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Structural geometry of the Himalayan Frontal Thrust Zone: Surghar Range, Pakistan

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ABSTRACT: *Surghar Range of the outer Himalayas in Pakistan represents the active deformational front of Kohat fold and thrust belt. The range is migrating southward in response to the underthrusting of Indian craton underneath its sedimentary cover. The structural geometry of the range, in the vicinity of Chichali pass area is characterized by a south facing anticline i.e., Surghar anticline at the level of Jurassic. It is interpreted to be a fault bend fold above a major ramp detached within or at the base of Triassic rocks. The range front is thrust southwards over Punjab foreland along Surghar Fault, which is interpreted as south verging fore thrust. The thrust sheet above Surghar Fault displays contrasting structural geometries along strike. The Surghar Fault is believed to be a strongly emergent thrust in the west (north of Kutki village) having shallowly folded thrust sheet. Eastwards, the Surghar Fault translates into a tip-stick thrust front (north of Chapri and Tola Mangli village) with its thrust sheet being tightly folded and disrupted by several out of sequence thrust faults. The restored cross section along Kutki section reveals that 5.6 km shortening has taken place along Surghar Fault. The constraints upon the timing of deformation suggest that uplift along range front started about 2.3 Ma ago.*

INTRODUCTION

The Surghar Range is an arcuate mountain belt, forming the southeastern proximity of Kohat plateau. It has east-west orientation, switching to a northsouth trend while bordering the eastern flank of Bannu Basin (Fig.1). It represents the leading deformational front of Kohat fold and thrust belt and is the southern most surface expression of tectonic uplift associated with Himalayan orogeny. Being an active range front, it has been tectonically uplifted and deformed accommodating significant amount of shortening.

Little attention has been paid to the understanding of tectonic evolution of Surghar Range, whereas its eastern analog i.e., Salt Range has been well documented and defined by previous workers (Gee, 1980; Burbank & Raynolds, 1984; Yeats & Lawrence, 1984). Previous studies in the Surghar Range have been mainly concentrated on the understanding of its stratigraphic framework. Significant contribution owes to Danilchik and Shah (1987) producing an excellent map of the north-south trending segment of the range. Most of the east-west trending segment is unmapped except the northern Chichali pass area, which is included in Kohat Quadrangle map of Meissner et al. (1974).

We discuss the structural geometry of this frontal thrust zone in order to work out

the style of deformation, its lateral variation along strike, the nature of frontal thrust, the amount of shortening and timing of deformation.

GEOLOGIC SETTING

Beginning about 55 million years ago, the continent- continent collision of Eurasia and India produced the present day spectacular Himalayan arc of the world (Molnar & Tapponier, 1975). In north Pakistan, the Himalayas along with its associated mountain ranges trend east-west, switching to a north-south trend in the west (Fig.2). The Surghar and Salt Range is the southern most of these east-west trending ranges and represent the active deformational front. Towards north, the Kohat plateau separates it from Kohat Range and towards west the flat lying Bannu Basin separate it from the northern Sulaiman Range (Fig.2).

The exposed stratigraphic sequence of the range in the vicinity of Chichali pass area consists of about 1 km thick succession of Jurassic to Eocene rocks unconformably overlain by Lower Siwalik Group (Fig.3). The Datta Formation marks the base of Jurassic sequence and contains red, grey and white sandstone with siltstone, shale, mudstone, marl and fire clay horizons. It grades upward into medium-bedded limestone, marl and sandstone of the Shinawari Formation, which is disconformably overlain by medium-bedded, grey limestone of Samana Suk Formation. The Glauconitic sandstone and shale of Chichali Formation disconformably overlies the Samna Suk Formation and passes upward into massive sandstone of Lumshiwal Formation. The Lumshiwal Formation is unconformably overlain by Patala Formation, which includes sandstone, nodular limestone, carbonaceous shale and marl. The Paleocene

