Alluvial Soil Collapse at Karanda Village, Ghazipur District, Uttar Pradesh - A Natural Hazard of Great Societal Importance

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Abstract

A sudden land cave-in occurred at Karanda village, Ghazipur district, Uttar Pradesh in the morning of 28.8.2006, creating panic amongst the residents. The cylindrical opening of 0.7m radius extends upto a depth of 10.4m.Occcurrences of such failure in the adjoining houses were also reported earlier. The subsurface soil profile exposes fine silt- clay and the depth to water table(DWT) measured is 3.8m in the adjoining dugwells. The DWT in the area varies from 12 to 15m.

The affected area falls in the Holocene terrace fill of the Ganga river system. The site is located 3km west of Ganga river. A remarkable geomorphic feature noted is the palaeobank of the Ganga river skirting the Karanda village. The size fraction analysis of the collapse soil profile indicate dominant particle size falling less than 0.020mm. The chemical analysis of the ground-water indicate high bicarbonate content. The elemental analysis of soil indicates 62% of SiO_2 , 14.4% Al_2X, 6%Fe_2X andCaO , MgO and K_2O together constituting 6% and rest P_2O_5 includes trace elements.

The analysis of mechanism of collapse includes study of basement configuration, morphotectonic features, litho-assemblage and genetic origin of the sediments. The study indicates dissolution of earth materials in a palaeogeoenvironment condition in response to local whirlpool/eddypool and subsequent river avulsions exposing the surface as terrace fills. The affected area of 350 sq metres appears to be vulnerable towards gradual process of soil liquifaction, dissolutions and collapse of susceptible subsurface sediments.

Introduction

A sudden land collapse has occurred in the Karanda Village, Ghazipur District, Uttar Pradesh on 28.8.06 at 0700 hrs in the house premises of Sri Samesher Ansari (N 25° 29.412; E 83°27.946) creating fears amongst the residence albeit no casualities were reported except loss of house hold materials (Photo-1, Fig-1). Such phenomenon was also observed in the adjoining areas earlier in the house of Prabhunath singh (N 25° 29.401; E 83°27.873) (Photo 3 and 4) in 2003. Regionally, linear surface cracks are also reported recently from areas located in the Holocene Terrace Alluvium from Gorakhpur and Ballia - Bhadohi - Allahabad areas.

The cave - in - land has semicircular rim extending down the depth upto 10.4 m. The cylindrical opening exposes in-situ material at a depth of 4m with overburden of filled material consisting of soil and pottery pices (Photo-2; Fig-2). The surface cracks of 1 mm opening were observed at a distance of 1 m and 1.80 m from the centre of the verticle hole. The surface cracks trends along both east-west and north - south directions (Fig-3).

An attempt has been made to collect collateral data regarding nature of collapse, geochemical condition, geodynamic processes, morphotectonic features and possible causes of failure. The study aims to help the inhabitants in preluding such natural disasters in future.

Geomorphological Set Up

The regional geomorphic setting indicate that

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the area falls within the Ganga flood plain regime. Regionaly east - west flowing Ganga river takes a sudden 'U' band in responce to regional tectonic framework. Geographically, the Karanda village is located at the north-east part of the 'U' shaped geometry of Ganga river (Fig-1) .The Holocene river avulsion led to development of three level of terraces (T_1, T_1' and T_2) each separated by scarp. The elevation difference lies between 69m and 64m above mean sea level (msl). The Ganga palaeobank is a well defined geomorphic feature, which seperates the flood immune (T_2) and annual flood prone (T_1) terraces. The affected site located on T_1' terrace , an intermediate level between T_2 and T_1, which is 135m away from palaeobank and 3 km west of present day Ganga river (Photo-5;Fig-4 and 5).

Photo-1 Planar view of cave-in-land in the premises of Shri Sameshar Ansari Karanda Village, Ghazipur District, Uttar Pradesh

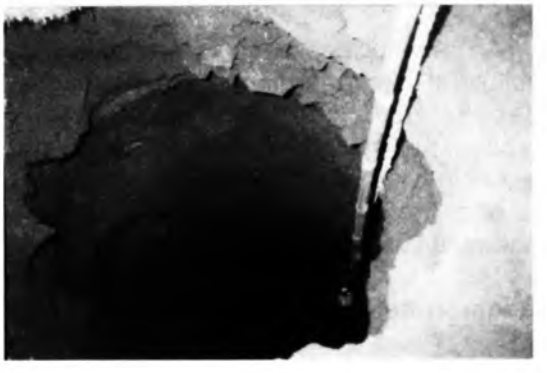

Photo-2 Cylindrical Opening of cave-in-land showing lithology and sampling depths in the premises of shri Sameshar Ansari

Photo-3 Outer rim of collapse land in the premises of Shri Prabhunath Singh, Karanda Village, Ghazipur District, U.P.

Photo-4 Section exposing top 6m clay and the hollow opening below being filled at later date Shri Prabhunath Singh, Karanda Village, Ghazipur District, U.P.

