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Review Paper

Structural and tectonic deformation of the Tibetan plateau since Cretaceous: An upshot of Indian-Eurasian collision

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Abstract

The Himalaya, Tibet, and the Karakorum are the most spectacular upshot resulted in response to the Indian and Eurasian plate collision.The collision resulted in the crustal thickening and shortening of the region during the Cenozoic era with an estimated magnitude of >50%. Tibet is further distributed into North, Central, and the Southern segments, which are constrained and parted by different faults/thrusts and sutures zones. A number of geophysical and geological researcheshave been approved and are still continuing to understand the tectonic activities going on in the area. Late Cenozoic has been marked as an important era in developing of most noticeable changes occurred in the region including of;east-western crustal extension alongthe central Tibet, as well as the clockwise rotation of the Tibetan plateau (since ~10-13 Ma). This extension lead to the generationof grabens, strike-slip faults and resultingthe uplift of the central Tibet. The tremendous magmatic activity occurred in Lhasa block during Cambrian era, are believed to be the product of subduction of Proto-Tethyan Ocean underneath the Australian Gondwana. Similarly, the Late Devonian to early Carboniferous magmatism is associated with the back-arc evolved in the Songdo-Tethyan Ocean, while the Late Triassic to Early Jurassic magmatism is associated with the development of Indus-Yarlung-Zangbo Tethyan back-arc basin. However, climatic research of thesouthAsia highlighted that the uplift period of the Tibetan plateau was initiated duringLate-Miocene (~8 Ma). The calculated NS crustal shortening and EW extensional rates of the Central Tibetan plateau alongAltyn Tagh Fault are about ~10-12mm/yr. and ~8-10mm/yr., respectively withless than 20km of the slip; which is identical to the GPS studies of the region. The cooling and exhumation events (not later than ~22-25Ma) in the southcentral Tibetan plateau are the product of the Cenozoic collision.

Keywords: Tibetan plateau, Altyn tagh fault, West kunlun fault, Longmu-gozha Co fault, Weak crustal zone, East-Kunlun-Fault, Karakoram fault, Indus-Yarlung suture zone, Karakorum- Jaili fault zone.

Introduction

Tibet, covering ~3 million km^2 and with a maximum elevation of >5000m is called the *"Roof of the world"*. Tibet, Himalayas, and the Karakorum are the most remarkable upshots of the impact between Indian and Eurasia, during the Cenozoic era. Numerous researches have been approved in the Tibetan Plateau regarding various aspects, mainly about the evolutional history, tectonics and the uplift of the plateau[1-4]. Different geophysical and geological studies have been carried out in order to fully understand the surface and subsurface tectonic activities in the region; the different topographical heights in the zone from east to west, and, surfacing of the igneous rocks at different locations via volcanism or rifts[5].

The concept of Isostasy, introduced by Airy[6], was the main initiative for the birth of geophysical tools in-order to assist the geological studies[7]. During the late 19th century, scientists have realized that the geophysical technique can be a useful tool to solve the geological problems and hence, the Tibet and Himalayas became the prime ground to investigate the orogenesis and isostatic equilibrium. The invention of Gravity-meter played a dynamic role in understanding the theory of isostasy[6,5]. During the last three decades, a remarkable development has been made in the investigation of the subsurface behavior of the Tibetan-Himalayan region, through the integration of the geophysical techniques with the geological phenomenon. During Eocene to Miocene, major structural changes occurred among the central and southern portion of the Tibetan plateau, which uplifted these portions, while the northern portion remained unaffected and low elevated until the Pliocene-Pleistocene[8]. The present review manuscript is an effort to describe a brief introduction to the Tibetan plateau, established upon its evolutional antiquity, insight of the geological and geophysical studies approved out in the region by various researchers.

Geologic evolutional history of the Tibetan Plateau

There are huge controversies regarding the evolutionary history of the Tibetan plateau; several researchers proposed various models of evolution. Argand[9] proposed that the plateau is subsequentof the post-collisional conjunction between the Indian and Eurasian plates. Similarly, Molnar[3] proposed that the collision resulted the crustal shortening and thickening up to ~80km, which shaped the remarkable mountain ranges of the Tien-Shen, Karakorum, and the Himalayas,. In addition to the Argand's hypothesis, another model suggests that the plateau uplifted is because of the subduction of the oceanic plate under eastern-Eurasia and Indonesia[4].

