GEOCHRONOMETRIA 37 (2010), pp 29-35
DOI 10.2478/v10003-010-0021-5

Available online at
versita.metapress.com and www.geochronometria.pl

LUMINESCENCE DATING OF THE SEDIMENTS FROM A BURIED CHANNEL LOOP IN FATEHABAD AREA, HARYANA: INSIGHT INTO VEDIC SARASWATI RIVER AND ITS ENVIRONMENT

H. S. SAINI and S. A. I. MUJTABA
Geological Survey of India, Faridabad, 121001

Received 3 February 2010 Accepted 15 September 2010

Abstract: Geomorphology and sedimentary composition of an archeologically important palaeo-channel segment of the Vedic Saraswati River in northwestern Haryana have been evaluated and its temporal relation with the surrounding upland examined with the help of OSL dating. Sediment composition and OSL ages suggest that the channel received enough water supply between 5.9 and 4.3 ka ago, and even before. Several lakes and ponds had developed during this period in the surrounding areas. It was a wet phase in this area as well as in Rajastahn. After ~4.3 ka, the river got starved of regular water supply, became sluggish and finally dried up. Reduced water supply, indicative of decreased rainfall, occurred between 4.3 and 3.4 ka ago. The environmental history of the channel might have influenced the Harrapan archeology of the area.

Keywords: Northwestern Haryana, Vedic Saraswati, Palaeoenvironment

1. INTRODUCTION

The northwestern Haryana Plains are constituted by over 400m thick column of Late Quaternary alluvial sequences covered with aeolian sediments, constituting the northeastern fringe of the Thar Desert (Thussu, 1995; Saini and Anand, 1996; **Fig. 1**). The area experiences arid to semi-arid climate and drained by Ghaggahar River, which originates in Siwalik ranges and disappears in northern tip of the Thar Desert. Drainage disorganization and disappearance of Harappan society are the two important issues associated with these plains. The first issue concerns the Vedic river Saraswati, mentioned in *Rigveda* as a mighty Himalayan river of the *vedic* period. It does not exist now. The second issue is related to the disappearance of Harappan civilisations whose mounds are scattered on these plains (**Fig. 1**; Joshi *et al*., 1984). Harappan or the Indus civilization was one of the four great urban civilizations of the world that is believed to have flourished between around 2700-1700 BC in the valleys of Indus and Ghaggar-Hakara systems. The ancient Saraswati river is also believed to have existed during this period. Some important mounds of these civilizations in the present area occur at Wannawali and Rakhigarhi. The natural or anthropogenic causes of their disappearance are not comprehensively known.

The course of the Vedic Saraswati was first surveyed by an archaeological expedition (Stein, 1942). Later, it was investigated by Oldham (1893) and Wilhelmy (1969). After about a century, the issue regained attention leading to several remote sensing based studies (Yash Pal *et al*., 1980; Sood and Sahai, 1983; Ghose *et al*., 1979; Sahai, 1999; Gupta *et al*., 2004; Radhakrishna and Merh, 1999; and references therein). Maps of palaeodrainge including old channels of Saraswati and archaeological mounds in northwestern India have been prepared and discussed. However, most of the inferences remained unsubstantiated due to the lack of geomorphological truths, sedimentological characters and absolute ages of the buried channels. The important questions yet to be resoled are: 1) whether any such river ever existed, 2) if yes, the time and duration, 3) the course of the river and 4) causes of its disappearance.

Most of the previous studies show a prominent loop like zone in Fatehabad area as an important segment of the Saraswati palaeocourse (Yash Pal *et al*., 1980). The loop stands out as high moisture zone in aerial photos and imagery (**Fig. 1**). It is usually dry but flooded when rainfall exceeds 800mm, as last happened in 1996. In the imagery, the zone extends westward from Fatehabad and joins the floodplains of Ghagghar. In the field, the ex-

Corresponding author: H. S. SAINI
e-mail: hssainigsi@gmail.com

ISSN 1897-1695 (online), 1733-8387 (print)

tended part is differentiable by clay dominated surface against the sandy surface of the surroundings. This study evaluates the ground geomorphology of the area and reconstructs the environmental history of the palaeochannel with the help of OSL dates which may provide a clue to the understanding of the Harappan history.

2. FIELD STUDIES AND SAMPLING

Morphology of the palaeochannel was mapped by taking field traverses along and across the high moisture loop. The southern bluff line representing the palaeobank of the channel was identified between Fatehabad and Hosanga as shown by bold line in **Fig. 1**. The bluff line is represented by ~5m high scarp which separates the palaeochannel from the surrounding upland. West of Fatehabad and east of Hosanga, the sharpness of the bluff line was found to disappear gradually. The northern bluff line could not be precisely mapped due to the absence of discernable scarp, therefore it was marked by a dashed line. Other features noted to demarcate the loop zone included a low lying plain topography, clayey topsoil lithology, absence of dunes, fresh ground water and flood prone nature. The surrounding upland, on the other hand, showed an abundance of dunes, rugged topography, sandy ground lithology and saline ground water.