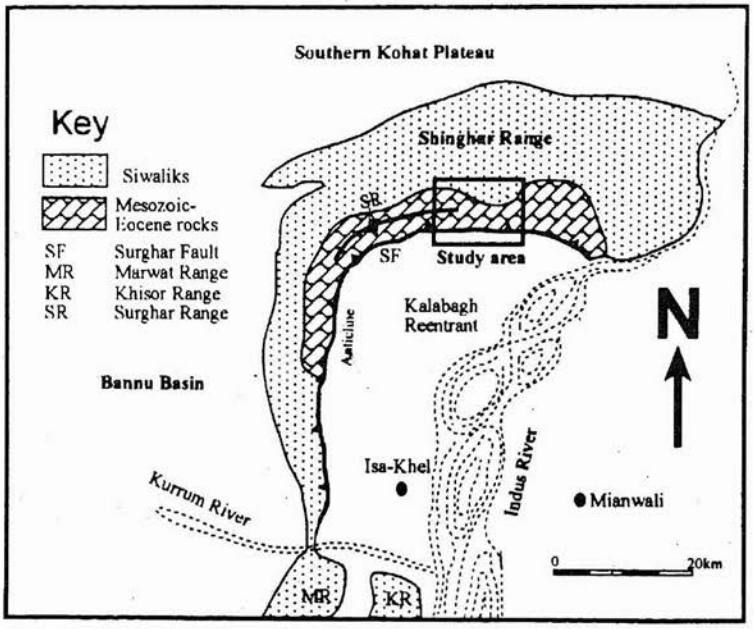


Fig. 1. Generalized geological map of Surghar Range (Modified after Khan & Opdyke, 1993).

sequence is transitionally overlain by marl, limestone and shale sequence of Nammal Formation. The Nammal Formation is in turn overlain by nodular, massive Sakessar Limestone. The Siwalik Group rocks lies unconformably on top of the Sakessar Limestone.

STRUCTURAL GEOMETRY

The Surghar Range is characterized by irregular map pattern in the vicinity of Chichali pass area, having east-west trend in general (Fig.4). Its structure is dominated by a south facing asymmetric anticline named as

