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NEOTECTONICS IN UPPER CHAJ DOAB PUNJAB PAKISTAN

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Abstract: *The upper Chaj Doab is a part of Punjab Plain and borders Sub Himalayas that had undergone faulting and folding. The area is dominantly composed of alluvial sediments. It is drained by the River Jhelum and the River Chenab. There are two prominent scarps/upland in the area. Gondal bar Scrap runs over 40 km from Charund to Rerka and beyond. Bahlulpur Scrap upto* 18 *km from Kotali Baidan to Sheikh Chogahi in District Gujrat. Gondal bar scarp exposes fluvial quartzose sand capped by flood plain silt and clay with profuse quantity of calcareous nodules. Bahlulpur Scarp exposes alternating beds of laterally accreted (point bar) quartzose sand and vertically accreted (flood plain facie) clayey silts to silty clays. The top member (clayey silt and silty clays) of both the scraps contains cultural debris suggesting Quaternary age of these deposits. Field study and regional context suggest that Bahlulpur and Gondal Bar Uplands vis-à-vis Dinga Basin are neotectonic features developed under south ward propagating compressional stresses which have accommodated themselves in this area. The neotectonic study has direct implications in combating with ground water, water logging and soil salinity, flood hazards and foundation problems encountered during execution of development projects.*

INTRODUCTION

Upper Chaj Doab is the north central part of the Punjab plains and lies on the northeastern rim of this basin where it joins Himalayan foothill zone. It is bounded in east south west by River Chenab and in north west by River Jhelum. It is located between 73°30'-74° 28. East and 32°-7' to 33° 0 North [Fig. I] Punjab plain is a geomorphic name and these plains are called Punjab foreland basin because they possess thick alluvium overlying Tertiary and older sedimentary deposits (Kidwai, 1962). Northern rim of this basin where it joins foothill zone i.e. Salt Range in northwest, Pabbi hills in north, Jammu hills in northeast is under considerable structural strain (Wadia 1992). The northern margin of Punjab basin is marked by major fault scarps that separate the basin from Himalayan foreland fold and thrust belt [HFFTB]. Indo Pak shield (basement) protrude the Quaternary alluvium in Central Chaj Doab in Sargodha Chiniot area. Sargodha ridge is a neotectonic feature (Gee, 1983) and it may have formed by late Cenozoic faulting. The Salt Range in the north of upper Chaj Doab is marked by southward moving Sa]t Range thrust which is still active (Yeats and Lawerence 1984). The deformation in Salt Range and Pabbi area is thin skin type, which involves the sediments over Cambrian and does not stop at Salt Range and Pabbi area but continues further south in upper Chaj Doab. The convergence of basement under Salt Range formation is merely 12 mm/year (Lillie et al., 1987) which suggests that basement of Punjab is still active. Punjab Seismic zone has been marked by Yeats and Lawerence (1984), which is parallel to Indian Himalayas. The seismic instability of the area is well known with earthquake of magnitude level m.a.4 (Quitmeyer et al., 1979).

A number of lineaments have been reported in the Punjab basin (Upper Chaj Doab), that may be active faults (Kazmi 1979, Kazmi and Rana 1982). One of these lineaments has been studied on ground by Yasin et al. (1993) and they have shown the possibility of quaternary faulting whereas other features had not been properly appraised. It has been tried to present here all neotectonic features controlling geomorphology, ground water and surface water regime and most importantly hierarchy of fluvial sedimentation in upper Chaj Doab.

OUT LINE GEOLOGY OF UPPER CHAJ DOAB

Upper Chaj Doab contains more than 500m thick Quaternary deposits (Kidwai, 1962). Below this alluvial cover older sedimentary deposits either consolidated or unconsolidated overlies igneous/metamorphic rocks of Indo Pak shield/basement. Kidwai (1962), Kazmi and

