PS Understanding the Deformation of the Naga Thrust Triangle Zone, NE India, Using Structural Modeling of 2D Seismic Data*

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Abstract

Seismic interpretation of structures associated with complex zones can be tested for viability using multiple methods. Combined methods of multiscale waveform inversion and prestack depth migration provide a two-step process to describe large wavelength and small wavelength features in the same image. This provides a detailed base image for balanced reconstruction of a cross section. The processed seismic line created in this study was interpreted and restored to provide a mechanically feasible model for the Naga Thrust Triangle Zone (NTTZ).

2-D seismic data was acquired in the central part of the Naga Thrust and Fold Belt (NTFB) in NE India. The study area is approximately 20 kilometers southwest of the Digboi oil field. The initial 2-D seismic data was imaged with a combination of traveltime inversion and prestack depth migration (PSDM). An improved image was acquired from a combination of multiscale waveform inversion and PSDM. The seismic line was interpreted using images from all stages of the processing and was restored using line length and key bed balancing techniques.

The cross-section created indicates minor deformation above the Naga thrust, via a series of back-thrusts, with a shortening of around 5% in this hanging-wall block. Beneath the Naga Thrust, within the triangle zone, several thrust blocks are interpreted, creating an antiformal stack similar to classic triangle zone structures in the Alberta Foothills, Canada. Overall shortening across this region is around 40%.

Structural interpretation in this study area provides insight into the geologic history, continued structural deformation and future hydrocarbon exploration of this region. Further study of migration and maturation may prove the potential of petroleum systems in sub-thrust features of the NTTZ. Large sub-thrust traps beneath the Naga Thrust are possible as shown in this restored cross section. This study provides insight into the use of traditional and non-traditional geological processing methods in combination with traditional structural methods. This inter-disciplinary approach can provide transformative insight for interpretation of previously constructed models.

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1.Introduction

Seismic interpretation of structures associated with complex zones can be tested for viability using multiple methods. Combined methods of multiscale waveform inversion and prestack depth migration provide a two-step process to describe large wavelength and small wavelength features in the same image. This provides a detailed base image for balanced reconstruction of a cross section. The processed seismic line created in this study was interpreted and restored to provide a mechanically feasible model for the Naga Thrust Triangle Zone (NTTZ). The seismic line was interpreted using images from all stages of the processing and was restored using line length and key bed balancing techniques. Literature and well data confirm detachment in the upper Barail group in the foreland. Literature also confirms foreland normal faults with a parallel trend of the Naga Thrust. The well data in this seismic line above the Naga Thrust was used as a guide for stratigraphy thicknesses. Initial modeling in kinematic modeling software of the detachment surface for the Naga Thrust in the Upper Barail group led to investigation of other possible decollement surfaces and structural geometries.

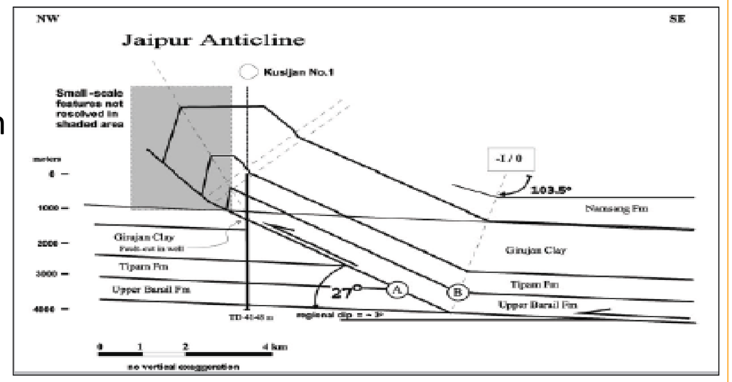

Figure 1 (Above): Contrasting model of the deformation in the Jaipur Anticline, related to the Naga Thrust, showing simpler deformation as a fault-bend fold with the detachment in the Upper Barail

