9th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2012"

P-199

# Regional Kinematics of Tripura Cachar Fold belt and its Syncline Exploration Strategy

***S. Gangopadhyay*, N. C. Lohani, S.D.Saikia, N.Phanisekhar, S. Gupta, A. Bharadwaj,*** *ONGC*

***Summary***

*In the North Eastern India, Tripura Cachar fold belt's(TCFB), NS structural trend and Assam ArakanYoma fold belt's (AAYFB), NS trend are diverging. TCFB is expanded in NW direction upto 24$^0$N and then positioned with a clockwise swing, whereas AAYFB runs in the NS direction and takes clockwise swing at 24$^0$N. In the north, TCFB spread in east west direction and in the south, TCFB almost parallel or merges with AAYFB. Present paper explains the kinematics of evolution of two different trends and spreading of TCFB in EW direction, which can be used as clue to understand the structure style in this area. In the light of the structural mechanics, we have explained the strategy to search subsurface structures in the synclinal part which is anticipated to be prospective for hydrocarbon exploration.*

***Keywords****: AAYFB- Assam Arakan yoma fold belt, TCFB- Tripura Cachar fold belt, HHL-Haila hakaula lineament, PDZ-Principle displacement zone*

## Introduction

AAYFB and TCFB formed due to polyphase tectonics from mid-miocene to plio-pliestocene as per the data analysed and model built so far. The distinct episodes are (a) Indian plate broke up from African, Eurasian, Antarctic plate and started drifting towards N-NE at late cretaceous. (b) It collided with Burmese plate at the east. (c) It collided with Eurassian plate at the North. In Fig-1, we see from south to north that AAYFB gradually expands in east to west direction. In southern part it is narrow in EW direction, whereas in Cachar Tripura area it has expanded maximum in EW direction. Detail observation shows that, as we approach from south to north(22$^0$N to 24$^0$N) in the TCFB area, there are two distinct trend of structural orientation(NS, NW-SE) of the folded structure which implies two different stress directions. After 24$^0$N the structures started bending in the clockwise direction and gradually plunge there. Intensity, stiffness of the folds and elevation of the structures gradually diminishes in the western side. If I join the northern tip of the plunge of the fold, it takes a distinct NE to SW trend. This trend coincides with a major lineament/weak zone called Haila Hakula lineament(HHL) already mapped earlier. Now in the same region, where compressional stress is propagating from eastern side, how this oblique trend is evolved? How TCFB is expanded maximum in EW direction at 24$^0$N? And how after 24$^0$N structure bends in clockwise direction?

## Kinematics

We have thought a vector model to explain the kinematics of TCFB, which will give answers to the above questions. Before going into detail it is better to discuss about some pre-existing concepts in the following. a) Indian plate rotates counter clockwise, and collided with Burmese plate in oblique sense. This statement is true partly, but in the study area, the collision is observed to be almost perpendicular, as per the trend in the structure (Neilsen .etal) is seen. Oblique collision will generate strike slip movement in NS direction. Strike slip movement will generate transpressional and transtentional structures in the restraining and the releasing bends, and those structures will be trending oblique with the strike slip direction. In the principle displacement zone(PDZ) it will generate compressional bridges. These

*Oil and Natural Gas Corporation Ltd. A&AAB, Jorhat, India*
*Email: subrata_gangopadhyay@rediffmail.com*

structures are rarely visible in our study area. Even if we consider that the plate is rotating only, it will generate a rotating stress vector, and for that it will generate different structural trend, than what we observed today. b) Northern side Dauki fault and Halflong thrust are oriented in EW direction, and major compression is propagating from eastern Burmese plate side. Sylhet trough is situated between Dauki fault and HHL where major structuration from northern side is absorbed to maximum extent. Trend of Dauki fault and Halflong thrust shows that they can't generate this type NS to NE-SW structural trend. So, what is the answer?