Sedimentary assessment of palaeochannel and upland was acquired through the study of sections in pits, wells and canal diggings. Gross lithological characters were used to interpret the depositional environments of the sediment layers. Two sections in palaeochannel near Razabad village (L1 & L2) and three on the upland near Hosanga (L3), Bhutha Kalan (L4) and Jhalania (L5) were sampled for OSL dating. OSL samples of sand were taken in 8” x 2” stainless steel tubes while finer sediments were collected in 10” x 2.5” tubes from freshly exposed surfaces. OSL ages of 11 samples were determined. Lithology of a few shallow bore-hole were collected from surrounding areas.

Based on the topographic, lithologic and OSL age data, a geomorphological and stratigraphic reconstruction was developed along NW-SE line.

3. OSL DATING

The middle part from each sample tube was selected to determine the depositional ages by OSL technique (Aitken, 1985 and 1998). The outer parts were used for dose rate and water content measurements. A selected portion was treated with 1N HCl solution to remove the carbonates and 30% H_2O_2 to remove organic impurities. The dried sediments were sieved to separate a 90-150 µm grain size fraction from which quartz grains were separated using a sodium polytungstate solution of 2.58 g/cm^3 specific density. The 20 µm outer layer of quartz grains was removed by etching with 40% HF for 80 minutes and then by HCL for 20 minutes. This was done to remove feldspars and the alpha irradiated layer.

The quartz grains were temporarily mounted on stainless steel discs (9.6 mm diameter) as a monolayer, generally over a circular area of 4 mm diameter with the help of silicon spray. Luminescence measurements were carried out using a Risoe TL/OSL Reader 15-20 DA, equipped with a calibrated Sr-90 beta source. The stimulation was made using blue LED’s (470±30 nm) and the luminescence was detected in the UV range through a Hoya UV-340 filter placed in front of an EMI9671 photomultiplier tube. Luminescence was recorded in 250 channels (40 s) in which counts of first five channels were considered for further calculation after subtracting background counts of the last 25 channels.

The aliquot discs were placed in alternating holes of the sample carousel to avoid irradiation/stimulation cross-talk. Generally four pre-dating tests were conducted on

