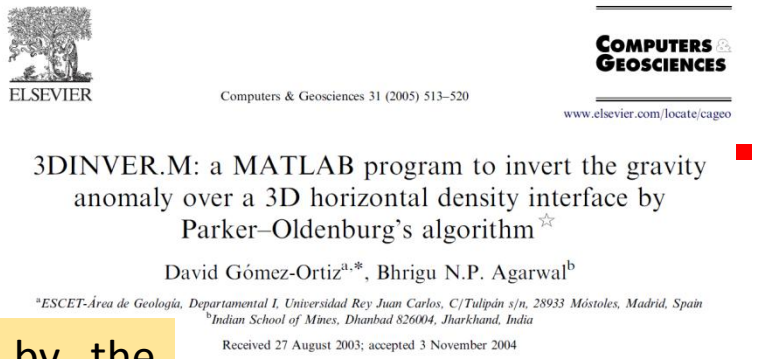
Marine Geophysical Researches 23, 25–42(2002) | Cite this article

- Most of the studies are based on **seismological** method.
- Studies based on gravity method have been done along the profile.
- The area needs to reinvestigate in light of gravity data.

GRAVITY DATA, PROCESSING AND METHODOLOGY

Gravity data and processing

- Satellite derived **World Gravity Model 2012** (WGM 2012) is used in the present study.
- EGM 2008 gravity data is publicly released by the National Geospatial-Intelligence Agency (NGA) EGM Development Team.
- This gravitational model is complete to spherical harmonic degree and order **2190.**
- EGM 2008 gravity data is generated by the integration of GRACE satellite gravity, altimetry and additional terrestrial data with an average **spatial resolution of 0.1°** .
- Free Air anomaly data is processed for the Bouguer and Terrain corrections using Bouguer slab density of 2.67 gm/cc and ETOP1 elevation data.



ELSEVIER

Computers & Geosciences 31 (2005) 513–520

COMPUTERS & GEOSCIENCES

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3DINVER.M: a MATLAB program to invert the gravity anomaly over a 3D horizontal density interface by Parker–Oldenburg's algorithm ☆

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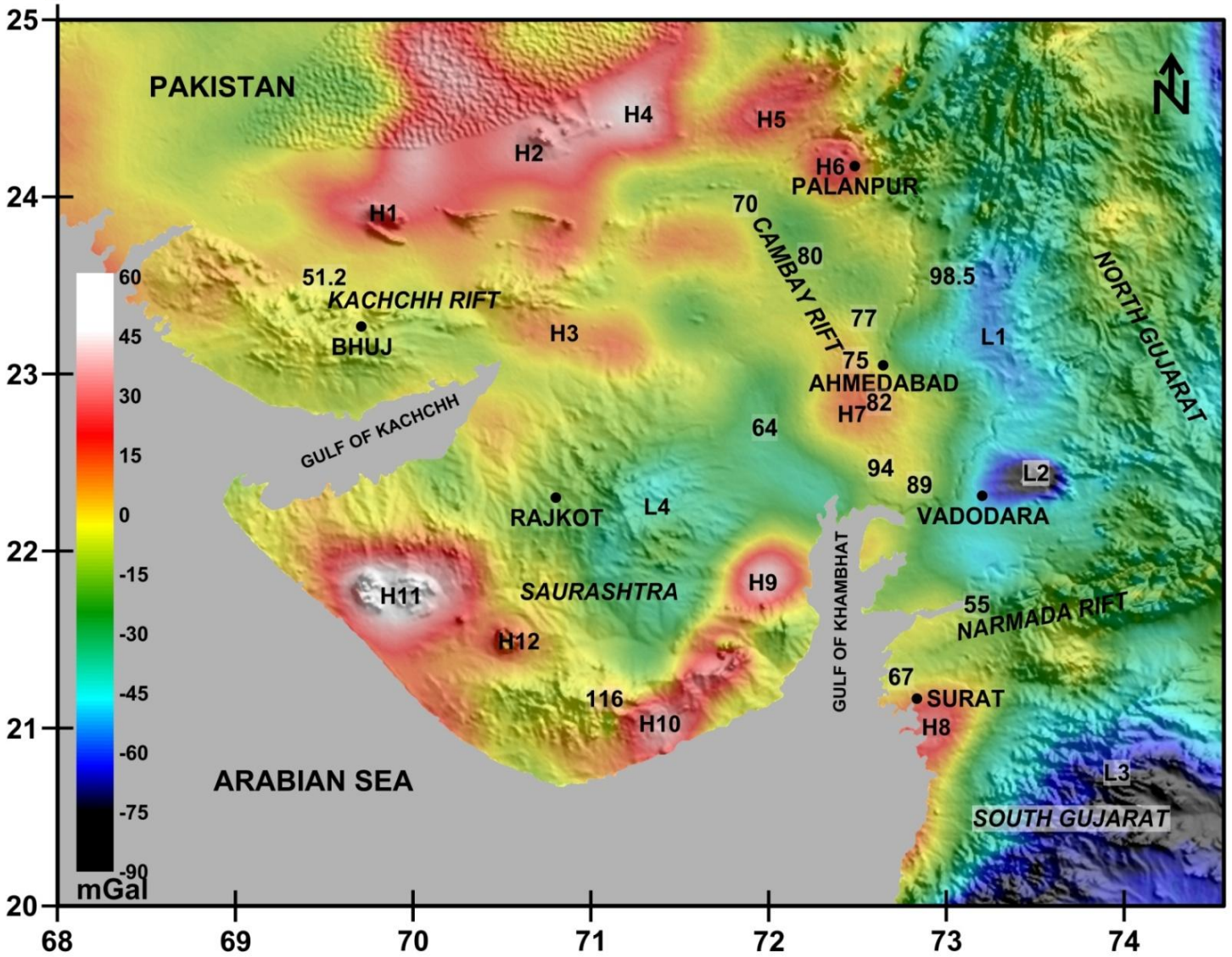
Inversion modelling