Structural evolution of the Tibetan plateau over the clock of geological timescale is as follow; During *Cretaceous,* the central Tibet was deformed causing folding, faulting and piling up of the crust along the Bangong-suture-zone. *Late Cretaceous* to *Early Eocene* marks the rise of Andian Mountains and an ample amount of magmatic activities along with the formation of backarcfold and thrust belt in the southern portion of the Eurasian plate. The condensing of the crust underneath Tibetan plateau was initiated during the *late Cretaceous* as a subsequent to the subduction of Indian plate beneath the Eurasian. There are two schools of thought regarding the subduction and slab-breakoff mechanism; one group of researchers highlighted the Indian slab breakoff after subduction and next group debated about this mechanism and emphasized that the subducted Indian plate moves parallel to the Eurasian. The NNE part of the Tibetan plateau contains both the fluvial and detrital sediments. The crustal shortening resulted in numerous thrust/faults and the formation of the basins in the central and the southern Tibet[4].

The overall extent of the crustal shortening during the early *Cenozoic era* is generally unknown. On a local scale, it is assumed to be more than 50% and is suggested to be caused by Eurasian plate subduction underneath the Tibetan plateau. The consequent shortening of the Indian plate along Central Himalayas is estimated to be between ~500-1000km[4]. During *Eocene to Miocene*, major structural changes occurred along central and southern portions of the Tibetan plateau, which elevated these portions, whereas the northern part remained unaffected and stayed at low elevation until the *Pliocene-Pleistocene*[8], 8~10Ma ago. The left-lateral strike-slip fault along SW of the Sichuan Basin initiated the clockwise rotation of upper crust in the region[4,8].

Late Cenozoic marks the most noticeable changes in the region including of east-western crustal extension in the central Tibet. This extension began nearly 13-18 Maago and resulted in the formation of NW right-slip faults, NS trending grabens, and NE trending left-lateral strike-slip faults. Whereas, uplift of the central Tibet followed much earlier than 10~15Ma[8,10,11]. There were various arguments regarding the initiation of uplift and present elevation state of the Tibetan Plateau i.e. nearly 8 Ma by Harrison, et al.[12], ~14 Ma by Edwards and Harrison[13,] Edwards, et al.[14], Margaret Coleman and Hodges[2]), and before ~15 Ma by Spicer et al.[15].

Meanwhile, during the *early Cenozoic* (~52Ma), the Xining Basin (with confirmable Cenozoic deposits) was developed along the northeastern portion of the Qinghai-Tibetan Plateau.The formation of this basin results through the right-handed rotation of central Qilian with reference to the southern Qilian Block. Recent paleomagnetism studies disclosed the fact that the central Qilaian block revolved 24^o clockwise during the age of 49-29Ma[16]. The development of Laji-Shan along the northern margin of the Xinian Basin and Daban-Shan at the southern margin of Xinian Basin started during the periods of 88-12Ma and 60-32 Ma, respectively. During *Early Cenozoic* (50~30Ma), significant exhumations and thermal events occurred in both Laji and Daban Shan[17]. The disinterment in the Laji Shan during this period is suggested to be triggered by the collision of Lhasa with Qiantang. However, it'sexhumation during the period of 17~8Ma is believed to be the result of compression initiated by the clockwise spin of the southern Qilian Block in relevance to the central Qilian Block[16]. Slow uplift rates of both Laji and Daban mountains during this era was believed to be the outcome of isostatic equilibrium attempt generated by the footwall of normal faults among both northern and southern premises of the Xinian Basin[10,16,18].