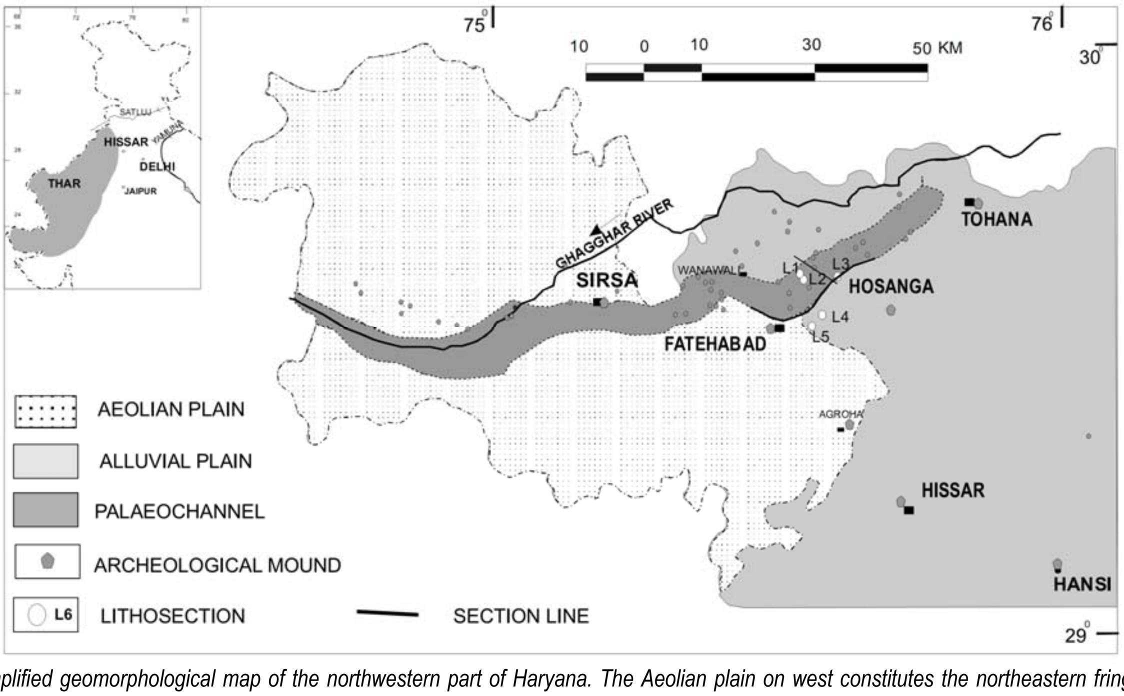

Fig. 1. *Simplified geomorphological map of the northwestern part of Haryana. The Aeolian plain on west constitutes the northeastern fringe of the Thar desert. The palaeochannel zone has a marked southern bluff between Fatehabd and Hosanga. Section line and locations of studied sections are also shown.*

each sample before actual measurement of D_e. These included feldspar screening, rough dose estimation, pre-heat plateau test and dose recovery test. When feldspar signals were recorded, the sample was retreated with HF. Generally the IRSL/OSL ratio was kept below 1%. Nevertheless, an additional step of IRSL at 75°C per sec for 100 sec was given before each blue OSL measurement. Blue light stimulation was carried out at 125°C for 40 s.

A preheat temperature of 220°C for 10 s and TL of 180°C (in-lieu of preheat) were found suitable. The heating rate used was 5°C/s. The dose recovery was within ±10% of the administered dose.

The equivalent dose (D_e) was measured following the Single Aliquot Regeneration (SAR) protocol (Murray and Roberts, 1998; Murray and Wintle, 2000; Wintle and Murray, 2006). Sample discs with recycling ratio within 10% and recuperation of less than 5% were considered for final calculation of the D_e values. The commercial software "Analyst" was used for the calculation of individual D_e values. Calculation of D_e's was repeated from the spreadsheets provided by A.S. Murray, Risoe National Laboratory, Denmark. It was found that average D_e values of well bleached samples were similar in both calculations. The spreadsheets were helpful in discriminating the recuperation, sensitivity changes and recycling ratio.

The growth curves and distribution pattern of D_e values of some samples representing variations are shown in **Fig. 2**. The samples had near normal distribution of D_e values, therefore, weighted averages were employed for age calculation using Grun software. The dose rates (D_r) of samples were calculated from the concentration of U and Th (analyzed by ICP-MS at the Chemical Laboratory, GSI, Hydrabad) and K (by flame photometer at Chemical Labs, GSI, Faridabad). The OSL ages are compiled in **Table 1**.

4. LITHO-SECTIONS IN PALAEOCHANNEL LOOP

Two sections in Rangoi canal digging near Razabad village were selected for sampling. Both sites, around 500 m apart, showed matching lithological arrangement except varying thickness of the sediment layers. They revealed four gradational layers of a fining upward alluvial sequence (**Fig. 3**). Layer-1, at the top, is a bed of hard, pink clay that forms the ground surface of the palaeochannel. It is thinly laminated. Layer-2 is pinkish and massive to faintly laminated silty-clay, slightly coarser than the layer-1. Layer-3 sediments are of intermediate granularity between layer 4 and 2. It is formed by silty-sand in the lower part and sandy-silt in the upper part. Layer-4 comprises light grey fine sand with an oxidized top. In nearby bore wells, it is reported to continue up to ~8m depth. Layer-4 represents an active stream channel, layer-3 with increasing proportion of mud denotes a de-