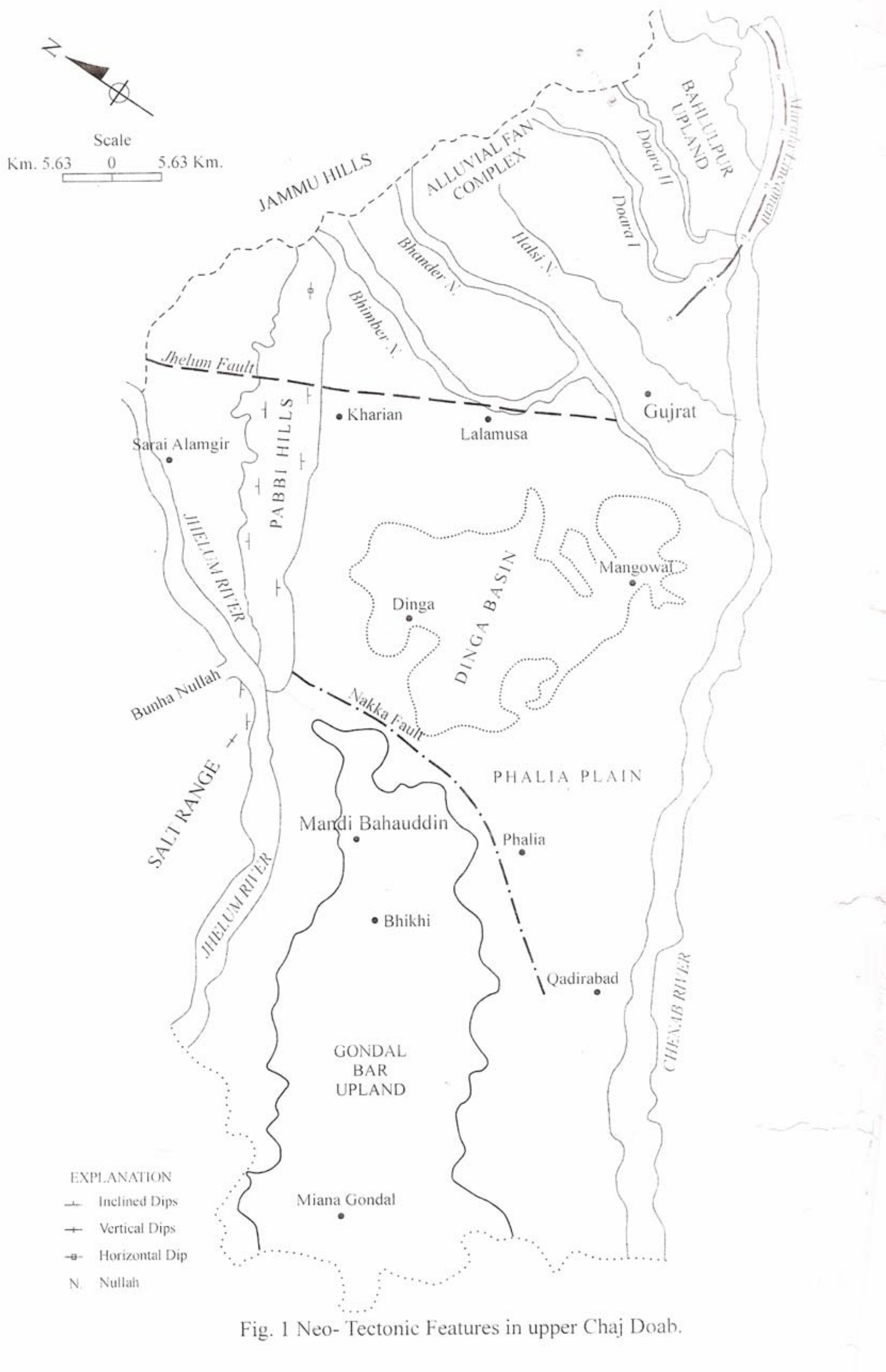

Fig. 1 Neo- Tectonic Features in upper Chaj Doab.

Rana (1982) have delineated a buried ridge and a monocline in the basin. Whereas Farah et al. (I977) considered Kirana hills as part of east-southeast trending Sargodha ridge of raised continental crust, which extends from Indus river at least as far as Indian border at Sutlaj river. This ridge is expressed by positive gravity anomaly and is a horst like block of continental crust. Conventionally it is believed that Kirana hills are old remnants of Palaeozoic geomorphic feature of Indian shield where as by recent research, it has been considered to be a neotectonic feature (Gee, 1983) where as sharp topographic break between Sargodha high and surrounding plains is suggestive of its relative youth (Yeats and Lawerence 1984). It is part of seismically active Punjab Seismic Zone (Seeber and Armbuster, 1979), which extends as far as Dehli (Menke and Jacob 1976). Sargodha ridge is parallel to Indian Himalayas therefore; Lefort (I975) suggested the possibility of a new thrust fault in front of Himalayas "a new MCT". The strike slip fault plain solution may indicate that the seismicity is actually controlled by transverse faults (Validya, 1976) which themselves localize position of re-entrants in [HFFTB] Himalayan foreland fold and thrust belt of Pakistan.