Cenozoic has been a vital era in the evolutional antiquity of the Tibetan plateau. Along with the ongoing topographic and structural changes, volcanism is one another notable event. The *Cenozoic* volcanism resulted due to the Indian and Eurasia collision that played a keyrole in the evolutionary history. It has presented a schematic variation among the different collisional boundaries. Along the contact-collisional boundaries (soft/syn-collision) such as Lhasa of the southern Tibet and Qiangtang of the central Tibet, it is rich in Na+K (65-40a).While at all-sided-collisional boundaries (hard collision) it is chiefly composed of potassic-ultrapotassic + adakitic (aged ~45-25Ma)[19]. It is recommended that the topographic growth of Tibetan plateau was initiated from its south towards the north. The southern part of the plateau gained its present position during *Oligocene* whereas, the northern part acquired during the *middle-Miocene*[1,8,19].

Derivation of the Amdo, western Qiangtang, and the Tethyan-Himalaya resulted because of the impact amongst the Indian-Eurasian plates, whereas, the Lhasa-Terrance is the by-product of the Australian-Gondwana collision[11]. The *Cambrian* aged magmatic rocks discovered in the Lhasa are suggested to be the product of sub duction of Proto-Tethyan Ocean underneath the Australian Gondwana, as though the geology of the central Lhasa is largely similar to northern Australia[11]. The Late-

Devonian to early-Carboniferous magmatism found in Lhasa is associated with the evolution of the back arc in the Songdo-Tethyan Ocean. The *Late Triassic* to *Early Jurassic* magmatism of the Lhasa is associated with the development of Indus-Yarlung-Zangbo-Tehyan back-arc basin (Figure-1)[1,11]. Important climatic changes in South-Asia occurred during the period of *Late Miocene* (~8Ma), which are according to some researchers, also assumed to be the uplift period for the Tibetan plateau[2,20]. The minimum age of extension caused by the uplift of the plateau can be measured by dating the north-south trending normal faults resulted due to the gravitational collapse of the plateau, existing in the southern Tibet. In north-central Nepal, the $^{40}Ar/^{39}Ar$ dating of a normal fault indicated the age of ~14M.yr, whichgives an idea of EW extension in the Tibetan plateau started long before the late Miocene and continued till the plateau had attained its mean high elevation for the gravity collapse[2].