- **3DINVERSE MATLAB** code is used to invert the Bouguer anomaly.
- This code is based on the formulation of **Parker and Oldenburg**. It calculates inversion for a simple two-layer model with fixed density contrast over the interface, the Moho or Lithosphere.

Forward modelling

- Commercial software package **GMSYS** (Gravity and Magnetic Modelling Software) is used.
- It calculates the gravity response of multiple polygonal shaped bodies of finite strike length based on the formulation of Talwani et al. (1959).

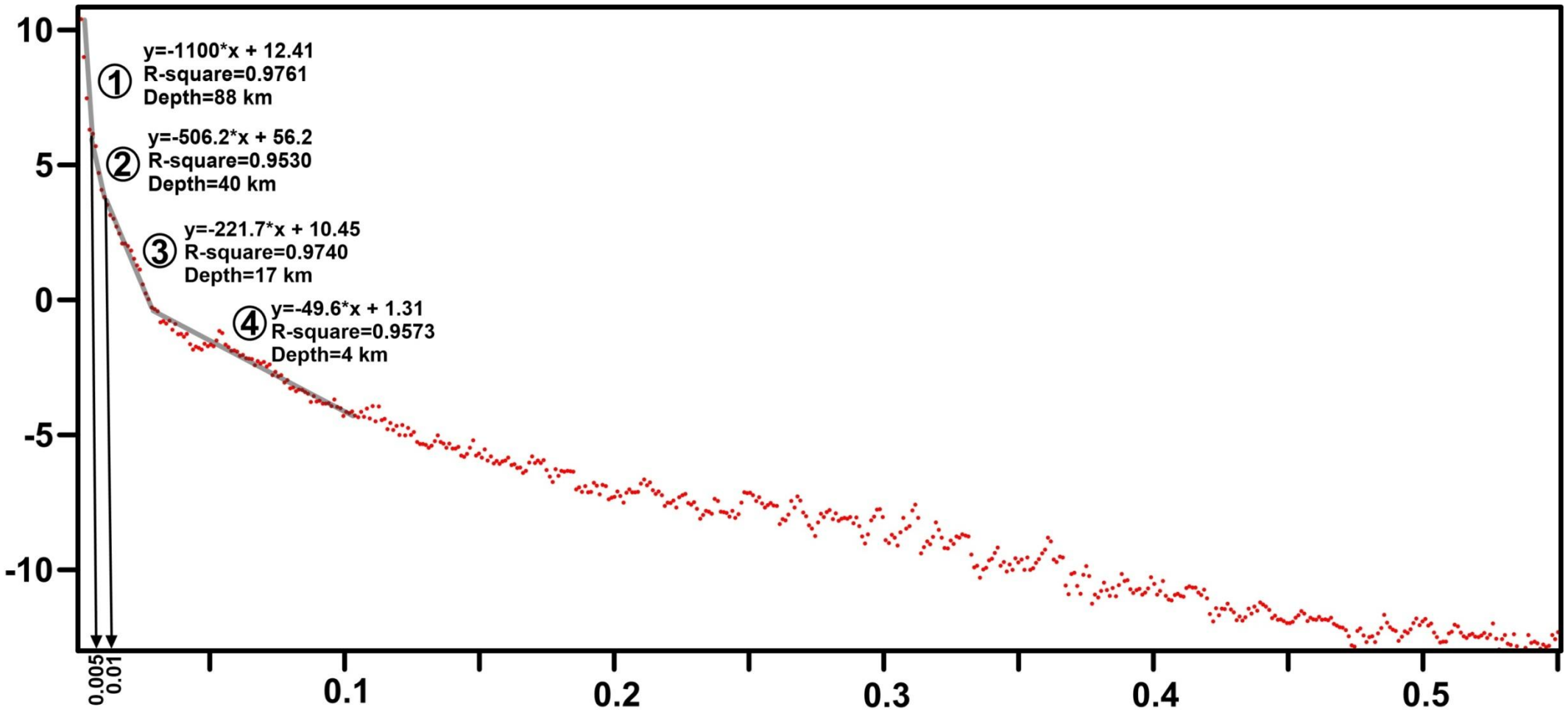