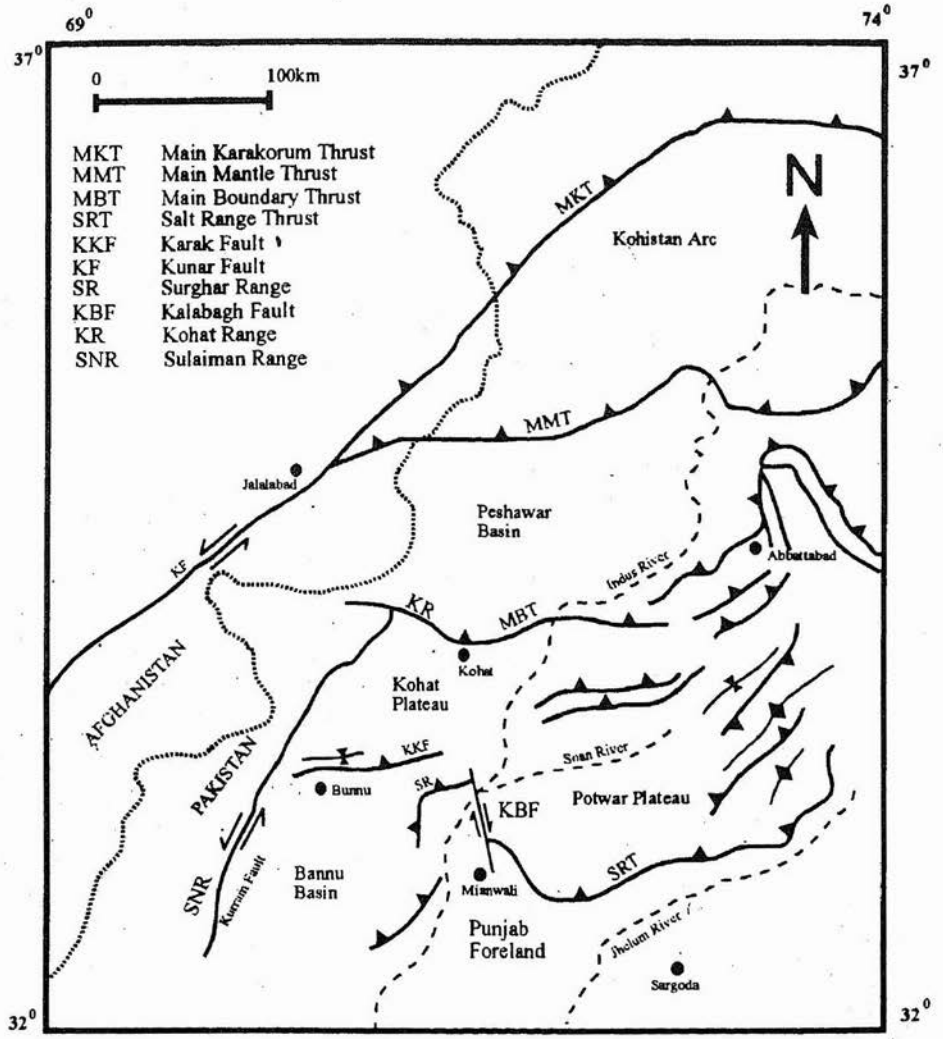


Fig. 2. Tectonic map of north Pakistan, showing major structural features and towns (modified after Kazmi & Rana, 1982).

