

Neotectonic Evidences of Rejuvenation in Kaurik-Chango Fault Zone, Northwestern Himalaya

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Abstract

Neotectonic investigations using morphotectonic parameters such as basin asymmetry, drainage anomalies, digital data interpretation and geomorphic field evidences were carried out in Satluj river valley downstream of Khab in the Kaurik Chango Fault (KCF) zone. The study reveals the presence of a north-south trending fault which is similar to the KCF. Unpaired, tilted terraces, V shaped valleys, deep gorges and lakes are the manifestations of fault movement in the area. Presence of deformation structures preserved in the palaeolake profile at Morang indicates that the area has also been seismically active in the past. In this paper we present a conceptual model of the formation of lakes in KCF zone. Morphometric analysis was carried out with the help of Digital Elevation Models (DEMs) and field investigations.

Keywords: Neotectonics, Kaurik Chango, Kinnaur, Satluj

1. Introduction

Himalayan mountain range was created as a result of the collision of the Indian and the Asian plate. Ensuing tectonic turmoil is witnessed in the form of intra-continental deformation along major faults and thrusts [1-4]. The Himalayan region is dissected by several NW-SE trending regional thrusts namely Indo Tsangpo Suture Zone, Main Central Thrust and Main Boundary Thrust. These thrust planes and their subsidiary fault systems are the foci of several devastating earthquakes. In the Satluj-Spiti river valleys, a number of N-S trending faults have disturbed the Precambrian-Palaeozoic succession of the Tethys Himalaya [5-8]. Kinnaur lies in the Higher Himalayan region between Main Central Thrust (MCT) and Indo-Tsangpo Suture Zone (ITSZ).

The expression of active tectonism in Kinnaur is reflected in tilted terraces, V shaped valleys, convex slopes, rampant landslides and gorges. Kinnaur is a seismically active segment of the Himalaya. A major earthquake of magnitude > 6.8 occurred in this region in 1975 [9]. The region exhibits diverse deformation including strike-slip, normal and thrust faulting [10]. Kaurik-Chango fault has been studied in detail by several workers [9-13]. Several palaeolake profiles have been reported along the Kaurik

Chango fault in the upper Spiti valley [10,12-15]. However, research has not been done in the area between Khab and Akpa. This paper is an attempt to study the neotectonic activity in the area using morphotectonic parameters. The study area lies between 78°00' and 79°00' E and 31°25' to 32° N in the rugged Higher Himalayan terrain characterized by barren slopes and steep gradient.

2. Geology of the Area

Satluj River has been studied in detail by a number of workers [7,16-19]. The study area comprises thick succession of medium to high grade metamorphic rocks and their sedimentary cover. The succession is emplaced by granite intrusions of varying ages. Rocks of Vaikrita and Haimanta Groups are exposed in the region **Figure 1(a)**. Vaikrita Group comprises psammatic gneiss with quartzite bands, banded gneiss, granite gneiss, quartz mica gneiss. Haimanta Group comprises grey-purple quartzites, black carbonaceous phyllites and quartz mica schist interbedded with amphibolites and calc schists [19].

Figure 1(b) shows the SRTM image of the study area. River Spiti takes an abrupt southerly turn and flows parallel to the Kaurik-Chango fault near Sumdo. Seven terraces have been observed on the eastern bank [19]. There

is no evidence of terraces on the western bank. This may be due to the shifting of the river westward owing to the uplifted eastern block of the Kaurik Chango fault [20]. Quaternary fluvio-lacustrine deposits occur all along the Satluj valley downstream of Khab. These deposits are well preserved on the eastern bank. Several evidences gathered during the present work between Khab and Akpa indicate that Kaurik-Chango fault extends downward

upto Akpa showing an uplifted eastern block. There are indications of tectonic and seismic activity similar to those in the Spiti valley.

In this paper, several morphotectonic indices were used to analyze the tectonic deformation in the area. Digital Elevation Model and satellite data were used to study the landscape evolution of the region. Field investigations were carried out to verify the data generated in the lab.

