DISCUSSION

Comment 1

(Comments on the paper "**Desert Quaternary formations and their morphostratigraphy: Implications for the evolutionary history of the Thar**" by R.P. Dhir, S.N. Rajguru and A.K.Singhvi. Jour. Geol. Soc. India, v.43(4), 1994, pp. 435-448).

Author's efforts in building Quaternary morphostratigraphy and evolutionary history of the Thar are laudable. However, there are mis-representations and factual omissions that might create confusion rather than help to solve enigmatic challenges of Quaternary geological studies in the Thar desert.

1. A complete geologic depositional record of the Quaternary continental sedimentation in the Thar desert has never been encountered in any single sector thus implying uneven evolutionary growth and the significance of aeolian versus fluvial processes. Detailed field work in Rajasthan by several GSI workers have confirmed that various episodic depositional phases all through the Quaternary times have developed in mutually separated but coeval sub-basins or depocentres (Wadhawan, 1991). Ghaggar basin in the north and Shahgarh - Kishangarh tract west of Asu Tar - Ghotaru (Ramgarh) preserve a thick (over 300 m) pile of continental alluvium/fluviolacustrine sediments whereas the Luni (Palaeo-Luni) basin in the Nagaur - Jodhpur Barmer region has had its own distinctive assemblage of continental sediments of Quaternary age. Therefore the Figures 2 and 5 in the paper by Dhir *et al* (1994) though admittedly generalised can be misleading as these are highly schematic and conjectural in nature. These figures may also reflect, inadvertently, the inferred intensity of development of a particular aeolian or fluvial episodic subfacies in marked preference to the other in western Rajasthan though it is perhaps not intended by the authors.

2. According to the authors, "a fairly widespread alluvial sedimentation of variable thickness, presumably of major part of Pleistocene age, occurs along the tracts, Jalor to Degana through Pali and Merta... and north of Barmer - Jaisalmer - Pokran region." While carrying out field work in parts of Naguar and Jodhpur district, it was observed that a matured sequence of alluvium comprising gritty/pebbly conglomerates, sandstone and siltstone/claystone occurs exposed at or near to the surface along Luni riverbed (middle reaches : Bilara - Silor, etc.); Undri - Dhandannia - Balesar, etc. These formations along with the sedimentary rocks of Marwar Super Group and Precambrian Malani Igneous Suite form a vast pediplane with local colluvial fills/spreads in the vicinity of residual hills/ dissected plateau and are capped by calcrete duricrust (lithic calcrete). Weathering of these calcretes resulted in profiles marked by more than one phase of iron (ferricretised) and carbonate (calcretised) rinds. A thin alluvium of coarser clasts and silty clays mostly as sheet wash infillings of recent past are generally seen resting above this weatherd duricrust, save for the narrow infilled depressions/tectonic trough in Shegarh - Tena (Jodhpur), Mehta - Degana - Sanju (Naguar) area (Wadhawan, 1988; Wadhawan and Sural, 1991). Ostensibly this all pervasive pediplane with the calcrete duricrust above the sedimentary formations suggests transformation in the climate signifying a period of major aridity. Further, it has been amply demonstrated the world over that a major climate change from humid tropical to arid desertic conditions marked the boundary between the Tertiary and Quaternary (Barron, 1989; Rajaguru and Deodhar, *pers. comm.*). Heron (1938) recognised three distinct planation surfaces namely : 1) accordant summits of the Aravalli ranges, 2) extensive pediplanes in the east of the Aravallis, and 3) older alluvial deposits of Indo-Gangetic plains and suggested late-Mesozoic, Tertiary and Pleistocene/

Sub-recent ages respectively. Dassarma (1988) interpreted the present topography and geomorphic features of Aravalli ranges as neotectonically rejuvenated ages of the late Tertiary or early Quaternary age. Palynological evidence from the Shumar formation of fluvial/fluvio-lacustrine origin of late Neogene period supports the existence of semiarid to arid climate in Jaisalmer region during the late Tertiary (Lukose, 1977).