Yeats and Lawerence (1984) had suggested the possible mechanism of Sargodha ridge emplacement. It may had formed by loading of the shield by Himalayan thrusts producing bending moment stresses resulting in an outer swell that is Sargodha ridge. Alternatively they suggested that buoyancy prevent further subduction at Himalayas and a new seismically active subduction zone had formed within basement at Sargodha ridge.

The rock units making up Sargodha ridge has been named as Kirana group (Shah 1977, Alam et al. 1962). These rocks consist of metasediments, andesites, rhyolite, tuff beds etc. Lillie et al. (1987) have suggested that low strength of evaporites under sub Himalayas i.e. Salt Range and Pabbi hills have allowed the decollement to extend far out over the Punjab foreland. Gee (I 983) suggested that this southward movement of decollment have developed folding in the strata underlying Quaternary alluvium. Lillie et al. (I987) have suggested that active foreland thrusting is occurring on continental scale as basement is over ridden by its own northern margin in a series of south ward migrating thrust sheets from Himalayas, which shed their erosion products onto active fore deep of Jhelum plain & Upper Chaj Doab which itself is migrating south ward (Acharyya and Ray, 1982, Johnson et al. 1979). In the northern part of Jhelum plain (Upper Chaj Doab) river flows west south west of Salt Range along the axis of fore deep (site of topographic minimum). Lillie et al. (1987) have shown that most of the deformation in Salt Range is late Quaternary. The Siwaliks and older strata are thrusted southward over river Jhelum plain and are strongly deformed. These beds are overlain by an angular unconformity by undated fan gravels and alluvium (Lillie et al., 1987) of Salt Range provenance. These younger sediments themselves are folded and over ridden by Salt Range thrust/suggesting that deformation is still active. Lillie et al. (I987) have shown that river Jhelum had removed the southern flank of Lilla anticline as it formed. This appear to be a blind sledrunner thrust extending south from the Salt Range implying that a portion of relative motion between Paleozoic sediments and basement took place south of Salt Range. This thrust front has recently been propagating further over the foreland as a giant sledruner (Baker et al., 1988). It is suggested that Salt Range thrust has been moving over the foreland as a coherent mass for the last 2 m.y.

Burbank et al. (1986), suggested that Plio Pleistocene structural disruption in the north western part of Indo-Gangatic foredeep appear strongly dependent on the distribution of incompetent (Particularly evaporite) horizons in the Paleozoic succession. Kazmi and Rana (1982), Khan et al. (1986), suggested that there exists a thin cover of Palaeozoic and Tertiary rocks over the basement. Kidwai (1962) and Yeats et al. (I986) suggested the presence of Miocene (Rawalpindi group) under lain by Siwaliks and Quaternary sediments. Kidwai (1962) had given detailed geology of Upper Chaj Doab with cross sections. He had described that quaternary alluvium consist of unconsolidated sand, silt and clay whereas gravels occur in depth close to hilly areas which had been deposited in a subsiding trough by present and ancestral streams of river Indus. The clayey silt mounds (Tibbas) present in Punjab basin documents wide spread aeoline phenomena in Punjab basin (Wadia 1992).

The presence and exposure of lacustrine sediments along the northern peripheral regions suggested wide spread occurrence of lakes during last glacial period, such as in south western Afghanistan (Smith 1974) Yasin et at. (1993) pointed out the possibility of Quaternary faulting in Punjab basin.

THE SCARPS IN UPPER CHAJ DOAB

River Jhelum and Chenab are two main trunk streams draining the area, which flowed southwest to join each other at Trimu head. The area lying between these rivers is termed as Chaj Doab. Basement rocks are exposed in the central part of Doab close to Sargodha and Chiniot. River Chenab passes through a narrow valley cut in these rocks at Chiniot. In Upper Chaj Doab a number of lineaments have been mapped from aerial photographs and speculated to be active faults in Quaternary alluvium by Kazmi (1979) Kazmi and Rana (1982). The scarps examined in the field have been mapped and marked is Fig-1. There are two main scarps exposed along Gondal Bar and Bahlulpur uplands.