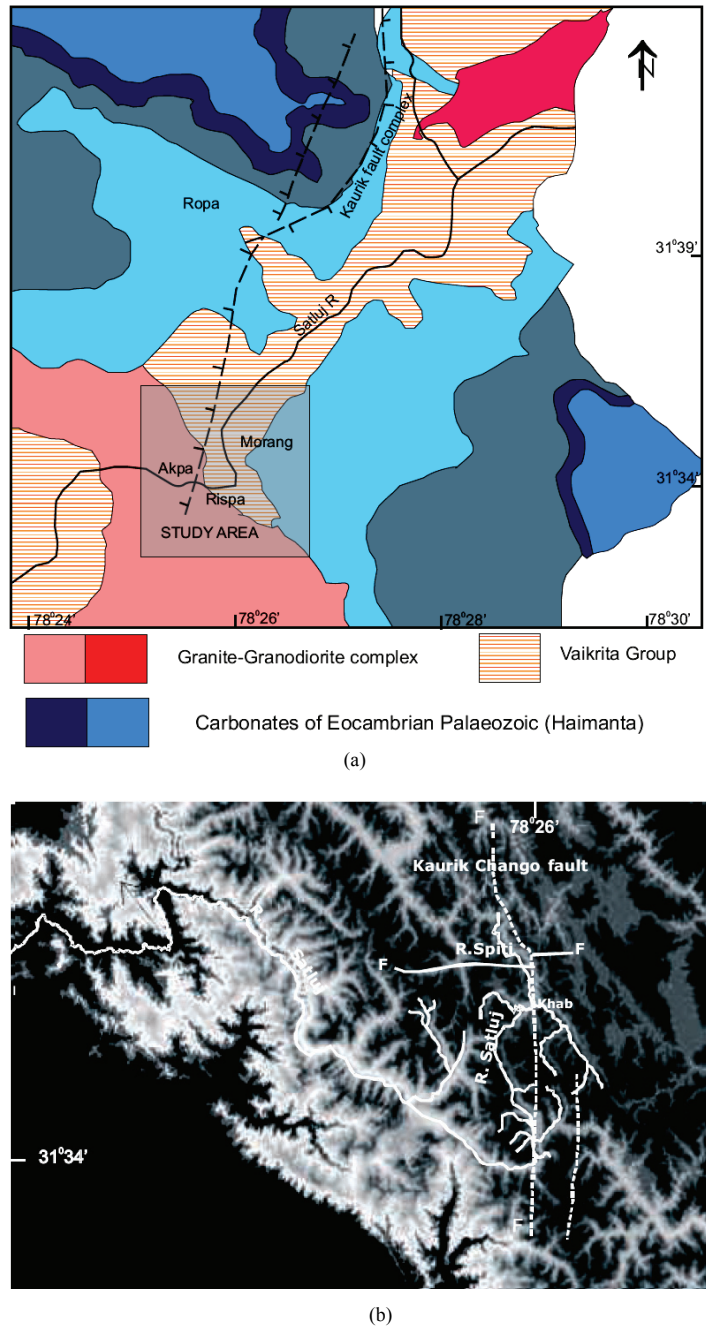
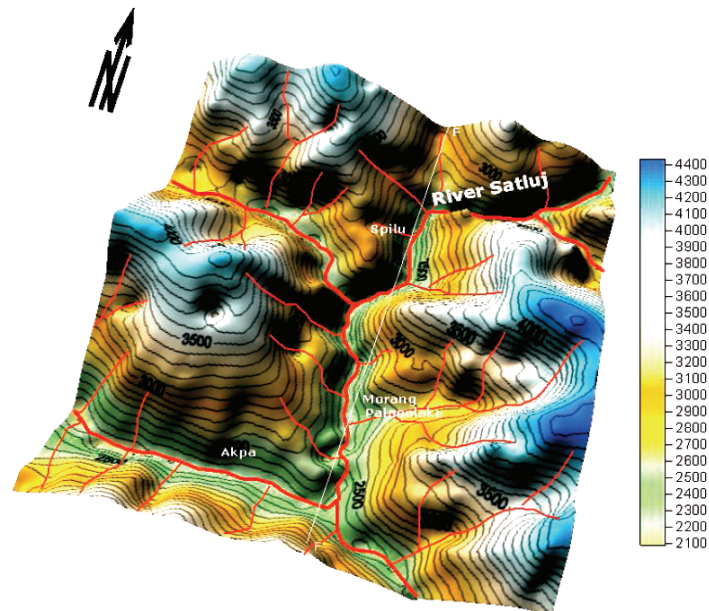


Figure 1. (a) Geological map of the study area (after Bhargava and Bassi, 1998); (b) SRTM image of Himachal Himalaya showing the location of the study areas. Also marked are the major drainage, thrusts and faults in the study area (image taken from NASA-SRTM program).