2. Geological Setting

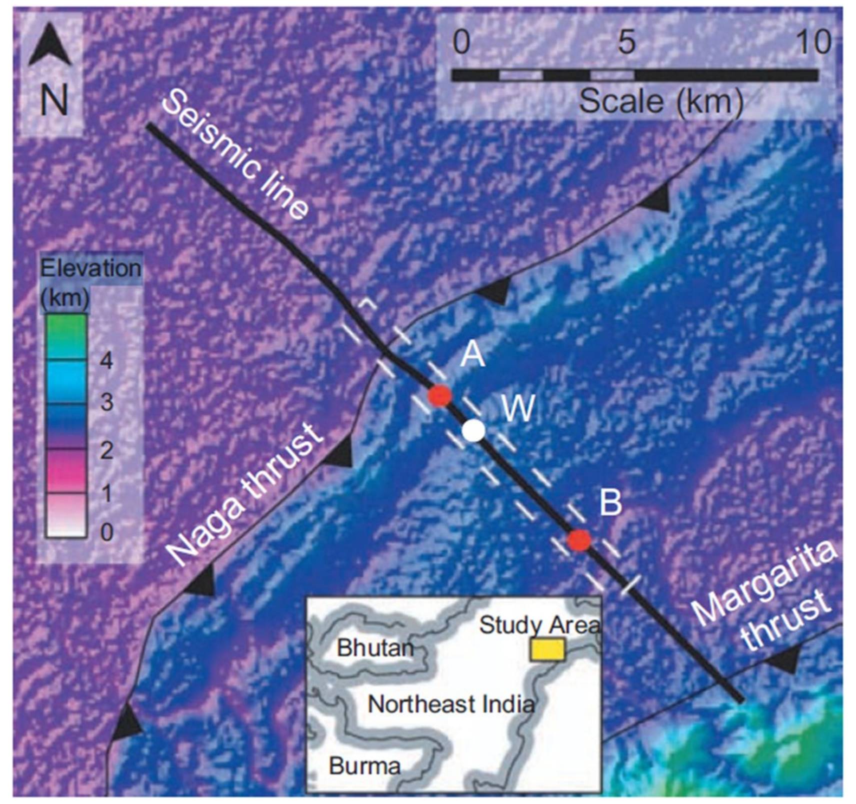

Figure 2 (Top Right) Location of study area in NE India, from Jaiswal et al., 2009

- NW-verging, NE-striking Naga Thrust and Fold Belt (NTFB) foothills of Himalayas in Northeast India
- 2D seismic data acquired in central part of the NTFB approximately 20 kilometers southwest of Digboi oil field.
- Mechanically, potential detachment surfaces occur within Upper Barail Group and Jaintia Group
- Barail and Jaintia Groups considered regional petroleum sources
- Tipam Sandstone formation behaves as coherent unit.