Ever since the regression of Eocene sea from western Rajasthan coincidental with the onset of the first stage of Himalayan orogeny, the sedimentation from Pliocene onwards was from the rivers (Auden, 1952; Ghosh, 1952, cited by Subrata Sinha, 1977). Therefore, in the absence of absolute geochronological determinations it would be difficult to define Pli-Pleistocene boundary and what has been referred to by Dhir *et al.* (*op.cit.*) as Quaternary alluvium could well represent in some cases the calcretised Pli-Pleistocene continuum in the western Rajasthan.

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Reply

We are thankful to Sundaram and Wadhawan for their comments on our paper. While welcoming these comments we earnestly wished that these were supported by some basic new data of the authors (or others). The criticism of Sundaram and Wadhawan on our paper is essentially limited to thickness of alluvial and aeolian cover as shown in Figs. 2 and 5 and some inferences drawn from these. While doing so they have cited some work of GSI and others on Quaternary stratigraphy and basinal control on sedimentation. In the following we address to their specific comments:

1. In our discussion of the information in Figs. 2 and 5, we have not made any statements on the regional source commonalty of aeolian or alluvial sedimentation or on the intensity of a particualr sedimentation process. Rather in the text (pages 438, 443) we have opined local or sub-regional sources both for the alluvial and aeolian sedimentation. Therfore, if one studies these figures with the text, there is hardly a ground for getting misled.

Admittedly, Fig. 5 does connote the existence of a secular, older alluvial strata underneath the thick mantle of aeolian cover even in the present day more aridic situations. As clearly stated in the paper, this was inferred with an element of uncertainty from the well logs. In western Thar, extensive stretches of well formed nodular calcretes, the types of which are not forming in this area today (and could not have formed under still more aridic periods in the past), seem to provide an additional evidence in support of our inferences. In marked contrast to our interpretations, Sundaram and Wadhawan suggest repetitive cycles of fluvial and aeolian sedimentation for the entire region during the Quaternary with the exception of Paleo Luni basin. Our studies on deep dune sections in Dhorimana area (W.Thar) and on 16 R (Didwana, E. Thar) (Misra *et al,* 1988; Singhvi *et al,* 1992) do not show evidences of such secular alluvial activity despite the fact that the basal members of these sections are dated to ~100 Ka to 200 Ka respectively. These and other sections invariably do show marked breaks in aeolian sedimentation and presence of a weaker calcareous silty sand zone, which has been interpreted by us as local fluvial reworking of sediments. Therefore, our present data set does not permit us to subscribe to an alternating fluvial aeolian sedimentation in the region.

In criticism of our spatial distribution maps, Sundaram and Wadhawan have quoted GSI work to state that Quaternary sedimentation is confined to three basins, namely, the Ghaggar, the Shahgrah-Kishangrah and the Luni basin (Wadhavan, 1991). This reference does not describe any boundaries of these basins. Thick aeolian sedimentation in northern half of the region stretches almost from the foot of Aravalli mountains to a distance of over 300 km in westerly direction. Thus an emphasis on Ghaggar basin alone for this entire stretch seems misplaced to the north and south of the Kishangrah basin and also the Luni basin. In the section by Wadhawan (1991), the concept of basinal controls does seem to carry some justification but its validity over large stretches (both to the north and south of this section) is not apparent. Undoubtedly, the large spatial variation in thickness of Quaternary sedimentation is as yet enigmatic and must have some controlling factors, amongst which could also be local or regional faults, prior drainage pattern etc.