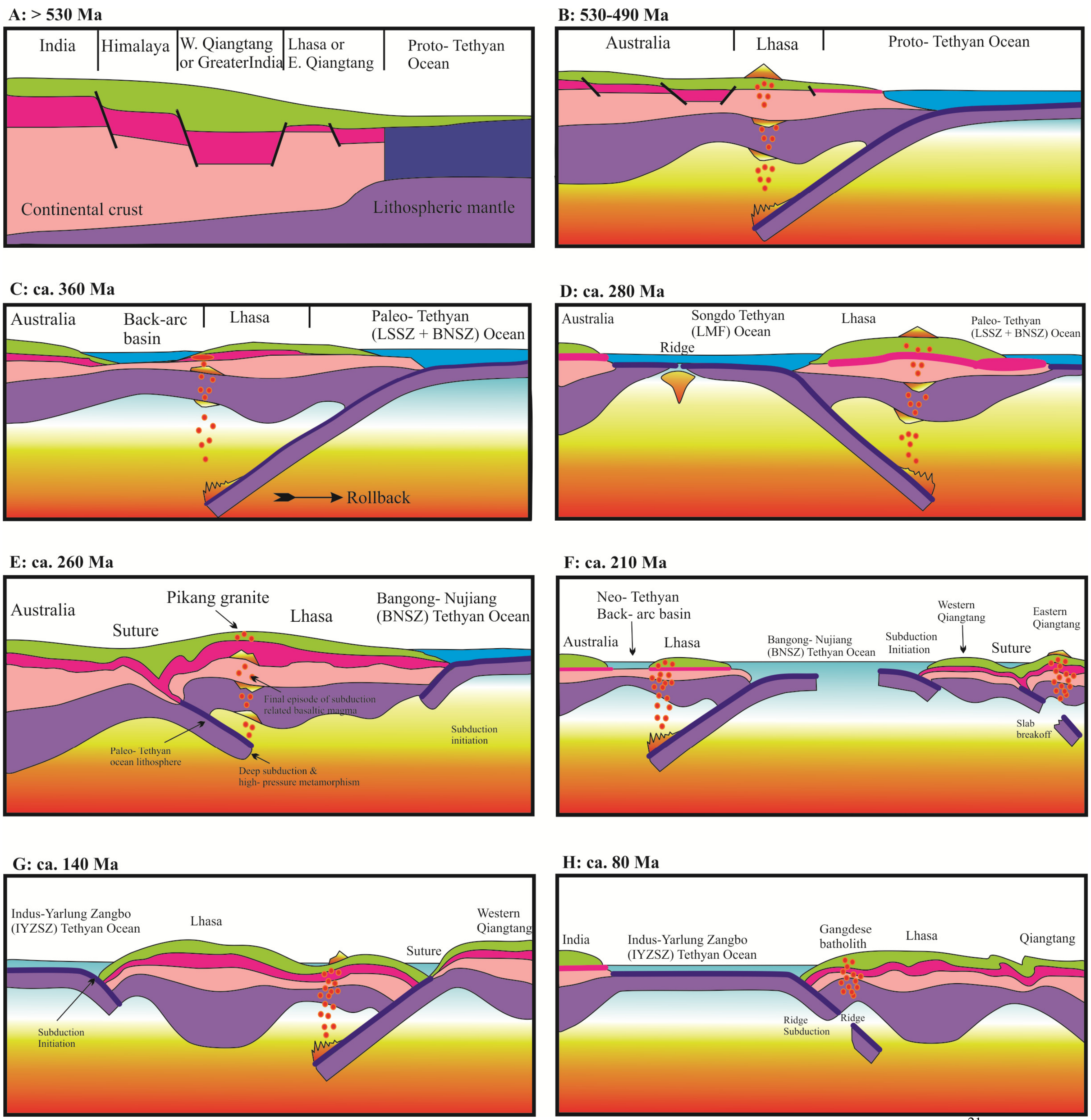

Figure-1: Evolutionary history of Tibetan plateau since Paleozoic to Early Cenozoic modified after[21].

Tectonic structures of the Tibetan Plateau

Karakorum, Himalaya and the Tibetan plateau are the most splendid features of Indian-Eurasian plate collision and are having a significant structural importance. The Himalayan thrust and fold belt is stretched to the length of 2400km in a neast-west direction[22]. Its eastern premises are Namche Barwa syntax while in the west is Nanga Parbat syntax (Figure-2). In accordance to define the detailed structure of Tibetan Plateau, it has been described under the following headings.

North Tibet: North Tibet is confined in its north by Anyimaqen-Kunlun-Muztagh suture zone (AMS) while in itssouth by Jinsha suture zone (JS). A ~1200km long NE trending left-lateral Altyn-Tagh fault (ATF) runs parallel to the AMS suture zone. ATF marks the southern periphery of the rigid Tarim basin and in the west, it is kinematically associated with left-lateral Karakax fault while in the further west it is linked with the Western Kunlun fault (WKF). In most SW, ATF acquaintances with the left-lateral LongmuGozhaCo fault (LGF), which is adjacent to the epicenter of Mw 7.1 magnitude earthquake of March 20, 2008[23]. Established on the offset of the Paleozoic magmatic belt[24,25], the slip magnitude of ATF is almost 550km. The estimated slip rate of the ATF determined by using cosmogenic dating was ~20mm/yr[26,27] while later using the different modern techniques on same data it is estimated roughly ~10mm/yr[23,28]. The slip rate measured through GPS velocities and Quaternary fault slip rates, along the central portion of the ATF,is ~13.7- 17.8 mm/yr[29]. Along with the ATF, many adjacent ENE trending faults are associated, such as SW dipping Dalong fault and double-bend Akato-Tagh. Tanghe-Nan-Shan and Hexi-links in NE of the ATF are suggested to be generated thru the northeastern growth of the Tibetan plateau during the Indo-Asian collision[23].