1- GONDAL BAR UPLAND SCARP

The lineament along Gondal Bar scarp is well exposed at Channi Rahim Shah on Kuthiala- Phalia road, from here scarp has north east south west trend and best exposures are at Pandowal Jand and Rerka zarin in south west where as in north east at Bohat and Charund. The trend at Charund is almost north south. In this area Kazmi (1979) had marked a lineament named as Mangla fault, which extends northeast and passes close to western margin of Mangla Lake and had a left lateral movement. This lineament on ground had been studied by Yasin et al. (1993) who showed the possibility of Quaternary faulting along Gondal Bar scarp with north south and north east south west trending two faults. Near Channi Rahim Shah the low ground rises gradually for about 400 meter as a ramp and then it rises abruptly in a scarp, which is about 5- I 0 meter high. Quartzose sand is exposed at the base of scarp that fines up to silt and clay showing abundant calcareous Kankers (Gondal and Ahmed 1994). The sediments on top of this scarp can not be older than Holocene as these shows red earthen pottery fragments and cooked animal bones which suggested them younger than the earliest human settlements in the area. The fluvial faceis exposed in the scarp vary from place to place and appear to be cut by the scarp along their depositional strike. At Bohat the sand facies cut laminated silt and clay facies with some marsh plant rootlets and leaf imprints. This facies appear to be deposited in a shallow lake, which extends to Mangat. Detailed study is needed to establish depositional hierarchy. The up and down sides of scarp are different regarding ground water regime and gradational processes. On down side of scarp, swamps are common with a number of small-scale alluvial fans parallel to the scarp. Especially in Pindi Lala, Bohat and Charund area north of Phalia Town. Vegetation on the both sides is different. Gondal bar upland slope is drained to the north west whereas central part of this feature is slightly depressed which is ponded during moon soon e.g. Bhikhi, Khai, Ajowal, Rukan and Wariat area. Gondal bar posses a mature soil profile i.e. Kanker horizon is available through out the bar upland at 3-4 feet depth. The Kanker horizon is 2.5 to 4 feet thick bed underlain by alluvial, cross-bedded sand where as such a horizon close to Phalia Town is available at 400 feet depth (Wasid 2-1980).

2- BAHLULPUR UPLAND SCARP

The second scarp exposed close to Murala Head works where river Chenab enters Punjab plain is a piedmont scarp some times called scarp lets (Thornbury 1972) which runs from Kotali Baidan and beyond to Sheikh Chogahi with a curvilinear trend of north west to south west in district Gujrat. Near Bahlulpur, old flood plain of river Chenab gradually rises for about one km laterally then it rises abruptly in a vertical bluff. The relative height difference across vertical bluff and Chenab flood plain is nearly 25m. This scarp is well exposed at Kotali Baidan, Kuri Bahlulpur, Shampur and Sheikh Chogahi, Beyond Sheikh Chogahi, the bluff suddenly diminished in height till the confluence area of Doara I and river Chenab is approached.

It possesses alternating beds of laterally accreted (point bar) deposits of light grey to buff coloured, fine to medium grained parallel to cross bedded quatzose sand bodies. It is 0.5m to 2m thick interbedded with vertically accreted over bank fine deposit (flood plain facies). Its colour varied from reddish brown to yellowish brown clayey silts to silty clays with 2-3 m thick massive beds. Silts O.75m thick cap the top of these deposits with profuse quantity of Kankers/Calcareous concretions from fine to coarse grained in texture. This Kanker bearing silt sharply changes upwards to sandy soil (thin veneer), which at present is erosional surface. These sediments appear to be deposited by fluvial processes of river Chenab in middle late Pleistocene times (Rafique, 1967). Share of aeolin sedimentation in these deposits cannot be rolled out.

The up and down side of the scarp are different regarding vegetation, ground water regime and gradational processes. Abnormally small scale alluvial fans are common along the base of bluff developing ramps which have been incised by transverse steep ephemeral streams draining ponded drainages up valley with well developed three pair of level terraces in the vertical bluff. In contrast this upland is poorly cultivated with rolling topography and representing bad land area/geomorphology of the scarp area. The human settlements are mainly located on the upside of the scarp where as major cultivation is on down thrown side.