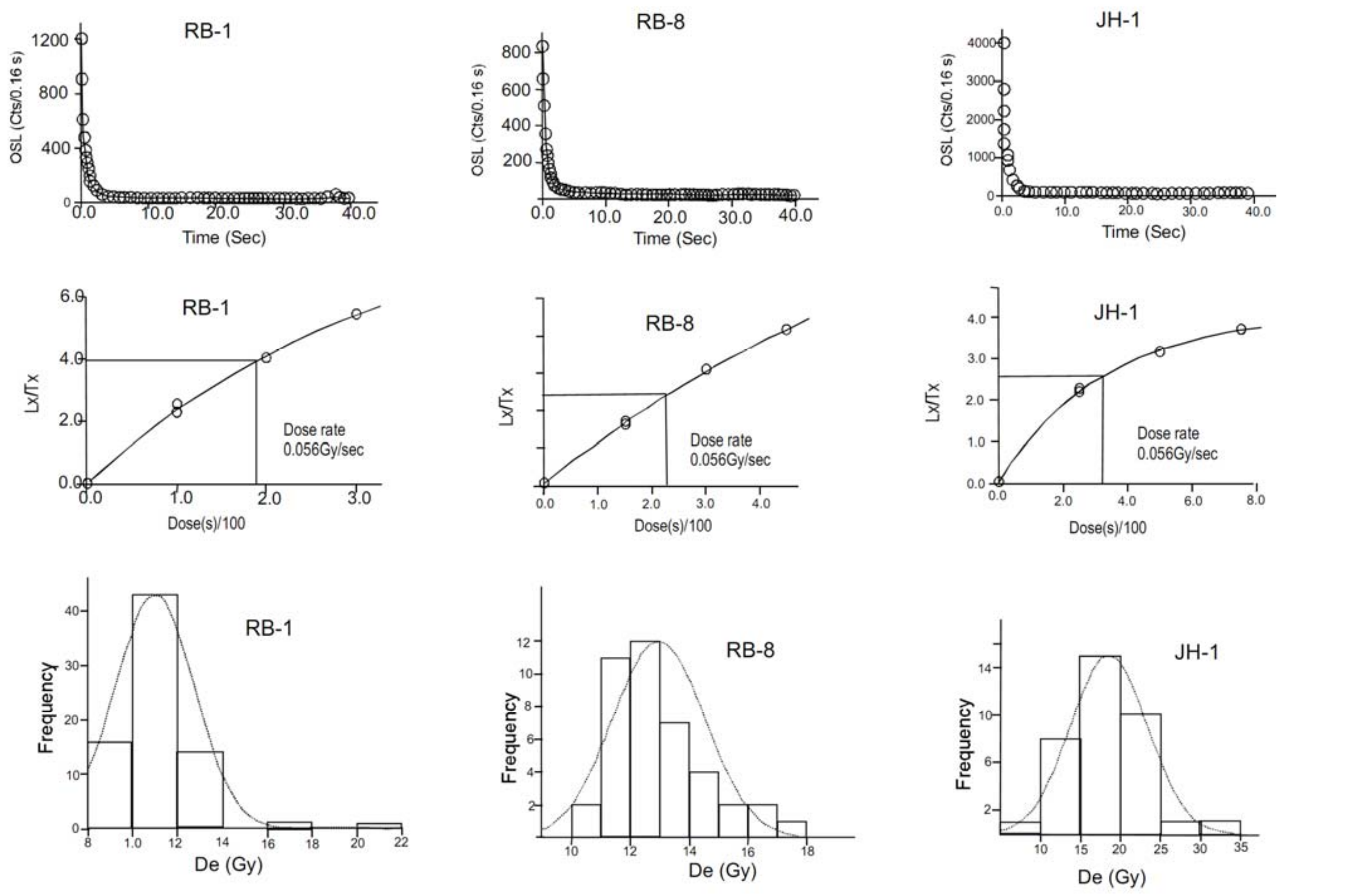

Fig. 2. *Shine down curves, growth curves and histograms of three representative samples.*