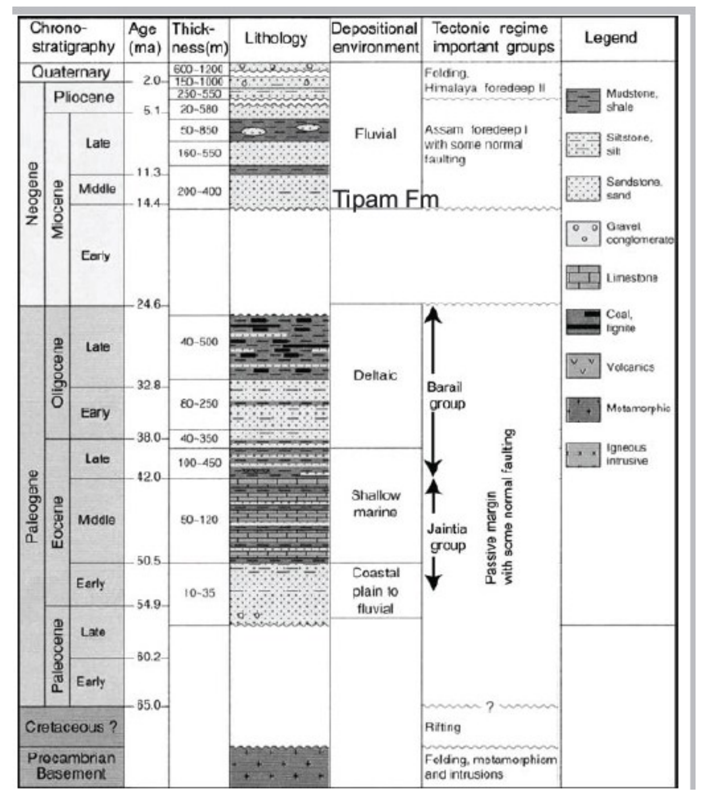

Figure 3 (Bottom Right): Stratigraphy in study area, from Jaiswal et al., 2009

3. Seismic Processing

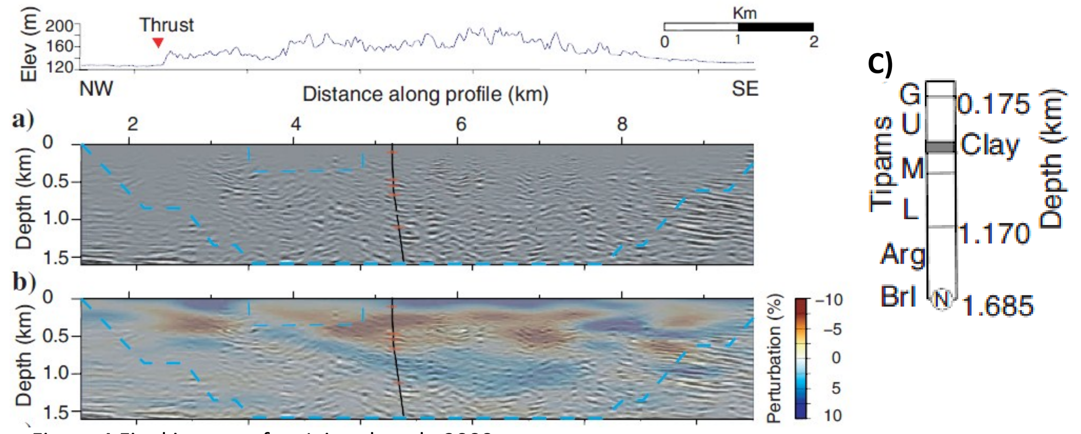

Figure 4 Final images after Jaiswal et al., 2009.

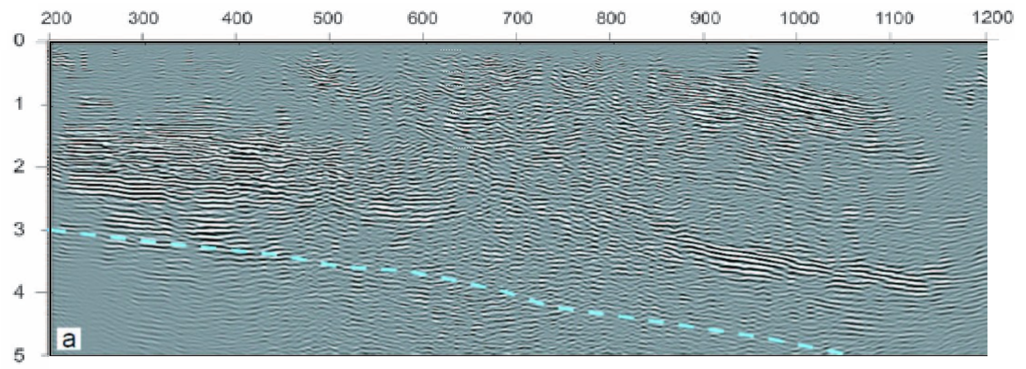

Figure 5 Prestack depth migrated seismic image after Jaiswal & Zelt, 2008

- Image obtained by a combination of multi-scale waveform inversion and Prestack Depth Migration (PSDM) (Figure 4b)
- Waveform inversion provides a physical property map of selected region of seismic image, close to the Naga Thrust
- Combined images provided more detailed structural features related to the Naga thrust fault
- Perturbations from the final waveform inversion model were overlain on the seismic depth image (Figure 4b), resulting in a good correlation with the formation tops from an exploration well (Figure 4c)
- Lithologic well markers indicate G = Girujan, UML = Upper, Middle and Lower Tipam Formations (Figure 4c)
- Combination of Figure 4 with the larger PSDM image in Figure 5 used for Structural modeling

4. Structural Modeling

Interpretation 1

- Thickening of Barail Group toward Southeast
- Consistent Decollement (Upper Barail) hinterland to foreland
- Backthrust geometry
- Key bed Tipam Sandstone
- No pre-existing structures

Interpretation 2

- Consistent Thickness of Barail Group
- Step-up in Decollement hinterland (Jaintia) to foreland (Upper Barail)
- Stacked thrust geometry in subthrust
- Key bed Tipam Sandstone
- Pre-existing extensional faults