At further NE, the ATF associates with the Qilian-Nan-Shan fold and thrust belt. Based on structural distribution, the Qilian Mountain is divided into three parts, which are; a complex structured Northern-Qilian-Shan, a transitional Central-Qilian-Shan, and a relatively simple structured Southern-Qilian-Shan. The electrical data displayed the presence of the relatively high conductive layer underneath the eastern margin of the Qaidam basin and the southern Qilian Mountain, at the depth of about middle-lower crust[30]. The seismic data at the Qilian Mountain specifies the presence of an undulant Moho beneath the northern Qilian, with crust thinning from the south towards the north. It also encountered the presence of alow-velocity cover beneath the central Qilian block, which plays a key role in the extension of Tibetan plateau[31,32]. Established on the results from gravitational, geomagnetic, and PandS-wave velocities, the northern margin of the Tibet reveals different structures underneath the Tarim basin and Qaidam basin. It is therefore suggested that these two basins were generated by two different terranes and the presence of strong deformation in the basement and internal of the Qaidam basin is outcome of the tectonic evolution of Tibetan plateau[21,33].

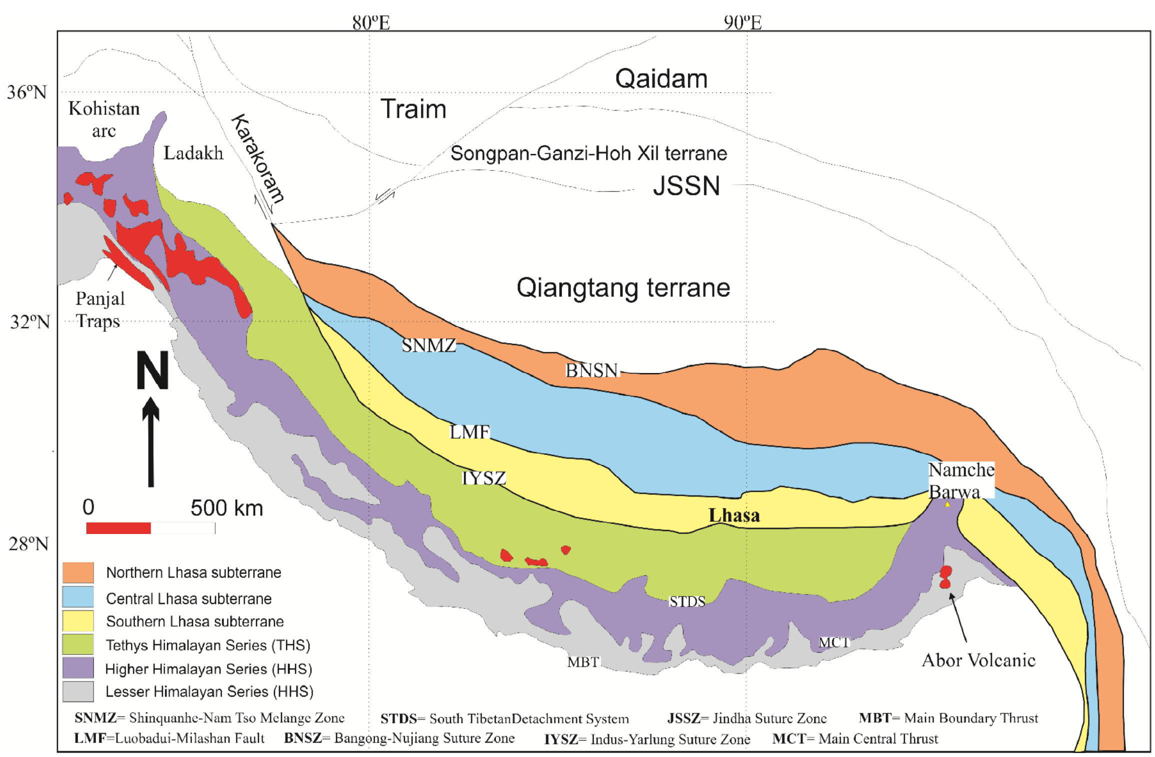

Figure-2: A composite structural map of Tibetan-Himalayas regions revealing the Indo-Asian collisional zone presenting the major structures in the area(modified after Michael Taylor and Yin[23]).