Basement Configuration

A regional picture of basement configuration of the area referred here is to understand

the role of geofractures in subsurface movement of earth materials. The geophysical survey carried out by Sastri *et. al* (1971), Rao(1973), Mall et al (1987) decipher ridges and depressions (Horst and Graben) basement structures which are controlled by primary crustal geofractures. The gravity contour map(Prasad *et al*, 1998) depicts the basement profile wherein the present Ganga course is following the axis of gravity low flanked by gravity high axes on either side. The study area falls within the concentric zones of gravity low (Fig-6). This has greatly influenced the processes of Quaternary sedimentation during Pleistocene-Holocene time.

Photo-5 Photo showing palaeobank skirting Karanda Village seperating T_1 (foreground) and T_1' with inhabitants and Vegetation, Ghazipur District, U.P.

Geological Set Up

Geologically the area exposes the Holocene sediments-the Terrace Alluvium(Karanda Formation) broadly consisting of dark grey to light brown silt,clay and micaceous, fine to medium grained sand. The surficial deposits of the Terrace Alluvium is classified as grey silt - clay and black clay member (Photo-6). The borehole logs, located in the terrace zone, indicate that the grey to dark grey silt-clay and micaceous sand of Holocene age varies in depth from 10m to 20m below ground level (bgl). This Holocene lithoassemblage lies over the fine to medium grained sand and brown silty clay commonly interstratified with thin compact calcrete (*kankar*) layers of

Photo-6 Photo showing expanse of black silt-clay member of Karanda Formation (Terrace Alluvium), Karanda Village.

Pleistocene age described as the Varanasi Older Alluvium. The calcrete and conglomeratic layers are exposed at Guraini and Prahladpur(Gopendra Kumar et al 1996) upstream of Karanda village (Fig-1). The wall of the collapse section exposes insitu grey silt -clay unit at a depth of 4.5 m. The underlying saturated clay silt zones is measured at 6 m depth followed by calcareous silt - clay lithounit continuing upto 10.4 m. The overburden/filled-in material contains broken pottery pieces and soil.

Sediment Character

Sediments were collected to study the grain size (Table-1A and 1B) and geochemical properties (Table- 2 and 3). Samples were collected from the insitu collapsed wall at different depths and surrounding areas for comparative studies of soil character.

The grainsize analysis of the collapsed material indicate dominant partcle size falling less than 0.020 mm constituting about 60% . The adjoining samples indicate 40% of the finer fraction falling less than 0.020mm size.

The soil elemental analysis indicate SiO_2 (62%) , Al_2X (14.4%), Fe_2X (6%) and CaO , MgO and K_2O together consituting 6% and rest P2O5 including trace elements. It is characteristically noted that the chemically finer fraction (0.020 mm) constitutes of SiO_2 and clay fractions made of illite and

Table: 1A Size Fraction analysis of the samples collected from the wall of the cavity (Fig. 2), Karanda village,Ghazipur District.

Depth of samples (in metre)	Mechanical Analysis(Sieve Opening in mm)								Pippete analysis(Sedimentation analysis- finer particle size in mm)		
	6.300	4.750	2.360	1.180	0.600	0.300	0.150	0.075	0.020	0.006	0.002
3.0m bgl	100.000	97.040	95.921	94.861	93.492	91.542	90.112	86.444	44.857	35.853	17.123
4.0m bgl	100.000	99.513	99.433	98.775	98.091	97.197	95.679	93.022	49.046	38.581	19.201
5.0m bgl	100.00	100.000	100.00	100.000	99.832	99.488	99.040	98.162	40.075	42.349	25.988

Table:1B Size Fraction analysis of the samples collected from the adjoining areas, Ghazipur district.

Sample location	Mechanical Analysis(Sieve Opening in mm)								Pippete analysis (Sedimentation analysis- finer particle size in mm)		
	6.300	4.750	2.360	1.180	0.600	0.300	0.150	0.075	0.020	0.006	0.002
Mirzabad 25°35';83°52'	100.00	100.000	100.00	100.000	99.938	99.744	99.189	97.403	61.096	50.138	28.628
Suhuwal 25°43';83°39'	100.00	100.000	100.00	100.000	99.958	99.731	99.306	97.570	48.191	42.093	23.392
Lahuadih 25°38';83°50'	100.00	100.000	100.00	99.943	99.863	99.651	99.275	97.739	46.646	38.908	21.397
Basnian 25°36';83°55'	100.00	100.000	100.00	100.000	99.945	99.815	99.341	97.142	56.075	37.861	22.885

montmorrillonite(Kar *et al* 1997). The environment of deposition of such very fine sand(SiO_2) indicate sediment in suspension and its deposition at isolated locales probably due to localised whirlpool and ebb current condition.

Groundwater Regime

The Karanda village is dotted with dugwells indicating availability of profuse near surface groundwater. The depth to water table varies from 3.80m during monsoon to 15 m during summer. The groundwater fluctuations of 3m recorded between 12 m and 15 m depths. The tubewells have encountered aquifer zones between 30-40 m in the area. The bed level of the Ganga river is about 10m below in respect of collapsed site during dry season, however, during the monsson period the area gets flooded.