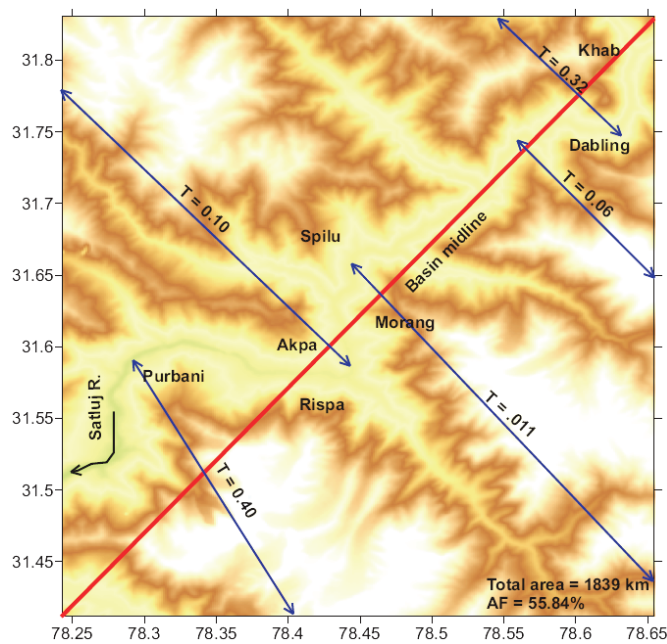
3. Methodology

Digital data interpretation was carried out with the help of a 3D Digital Elevation Model (DEM) and 2D topographic map to the scale 1:50,000. The softwares that were used to process the digital data are Surfer 9.6 and Globe Mapper. The Digital Elevation Model (DEM) **Figure 2(a)** of the area indicates significant changes in the topography and development of geomorphic features

such as fault facets, abruptly changing river course, meandering and widening of the river, formation of terraces, vertical down cutting and formation of gorges. The uplifted eastern block can be seen clearly in the model. SRTM data of the study area was downloaded from the site (<http://srtm.csi.cgiar.org>). Basin asymmetry was calculated with the help of the SRTM data **Figure 2(b)**. Asymmetry factor AF is defined as $AF = 100 (A_r/A_t)$ where A_r is the area of the basin to the right (facing downstream)



(a)



(b)

Figure 2. (a) Digital elevation model of the study area; (b) SRTM image of the study area showing basin asymmetry.

of the trunk stream and A_t is the total area of the drainage basin. In case of tectonic tilting, the value of AF becomes greater than 50 and the tributaries present on the tilted side of the main stream grow longer than those on the other side [21]. Transverse topographic symmetry factor (T) is defined as $T = D_a/D_d$ where D_a is the distance from midline of the drainage basin to the midline of the active meander belt. D_d is the distance from the basin midline to basin divide. Value of T ranges between 0 to 1. $T = 0$ implies a perfectly symmetrical basin and $T = 1$, a perfectly asymmetrical one [20,21].

The landscape morphology of an area is governed by drainage of the rivers and their tributaries. Tectonic deformation has a direct impact on the drainage of that area. Tectonic deformation changes the channel slope which is responsible for variation in the channel morphology [22-27].

Drainage map and stream profiles were prepared with the help of the SRTM data. Valley incision is used to define relative uplift [24,28]. Cross valley profile for the Satluj basin was prepared with the help of SRTM data. A high valley-floor-width to valley-height ratio (seen in a broad valley) indicates tectonic stability. On the other hand, a low valley-floor-width to valley-height ratio (seen in a narrow valley) is associated with recent tectonic movement [29]. Asymmetry Factor calculated for the Satluj river basin is 55.84 indicating that the basin is asymmetrical. Transverse Topographic symmetry factor (T) calculated for the basin is given in **Table 1**. The data clearly shows that the basin is tilted towards the northwest **Figure 2(b)**.