The east trending left-slip Kunlun-fault-zone is extending about ~1000kms and marked as an active structure in the northern Tibet. It runs correspondent to the Anyimaqen-Kunlun-Muztagh suture zone (AMS). The western-Kunlun fault further ruptures into sinistral splays, which are seismically vigorous and their kinematics are linked with the normal faults to the south[34]. The chief segment of Kunlun fault is the primary cause for the November 2001, 7.8Mw magnitude Kokoxilli earthquake, which is the highest magnitude earthquake recorded ever for any continental strike-slipevent[35-37]. The slip rates of Kunlun fault measured thrulate-Quaternary-slip-rates technique and the GPS velocities, are described as10-11.7$^{\pm 1.5}$ mm/yr.[29]. The cosmogenic dating technique used to monitor slip rates for the principal division of the Kunlun fault, displayed the slip rate of 11.5± 2mm/yr[38,39]. The slip rates of the eastern segment of the KKF indicates a decrease of <2mm/yr. This decrease in slip could be due to the deformation happening along the interior of eastern Tibet, which was triggered either by the eastward propagation of the KKF or thru off-fault-strain adjusting the vertical axis spin of the fault[23,40]. Magneto telluric sounding data displayed the presence of a weak crustal zone (WCZ) at the depth of middle to lower crust. It indicates the existence of a regional scalenorth-dipping thrust fault mounting the mantle wedge to its south and resulting in condensing of the crust in the region. This data displays that the northeastern periphery of the Tibetan plateau does not lie underneath East-Kunlun-Fault (EKLF), while it extends further to the northern boundary of the Hexi-Corridor[30].

Central Tibet: The central Tibet is constrained in its norththru Jinsha suture zone (JS), while in its south thru Bangong-Nujiang suture zone (BNS). The BNS is revived by the Karakorum- Jiali fault zone (KJFZ), which are NW trending dextral faults in an en-echelon pattern and comprising southern premises of the Central Tibet[23,41].

In order to better understand the geological progression of the Central Tibetan plateau, the focus should be taken on the boundary faults. The studies disclosed the kinematical linkage between the NS-trending rifts and the NW-trending left-lateral BN strike-slip fault, and the NW-striking right-lateral faults, (which are located at the south of the suture zone). Along the BNS, all the conjugate faults intersect with each other[23,41].

The earthquake data pattern recorded at the south-central Tibetan plateau is much complicated, especially it varies from east to west along the syntaxes. The NS-striking linear structures found in the south-central Tibet are designed in parallel to the maximum stress produced by the NS contraction of the Tibetan plateau[42,43]. It has been calculated that the NS crustal shortening and EW extensional rates of the central Tibetan plateau measured along AltynTagh Fault (ATF) are about ~10-12mm/yr and ~8-10mm/yr respectively[29].

The EW-trending sinistral faults present in north of the KJFZ fault zone, are conjugate to dextral faults present in the south. These left and right slip faults are kinematically associated with the northern/southern, north-striking normal faults. This conjugate system of central Tibet has ~1200km EW while ~300km NS extension. The eastern extension of this fault system is not well clear but then again it is presumed to be the eastern extension of the Jiali fault zone[23,44]. It is believed that this fault system assists the eastward extension of the Qiangtang terrene in relevance to the Lhasa terrane. If so, then eachright-slip fault has ~65km of the slip, which is the minimum slip of the Karakorum fault on the western Tibet[41]. The Qiangtang basin contains largely Jurassic marine deposits and it is the largest marine basin in the China[45]. The seismic data at Qiangtang basin displayed the basement located at deep in the southern portion of the basin while shallower in the north. The structural features associated with such deformational pattern are also varying from north to south of the basin. Along the north of the basin, we find the tight folds while in the south we have relatively gentle limbed folds[1,45,46].

According to the various studies, the strike-slip faults present in the central Tibet have less than 20 km of the slip[41]. The GPS studies carried out in the central Tibet displays the ≅15-20 mm/yr of EW extension, while, ≅10 mm/yr of the NS contraction[47,48]. Through In SAR studies, it has been discovered that the relatively high slip faults, such as dextral Gyaring Co fault (GCF) and the sinistral Riganpei Co fault system, are the location for 6.4Ms earthquake event of 9th January 2008[23,49]. The ^{10}Ar/ ^{39}Ar study at the different suture zones of the south-central Tibetan plateau has revealed that the cooling and exhumation is not later than ≅22-25Ma which resulted due to the Cenozoiccollision[50].