The quality of ground water of Karanda village indicates very high carbonate content (1711ppm) although the average carbonate in the adjoining areas and elsewhere of Ghazipur district content vary from 9 to 29ppm (Table-3). The value of carbonate and bicarbonate content in the groundwater of the Karanda village is possibly related to calcareous nature of the subsoil and are prone to dissolution.

Discussion

The present cave-in problem occcured as a cylindrical opening exposing the constituent material upto a depth of 10.4 m roughly corresponds to near surface aquifer. Contrary to the common belief that such collapse do occur in places earlier occupied by dug well, but the said collapse is found here to be of naturally occuring processes. The total volume of the removed materials is about 1225cubic metre Similar collapse was also reported from adjoining house (150m east) of Sri Prabhunath Singh (Photo – 4). The nature of failure reported as opening of 23 cm diametre verticle hole of unknown depth. When excavated it reached upto a depth of 60 feet, with adit in all four directions extending upto 3 m to 5 m in length. In the adjoining area the subsidence cracks in house wall of Sri Ramesh Kanaujia (Lat: 25° 29.425 N and Long: 83°29.854E) and others were also observed.

Table: 2 Chemical constituents of Soil of Karanda and adjoining areas, Ghazipur district, (analysed by ICP AES)

Sample location	Elemental analysis																											
	SiO_2 %	Al_2X %	Fe_2X %	CaO %	MgO %	K_2O %	MnO %	TiO_2 %	P_2O_5 (g/t)	Li (g/t)	Be (g/t)	B (g/t)	V (g/t)	Cr (g/t)	Co (g/t)	Ni (g/t)	Cu (g/t)	Zn (g/t)	As (g/t)	Sr (g/t)	Y (g/t)	Nb (g/t)	Mo (g/t)	Ag (g/t)	Cd (g/t)	Ba (g/t)	La (g/t)	Ce (g/t)
Karanda*	62.1	14.4	5.9	1.9	1.8	2.1	0.06	0.66	658	< 10	< 2	82	89	93	16	43	33	65	< 20	100	21	23	< 5	< 1	2	440	32	31
Dharamv-arpur*	65.2	10.8	4.4	3.2	1.3	1.7	0.05	0.57	847	< 10	< 2	87	71	75	10	29	22	40	< 20	120	20	23	< 5	< 1	2	333	31	<10
Barsora	66.9	13.6	4.3	<1.0	1.4	2.1	0.06	0.62	495	< 10	< 2	100	77	74	10	29	25	54	< 20	85	25	24	< 5	< 1	< 2	412	36	60
Suhuwal (B.C.)	51.9	15.2	6.7	1.4	2.0	2.4	0.09	0.78	732	20	< 2	55	116	119	16	63	55	86	< 20	86	24	23	< 5	< 1	< 2	458	29	42
Lahuadih (B.C.)	55.5	14.1	6.4	2.8	1.8	2.3	0.07	0.63	510	21	< 2	67	92	87	11	44	30	57	< 20	115	23	23	< 5	< 1	< 2	391	29	16
Reotipur*	60.6	14.8	5.5	<1	1.9	3.6	0.07	0.53	1125	38	< 2	100	86	73	13	36	27	69	< 20	85	< 20	25	< 5	< 1	< 2	538	31	53
Tarighat*	50.8	15.1	17.4	1.6	2.0	2.3	0.09	0.76	910	24	< 2	52	114	114	16	63	49	77	< 20	84	22	23	< 5	< 1	< 2	401	28	42
Baraura (O.A.)	54.9	15.5	6.4	1.8	1.9	2.4	0.08	0.67	229	25	< 2	69	101	99	14	51	38	76	< 20	90	24	23	< 5	< 1	< 2	471	31	44
Mohanpur (O.A)	55.1	15.8	7.3	1.4	1.9	2.2	0.10	0.74	543	<10	< 2	54	111	110	16	62	54	93	< 20	84	22	23	< 5	< 1	< 2	435	27	39
Derhgaw-an (O.A)	61.5	15.0	5.6	<1	1.8	2.8	0.08	0.58	1103	<10	< 2	95	87	81	28	40	28	72	< 20	85	22	24	< 5	< 1	< 2	518	32	52
Note O.A. - Older Alluvium clay; B.C. - Black clay of Terrace Alluvium; *- Grey silty clay of terrace Alluvium																												

Table-3 Quality of Groundwater around Karanda , Ghazipur district, Uttar Pradesh

Sample details			Elemental analysis												
Locality	Source	Depth	pH	Sp conduct ance	CO_3 (ppm)	HCO_3 (ppm)	Cl (ppm)	F (ppm)	NO_3 (ppm)	SO_4 (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Li (ppm)
Karanda	Handpump (mark-II)	30m	7.86	531	1711	346	16	0.8	7.1	76	42	27	43.1	4.7	1.0
Karanda	Dugwell	10m	8.71	398	126	188	15	0.8	13.3	47	58	6	41.5	4.7	1.0
Mednipur	Borehole	50m	8.39	438	9	215	26	0.6	11	31	22	31	39.8	3.8	1.0
Dharampur	Handpump (mark-III)	33m	8.30	512	19	185	32	0.2	34	36	26	12	19.0	5.9	1.0
Nandganj	Handpump	40m	8.51	596	29	290	20	0.8	7.7	5	10	41	71.7	3.8	0.9
Ghazipur	Ganga river	Surface water	7.85	1330	-	502	147	0.9	30.5	43	62	60	86	58	0.9
Brahmanpura	Dugwell	8m	8.52	681	29	112	47	0.3	15.5	72	20	37	268.9	7.6	1.0
Nandganj	Dugwell	12m	8.37	454	17	193	35	0.3	17.6	55	34	35	19.9	3.2	0.9
Suhuwal	Dugwell	8m	7.38	434	-	244	12	1.2	6.8	18	20	9	47.7	4.6	0.2