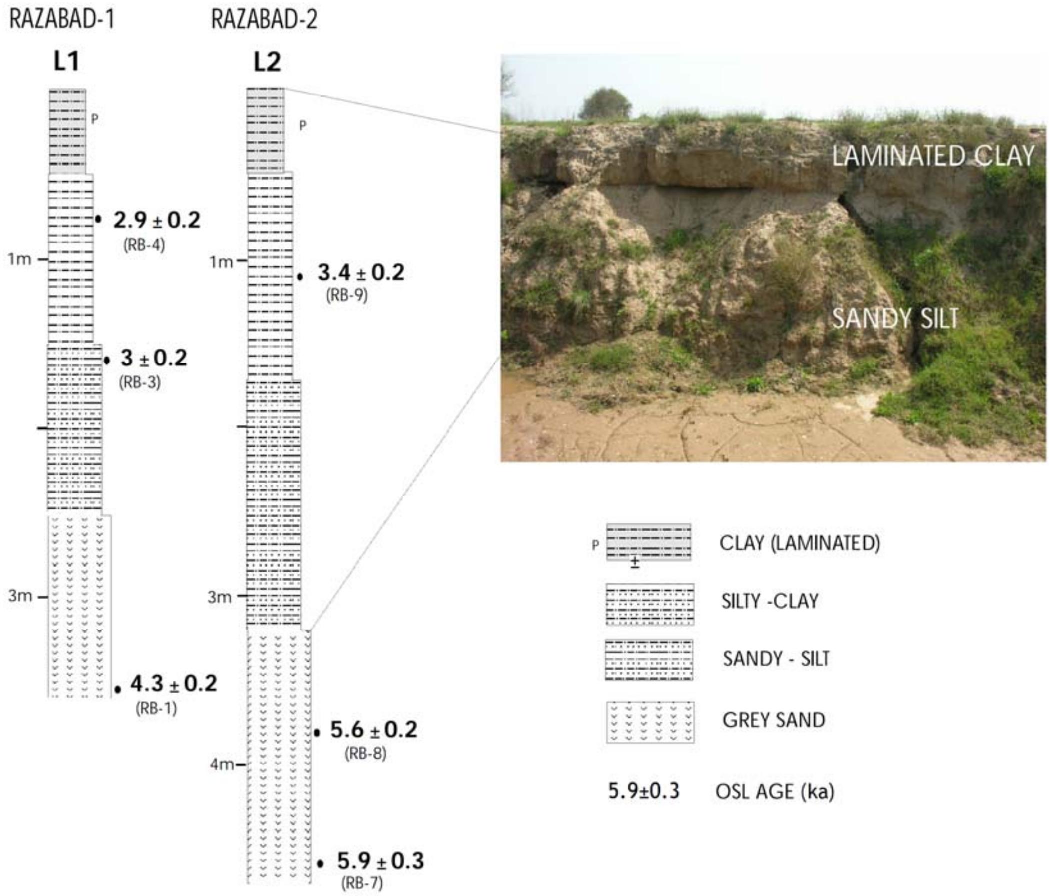

Fig. 3. *Lithologs of two nearby sections in palaeochannel near Razabad with OSL ages. A field photo of the canal digging exposing fine sequence is also shown. The channel sand lies below the floor of canal digging.*

generating phase of the channel, layer-2 represents a further worsening and layer-4 is indicative of a defunct channel with ephemeral lacustrine like condition as today.

OSL Chronology of Razabad Sections

The samples at 3.5 m depth (RB-1) from sand of layer-4 has yielded an age of 4.3±0.2 ka while the sample RB-7 from the same layer but at a slightly greater depth (4.7 m) has given an age of 5.9±0.3 ka (**Fig. 3**). On the basis of these ages, it can be inferred that this channel was active between ~6 and 4.3 ka, for about 2000 yrs. In the absence of dates from the true base of the channel sand, its history older than 6 ka can not be commented upon. The oldest age from the overlying channel mud is 3.4±0.2 ka (RB-9), which implies that by this time the

Table 1. *Analytical details and OSL ages of samples used in this study.*

Sample	Depth (m)	U (ppm)	Th (ppm)	K (%)	Water content (%)	Aliquots	Dose rate (Gy/ka)	Average De (Gy)	Age (ka)
Hosanga									
HS-3	1	2.41	12.96	1.55	10±5	32	2.9±0.2	35±2	12±1
HS-2	3	3.06	13.1	1.75	10±5	35	3±0.1	49±1	15.4±1
HS-1	4	2.69	13.55	1.93	15±5	47	3±0.1	62±1	20±1
Jhalania									
JH-1	0.35	2.68	14.68	1.75	15±5	36	2.97±0.1	19±1	6.4±0.4
Bhutha Kalan									
BK-1	0.7	2.97	14.2	1.83	10±5	34	3.2±0.17	28.1±0.5	8.7±0.5
Razabad									
RB-4	0.8	2.36	12.56	1.7	10±5	25	3.01±0.2	8.8±0.3	2.9±0.2
RB-3	1.6	2.9	15.16	1.55	10±5	57	2.98±0.14	9.06±0.2	3±0.2
RB-1	3.6	2.44	12.50	1.2	10±5	75	2.4±0.1	10.5±0.2	4.3±0.2
RB-9	1.3	2.67	15.75	1.4	10±5	41	2.87±0.1	9.8±0.1	3.4±0.2
Rb-8	3.6	2.44	12.10	1.05	10±5	41	2.27±0.1	12.9±0.3	5.6±0.2
RB-7	4.7	2.89	5.86	0.8	10±5	40	2.23±0.1	13.3±0.3	5.9±0.3

nature of the stream had gradually changed from a bed load to a suspended load. Since than, it has been a defunct channel witnessing infrequent ponding during heavy rains.

5. LITHOLO-SECTIONS IN SURROUNDING UPLAND

Hosanga Section

This is an important section situated on the bluff of the palaeochannel of the Vedic Saraswati in Fatehabad district. The section was selected to examine whether the palaeochannel sediments are younger/older or of the same age than the regional upland plain and whether any fluvial activity younger than that of the upland existed in the palaeochannel zone. The section revealed a simple lithological structure with an aeolian unit at the top, followed by an alluvial unit downward of unconfirmed thickness. The aeolian unit is around 2.5m thick and is expressed as a remnant hump on the ground. The sand is buff, well sorted with small pottery pieces embedded in the top 20 cm. The buff sand grades downward in the silt and silty clay constituting the uppermost layer of alluvial unit. The silt clay is underlain by loose, grey fluvial sand, coarser and more micaeous than layer-4 sand of the palaeochannel (**Fig. 4**).