4. Drainage and Stream Profiles

Drainage map of the area shows lower order streams joining the trunk stream at 90° . The streams on the eastern block are longer and more in number compared to those on the western block. River Satluj flows through a crystalline basement belonging to Vaikrita Group. The area lies in the Kaurik-Chango fault zone. Quaternary reacti-

vation of these faults has lead to bedrock incision by Satluj which flows in a gorge for most of its course in the study area **Figure 3(a)**. Longitudinal profile of Satluj shows a change in elevation near Spilu. Between Spilu and Akpa, the river has carved a deep gorge. This abrupt change in river morphology indicates that the river course in this region is tectonically controlled **Figures 3(b)–(c)**. Low valley floor width to height ratio suggests that the river is cutting downwards due to the tectonic activity in the region.

5. Geomorphology

The Satluj river basin under investigation is a rectangular basin with an area of 1839 sq km. The mean height of the basin is 3118.3 m. River Satluj is a 4th order stream as per the Horton–Strahler method of stream ordering. The highest point in the basin is about 4400 m. The total basin relief is 2400 m. The streams on the eastern block flow in escarpments along most of their course. Landslide cones and springs are rampant on the eastern block **Figure 3(e)**. The river flows in a narrow valley for most of its stretch from Spilu to Morang **Figure 4(a)**.

River Satluj has carved three levels of unpaired terraces at Akpa **Figure 4(b)**. The river in this region deflects abruptly towards the west. Tectonic rejuvenation of the N-S fault has also caused the tilting of the terraces **Figure 4(c)**. Landslide cones and springs are rampant along the N-S lineament **Figure 4(d)**.

In Morang, fluvio-lacustrine deposits are exposed for about 1 km **Figure 4(e)**. These deposits are 60-70 m thick. The sedimentary succession is represented by laminated clay-silty clay and horizontally bedded sands. Laminated sediments dominate the lake section. Presence of lacustrine deposits also suggests that neotectonic movements along the N-S fault were responsible for blocking the river and forming a lake. The uplifted eastern block led to the damming of the rivulet, Khokpa nala. Ensuing landslides facilitated the formation of a lake on the footwall

Table 1. Morphometric characters of Satluj river showing active nature.

River Basin	Basin Area Total (Km ²)	Basin Asymmetry (AF)	Topographic symmetry factor (T)	Valley Floor width Ratio (Vf)	Mean Height
			0.32	1.2	
			0.06		
Satluj River	1839	55.84	0.011	2.3	3118.3 m
			0.10		
			0.40	0.60	