3- DINGA BASIN

The central part of upper Chaj Doab is bounded in north east by Jhelum fault with north south trend having a left lateral movement cutting across Pabbi hills parallel to G.T. Road propagated Upper Chaj Doab (Kazmi 1979), It had been concealed by small scale alluvial fans prograding basin ward from Bahlulpur uplift/old piedmont. Northwestern boundary of central upper Chaj Doab is marked by Nakka fault (Yasin et al. 1993). Which is a continuation of Mangla right lateral wrench fault (Kazmi (1979). The northern north eastern boundary is marked by Pabbi anticlinal flexure which has got surface expression since 0.4m.y. before present (B.P) (Johnson et.al. 1979) where tectonic compressional stresses originating in HFTB [Himalayan Frontal Thrust belt] are being accommodated in this area developing thin skin fault controlled folding i.e. Pabbi decollment. In front of this Pabbi anticlinal flexure site of subsidence is developing due to localized rifting along northern margin of Punjab basin. This subsiding area is known as piedmont basin (Fraser 1958, Rafique 967) and Dinga basin (Gondal and Ahmed 1994). Along southern flank of Pabbi decollement dipping 35° south alluvial fans have been developing due to mass wasting and stream activity, which coalesced laterally overlooking ox-bow lakes along Gondal Bar scarp at Charund and Keerbawa in north west of Dinga basin. Along the northern northeastern flank of this basin where thrusting is actually taking place with an uplift rate of 1.3m3m/l000y (Johnson et al. 1979). There are a number of small scale to medium scale laterally coalesced alluvial fans prograding over this basin and documenting a series of intra-formation discontinuities. Localized deposition occurs along the fans causing a new fan segment to prograde basin ward. The southern southwestern boundary of this basin is marked by a few alluvial fans, which represents its passive margin. This basin consists of a number of sag basins with poor seasonal drainage representing an open shallow ephemeral alluvial lake. The sedimentary strata' exposed in the bluffs of seepage drain and auger holes consist of severely shrinking/swelling silty clays upto a depth of 5 meters.

DISCUSSION

The origin of bars/uplands in Punjab basin has been suspected by Khan (1991) to be geomorphic or structural in nature. The area under study is comprised of fluvial sediments vis-à-vis aeoline deposits of clayey silty mounds with effusive salts locally known as Tibbas. Simple fluvial terraces are commonly parallel to the streams responsible for their formation (Selby, 1985) but Mial (1981) has described that rivers. tends to run either parallel or perpendicular to structural strike. Gondal bar scarp is not parallel to any major stream instead there are a number of oxbow lakes, marsh lands lying opposite of this scarp. The coalesced alluvial fans originating from Pabbi hills to Charund and Keer Bawa north west of Dinga basin over looked Ox bow lakes. Rafique (1967) described it as an old levee remnants whereas Fraser (1958) called it as an old spillway rout of river Jhelum which was flowing south ward and later on switched over to present route due to uplift of Pabbi on left bank of river Jhelum. Bahlulpur scarp parallels river Chenab on right bank with steep bluff where as such a feature is not available on left bank side. Alexander et al. (1987) suggested that intrabasinal faulting may act as floodwater dams and produced raised topography where more rapid pedogenesis and localized erosion will occur. It was further suggested that river tends to flow toward topographic minimum. In a simple half graben the area of maximum subsidence will be adjacent to main fault, which had been rapidly occupied by alluvial fans prograding from footwall i.e. southern limb of Pabbi decollement, which pushed the axial river path *further from* the locus of maximum subsidence. The neo-molasic alluvium presently lying against Siwaliks foot hills will be involved in future upheaval as exhibited by Siwaliks to the old rocks. The inner boundary of Siwaliks is a faulted one as for as Chenab in the east, southeast and south (Wadia 1992) beyond which west ward the fault is gradually concealed and replaced by anticlinal flexure/decollement. This fault cuts obliquely Jhelum fault/lineament close to Lala Musa and passes over Gujrat to Sheikh Chogahi defining the southwestern boundary of Bahlulpur upland where lineament had been concealed by alluvial fans. This Hneament had been mapped by Kazmi (1979) under Kalar Kahar fault with a WNW trend and right lateral movement. As a consequence of the past and continuing collision of Indo-Pak with Eurasia, propagating faults and folds had disrupted proximal margins of Punjab alluvial basin and this deformation along northern margin of Punjab foredeep had disrupted molasic deposition in this basin (Burbank et al. 1986). The studied scarps are situated very close to the active Himalayan foreland fold and thrust belt [HFFTB]. The uplifted seismically active Salt Range thrust is very close to the Gondal bar upland in the north west where as northern tip of Gondal bar is near Pabbi hill which is still active with an uplift rate of l.3m-3m/lOOO years and surface expression of Pabbi began to develop sine 0.4 M.Y ago (Jhanson et al. 1979). Bahlulpur upland is close to Jammu hills in the north -north east and Pabbi hills where localized deposition occurred along the fans, carrying a new fan segment to prograde basin wards. The portion of fans in fault footwall suffers uplift, incision nick, point retreat, terrace formation and surface soil development (Leeder et al. 1987).