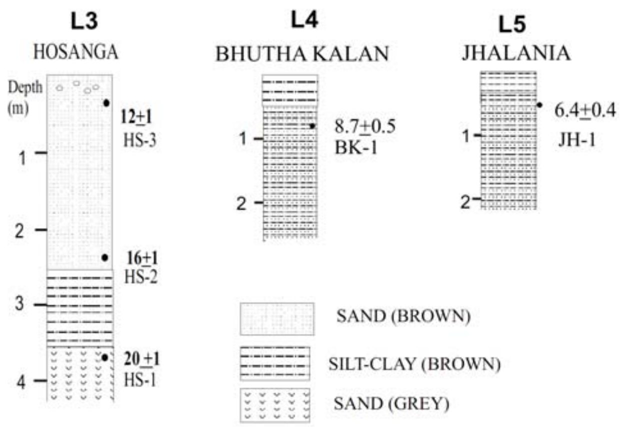

Fig. 4. *Lithologs from three sections on upland with OSL ages. For locations, please refer Fig. 1.*

OSL Chronology of Hosanga Section

The age of the base of aeolian unit is 16±1 ka (HS-2) and of the top is 12±1 ka (HS-3) (see section L-3, **Fig. 4)**. The underlying grey fluvial sand has produced an age of 20±1 ka (HS-1) which suggests the existence of an alluvial phase older than the layer-4 fluvial phase of the palaeochannel.

Jhalnia-Bhutha Kalan Sections

These two sections were studied to determine the age of the topmost bed of the sediment column of the regional upland (L4 and L5, **Fig. 4**). At both places, there is a 20-50 cm thick bed of silty clay at the top underlain by brown sandy silt with pea-sized carbonate nodules. The lithology appears to represents deposits of an ephemeral stream. At both locations the sandy silt was sampled for OSL dating.

OSL dates of Jhalnia and Bhuta Kalan Sections

The sample from Bhuta-Kalan from a depth of 0.7 m from the ground gave an age of 8.7±0.5 ka (BK-1) while the sample from Jhalnia at 0.35m depth showed an age of 6.4±0.4 ka (JH-1) (**Fig. 4**). These samples lie at almost the same level of HS-3, but show much younger ages of deposition. It shows that after the aeolian deposition of Hosanga, the area witnessed some ephemeral alluvial activities which deposited finer sediments in the interdunal areas.

6. SEDIMENTRY EVOLUTION AND ENVIRONMENT

The NW-SE section elucidates the geomorphic signature of a desiccated stream channel (**Fig. 5**), which has

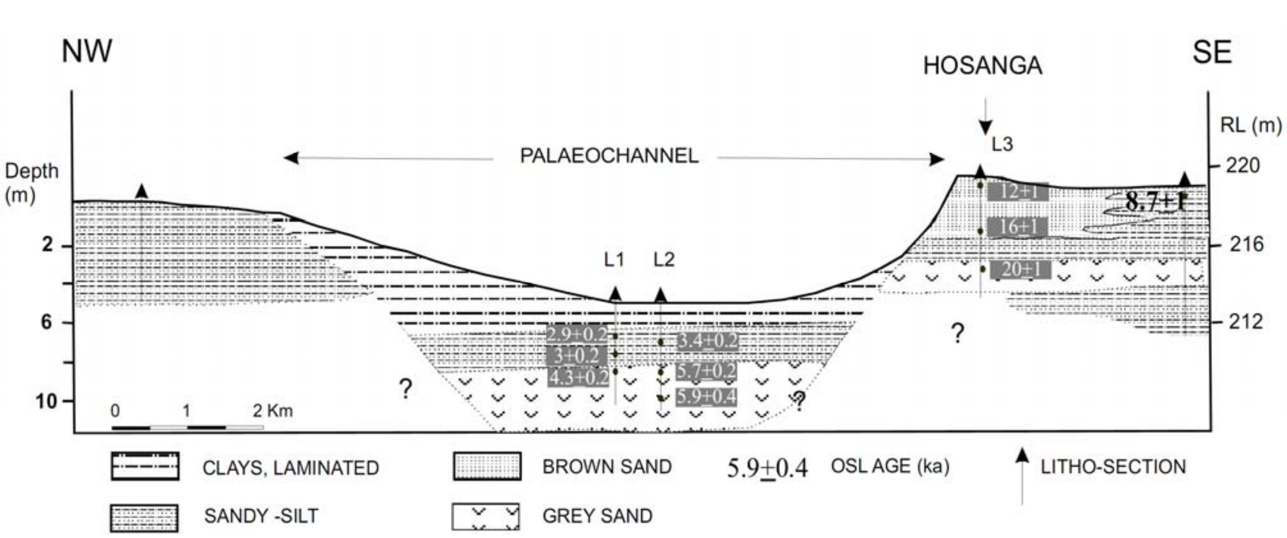

Fig. 5. *NW-SE section across the palaeochannel showing its geomorphology and shallow lithological architectures. The landform and OSL ages of channel and upland sediments are also given which confirm a younger status for the palaeochannel sediments.*