Causes of collapse

Land subsidence/land-cave-in is a general phenomenon of sudden sinking of the earth surface owing to subsurface movement of the earth material. The principal causes can be:

i) Aquifer overdrafting
ii) Underground mining
iii) Sudden change of hydraulic regime
iv) Natural compaction and expansion of soils, and
v) Dissolution and collapse of suceeptable subsurface sediments

The cause of collapse due to overdrafting of groundwater is ruled out in the area as it is located in the flood plain of the Ganga river system. The near surface as well as deeper aquifer produce plenty of water for drinking purpose. Hence, overdrafting of the groundwater is absolutely minimal. The observation of collapse depth(10.4m) in the area corresponds to the static water level of the area as well as with the bed level of Ganga river(Profile A-B, Fig 4). Considering the underground mining option, the area falls in alluvial tract and is free from such mining activities. The area falls in subtropical climatic condition with sufficient rain fall with perenial Ganga river draining the area. The annual ground water fluctuations of 3m recorded is between 12 -15m at places and no catastrophic change in hydraulic regime is reported from the area. The constituent material of the affected site contain fine silt and clay having swelling index as negligible thus possibilities of collapse of subsoil in the house of shri Ansari due to swelling and shrinkage property is unlikely.

The Karanda area needs special mention owing to its cylindrical failure. Such collapse could be related to the sediment character and its genesis. The Terrace deposits in the Karanda area is laid down by the Ganga river due to avulsion/migration/shifting of its course during Holocene time (Khan and Prasad 1997). The geodynamic condition of deposition is aptly reflected by the present day geomorphic setting as well as a basement configuration (Prasad *et al* 1998). The tectonic setting indicates that the affected area falls in a palaeo-geomorphic lows. This palaeo geomorphic lows coincides with the concentric basement lows (Fig-6).

Neotectonic Signature

Regionally the neotectonic signatiure is well documented in the form of river metamorphosis in the area. The east - west flowing Ganga river near Dhanapur, west of Karanda village takes a sudden southern plunge and form a U band in the downstream near village Zamania. This sudden southerly movement of the Ganga river is attributed to NW-SE geofractures along which vertical movements is recorded in the form of upheaval of Quaternary older sequence (Banda Alluvium) exposing the conglomerate bed at Dhanapur - Prahaladpur Ganga river section. At Zaminia where the Ganga river takes a U turn a high tectonic scarp of 20-25 m height is exposed. Three levels of kankar horizons of 12,290±140 yrs B.P. (Prasad and Kar, 2005) showing shallow dip of 4 ° to 5 ° towards north is exposed. The tectonic scarp exposing shallow dipping Quaternary sequence indicate gradual vertical movement and concommitant downcutting of Ganga river in response to neotectonic adjustment in the area. This upliftment of Dhanapur-Zamania tectonic block, in which the Karanda village is a part, also influenced the N-S flowing course of Karamnasa river, a southern bank tributary of Ganga river (Fig-6). Along the deflected course of Karamnasa river a palaeotectonic depression in the form of palaeobank swamp(Prasad et al 1998) is recorded in thea area. This subdued tectonic changes in the form of vertical movements along the geofractures needs immediate attention. Although no major movement is recorded in the area, however minor movements is not rulled out.

The palaeotectonogeomorphic set up governs the channel configuration of Ganga river wherein it takes a 'U' band to partly circumvent the basement low. This shift of channel configuration possibly resulted in a high energy eddy current in areas of basement lows. Such palaeowhirlpool areas are prone to (i) unstable sediment column (ii) areas of sediment dissolution and (iii) easy subsurface earth movement.

The study suggests that part of the Karanda area is located on such palaeo whirlpool areas susceptible to land subsidence. The calcareous sediments are possibly in a state of semiconsolidated condition and dissolution and removal of such fine calcareous sediments are in continuation over a long period of time.

Conclusion

Considering the tectonic setting of the area as well as suscceptible nature of sediments for easy removal, the possibility of palaeo-eddy pool under incipient dissolution condition of overlying strata over a period of time has resulted in isolated cylindrical collapse in Karanda area, although manifestation of such slow process of subsidence is witnessed in the area as a surface cracks and minor ground settlements.Since Karanda area is basically under agricultural occupation and anuually flooded such minor change in surface topography went unnoticed. As such this sudden collapse has created a commotion among the residence.