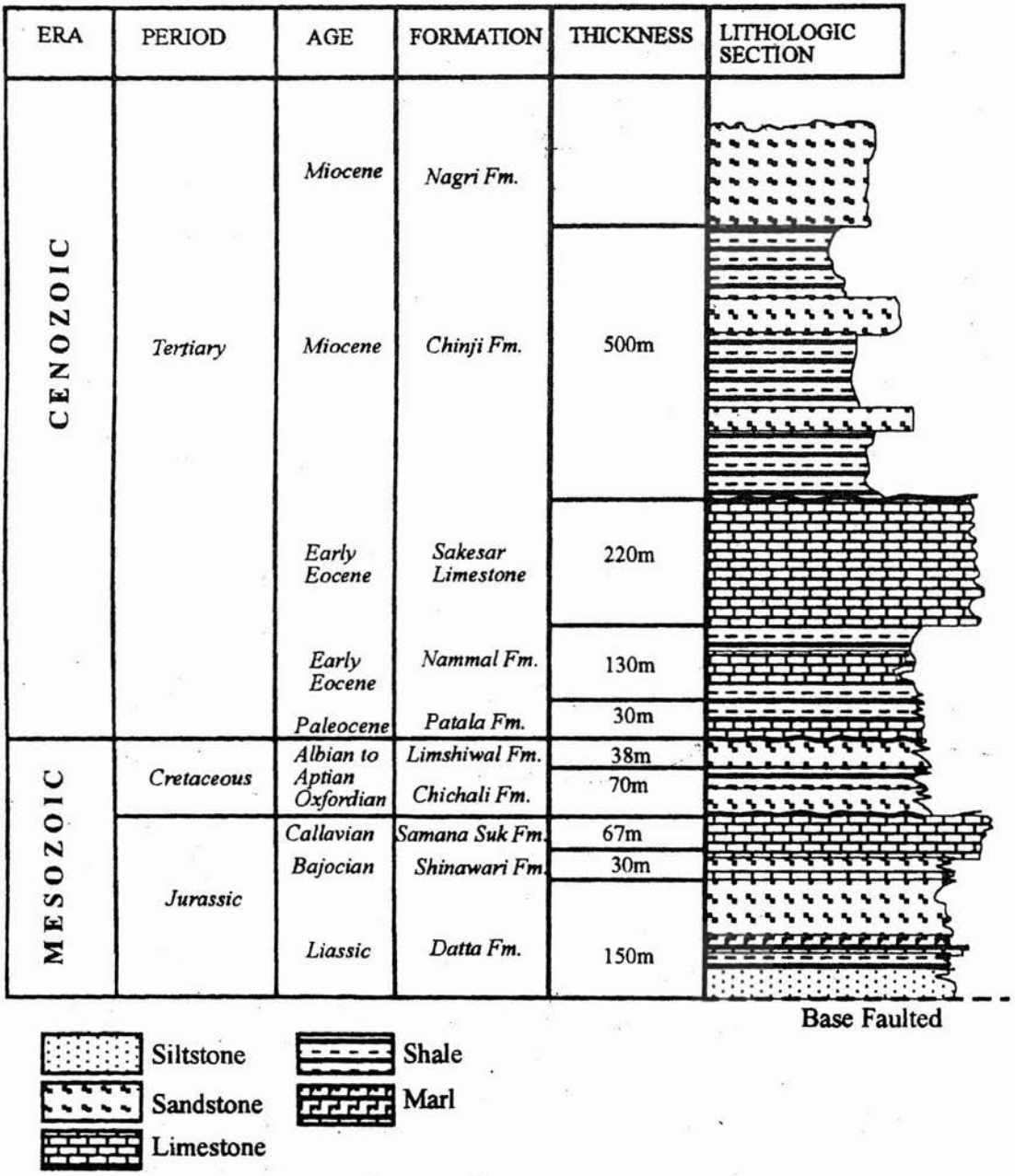
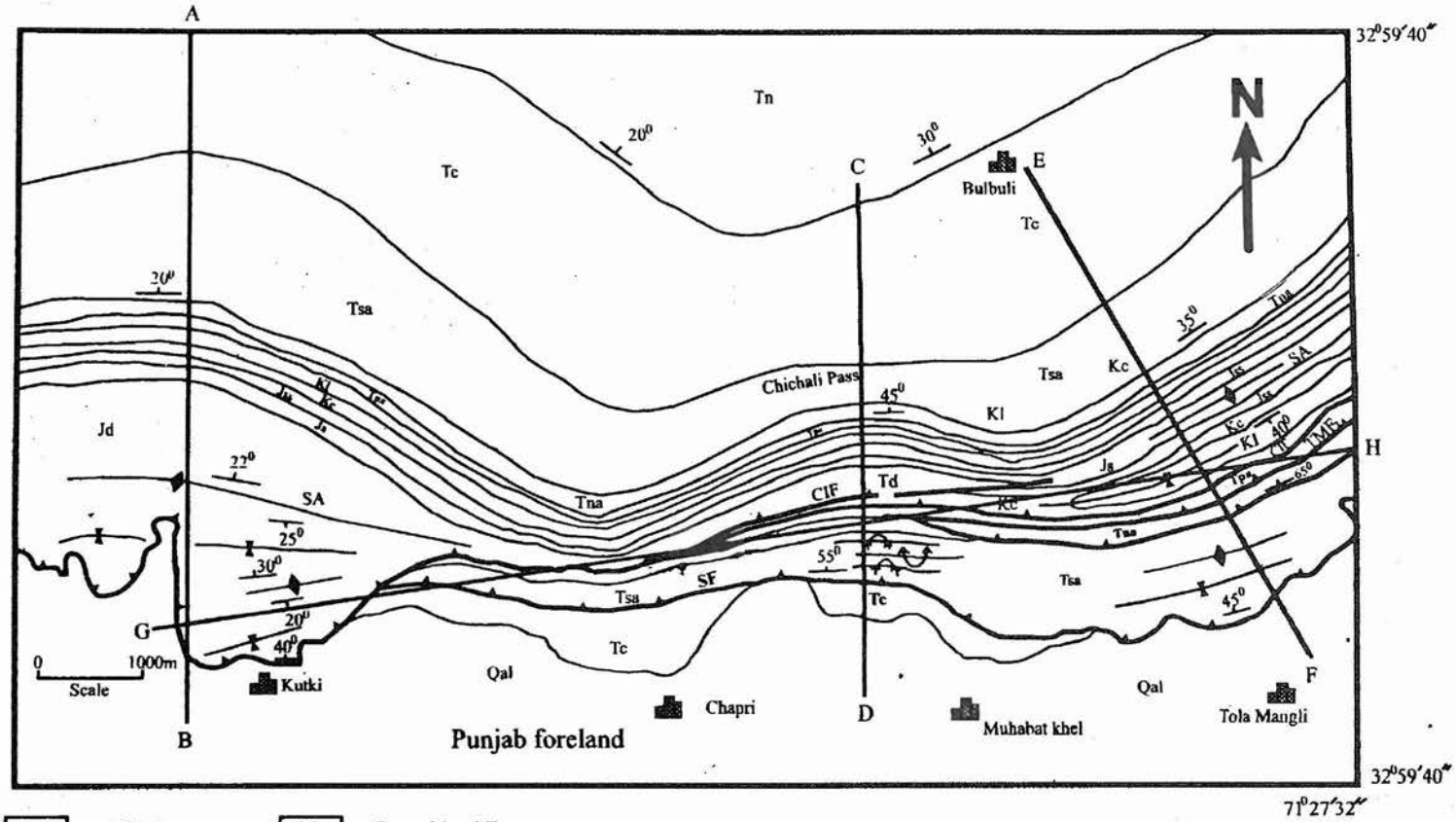