The mechanics basically involves in stress compartmentalization, and stress orientation after interacting with a fault/weak zone running oblique with the principal stress direction(Fig-2). The magnitude of those components depends on the angle of which principal stress acting on fault(considering no energy loss in interaction). In the Fig-2 principal stress vector F1 acting on fault and divided into two components F2 and F3. F2 will act along the fault and try to generate shear force(strike slip movement). F3 component will interact with principal stress F1 and generate resultant stress F4, which has got different orientation than F1. Now as we go far from interacting fault the magnitude of F3 component diminishes, and so, resultant stress F4 slowly rotates and angle 'b' between F1 and F4 start diminishes. The magnitude of F4 depends on the magnitude of F3, and the angle between F1 and F3. F2 again interacts with F4 to give a resultant stress which also favours the block movement. F3 component will introduce some amount of mild folding/curvature, whose axis will be along EW trend. This is the basic mechanics of stress field in the study area. Now in the light of this model, the disposition of the structural trend in the study area is divided into three blocks viz. A,B,C (Fig-1). We will explain mainly the A, B block as it is in our area of interest. Block A is bounded by fault s1 and s2, block B is bounded by fault s2 and s3, and block C is having fault s3 and s4. Fault s1, s2, s3 and s4 are strike slip faults (Fig-1). In block A, structure is bending clockwise in NE direction, where in block B, the TCFB spreads out maximum in NW direction with a different trend than AAYFB. Block C consists of fault s3 and s4, where s3 is oriented in NNE- SSW direction and s4 is running NS direction. All these major faults were earlier mapped by the geoscientists in this area. For simplicity, a simple model is shown where the eastern edge of the Indian plate is drifting and colliding with Burmese plate (Fig-1, inset). This part of the collision is almost perpendicular to the Burmese plate (Neilsen .etal). Indian plate goes below Burmese plate, compression started and it activates the thrust propagation from east to west direction. At the proximity of the plate boundary thrust are parallel to each other as the force acting on the plate is unidirectional.

**Block A:** This block is bounded by s1(HHL) and s2. Here the input stress field itself takes a clockwise bend, which itself some amount responsible for the structural style in this block. The stress compartmentalization is shown in (Fig-3) in this block after principal stress interacting with s1. F2 tries to initiate strike slip movement. Near s1, the bending tendency of the structure shows ductile nature and relatively high bending of the structure suggests that the stress is adjusted by making a bend of the structure. The upliftment of the Narayanchara/Hilara structure (west of Tukbai/Pathimara) is more than Tukbai/Pathimara structure in this area, which suggests the strike slip action also enhances the compression in this area along with the main compressional stress. As we go far along the s1, the magnitude of F2 decreases (as F1 decreases), and hence the bending of the structure is less. Impact of F4 will create a clockwise rotation of the structures in this block to adjust the space problem between s1 and s2, and this rotation will generate NW-SE trending shear zones(strike-slip fault). The F4 will activate pre existing weak zones and initiate strike slip movement in NE-SW direction, and simultaneously it will generate some new strike slip fault in NE-SW direction. These are also responsible for the en-echelon pattern and asymmetric disposition of the structure. F4 will also favour some strike slip movement near s2. Clockwise rotation of structures in block A will drag the block B structures to rotate anticlockwise near s2.

**Block B:** This block is bounded by s2 and s3. Here we can see the two distinct trends of TCFB and AAYFB. Fault s2 is almost trending EW direction and situated at $24^0$N. The angle between stress F1 and fault s2 is low. The stress compartmentalization is shown in the (Fig-4). Here F2 is more, and F3 is less. F2 component acts along s2 to generate shear action. This shear action is combined with the anticlockwise drag generated in block-B (anticlockwise drag in block-B is the effect of clockwise rotation of block-A structures). The force action of F2, F4 and anticlockwise drag are combined responsible for maximum spreading of the structure in EW direction at $24^0$N. In this block structure spreads out maximum at the west and there is space abundance between s2 and s3. Orientation of s3 is NNE-SSW. This s3 restricts the F4 to go beyond it. Due to space abundance and restriction of F4 low structuration is created at the SW part of block B. F4 will activate some pre-existing strike slip fault and generate some new strike slip fault in this block.