been referred as a part of Vedic Saraswati River by previous workers. This segment has a sharp southern bank and a gradual northern bank whose upstream and downstream continuity is not fully confirmed. The section also shows that the sediments of upland surface are older than those in the palaeochannel and confirms the existence of a younger phase of fluvial activity. The upward fining of sediments in the palaeochannel is an evidence of progressively reducing water supply to the stream and can be interpreted in terms of declining rainfall. The sand at the lower part of the section represents an active channel whose detritus supply was ensured by rains higher than today. With the help of OSL dates a part of this wet phase can be conclusively constrained between ~5.9±0.3 and 4.3±0.2 ka, and even before. It means that for ~2000 yrs, during Mid-Holocene, northwestern parts of Haryana as well as the catchment of the palaeoriver had witnessed a wet climate. The inference is corroborated by numerous carbonate lake deposits in western and central parts of Haryana, especially in Riwasa-Charkhi Dadri area (Bhatia and Singh 1988; Saini *et al.*, 2005). The argillaceous limestone in these lakes was precipitated between 6238±37 and 4491±35 ^{14}C yr BP (Pant *et al.*, 2005), under wet and warm conditions. The Lunkaransar lake in northern Rajastan also witnessed high water level between 6300 and 4800 ^{14}C yr BP (Enzel *et al.*, 1999), and so did the other lakes in Rajastan (Singh *et al.*, 1974 and 1990). Based on these data, it is possible to suggest that summer monsoons were much stronger during Mid-Holocene over a large area of the Thar desert and its northeastern fringe in Haryana. Such conditions appear to have changed some times between 4.3 and 3.4 ka, when Fatehabad palaeochannel was transformed from a bed load to a vigour-less suspended load stream due to decreased rainfall. The oxidized top of channel sand and decreasing grain size of overlying sediments indicate an increasing role of aridity and decreasing carrying capacity of the stream. It can be safely estimated that after ~3.4 ka and up to 2.9 ka the rains had reduced substantially. As a result the Fatehabad channel gradually became defunct and was receiving only fine clay sediments during episodic heavy rains. This wet phase of Mid-Holocene could be a congenial period to support and sustain large agriculture-based population whose remains are scattered close to the palaeochannel (**Fig. 1**). Some absolute dates from these archaeological mounds would be helpful in establishing the relation between the history of Fatehabd channel and Harrapans.

At this stage, it is difficult to comment on the source and catchment area of the palaeochannel as to whether it originated in glaciated higher Himalayas as envisaged. With available nature of sediments up to 4.5 m having an apparent deficiency of mica, the channel appears more of a piedmont origin like the present day Gahgghar. Well-bleached luminescence behaviour of quartz is more akin to the locally reworked sediments. This point, however, needs detailed mineralogical investigations.

The 20±1 – 12±1 ka age brackets for upper 4m part of the sediments column at Hosanga conclusively make this surface older than the palaeochannel. The top sediment layer from Jhalania and Bhutha Kalan also pre-dates the palaeochannel sediments and supports the existence of a younger fluvial activity in the channel, which was identified from remote sensing only.

7. CONCLUSIONS

1) The high moisture loop in Fatehabad area, whose geomorphic signatures are confirmed in this study, is the remnant of a stream channel which actively existed during ~6-4 ka and before. A reduced discharge led to its degeneration sometime between ~4 and 3.4 ka. Since then, this relict has been dry and witnessed lacustrine conditions under abnormally high rains.
2) A wet phase prevailed in northwestern Haryana during Mid-Holocene, which sustained the streams and lakes in the area and possibly the Harrapans.

ACKNOWLEDGEMENTS

We thank Dy. Director General, Geological Survey of India, Northern Region for facilities, Sh R.K Khorana, (then Director) for his supervision and Dr Anil Joshi (Director) for fruitful discussions. Prof A.K. Singhvi consistently encouraged and motivated to complete the write-up.

REFERENCES

Aitken MJ, 1985. *Thermoluminescence Dating*. London, Academic Press: 359pp.