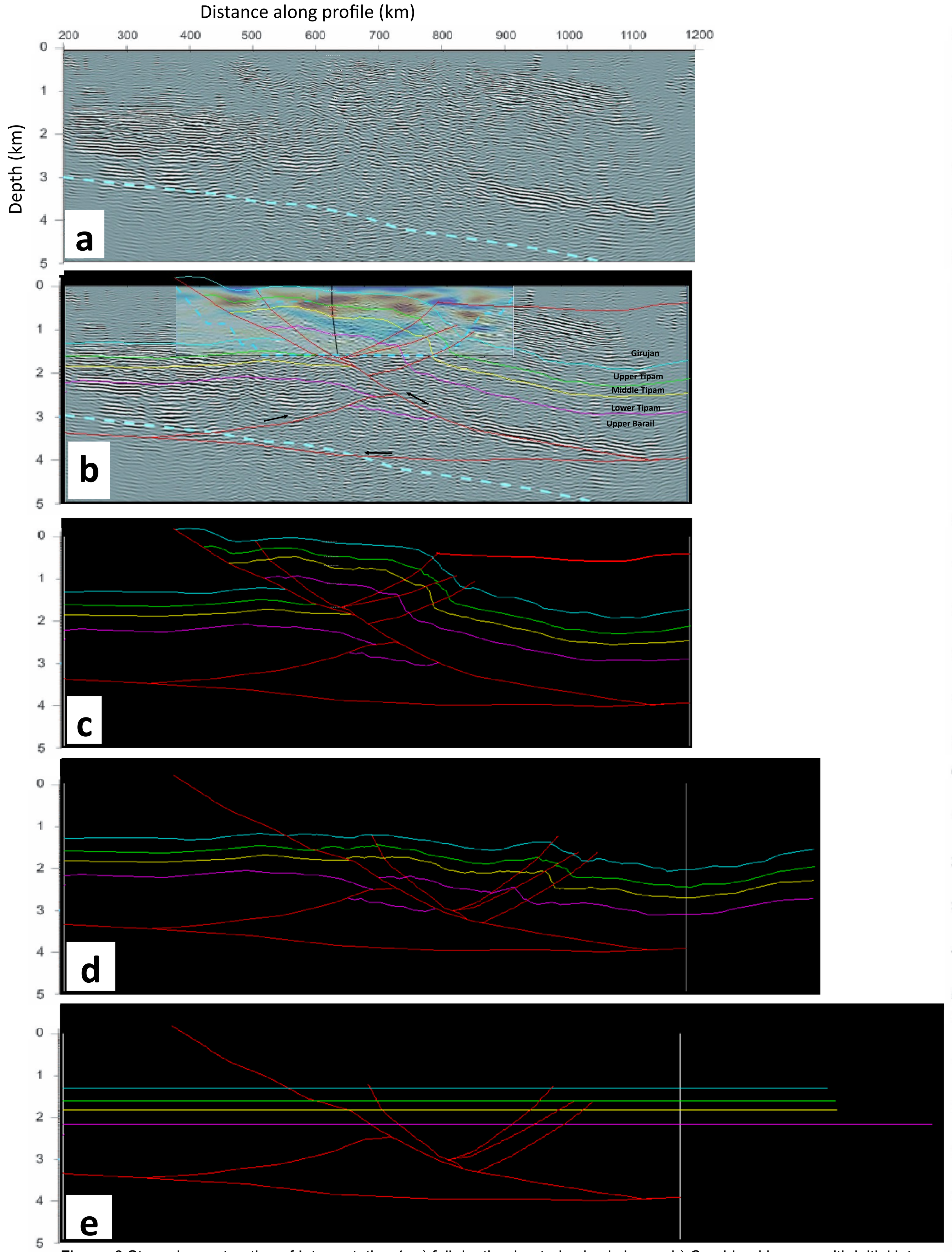

Figure 6 Step-wise restoration of Interpretation 1, a) full depth migrated seismic image b) Combined images with initial interpretation and lithology from well markers, c) Interpretation without base seismic, d) model shows movement along the Naga thrust removed, e) shows final restoration. Decollement and faults indicated with red lines. Arrows indicate sense of motion