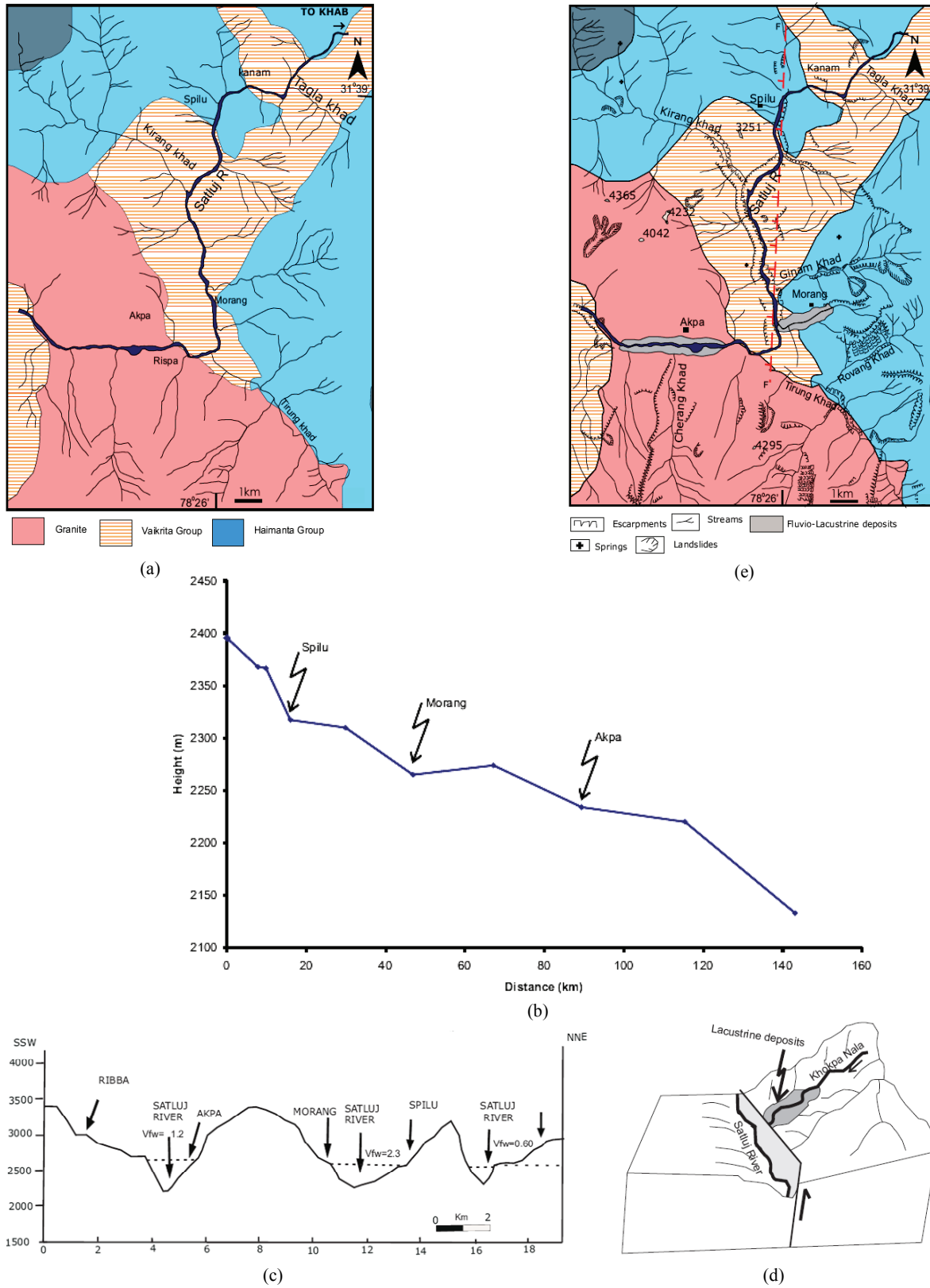


Figure 3. (a) Drainage map of the study area; (b) longitudinal profile of river Satluj in the study area; (c) cross valley profile of river Satluj in the study area; (d) hypothetical model showing lake formation in KCF zone; (e) geomorphological map of the study area.