Fig. 3. Generalized stratigraphic sequence of the Surghar Range in the vicinity of Chichali Pass area.



Qal	Alluvium	Kl	Lumshiwal Fm.		Strike/Dip	SF	Surghar Fault
Tn	Nagri Fm.	Kc	Chichali Fm.		Anticline	CIF	Chichali Fault
Tc	Chinji Fm.	Jss	Samanasuk Fm.		Syncline	CF	Chapri Fault
Tsa	Sakessar L. st.	Js	Shinawari Fm.		Overturned anticline	TMF_1	Tola Mangli Fault 1
Tna	Nammal Fm.	Jd	Datta Fm.		Overturned syncline	TMF_2	Tola Mangli Fault 2
Tpa	Patala Fm.				Thrust Fault	SA	Surghar Anticline

Fig. 4. Geological map of Surghar Range in the vicinity of Chichali Pass area, Mianwali and Karak districts of Punjab and NWFP provinces of Pakistan.

Surghar anticline. The backlimb of this anticline is less deformed having shallow to moderate dip angles and mostly characterize the main topographic expression of the range. The forelimb of Surghar anticline is dissected by a south verging forethrust along Chichali nala and is moderately south dipping north of Kutki and Tola Mangli village (Fig.4). The core of Surghar anticline is occupied by Jurassic rocks along most of its trace. The range front is marked by Surghar Fault along which Mesozoic Cenozoic rocks of the Surghar Range are thrust southwards over Punjab foreland. Contrasting geometric variations have been observed within the rocks along strike .In order to understand these variation, four cross sections along line A-B, C-D, E-F and G-H of Figure 4 have been constructed.

From north to south along line A-B, the Surghar Fault brings the rocks of Datta Formation over the Chinji Formation in the footwall (Fig.5a). The hanging-wall sequence is shallowly folded into a pair of south facing anticline and syncline .The ramp is believed to be detached within or at the base of Triassic sequence. The ramp instead of cutting through Surghar anticline, flattens at a shallow level and emerges at the surface 2 km forelandward, ahead of the bend in major ramp. The structural style along the section shows a steady shortening accommodation and easy propagation of thrust sheet towards foreland.

Cross section C-D has been drawn in the vicinity of Chichali pass area and displays contrasting geometry (Fig.5b) as compared to line A-B (Fig.5a). From foreland towards hinterland, the shallowly folded Chinji Formation is thrust over by the Sakessar Limestone along north dipping Surghar Fault. The hanging wall of this fault carries highly contorted Eocene strata. Further northwards the hanging-wall strata of Surghar Fault become the footwall sequence of Chapri Fault along which Chichali Formation is thrust over the Paleocene rocks in the footwall. Immediately north of Chapri Fault, the Chichali Fault brings the Jurassic rocks in its hanging-wall over the Chichali Formation in the footwall. Most of the faults in this section are steeply north dipping, having strongly folded overthrust sheets and the displacement is distributed through several thrust splays instead of a single frontal thrust as is the case in Kutki section (Fig.5a).