BOUGUER ANOMALY MAP



2. Complete Bouguer anomaly map of the study area

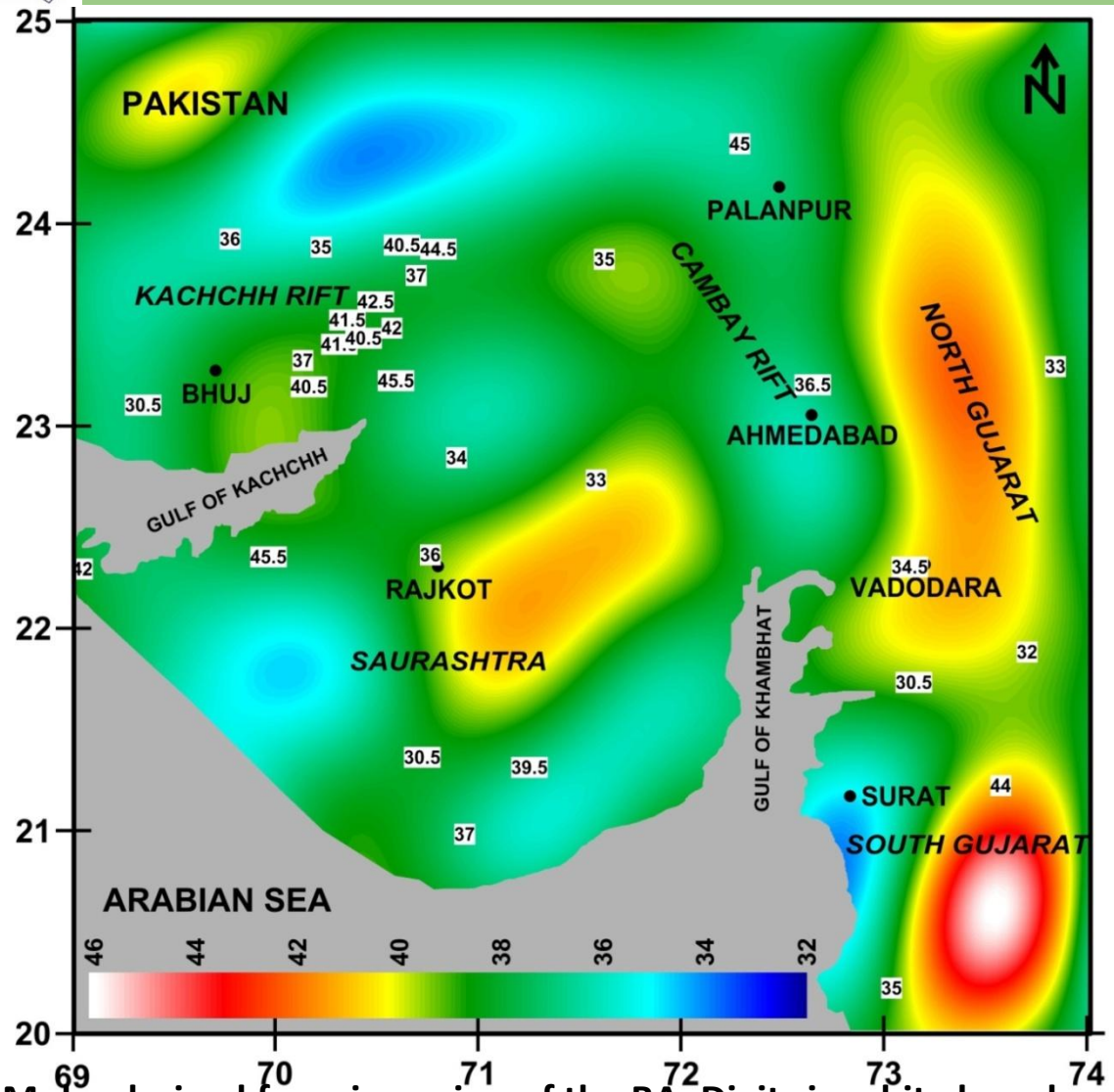
- The BA value over the WCMI varies between **-90 to +60 mGal .**
- The study area has eleven prominent gravity highs (H1-H11) and three prominent gravity lows (L1-L4).
- The Cambay rift is characterised by high BA along the central part.
- The Saurashtra peninsula has several gravity highs associated with **volcanic plugs**.
- Northern part of the Kachchh rift reflects high BA value which possibly associated with shallow depth of basement.