Southern Tibet: Southern Tibet is confined to its south by Indus-Yarlung suture zone (IYS) while initsnorththru Bangong-Nujiang suture zone (BNS). Its western margin is bounded by anactive right-lateral Karakoram fault (KF), which initiated during ~18-11Ma ago; whereas it's eastern structural boundary is the right-lateral strike-slipJaili fault zone[23,51].

In order to explain the age variations along the strike, the KF is assumed to be initiated along its middle segment at about 18 Ma ago and then followed by the southward propagation, while the northern segment of the KF is yet believed to be inactive and debatable. Due to the lack of the research data, the slip rate of KF is still not well estimated, however, somegeodetic and geological studies suggested its slip rate as 0-11mm/yr[48,52-54]. Therefore, it might be as low as 1-3 mm/yr. to as high as 10 mm/yr. The variability in the slip rates may be dependent upon the differential time or strike or the techniques used to measure it. If the results of cosmogenic dating carried out at two different locations of the KF are considered fact at this moment and the high slip rates are assumed to be correct then it is much greater compared to the geodetically computed slip rates, measure through InSAR[55-57]. The slip rates of KF monitored along two locations i.e. Menshi and Kailas are >7.1$^{+3.2/-1.7}$ mm/yr. and >7.9$^{+3.2/-2.5}$ mm/yr. respectively; whereas, the normal fault slip in Pulan graben is >1.6$^{+0.4/-0.3}$ mm/yr. The slip measured data alongside the KF displayed the slip along the southern KF is constant for about 200km i.e.>5~11mm/yr. at Gar basin, while, about 7~8 mm/yr. at Menshi- Kailas basins. It may then imply that the low slip and the constantly increasing velocity rates of the KF might be controlled through shallow depth brittle faults, which are interconnected with the steeply dipping ductile faults that lie in depths from middle to lower crust[53,58-60].

The mantle fluids are documented to be flowing along the KF and are reported lacking along the Indus-Yarlung suture zone (IYS), which is merely 35km south of the KF. This may be reasoned that in few million years ago, the KF has tectonically made its way till the mantle, which is tectonically significant[61-64].

The Karakorum-Jaili fault zone (KJFZ) includes a sequence of right lateral faults that southerly confining the eastward extension of northern Tibetan plateau[65]. The ^{40}Ar/ ^{39}Ar results show that the shearing initiation at the KJFZ is about ~18-12 Ma ago[66,67,60]. The generation of these two fault zones is supposed to be consequential of oblique collision between the Indian and Eurasian plates. Under these circumstances, the extension in the southern Tibet is not the key substitute in the rise of the plateau and the Indian-Eurasian collision may have been the reason behind the long rotational history of the Tibetan Plateau[67].

The Tibetan plateau is enduring north-south shortening and east-west extension, which can be observed through the development of numerous NS trending normal faults, rifts, and the grabens. North-trending rifts are one another prominent feature of the southern Tibetan plateau[68]. According to the rift-flank-topography and geophysical observations, rifts are only restricted to the shallow crust but on the other hand, rift spacing and involvement of intermediate depth earthquakes are evidence of the involvement of the lower crust and mantle[69]. It can be inferred that the formation of rifts and the strike-slip faults of central Tibet are interrelated[23]. Youngest rifts in the southern plateau, Yadong-Gulu Rift (YGR),shows a steeply dipping normal fault, suggesting a general shear rifting mechanism, which is attributing to an eastward horizontal shear at the base of the upper crust. The formation of NS normal faults is generally taken as the result of nearly-maximal uplift of the Tibetan plateau which finally resulted in gravity collapse. This may not be the only reason as through the results of the studies along YGR revealed that the horizontal shear may have given way to the Indian plate to indent northward[31,70].

Another prominent feature of southern Tibetan plateau is the NS trending normal faults and a few transpressional faults affected by EW extension of the plateau[42]. The GPS recording revealed no eastward moment of the plateau[43].