The study strongly recommends the urgent steps to be taken to (i) decipher such vulnerable areas to avoid future mishaps (ii) micro-gravity survey to delineate such subsurface susceptible areas(palaeo-whirlpool areas) and (iii) also setting up of MEQ stations to study subtle pulses, if any, being generated in the area resulting such collapse.

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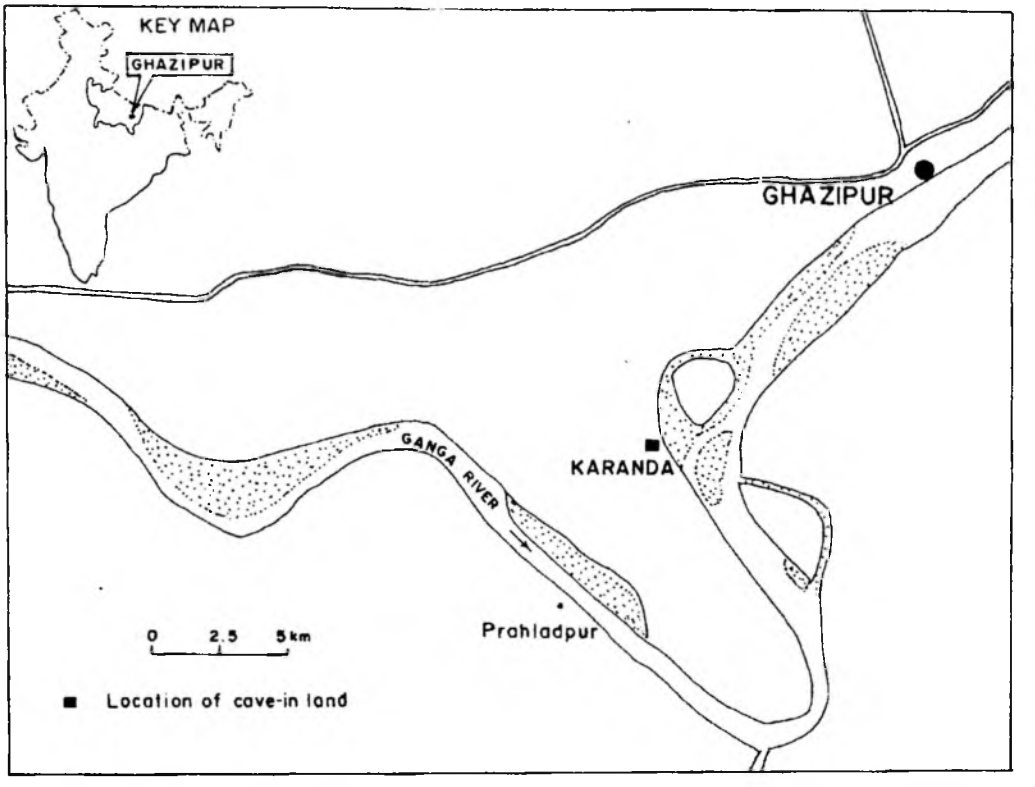

Fig. 1 Regional map showing point location of cave-in area Karanda village, Ghazipur district, Uttar Pradesh