POWER SPECTRUM ANALYSIS OF BOUGUER ANOMALY AND FILTER DESIGN



3. Power spectrum analysis and cut-off frequency optimization

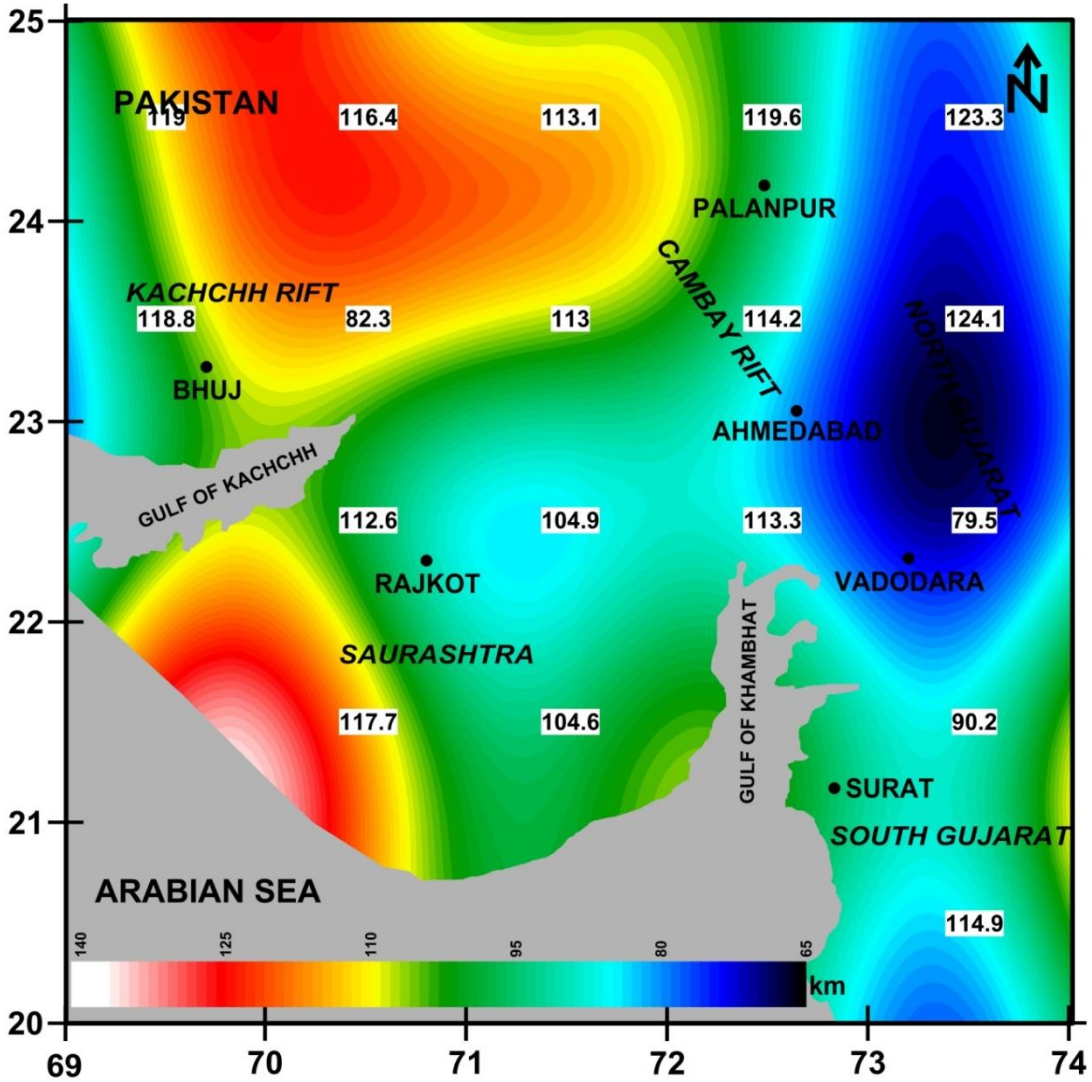
CRUST-MANTLE BOUNDARY



4. Moho derived from inversion of the BA. Digits in white box shows Moho calculated from RF (after Chopra et al., 2013; Rao et al., 2015)

Zones	Moho depth (km)
Kachchh rift	33-42
Cambay and North Gujarat	34-42
Narmada rift and South Gujarat	36-44
Saurashtra peninsula	34-41