**Block C**: In this block structuration is little complex. Orientation of s3 is in NNE to SSW direction. Stress compartmentalization is shown in (Fig-5). Fault s4 is NS trending strike slip fault, which ends and generates compressional splays at its tip. Here F1 is almost perpendicular to s3, so it directly acts to generate structures, with a very little strike slip component along s3. At the south low structural relief is formed due to releasing bend of the strike slip fault s3 (sinistral), shown in (Fig-5)

So in a nutshell the main mechanics of evolution of structures is that the compressive force coming from eastern side due to collision is responsible for thrust propagation and structure formation. This force is interacting with pre-existing faults/weak zones with an angle, and is compartmentalized, and finally the main force is rotated after interacting with the component force. The whole mechanism initiates structural disposition, structural rotation, strike slip zones, en-echelon structures, asymmetric broad synclines, depending upon the net direction, magnitude of the resultant compressive force, pre-existing shear zones in the area and their orientations, relative shear effect and space availability in between shear zones. Differential movement along the strike slip will be common in this area which will generate flower structures on those zones. Reidel shear related oblique structures are also identified along the principle displacement zone(PDZ) in this area at s2 shear zones (Fig-1). Vector model of block A explains the clockwise bending of the structure. Vector model of block B tells that, the slip along s2 due to F2 and F4 is mostly responsible for the two different structural trends(NS and NW-SE) in this zone. This also explains the cause of the TCFB to expand maximum in EW direction at $24^0$N.

## Syncline Exploration strategy:

Synclines are explored on the basis of the geomorphic anomaly, where we get buried structure in the synclinal part. One of the classical example of synclinal buried structure is Agartala dome (geomorphic anomaly), in Tripua, India which was previously thought as a syncline only. But how do we search a structure in the syncline for exploration if we don’t get any geomorphic anomaly? If a structural pattern is monotonous syncline and anticline, it is difficult to search a structure in syncline without a clue of geomorphic anomaly. But in the case of TCFB structural pattern, where structures are also governed by strike-slip fault/wrenching effect, close investigation of the structural pattern (anticline and syncline) will be helpful to get clue of the subsurface structures in syncline. This model will explain the strategy by describing a case in TCFB area, where a structure is analysed in the light of our kinematic model and latter that have been verified by the seismic data (In the area of interest few 2D seismic lines were available, which delineated the geomorphic anomaly in the area. One well has gone dry which might have drilled on the basis of those 2D lines. This work is to support the geomorphic anomaly(if available) in a better way, and to understand the particular part of the syncline where we can concentrate our data acquisition to search synclinal buried structures, even there is no geomorphic anomaly. In the (Fig-a) there are three anticlines A, B, C and in between there is one syncline(S). Orientation of these structures satisfies our kinematic model. The SW bending of the structure B along strike slip fault sf1, has dragged the structure C in NW. Structure A has NE bending along strike slip fault sf2. So, sf1 and sf2 can’t be a same fault which has bent structure B in SW and structure A in NE. The structural pattern and curvature of structure A and B are different, which implies a differential slip vector acting in this region. So it will definitely generate a compression (transpression) in between two structures, which falls in the synclinal part. Structures formed in the syncline are seen in seismic section. Another strategy is to locate the compressional bridge (Reidel shear) structures along the major shear zones/PDZ (Fig-b). By seeing the structural trend in the light of the proposed model we can identify major shear zones/PDZ and there orientations. Those shear zone related buried structures also will be developed in the synclinal area which may not be seen from the surface. Those structures also can be targeted.

## Conclusions

a) Proposed structural kinematic model shows that, structural trend in the TCFB area is formed due to stress compartmentalization after interacting with faults in this area. Structures due to plate rotation are not seen in this area. Dauki fault and Halflong thrust are also not responsible to form the TCFB trend.

b) Structural mechanics will develop strike-slip fault trend in NE-SW and NW-SE direction in this area.

c) En-echelon structures, uneven structural bending, asymmetric syncline are the result of resultant force F4, strike slip movement of structures, structural rotation and structural dragging effect.

d) Proper analysis of the structural style in the light of the proposed model will give clue to search the subsurface buried structures in the syncline part in this area which are anticipated to be prospective for hydrocarbon exploration.

(Views expressed in this paper are those of authors only.)

## References

Biswas S.K., Bhasin A.L, Ram Jokhan 1993: Classification of Indian sedimentary basins in the framework of plate tectonics (Dehradun: Indian petroleum publishers)

Ganju et.al (1982-87): Geological map of Tripura Cachar: Based on Geological field survey ONGC.