Eastern Tibet: Longmen-Shan (LS) has become a keen interest of the researchers in eastern Tibetan plateau, especially after the2008, Wenchuan earthquake of 7.9Mw magnitude. Several analyses have been carried out to examine the tectonics and exhumation rates of Longmen-Shan but due to less convergence rate (~3mm/yr), it had never been taken in regards to the crustal shortening factor in the past[48,71]. The high viscosity difference amongst the lower crust of the Tibetan plateau and rigid-stable block of Yangtze (which also blocked the eastward propagation of Tibetan plateau) is the reason for the upliftment of the Longmen-Shan. But then again, the uplift rate contrast between Tibetan plateau and the Sichuan basin resulted in sheer uplift of the Longmen-Shan and contributing to its high elevated topography within few million years[72].

The inversion techniques applied in the region exposed the presence of high-low-high resistivity layer in the Sangpan-Ganzi block, low-high layer in the Sichuan basin, while a complex conductivity structure in the LS area. Via electrical survey, a low velocity and high conductivity layer have been marked underneath the Songpan-Ganzi block at the depth of 20-45km, whereas, no such a layer has been reported below the SichuanBasin[73,74]. By imaging the electrical data, the fact surfaced is that Songpan-Ganzi is subducting underneath the solid and stable Yangtze block, which can be the possible reason for triggering of 2008 Wenchuan earthquake in the result of large stress accumulation along the subduction zone[46,75]. By investigating the magnetic effects upon the samples acquired within the fault plane of the Wenchuan earthquake, revealed that the Fe-bearing silicates and carbonates in the bulk samples and fragments have been dominant by dia/para-magnetics, while partially oxidized and Lepidocrocite had also been reported in minor quantity within the matrix of the rock[76].

Conclusion

Tibetan Plateau has gained the rightful attention of researchers from various fields of Geoscience, as already been discussed. Various models for the plateau uplift have been proposed, nevertheless, all researchers agree that the plateau uplift is mainly driven by Indian plate subduction and the convergence of Indian plate is responsible for the local structures within the plateau. The variation in GPS velocities in different zones, such as southern, eastern and central Tibetan plateau is an evidence of differential deformation. Had the Indian plate subduction? be the sole reason for the uplift of the plateau then the prevalent deformation and stress regime and the subsequent shortening and deformation would have been somewhat similar within various aspects e.g. their velocities. The plateau itself is composed of various terrains which have been brought together by the Indian plate convergence. The slower GPS velocities of as outhern plateau with respect to that of features in central plateau can hardly be justified by the Indian plate subduction or convergence. This variation can only be justified with an additional force due north via a hot plume.

The undulating Moho in the southern plateau is an indication of thick-skinned deformation which provides a strong evidence of

Indian plate collision and subduction. The subducting Indian plate material might have formed plumes which in turn are responsible for the higher GPS velocities in the central plateau. In addition, the high conductance of eastern Tibetan crust at a depth of 20-45km is an evidence of adequate fluid source. These fluids could also perform a vital part in slower deformation in the eastern plateau crust by condensing in response to the tectonic stresses and absorbing the stress that would have caused shear deformation otherwise.

As many of the researchers agree that the main driving force for the plateau uplift is Indian convergence and subduction, we believe that the local structures hence involved, also played their part in the present state of the plateau, such as, the eastern boundary of Eastern Tibetan plateau with respect to stable block of Yangtze.

From the present review study of the convergence in the Tibetan plateau, we believe that the Indian plate subduction and convergence might be the first order control of plateau uplift and convergence. However, it cannot be the sole reason for an uplift of such an extent and that an additional source of disturbance might be exploited to justify all the local variations in the structure. Such a source could be upwelling mantle plumes or stress redistribution through the local structures.

Abbreviations: Altyn Tagh Fault (ATF), Anyimaqen-Kunlun-Muztagh suture zone (AMS), Western Kunlun fault (WKF), Longmu-Gozha Co fault (LGF), Weak crustal zone (WCZ), East-Kunlun-Fault (EKLF), Karakoram fault (KF), Indus-Yarlung suture zone (IYS), Karakorum- Jaili fault zone (KJFZ), Yadong- Gulu Rift (YGR), Longmen Shan (LS).

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