2. In modification of alluvial cover distribution in south-eastern tract in Fig. 5 of our paper, Sundaram and Wadhawan suggest that thick alluvial cover is confined only to narrow infilled depressions/tectonic troughs, the tract as a whole being a duricrusted pediplain. We however, maintain that the area of 10 - > 30 metres thickness of alluvial cover shown by us is indeed dominated by secular fluvial activity. The buried pediments do occupy an appreciable extent in the region, but in a majority of these the overlying sediments have distally transported alluvium along with some local colluvial elements as a major component. (*see also* Taylor *et al.,* 1955). Our inferences are based on these observations.

We agree that the basal sedimentation in most of the basins could be of Pliocene or even preceding ages. What we described as Quaternary formations was based on morphological considerations and the same do have an element of uncertainty. As pointed out this debate can only be resolved by appropriate geochronological controls, the technology for which is yet to be developed. In fact, ours is the first systematic attempt to provide an absolute chronological framework to sediments of Thar and pending this we have not even made any mention of Plio-Pleistocene boundary in the region.

So to summarise, our studies so far indicate that during the Early - (or earlier) to Mid-Quaternary, the Thar witnessed a dominantly fluvial sedimentation and dominantly aeolian sedimentation occurred during the Late Quaternary. However, minor interludes of aeolian sedimentation during Early to Mid Quaternary and fluvial sedimentation during Late Quaternary cannot be ruled out. Also, in the absence of any reliable dating framework we consider it premature to enter into inferences on Plio-Pleistocene boundary in the region.

The Thar is indeed a store-house of climate responsive landforms whose potential in palaeoenvironmental reconstruction is yet to be realised. We are concious of the fact that our work is only a limited step in this direction and the region is wide-open for intensive record. We would indeed welcome a detailed publication/monograph from Sundaram/ Wadhavan or GSI describing their results and alternative hypothesis/models on the evolution of Thar.

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Comment 2

(Comments on the paper "**The Crystalline Thrust sheets in the Himachal Himalaya and the age of Amphibolite facies Metamorphism**" by O.N. Bhargava and U.K. Bassi Journal Geological Society of India, v. 43(4), 1994, pp 343-352).

I wish to put down certain points with regard to nomenclature and extension of the newly drawn Vaikrita Thrust by the authors.

1. As the authors regard the Vaikrita Thrust in Himachal Pradesh a continuation of the MCT (Heim and Ganser, 1939) and not the Vaikrita thrust (Valdiya, 1980), which is located at a higher tectonic level than the MCT in U.P. Himalaya, this thrust in H.P. could preferably be named as MCT- a term well entrenched in geological literature for over half a century. Assigning the same name (Vaikrita Thrust) to the two altogether different structures would only lead to avoidable confusion.

It needs to be mentioned that different thrusts including MCT, Vaikrita, Jutogh on either side of H.P.- U.P. boundary have not so far been physically traced into each other convincingly. So the inferences drawn remain largely speculative. It is therefore not surprising that if the authors join the MCT of U. P. (Heim and Gansser, 1939) with their Vaikrita thrust in H.P. Valdiya (1980) prefers to link the former with the Jutogh Thrust of H.P.

2. In its western extension, linking the Vaikrita Thrust of the authors with the Panjal thrust of Raina *et al.*, (1990) is not supported by the observations of the latter themselves. According to Bhargava and Bassi (1994), all through H.P., the Vaikrita Unit is invariably thrusted over Kulu Unit, which in turn, overrides the Largi-Shali belt along Vaikrita and Kulu thrusts respectively. If Panjal thrust of Raina *et al,* (1990) is identified as the Vaikrita Thrust, Vaikrita unit should have been thrusted along it on to the Kulu

rocks to tie up with tectonic set up of H.P. However, according to Raina *et al.,* (1990) it is the Salkhals (Kulu Unit) instead of Vaikritas, that is supported on the Panjal Thrust. The contradiction becomes still more glaring when Raina and Sharma (1990) regard Vaikritas (Chola Thach) absent in J&K and instead, Bhadarawh (Chamba) sequence overlies the (Kulu Unit) along an unconformity. Such marked contradictions in tectonostratigraphy on either side of this State boundary need to be resolved while making room for Vaikrita Thrust in J&K. I suppose the authors would like to reinterpret the observations of Raina *et al.,* (1990).