Islam S. Md., Hayashi D.: Numerical stress and fault simulation of Shillong plateau and its adjoining area in Northeast India, Bangladesh and Myanmar: Bull. Fac. Sci., Univ. Ryukyus No.89:27-58(2010)

Neilsen C., Chamot-Rooke N., Andaman Cruise Team: From partial to full strain portioning along the Indo Burmese hyper oblique subduction: Marine Geology 2009(2004)303-327

Rao S.V. et.al: Geological Field party report : 1984, ONGC

Rao S.V., et.al: Geology of the Naga foot hills, Nov,1985, Jorhat, ONGC

Wilcox R.E., Harding T.P., Seely D.R.: Basic Wrench Tectonics: AAPG Bulletin, V.57, No.1 (January1973), P-74-96

## Acknowledgement

Authors are grateful to Shri S.V.Rao, Dir(E), ONGC and Shri S. K. Jain, Basin Manager, A&AAB for their valuable support and guidance to publish this work.

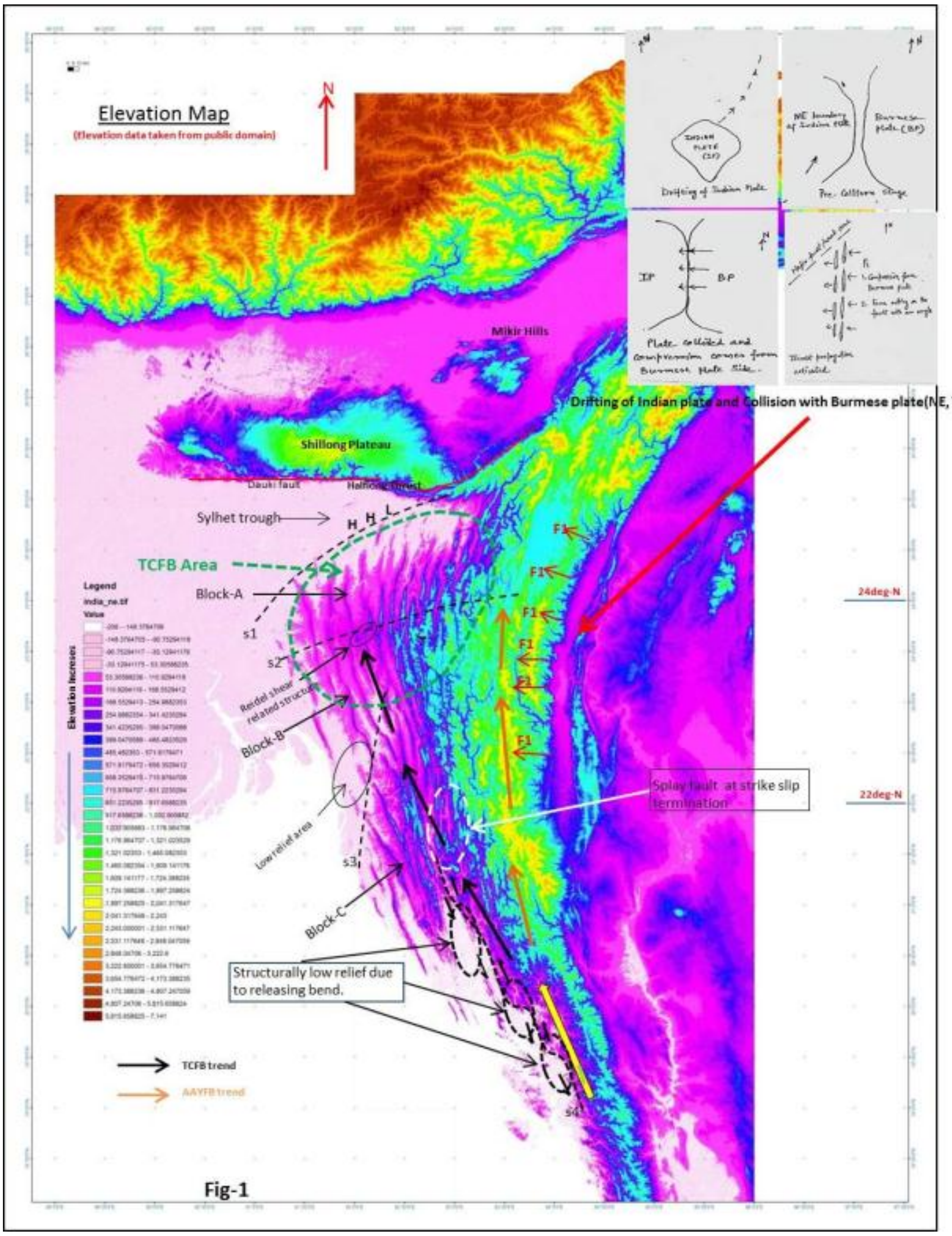
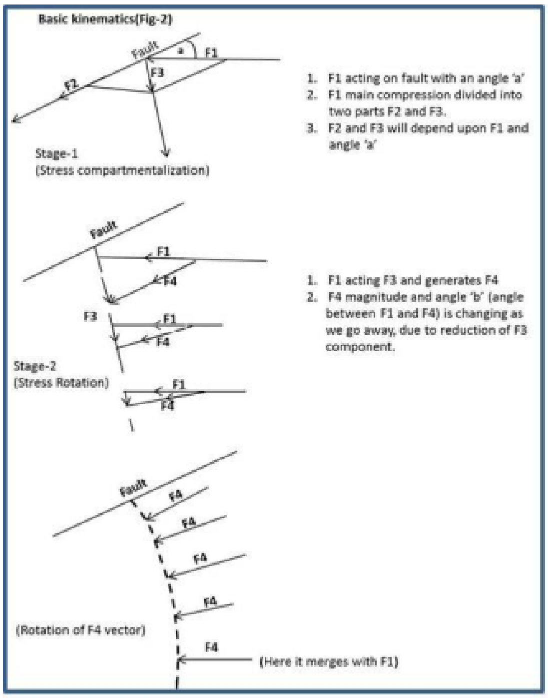
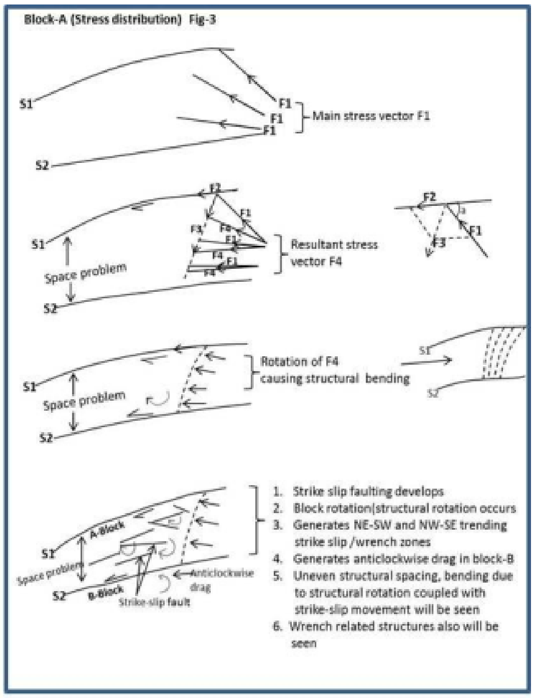
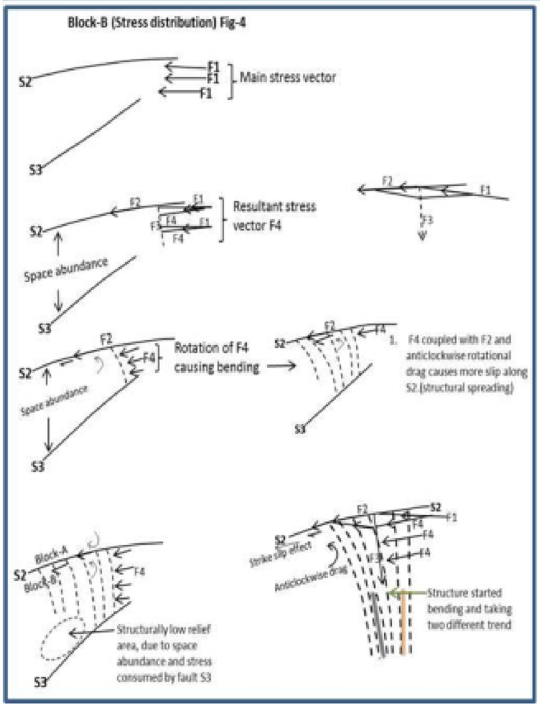
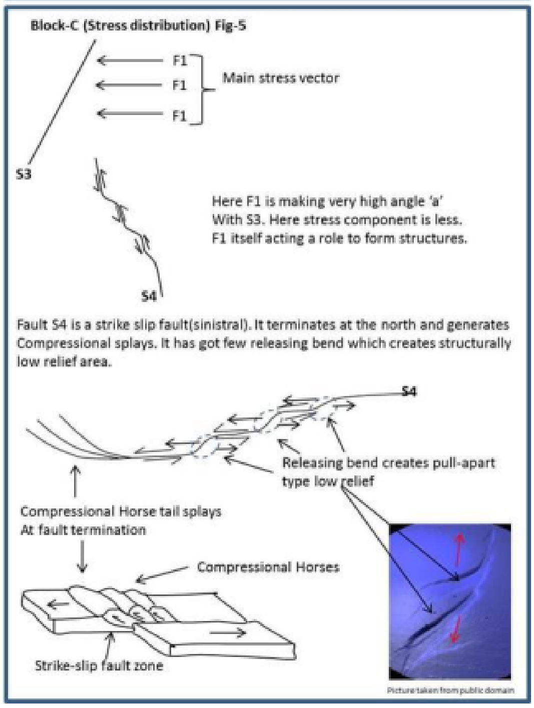