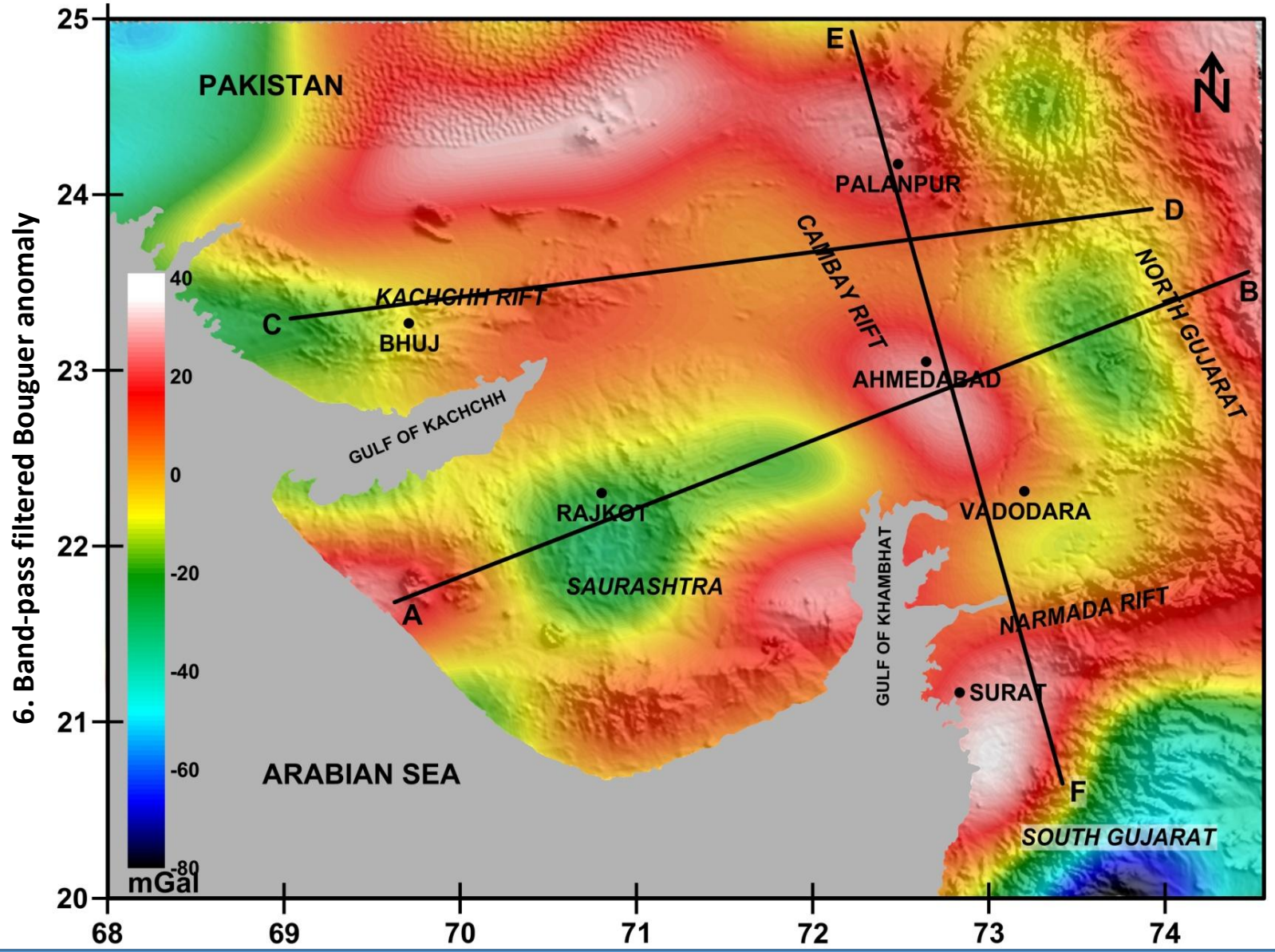
LITHOSPHERE-ASTHENOSPHERE BOUNDARY



Zones	LAB depth (km)
Kachchh rift	82-124
Cambay and North Gujarat	68-110
Narmada rift and South Gujarat	80-95
Saurashtra peninsula	85-135

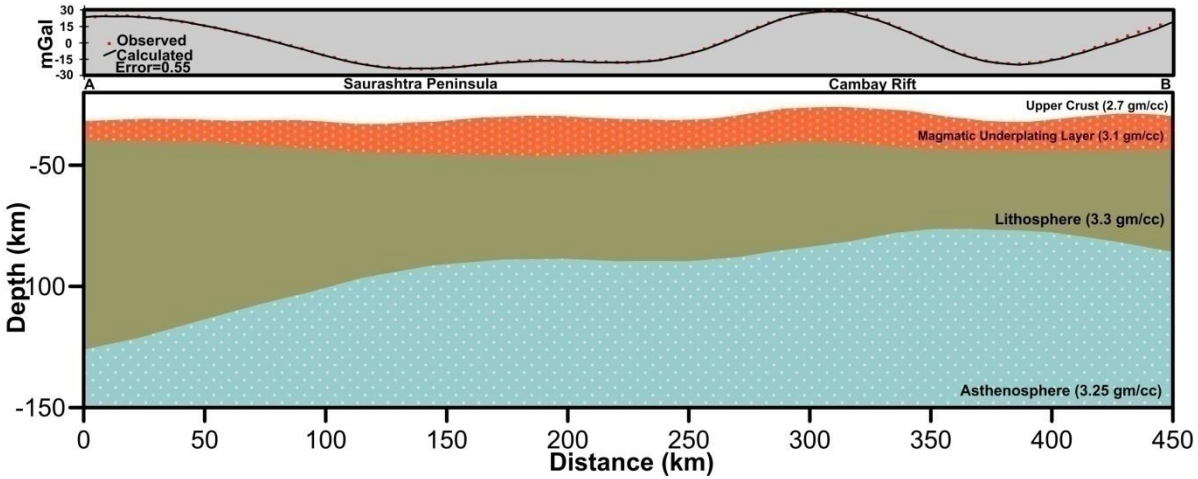
5. LAB derived from inversion of the BA. Digits in white box shows LAB calculated from SWT (after Sharma et al, 2019)