The alluvial terraces on the foot wall of Pabbi decollement (Southern limb) developed in alluvial fans had now uplifted above a general level of Punjab plain developing angular unconformity between upper Siwaliks/Pinjor stage and alluvial fan deposits, traceable up to 34 km in transverse stream emanating from Pabbi hills. This angular unconformity is also present along the southern margin of Slat Range where it is overlain by undated gravels of Salt Range provenance, which had also folded along southern margin of Salt Range, (Lillie et al., 1987). These gravels are present in sub surface at a depth of 160-194 feet along the northern margin of Gondal bar upland between Malikwal and Bahowal (Wasid-2,1980).

The fore land basins are characterized by sedimentation sourced from rising mountains and synsedimentary deformation of deposited strata (Tankard, 1986). Thrusting and thrust relate the deformation folding of sedimentary strata which result in foreland fold and thrust belts [FFTB]. Fault propagation and fault bend folds are common with blind thrust folds and strike slip faults in foreland fold and thrust belts, as FFTB advances toward the craton (Marshak and Woodward, 1988). Himalayan foreland fold and thrust belt [HFFTB] is still active (Yeats and Lawerence 1984). So Punjab foreland basin may be called active as it borders the HFFTB. The area under study falls on northern peripheral region of Punjab basin which has been propagated by faults (Kazmi, 1979) and blind thrust folds. (Gee, 1983). Upper Chaj Doab/Jhelum plain has a faulted contact with Salt Range where basement is converging underneath Salt Range at a rate of 12mm/year (Lillie, et al.; 1987). Salt Range decollement is sliding over salt/evaporite bed developing strain in adjacent neo-molasses deposits/Quaternary deposits composing upper Chaj Doab and is pushing them southward. Rise in Pabbi hill has been calculated to be l.3m-3.0m.m/I 000 years and its surface expression took place during 0.4 M. Y (Johnson et al. 1979). So in this context the studied scarps are more likely active faults rather then the bluffs of simple geomorphic terraces. Gondal bar scarp takes turn at Mekan and become north south so the scarp possibly represent two faults with north south and northeast southwest trend (Yasin et al. 1993). The lineament passing close to Gondal bar scarp had been named as Nakka fault. The Bahlulpur scarp is more a piedmont scarp, a definite evidence of active fault (Thornbury, 1972), an expression of the faulted inner boundary of upper Siwaliks as far as Chenab River in east south east (Wadia 1992). This lineament is named as Murala fault. The fault line in both these cases is away from the exposed scarps as these have retreated to their present position/ locations due to toppling, rotational and cantilever sliding of the scarp fronts. The area described previously as Dinga basin represents an open shallow ephemeral lake, which is subsiding relative to Pabbi hills, Gondal bar upland and Piedmont basin whose northern northwestern margin is still active.

The implication of possible faulting and folding in upper Chaj Doab are important. Faulting control the facies architecture in alluvial basin. Upper Chaj Doab has been divided into different blocks with a sense of movement vertical as well as lateral movement. Gondal bar and Bahlulpur uplands had been not over run by floodwater in recent past. Instead these act as dams to flood water where as low lying areas are prone to floods, water logging, salinity and marshland development. The low lying area/areas of maximum subsidence are favorite sites for river avulsion e.g. river Jhelum is flowing along the axis of actively subsiding foreland basin (Lillie et al. 1987) and similarly river Chenab is also flowing in such a low lying area. Big salt deposits capped by marine sedimentary rocks (Cambrian to Tertiary) lies in the north of Punjab basin, which extends southward as far as Sargodha ridge in the southwest (Shah, 1977 Kidwai, 1962, Yeats et al., 1986, Lillie et al., 1987). These rocks in subsurface may contain trapped marine water which may up well along the paths provided by the intrabasinal faulting. So soil salinity may also be related to this flow of marine water. Upper Chaj Doab fell in Punjab seismic zone with earthquake magnitude ma>4 (Quittmaer et al., 1979). So far the planning and designing of industrial complexes and urban settlement is concerned, proper consideration to neo-tectonic activity should be given for their safety and durability. In the water logged, saline and flood prone areas road/highway designing should be done with respect to related neotectonic element and sedimentary suite. .

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