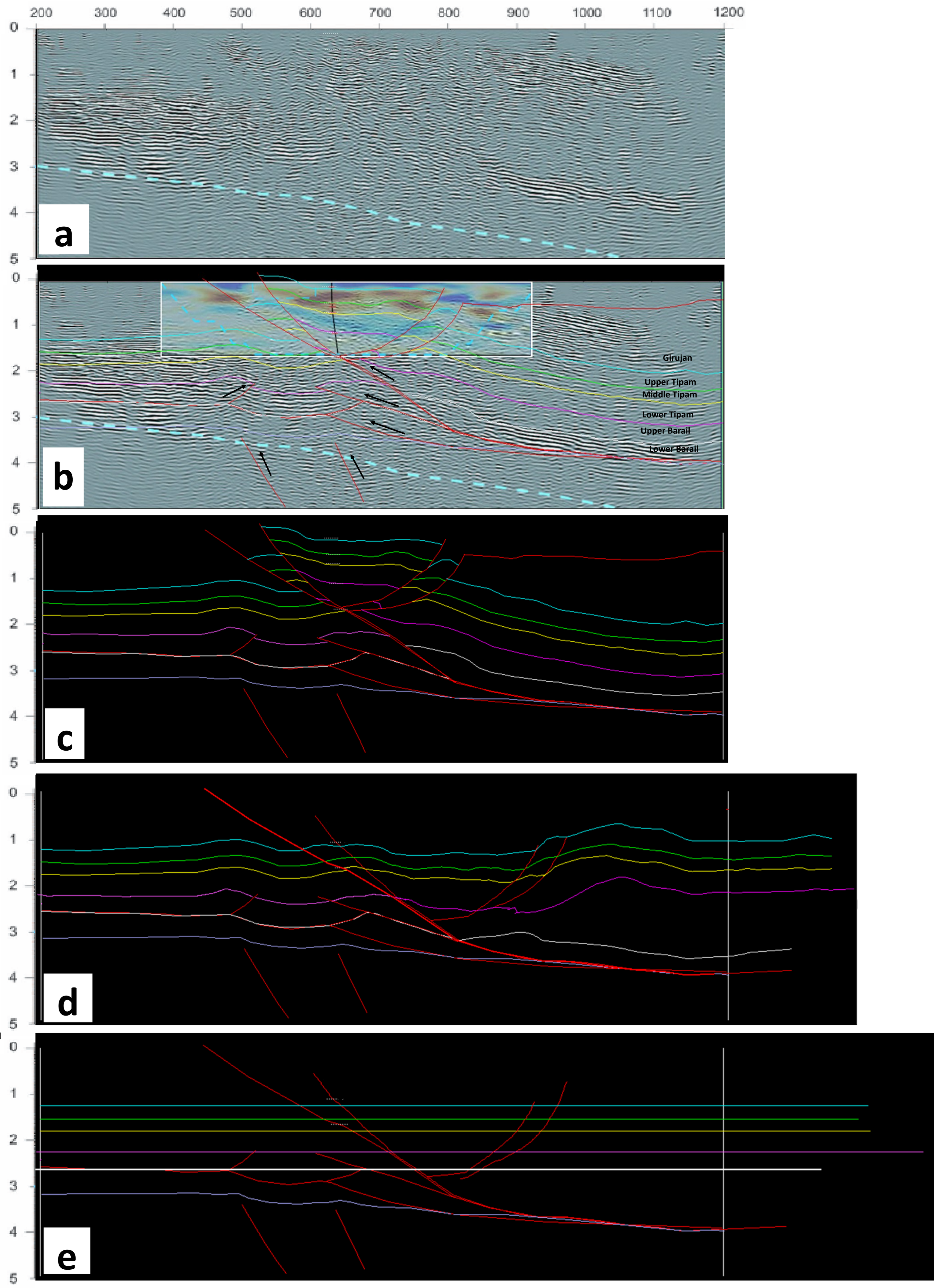

Figure 7 Step-wise restoration of Interpretation 2. a) - e) similar to Figure 6. Red lines indicate faults while other colors indicate lithology change. Decollement surface indicated by change in color from purple to white. Arrows indicate sense of motion

5. Conclusion

- Both of these interpretations are mechanically viable in restoration.
- Initial modeling of Interpretation 1, based on detachment in the Upper Barail, resulted in thickening toward the Southeast which is not supported by literature.
- Interpretation 2 significantly changed the subthrust geometry and interpretation of the decollement surface for the Naga Thrust and Fold Belt while remaining consistent to literature and well data.
- Interpretation 2 mechanically restores pre-existing extensional faults from tectonic activity affecting compressional structures suggested from literature
- Interpretation 2 most likely represents the deformation history of the Naga Thrust and Fold Belt.
- Structural interpretation in this study area provides insight into the geologic history, continued structural deformation and future hydrocarbon exploration of this region.
- This study provides insight into the use of traditional and non-traditional geological processing methods in combination with traditional structural methods, which can provide transformative insight for interpretation of previously studied data.

6. Acknowledgements & References

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Boyer & Elliott, 1982, Thrust Systems: AAPG Bulletin, v66, (9). P1196-1230.

Dahlstrom, 1969, Balanced Cross Sections: Canadian Journal of Earth Sciences, v6, p743-776.

Jaiswal & Zelt, 2008. Unified imaging of multichannel seismic data: combining traveltime inversion and pre-stack depth migration Geophysics, v73 (5) p269-280

Jaiswal et al., 2009. Seismic imaging of the Naga Thrust using multiscale waveform inversion. Geophysics, v74 (6) p129-140

Kent et al., 2002. Application of a ramp-flat fault model to interpretation of the Naga Thrust and possible implications for petroleum exploration along the Naga thrust front. AAPG Bulletin, v86 (12). P2023-2045

Michael et al., 2012. 2D Visualization of the Naga Thrust Triangle Zone, North East India, Using Structural Modeling of 2D Seismic Data GSA Abstracts with Programs, v44 (7)