FILTERED BOUGUER ANOMALY

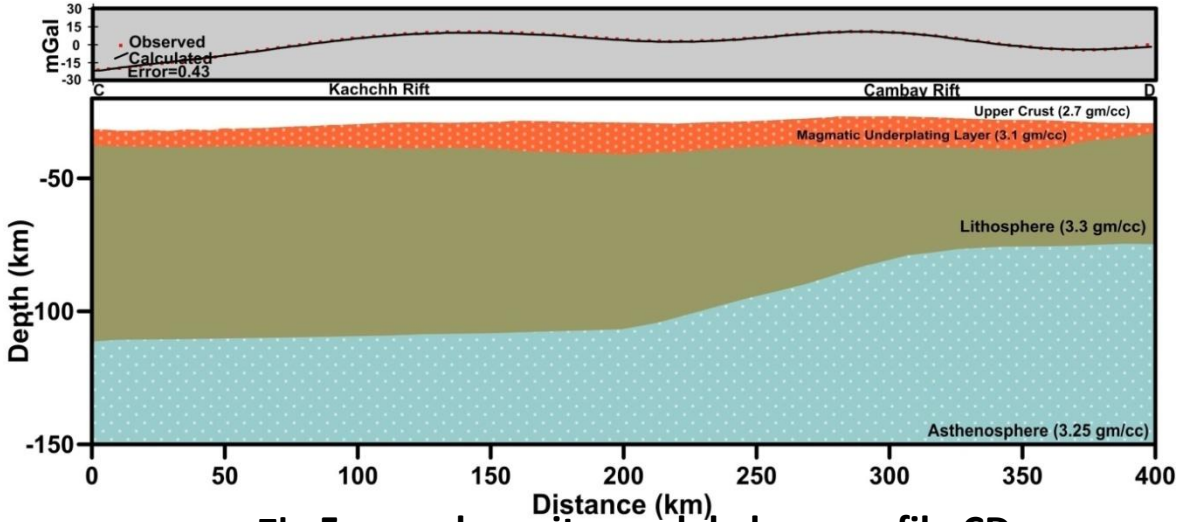


- Band-pass filter of cut-off wavelength: **100 and 500 km**
- AB, CD and EF are the profiles along which 2.5D gravity modelling is performed.
- Inverted Moho and LAB thickness are used as a constraint for forward modelling.

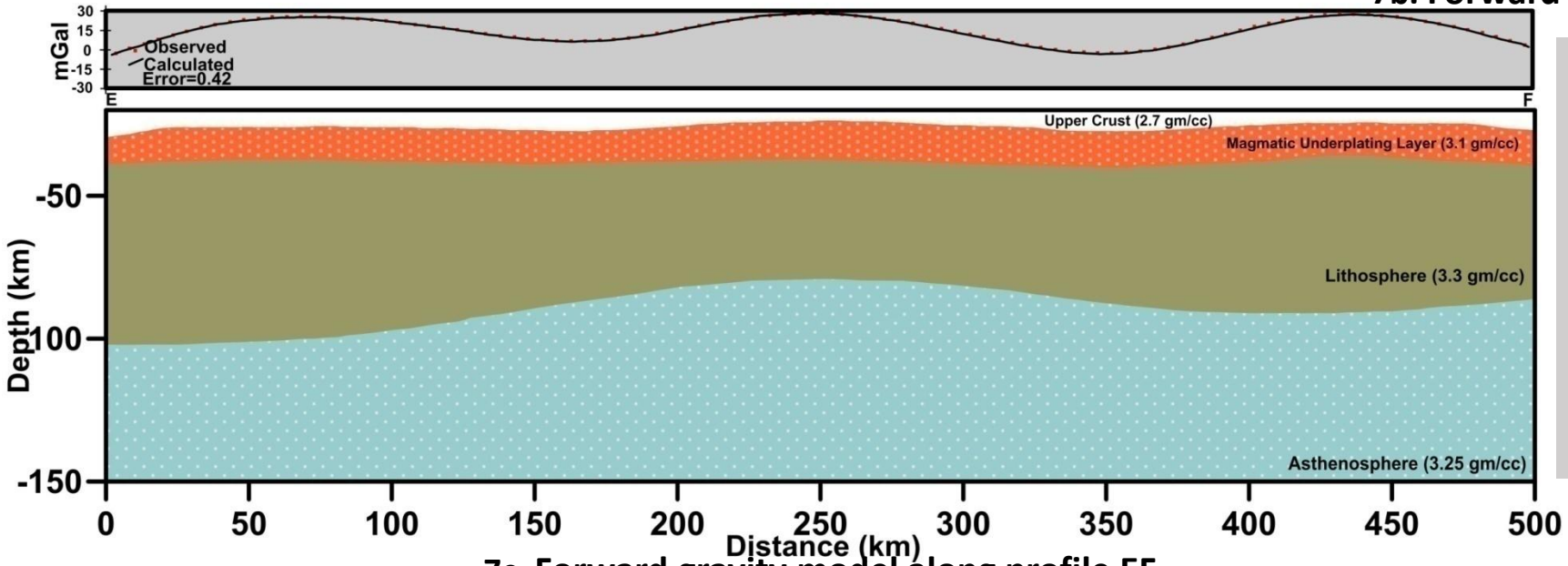
FORWARD GRAVITY MODELING



7a. Forward gravity model along profile AB



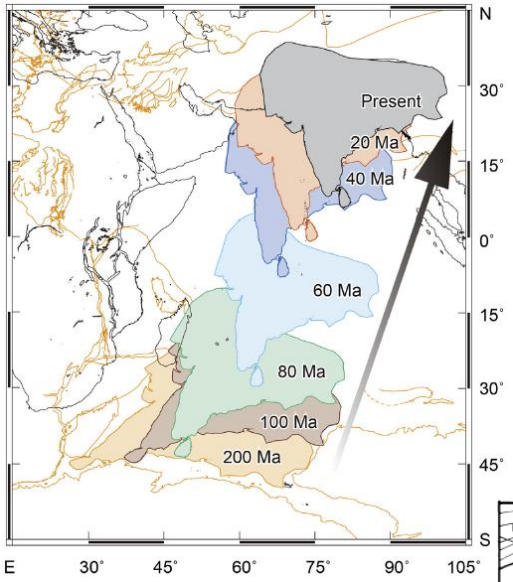
7b. Forward gravity model along profile CD