Elevation Map
(Elevation data taken from public domain)
N
Mikir Hills
Shillong Plateau
Dauki fault
Sylhet trough
TCFB Area
Block-A
Block-B
Block-C
Redel shear related structure
Low relief area
Drifting of Indian plate and Collision with Burmese plate(NE, TCFB area)
Splay fault at strike slip termination
Structurally low relief due to releasing bend.
24deg-N
22deg-N
Legend
Elevation Increses
TCFB trend
AAYFB trend
Drifting of Indian Plate
Pre-Collision Stage
IP
BP

Fig-1


Basic kinematics(Fig-2)
Fault
F1
F2
F3
1. F1 acting on fault with an angle 'a'
2. F1 main compression divided into two parts F2 and F3.
3. F2 and F3 will depend upon F1 and angle 'a'
Stage-1
(Stress compartmentalization)
F4
1. F1 acting F3 and generates F4
2. F4 magnitude and angle 'b' (angle between F1 and F4) is changing as we go away, due to reduction of F3 component.
Stage-2
(Stress Rotation)
(Rotation of F4 vector)
(Here it merges with F1)


Block-A (Stress distribution) Fig-3
S1
S2
Main stress vector F1
Resultant stress vector F4
Space problem
Rotation of F4 causing structural bending
A-Block
B-Block
Anticlockwise drag
Strike-slip fault
1. Strike slip faulting develops
2. Block rotation(structural rotation occurs
3. Generates NE-SW and NW-SE trending strike slip /wrench zones
4. Generates anticlockwise drag in block-B
5. Uneven structural spacing, bending due to structural rotation coupled with strike-slip movement will be seen
6. Wrench related structures also will be seen


Block-B (Stress distribution) Fig-4
S2
S3
Main stress vector
Resultant stress vector F4
Space abundance
Rotation of F4 causing bending
1. F4 coupled with F2 and anticlockwise rotational drag causes more slip along S2.(structural spreading)
Block-A
Block-B
Structurally low relief area, due to space abundance and stress consumed by fault S3
Strike slip effect
Anticlockwise drag
Structure started bending and taking two different trend


Block-C (Stress distribution) Fig-5
F1
Main stress vector
S3
S4
Here F1 is making very high angle 'a' With S3. Here stress component is less. F1 itself acting a role to form structures.
Fault S4 is a strike slip fault(sinistral). It terminates at the north and generates Compressional splays. It has got few releasing bend which creates structurally low relief area.
Releasing bend creates pull-apart type low relief
Compressional Horse tail splays At fault termination
Compressional Horses
Strike-slip fault zone
Picture taken from public domain