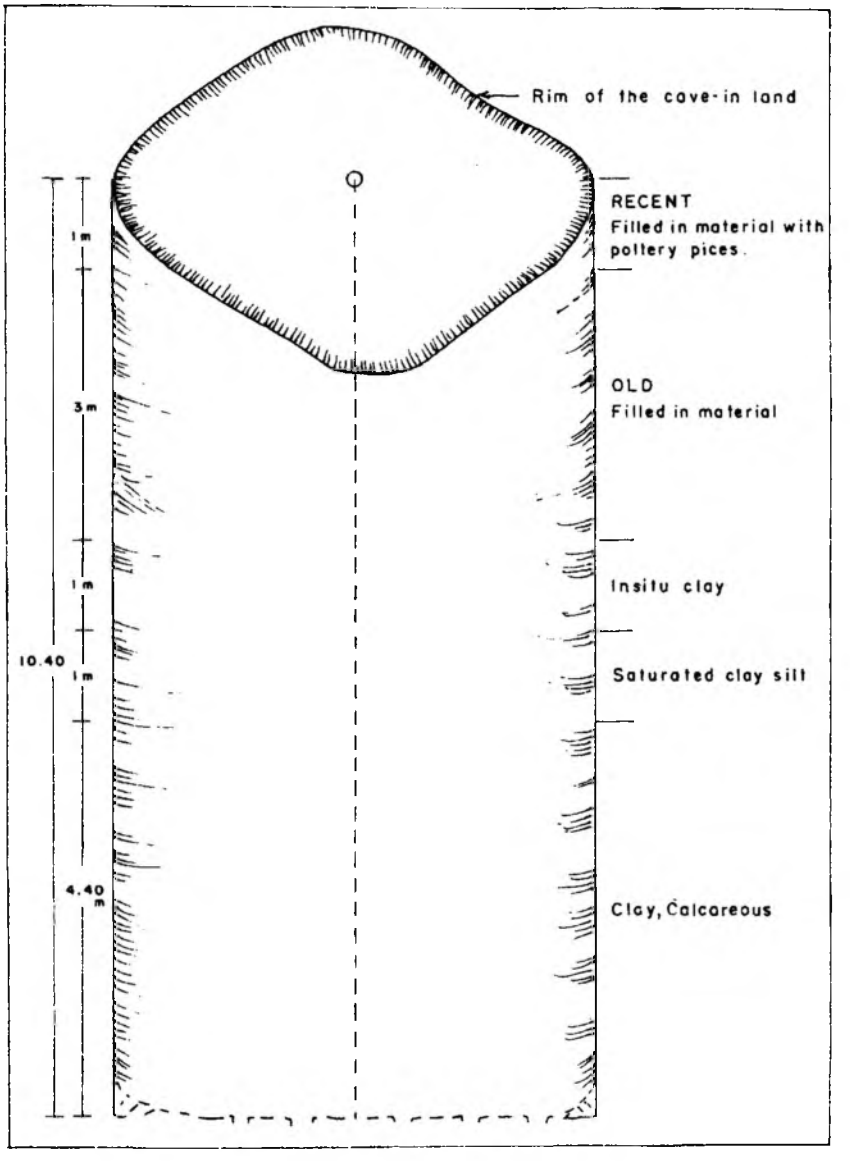

Fig. 2 Vertical sketch of cavein - ground
H/O Sri Samsher Ansari, Village Karanda
(Loc. N 25° 29.412 E 83° 27.946)