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Reply

1. It is difficult to understand what Prashra actually means to convey. Following international convention the thrust at the base of the Vaikrita Group has been named as the Vaikrita Thrust (VT) which also answers the original attributes of the MCT of Gansser (1964, 1990). Whereas other thrusts (e.g.Jutogh and Kulu) get tectonically overlapped, it is the VT (or its equivalent) which is traceable from J&K to Arunachal. It is along this thrust that the Vaikrita Group with the overlying Tethyan sediments of a different palaeogeographic province have been translated over the Lesser Himalayan domain and is thus of fundamental significance. The Jutogh and Kulu Thrust Sheets and their equivalents, possibly represent paleo-geologic-no-man's-land between the Tethyan and Lesser Himalayan basins.

2. The Jutogh Thrust has been meticulously delineated from Chaur Mountain upto HP-UP border by S.V. Srikantia and K.P. Reddy (GSI unpubl. report, 1972) where it is certainly below the MCT. Its extension in UP is a certainty and not speculative. Some enterprising geoscientists have to extend it further east through a difficult terrain.

3. Geology is best visualised in 3-D. The Chamba Tethyan basin rests over the Vaikrita sequence. The Vaikrita Thrust Sheet comes to rest over the Kulu Group, only after tectonically transgressing over an enormous thickness of the Jutogh Thrust Sheet (Fig.1). The contact between the Vaikrita or any sequence above it, with the Kulu Group or its equivalent therefore, cannot, by any means, be stratigraphic. Presence of VT in J & K is thus, a foregone conclusion. Its identification due to isograde rocks coming in contact may not be easy, as was the case in HP for all these years, yet not impossible.

The VT has to exist above the outer Dalhousie Gneiss (≡ Gahr) which extends into

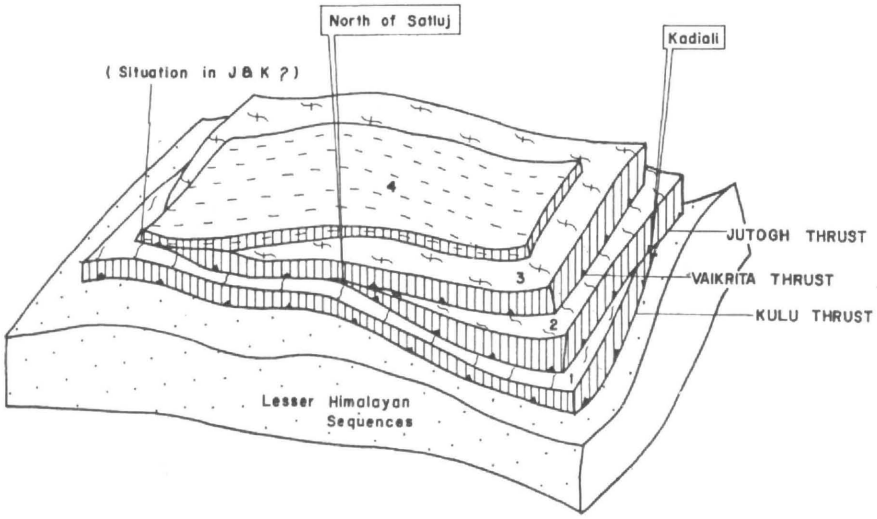

Fig.1 Schematic diagram showing relationship of Kulu (1), Jutogh (2), Vaikrita Thrust (3) Sheets and Tethyan sequence (4).

J & K, and below the Chamba basin rocks. It is a matter of furnishing local details in a regional framework. In such cases it is always ideal to pick up loose end from a known area (i.e.,HP) and extend it into unknown, rather than vice versa.