On a foreland to hinterland traverse along line C-D (Fig.5c), the folded rocks of Sakessar Limestone are thrust over the terrace deposits in the footwall along Surghar Fault. The hanging-wall sequence of this fault is shallowly folded and is thrust over by Nammal Formation along moderately north dipping Chapri Fault. Immediately northwards the hanging wall rocks of Chapri Fault are thrust over by the Paleocene rocks along Tola Mangli Fault 1. Upsection, another thrust splay i.e. Tola Mangli Fault 2 brings the Cretaceous rocks over Paleocene sequence in the footwall. The hanging wall of Tola Mangli Fault 2 is shallowly folded into a pair of south facing anticline (Surghar anticline) and syncline. The Surghar anticline is cored by the Shinawari Formation of Jurassic age and both of its limbs are intact in this section. The ramp is interpreted to be detached within or at the base of Triassic sequence and flattens at a shallow level. The displacement is distributed through a series of thrust splays instead of a single fault.

Cross section G-H has been drawn parallel to the strike of range in order to study the lateral variations in structural geometry. In the west, the Surghar Fault carries Datta Formation in its hangingwall over the Chinji Formation. The cross section depicts that the overthrust sheet propagated easily in the west and as we move eastwards

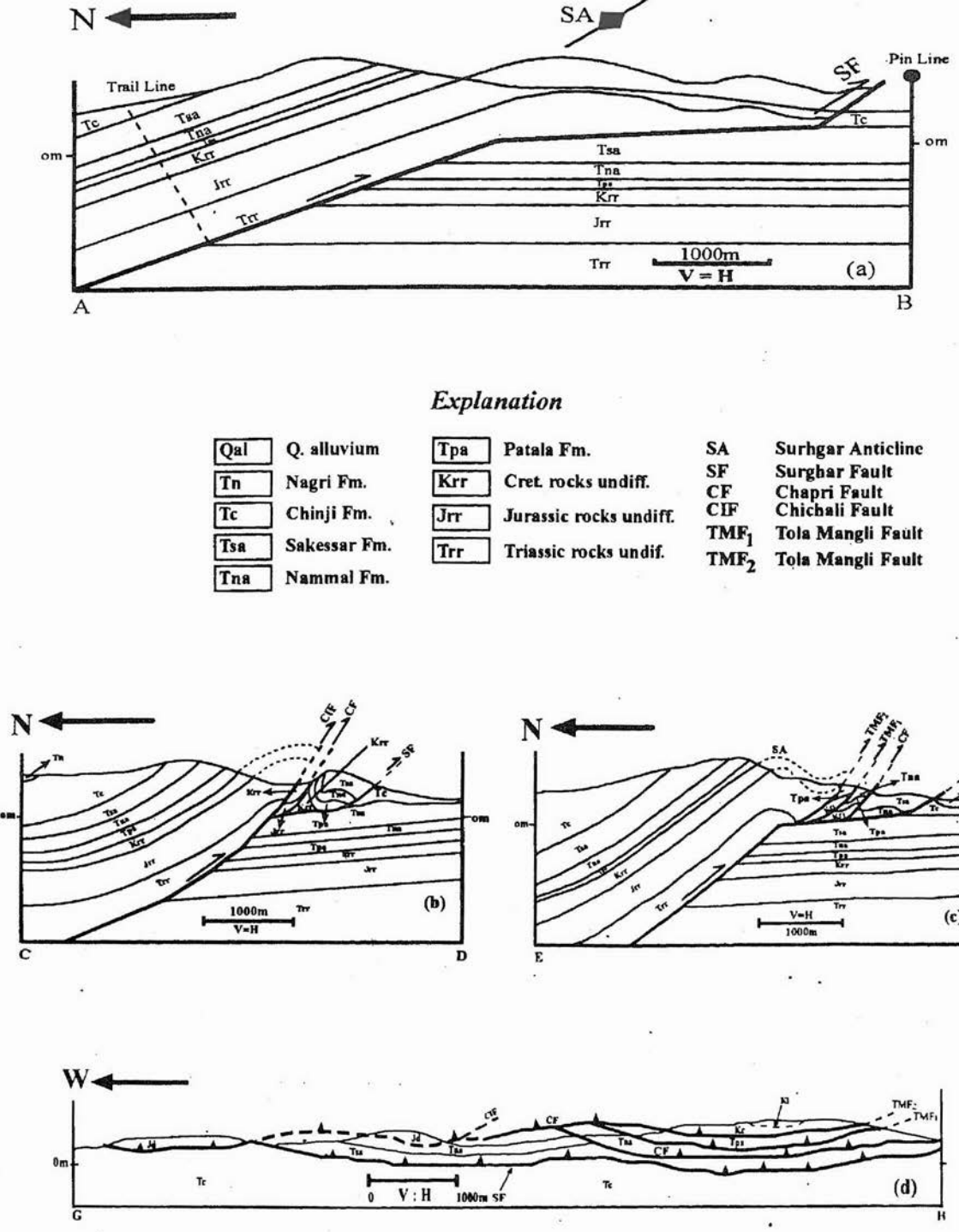


Fig. 5. Cross-sections (a-b, c-d, e-f, g-h on Figure 4) through Surghar Range, Chichali Pass area.

it seems that the displacement along Surghar Fault was stuck at some point and the hanging wall strata were deformed by the formation of another thrust splay towards hinterland. In the extreme east of the section the displacement is distributed through four thrust splays which seems to be the result of sequential failure of the hanging wall rocks in response to sticking of displacement along Surghar Fault.

STYLE, TIMING OF DEFORMATION AND AMOUNT OF SHORTENING

The variations in structural geometry along strike of the range can be explained in terms of motion along thrust sheet. The style of deformation in the west of the mapped area is typical of a thrust sheet that have propagated freely towards foreland with most of its shortening taken up by frontal fault and the thrust sheet is mildly deformed by shallow folds. It bears close similarities with the typical thrust sheet development of Morely (1986) where the sole thrust propagates rapidly to the surface instead of dying out periodically into the zones of high strain. The style of deformation changes