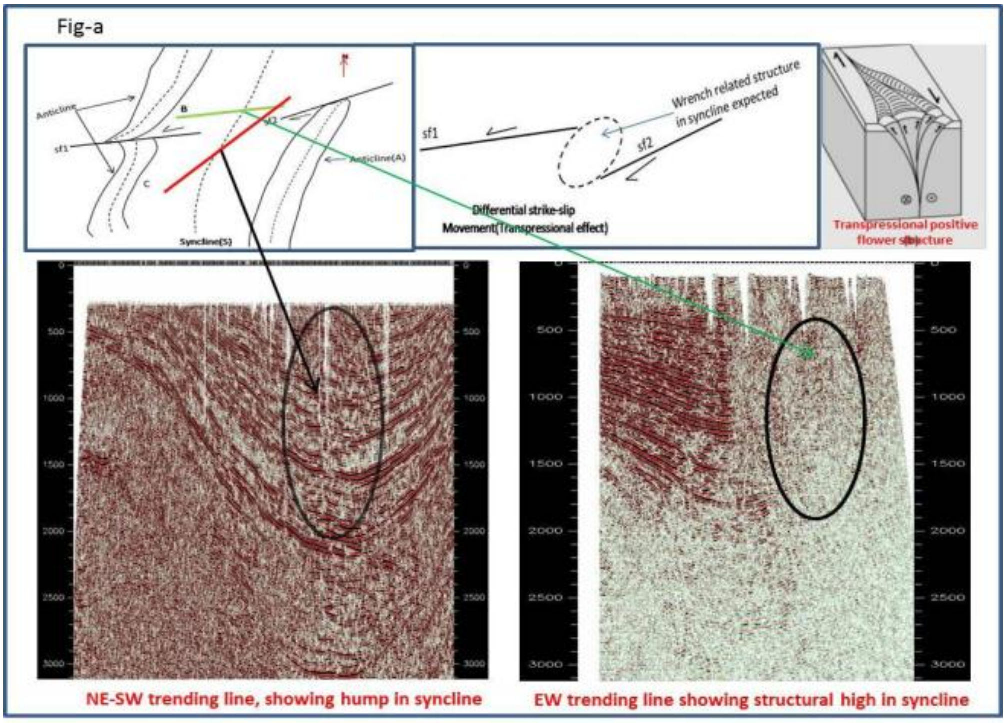


Fig-a
Anticline
sf1
sf2
B
C
Anticline(A)
Syncline(S)
Wrench related structure
in syncline expected
Differential strike-slip
Movement(Transpressional effect)
Transpressional positive
flower structure
NE-SW trending line, showing hump in syncline
EW trending line showing structural high in syncline

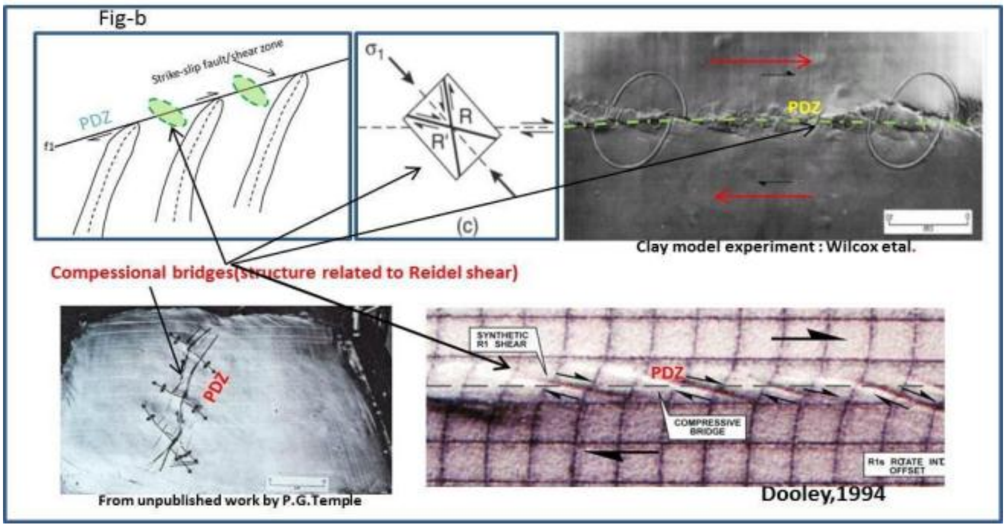


Fig-b
Strike-slip fault/shear zone
PDZ
f1
σ1
R
R'
(c)
Clay model experiment : Wilcox etal.
Compessional bridges(structure related to Reidel shear)
SYNTHETIC
R1 SHEAR
COMPRESSIVE
BRIDGE
From unpublished work by P.G.Temple
Dooley,1994