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Comment 3

(Comments on **"Geomorphology and Neotectonic Activity of the Gandak Mega fan and Adjoining areas, middle Gangetic Plain"** by Rakesh Mohindra and B. Parkash, published in Jour. Geol. Soc. India. Vol. 43, pp. 149-157, 1994).

The authors of the paper appear to be unaware of recent publications which deal not only with Quaternary geology but also on the geomorphology and evolution of the Indo-Gangetic Plains (Bhartiya and Nag, 1990: Dwivedi and Sharma, 1992: Khanna *et al.* 1991: Khan *et al.*, 1991: 1992: Khanna *et al.*, 1990, Gopendra Kumar, 1991, 1992; 1993; Krishnan, 1991).

The authors' visualisation of development of Indo-Gangetic basin due to collision of Indian and Chinese continental plates and its evolution to give rise to present geomorphology, may not be acceptable in view of well recognised Post-Upper Siwalik

orogenic movement during middle Pleistocene (HOM-3, Ravi Shanker *et al.*,1989; Gopendra Kumar and Singh, 1992). This movement obliterated the molassic basin and led to development of new basin, the Indo-Gangetic basin, which was much narrower and limited in the north by Foot Hill Fault (MBF 3, Gopendra Kumar *et al.*, 1989). It is in this basin that the sediments derived mainly from Himalayan Terrain were deposited in the form of large alluvial fans of various rivers to constitute the Varanasi Older Alluvium (VOA) (F_1, Khan *et al.*, 1992).

Another tectonic episode, mainly epeirogenic in nature towards end of Upper Pleistocene, coupled with glaciation resulted in upliftment and cesation of sedimentation to give rise to Indo-Gangetic Plain. Subsequent neotectonic reactivation along NE-SW trending basinal cross faults, resulted in block movement/adjustment, and with warming up in climate, led to heavy influx of detrital to give rise to Alluvial of detrital to give rise to Alluvial fan (F_2, Khan *et al.* 1992) for the deposition of Bhat Alluvium over the VOA. With further evolution of the drainage, the present Gandak, Rapti and Ghaghra rivers were developed carving out new but narrow and restricted Holocene basin defined by palaeobanks, for the deposition of next cycle of alluvial sediments- the Newer Alluvium, in the form of river terraces. The Gandak river has dissected the F_2 (YGP of authors).

The authors' geomorphological classification of the area, would have been more meaningful if they have taken geology into account. The identification of six different geomorphic units (OIGP, OSGP, ORP, OGHP, GN-Ghl and YGP) simply because these are separated by drainage channels without sufficient diagnostic distinguishing characteristics of the surface, may not be acceptable as all these surfaces excepting YGP, developed and are in existence since upliftment of Gangetic basin. The Gandak Mega Fan includes the geologic units corresponding F_2 of Bhat Alluvium and VOA forming an earlier Fan (F_1, Khan *et al.*,. 1991). Thus the surface developed over F_1 came into existence much earlier than F_2. It is the former surface which encloses signatures of an earlier drainage, and should have been prefixed with the word 'palaeo" and separated out from abandoned channels of the drinage.

The authors' visualisation of neotectonic tilting along faults to be the reason for eastward shift of the Gandak river, is also not acceptable. The Gandak river, in fact, oscillates within its entrenched channel defined by palaeobanks. The shape of the F_2 (part of the authors' YGP) suggests existence of a southeasterly slope of the surface prior to the formation of the fan F_2 made up of Bhat Alluvium. Tilting of the blocks calls for evidences such as development of dips in alluvial sediments, which in fact is lacking in the area.