rapidly eastwards in Chichali area (Fig.5b) and display stick- slip style of deformation. The Surghar Fault, which marks the range front is believed to be the early course of faulting. It was stuck at shallow level after initial displacement and uplift. The associated thrust sheet of Surghar Fault was passively folded, as is the case in Kutki section. The incremental strain was accommodated by the tightening of folds within the thrust sheet which was latter on sequentially failed giving rise to a north younging imbricate fan. The idea of stick- slip displacement is also supported by the development of low amplitude folds within Siwalik rocks located south of the Surghar Fault (Fig.6). Based on these observations it is believed that the range front is a weakly emergent thrust front in the vicinity of Chichali area .The tip-stick style of deformation continues eastward upto Tola Mangli area with the exception that the hanging wall anticline i.e. Surghar anticline is intact and the strain built up was concentrated in a wider zone within the Surghar thrust sheet. The restored cross sections along Kutki section reveals that 5.6 Km overall shortening has taken place along the frontal fault i.e. Surghar Fault (Fig.7).

According to Khan and Opdyke (1993) the present site of Makarwal anticline (Surghar anticline) was occupied by Paleo-Indus river from 7 Ma till 2.3 Ma and was flowing from west to east. The Indus was displaced 2.3 Ma ago from the present site of Surghar anticline. This shift of Paleo-Indus River can be attributed to the onset of tectonic activity at the site of Surghar Range.

CONCLUSIONS

The topographic expression of the Surghar Range is the result of a south verging anticline (Surghar anticline) at the level of Jurassic. The range front is marked by south verging forethrust namely Surghar Fault. The hanging wall strata of the frontal fault has been progressively collapsed into a series of north younging thrust splays giving rise to break-backward sequence of imbricate fan. All the structures have unidirectional vergence i.e. south, indicating south migration of deformation towards Punjab foreland. Along the strike, two distinct styles of range front geometries have been observed. In the west, north of Kutki village the Surghar Fault is found to be strongly emergent thrust front and changes to a tip-stick thrust front eastward in the vicinity of Chichali pass and Tola Mangli village.

Fig. 6. Low amplitude folds within the Siwalik rocks located in the footwall of Surghar Fault.

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