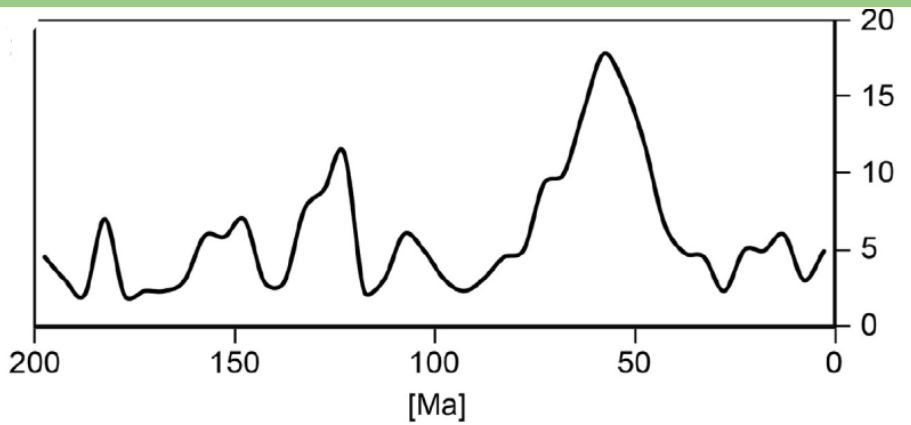


7c. Forward gravity model along profile EF

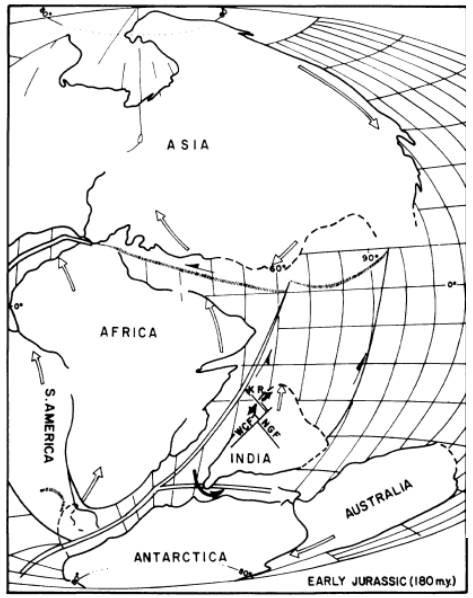
- Magmatic underplating layer (MUL) is present throughout the study area.
- The Cambay rift has thickest **MUL**.
- Thickness of the MUL decreases towards western part of the study area.