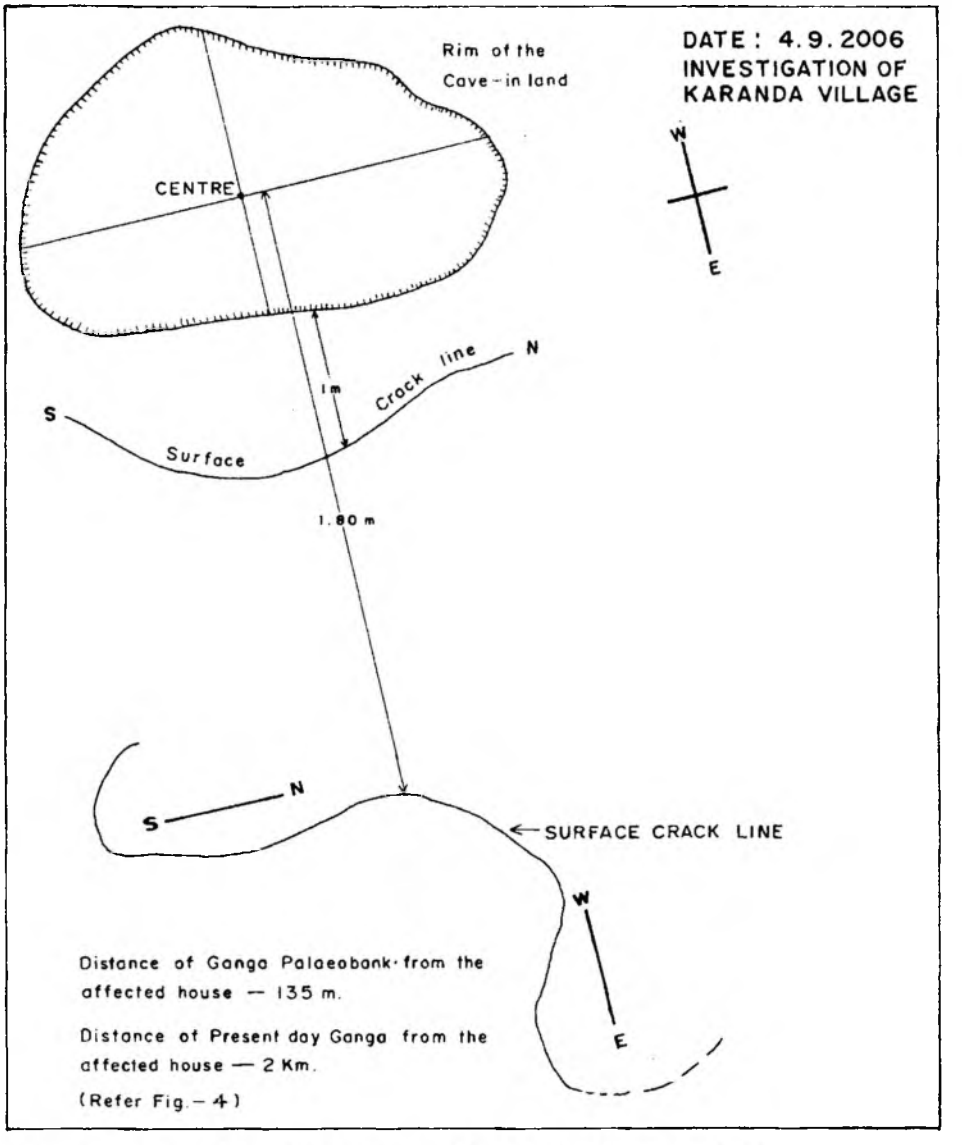

Fig. 3 Plan view of the affected part of the H/O Sri Samsher Ansari

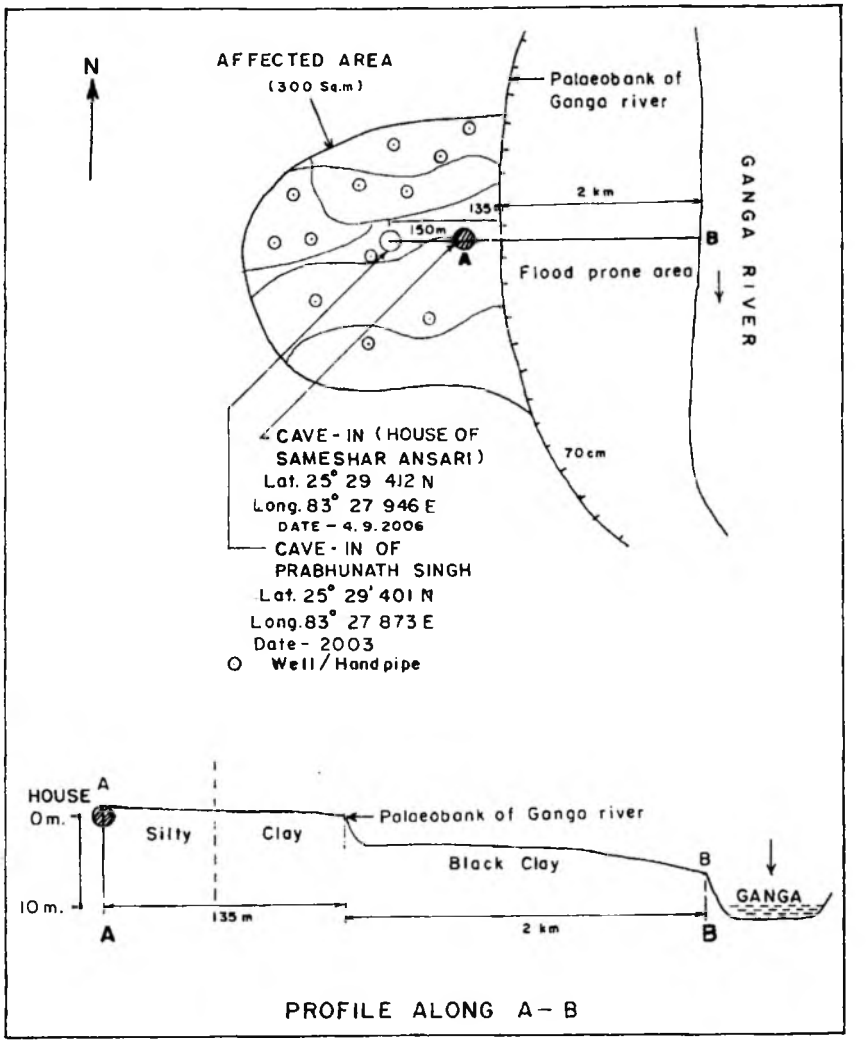

Fig. 4 Map showing affected area in respect of Ganga river

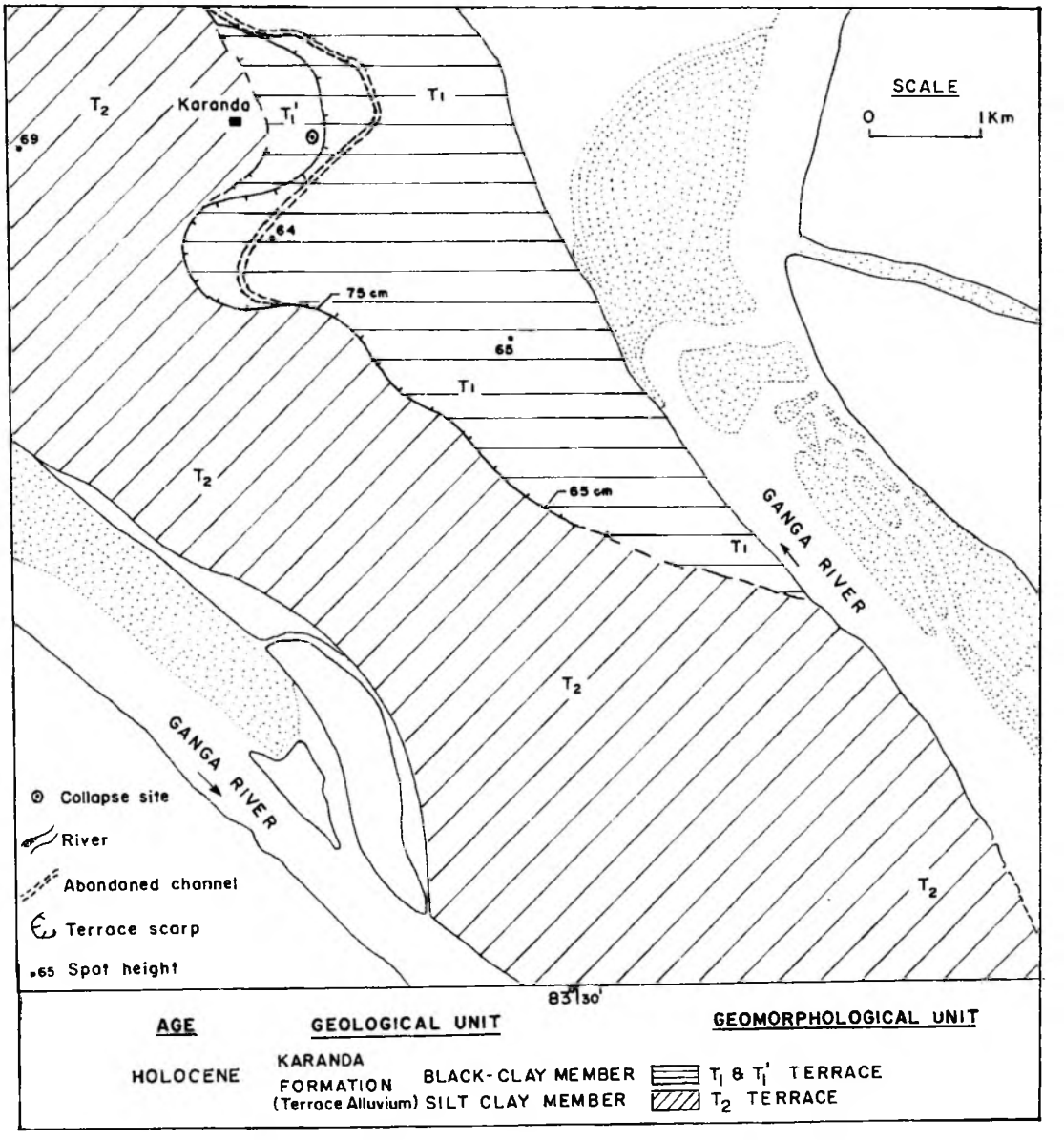