Aitken MJ, 1998. *An Introduction to Optical Dating*. Oxford, Oxford University Press: 276pp.

Bhatia SB and Singh N, 1998. Middle Holocene palaeoclimatic and paleoenvironmental events, in southern Haryana. *Proceeding Indian National Science Academy* 54 A(4): 574-584.

Enzel Y, Ely LL, Mishra S, Ramesh R, Amit R, Lazar B, Rajaguru S.N, Baker V R ans Sandler A, 1999. High –Resolution Holocene Environmental Changes in Thar Desert, Northwestern India. *Science* 284: 1224-1228, DOI 10.1126/science.284.5411.125.

Ghose B, Kar A and Hussain Z, 1979. The lost courses of Saraswati River in the Great Indian Desert: New evidence from LANDSAT imagery. *The Geographic Journal* 145(3): 446-451.

Gupta AK, Sharma JR Sreenivasan G and Srivastava KS, 2004. New findings on the course of River Saraswati. *Journal Indian Society of Remote Sensing* 32(1): 1-24, DOI 10.1007/BF03030845.

Joshi JP, Madhu Bala and Jas Raj, 1984. The Indus Civilisation: A reconstruction on the basis of distribution maps. In: Lal BB and Gupta SP, eds., F*rontiers of the Indus Civilisation*. New Delhi, Books and Books: 511-539.

Murray AS and Roberts RG, 1998. Measurements of the equivalent dose in quartz using a regenerative-dose single aliquot protocol. *Radiation Measurements* 29: 501-515, DOI 10.1016/S1350-4487(99)00253-X

Murray AS and Wintle AG, 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* 32**:** 57-73, DOI 10.1016/S1350-4487(99)00253-X.

Wintle AG and Murray AS, 2006. A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration protocols. *Radiation Measurements* 41: 369-391, DOI 10.1016/j.radmeas.2005.11.001

Oldham CF, 1893. The Saraswati and the lost river of the Indian desert. *London*. *Journal Royal Asiatic Society* 34: 49-76.

Pant NC, Saini HS, Mujtaba SAI and Tandon SK, 2005. Response of lake and dune systems to Holocene climate change: A study of the western plains of Haryana along northern margin of Thar desert. *Geological Survey of India Records* 137(8): 55-57.

Radhakrishna BP and Merh, eds., 1999. *Vedic Saraswati, Evolutionary history of a lost river of Northwestern India*. Memoir Geological Society of India 42: 329pp

Sahai B, 1999. Unraveling the lost Saraswati. In: Radhakrishna BP and Merh, eds., 1999. *Vedic Saraswati, Evolutionary history of a lost* river of Northwestern India. Memoir Geological Society of India 42: 121-141.

Saini HS and Anand VK, 1996. Lithostratigraphic framework and sedimentological evolution of the Quaternary deposits of north-western Haryana. *Geological Survey of India, Special Publication* 21(2): 227-231.

Saini HS, Tandon SK, Mujtaba SAI and Pant NC, 2005. Lake deposits of the northern margin of Thar Desert: Holocene palaeoclimatic implication. *Current Science* 88 (12): 1994-2000.

Singh G, Joshi RD, Chopra SK and Singh AB, 1974. Late quaternary history of vegetation and climate of the Rajasthan Desert, India. *London. Philosophical Transaction of the Royal Society,* B267 : 467-501, DOI 10.1098/rstb.1974.0006.

Singh G, Wasson RJ and Agarwal DP, 1990. Vegetational and seasonal climatic changes since the last full glacial in the Thar desert, north-western India. *Review of Palaeobotany and Palynology* 64 :351-358, DOI 10.1016/0034-6667(90)90151-8.

Sood RK and Sahai B, 1983. Hydrographic changes in Northwestern India. *Man and Environment* VII : 166-169.

Stein A, 1942. A survey of ancient sites along the lost Saraswati river. *Geographical Journal* 99(4):173-182.

Thussu JL, 1995. Quaternary stratigraphy and sedimentology of the Indo-Gangetic Plains, Haryana. *Journal of Geological Society of India* 46 533-544.

Yash Pal, Sahai B, Sood RK, and Agarwal DP, 1980. Remote sensing of the "Lost" Saraswati river. *Proceeding Indian National Science Academy (Earth and Planetry Sciences)* 89(3): 317-331.

Wilhelmy H, 1969. The ancient river valley on the eastern border of the Indus plain and the Sarsawati problem. *Zeitschrift fur Geomorphologie* N.F. Suppl. Band 8: 76-93.

Wintle AG and Murray AS, 2006. A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration protocols. *Radiation Measurements* 41: 369-391, DOI 10.1016/j.radmeas.2005.11.001.