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Reply

We are happy that G.S.I. scientists have taken note of our work. Replies to their comments are:

1) i. Our visualization of the Indo-gangetic Basin is that the present geomorphic configuration is essentially that developed in the Mid Miocene, with minor modification from time to time (Parkash *et al.,* 1980). It has evolved by folding and uplift of the successively more southerly areas at the northern edge, especially at the end of the Lower, Middle and Upper Siwalik times. This has been called accretionally intracontinental wedge (Herail *et al.,*1986). Even the uplifted parts of the Basin contributed significant detritus to sediments being deposited in the basin, causing cannibalism (Parkash *et al.,*1980, p.165; Parkash and Kumar, 1991). This is the first instance of cannibalism reported from a molasse basin, though such a process was considered to be common in flysch basins (Aubouin, 1965, p.95).

Along with folding and uplift of the northern margin, southern margin of the Indo-gangetic Basin migrated southward with time (Raiverman *et al.,* 1983, Fig.19; Lyon-Caen and Molnar, 1983).

ii. The concept of the G.S.I scientists about the Basin that Middle Pleistocene movements obliterated the 'molasse basin' and a new 'Indo-gangetic Basin' came into existence, has some flaws:

(a) Most of the Siwalik Formations with some facies change continue from the Folded part of the Basin (Siwalik Hills) into the subsurface of the Indo-gangetic Plains (Raiverman *et al.,* 1983, Fig. 19). In fact such a continuity was assumed long back even by Wadia (1961, Fig.41), when available subsurface data from the Indo-gangetic Plains were limited.

(b) Different stages in evolution of a basin, which maintains its essential character with time, should not be called separate basins and it also applies to the 'Holocene Basin' mentioned in the next point raised by Sri Gopendra Kumar.

(c) The concept of 'molasse basin' of Sri Gopendra Kumar is akin to that of the 'Siwalik Basin' introduced by others in Indian literature. In view of the points ii(a) and ii(b), it should be discarded.

2. Second point raised by Sri. Gopendra Kumar is recognition of the three stratigraphic units i.e., Bhat Alluvium, Varanasi Older Alluvium and Younger Alluvium from data obtained probably through tubewell lithologs.

We do not ascribe to this for the following reasons:

i. In the absence of the well recognised marker or datable beds, such correlation and stratigraphic division can be considered at the most as probable.

ii. The idea of upliftment and cessation of sedimentation giving rise to the Indo-gangetic Plains is not correct.

The Indo-gangetic Plain is presently one of the world's largest active fluvial basin. Though for short periods parts of the basin may be a stable upland leading to formation of soils (a normal process), other parts may continue to receive sedimentation. It also implies that the whole of the Indo-gangetic Plain does not behave in a similar manner at a particular time as demonstrated by Srivastava *et al.* (in press) from study of a few meters of surficial soils/sediments. Carrying correlation over long distances for fluvial sediments is a difficult proposition in a tectonically active basin like the present one.

3.i. The paper under discussion describing geomorphology of the area is complementary to another paper (Mohindra *et al.,* 1992), which discusses mainly soils. Different surfaces (called soil-geomorphic surfaces) were recognised on the basis of geomorphology and uniformity and degree of developement of soils. We find that six sets (soil chronoassociation, a term coined by Mohindra *et al.,* 1992) of soil-geomorphic surfaces can be recognised from the Upper Gangetic Plains instead of only two (Older and Younger surfaces/alluvia).

Application of soil-geomorphic surfaces was extended to the area between the Ramganga and Rapti rivers by Srivastava *et al.* (in press).

ii. In addition to the evidence for tilting of the Gandak megafan leading to shifting of the Gandak river across it over 105 km from west to east discussed in the paper, a systematic increase in the degree of development of soils from east to west over the megafan (Mohindra *et al.,* 1992) supports this.

iii. Tilting of the megafan by 15-20 m over a distance of about 105 km gives a minor dip, not discernible in the field.

We were aware of some of the publications of the G.S.I. scientists. However, we just did not to want to contradict them and for that reason did not refer to them. We strongly believe that the concepts of sedimentary basin and significance of soils in Quaternary studies should also be appreciated.

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