Fig. 5 Geological / Geomorphological map of Karanda area, Ghazipur district, Uttar Pradesh

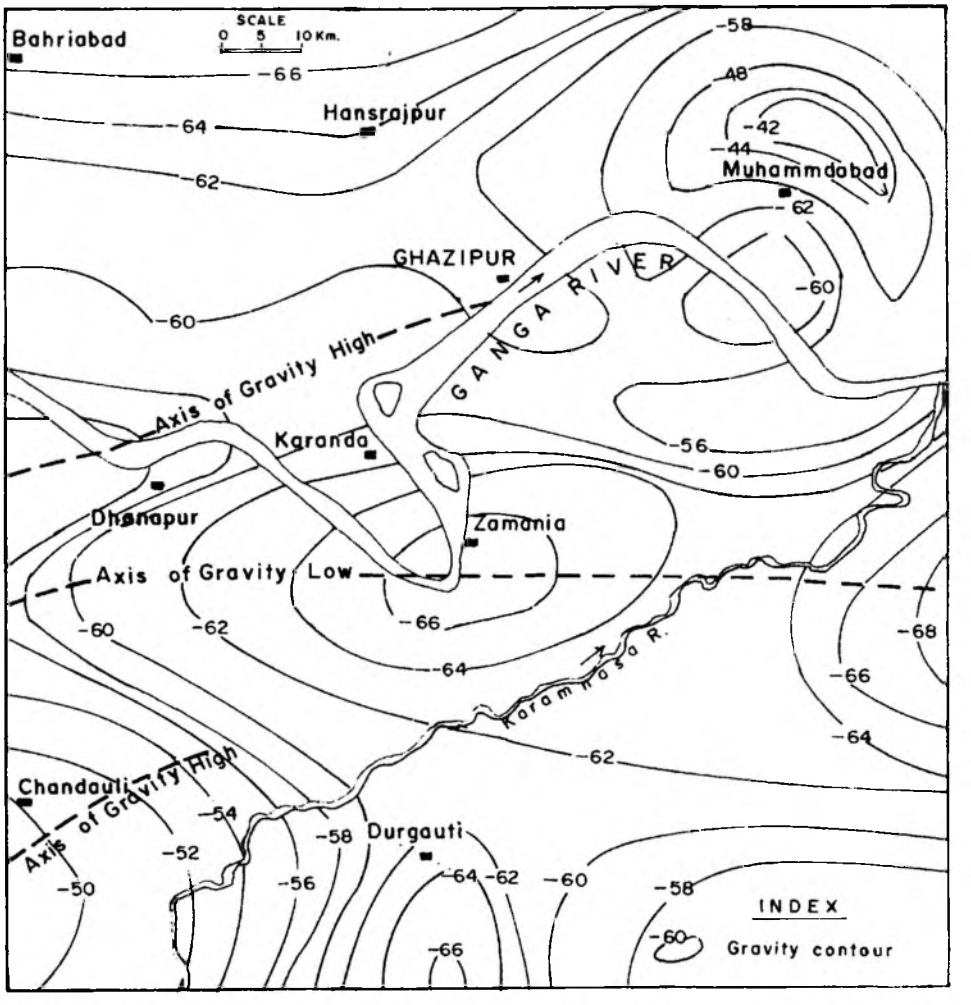

Fig. 6 Basement Configuration of Karada - Ghazipur area (After Mall, et al. 1987)