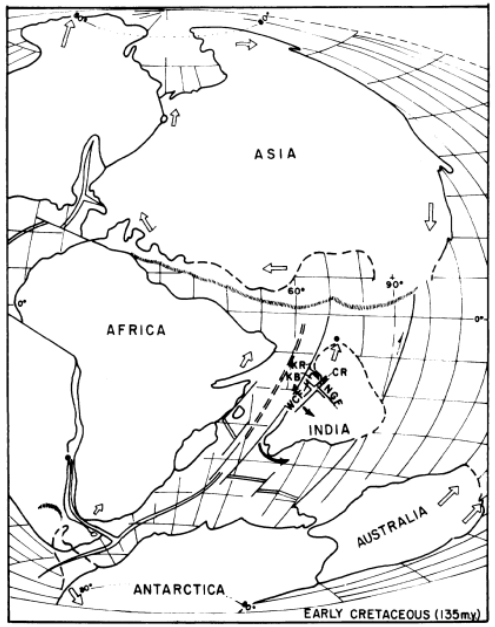
DISCUSSION

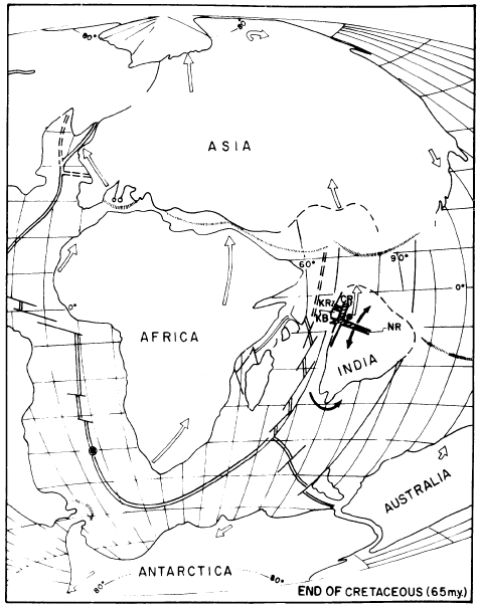




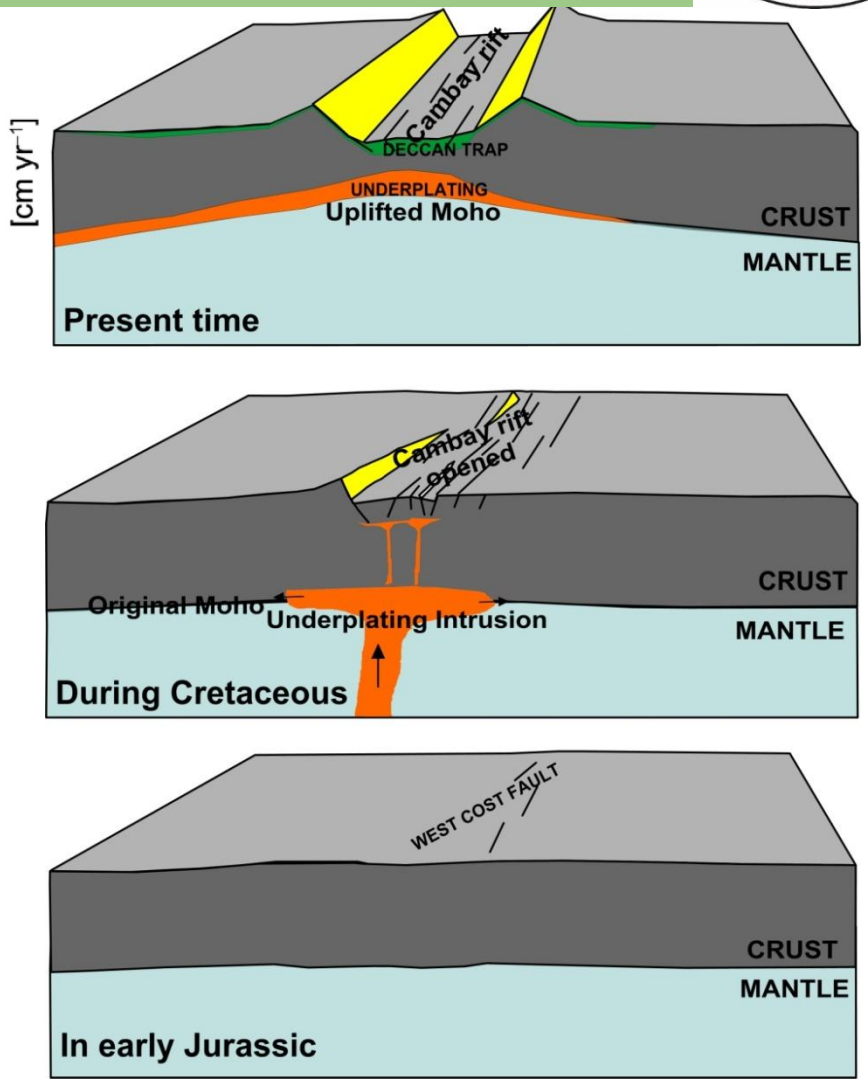
8. Position and speed of Indian plate from 200 Ma to 0 Ma (after Setan et al. 2012)







9. Development of the rifts (after Biswas 1982)



10. Formation of magmatic underplating layer and evolution of the Cambay rift (after Chouhan et al. 2020)

CONCLUSIONS

•The Moho depth variation in the Kachchh rift, Cambay rift and north Gujarat, Narmada rift and south Gujarat, Saurashtra and north Gujarat is 33 and 42 km, 34 and 42 km, 36 and 44 km, 34 and 41 km, respectively.

•2.5D forward modelling of the regional BA reveals the presence of the MUL in the lower crust throughout the NWDVP and having maximum thickness in the Cambay rift.

•The LAB in the Kachchh rift, Cambay rift and north Gujarat, Narmada rift and south Gujarat, Saurashtra and north Gujarat varies between 82 and 124 km, 68 and 110 km, 80 and 95 km and 85 and 135 km, respectively.

•The crustal and lithospheric thickness is shallowest over the Cambay rift where the MUL layer is thickest. This is possibly because this part is the zone of thin and weak lithosphere which might facilitate the Deccan volcanism. The present result also gives the favorable evidence for the existence of mantle plume theory.

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IMPORTANT REFERENCES

•Biswas, S.K., 1982, Rift basins in western margin of India and their hydrocarbon prospects with special reference to Kutch Basin. AAPG Bulletin, 66, 1497-1513.

•Gomez-Ortiz, David, Agarwal, B.N.P., 2005. 3DINVER.M: a MATLAB program to invert the gravity anomaly over a 3D horizontal density interface by Parker– Oldenburg's algorithm. Computers & Geosciences 31, 513–520.

•Oldenburg, D.W., 1974. The inversion and interpretation of gravity anomalies. Geophysics 39(4), 526-536.

•Parker, R.L., 1973. The rapid calculation of potential anomalies. Geophysical Journal International 31(4), 447-455.

•Pavlis, NK, Holmes, SA, Kenyon, SC & Factor JK 2012, The development and evaluation of the Earth gravitational model 2008 (WGM2008). Journal of Geophysical Research, vol. 117: B04406.

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THANK YOU