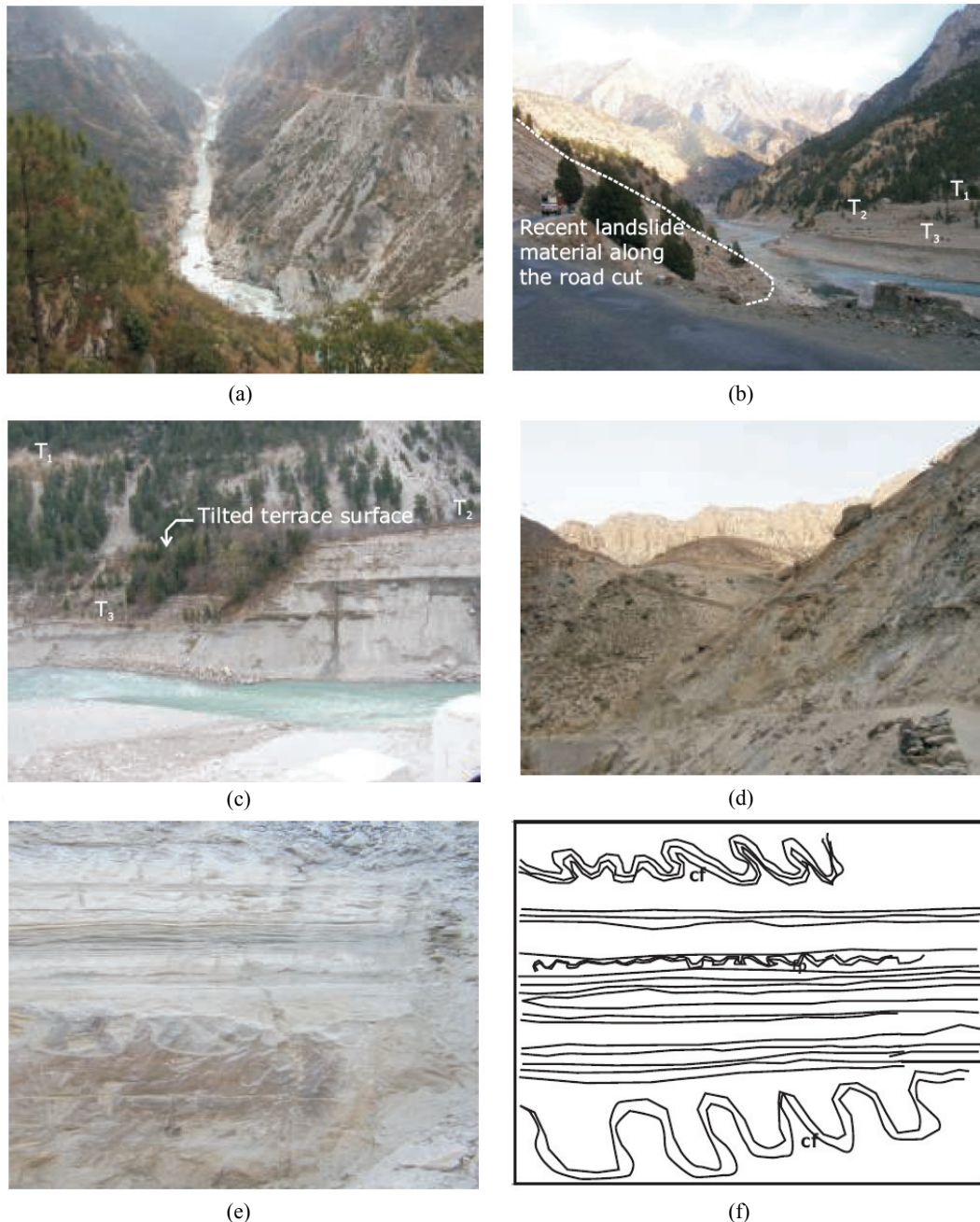


Figure 4. (a) River Satluj flowing in a narrow valley from Spilu to Morang; (b)-(c) three levels of unpaired terraces formed by the river at Akpa, showing tilted surface; (d) recent landslide material; (e) fluvo lacustrine deposits at Morang; (f) sketch of deformation structure in the lacustrine profile.

block **Figure 3(d)**. At least five levels of deformation structures are exposed in the palaeolake profile at Morang **Figure 4(f)**.

6. Discussion

Kinnaur and Lahaul Spiti districts of Himachal Pradesh were severely rocked by a major earthquake of magni-

tude > 6.8 in 1975. The earthquake was associated with movements along a subvertical N-S trending normal fault named Kaurik-Chango fault. Luminescence chronology of seismites in Sumdo suggests that activation of Kaurik-Chango fault and seismic activity dates back to Late Pleistocene [15].

In the present area of investigation, a N-S lineament was observed along which river Satluj flows for a consi-

derable distance before getting deflected near Akpa. A number of neotectonic evidences which were gathered during the study testify to its active nature. Morphotectonic parameters such as Asymmetry Factor (AF) and Transverse topographic symmetry factor (T) as well as the field evidences suggest that the Satluj river basin is tilted. DEM of the area also shows the difference in elevation of the two blocks. Drainage analysis clearly displays the effect of tectonic rejuvenation. Blocking of Khokpa nala, a small rivulet took place due to fault movement leading to the formation of Morang palaeolake on the eastern block. Several levels of deformation structures have been observed in the fluvio-lacustrine profile at Morang. Similar structures are seen near Kaurik Chango fault in Sumdo and Leo. Presence of deformation structures in the Morang fluvio-lacustrine profile indicate that the area lies in the tectonically and seismically active zone and has experienced several pulses of intense seismic activity. Neotectonic indicators such as the uplifted terrain, unpaired terraces, fluvio-lacustrine deposits, deformation structures, alignment of springs and landslides in the fault zone are strong evidences of the active nature of the N-S fault in the study area.

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