INVESTIGATION ON THE IMPACT OF CLOUDBURST IN TEHRI DISTRICT, UTTARANCHAL - 31 AUGUST 2001

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The catastrophic landslides of Gona village, which took place on 31 August 2001, has been subjected to field investigation. Our study indicates that a combination of several factors are responsible for this tragedy, but the action of water during the cloudburst was the main triggering factor.

Introduction

On the fateful morning of 31 August 2001 (00.15 to 1.30 AM), heavy downpour (cloudburst) killed seven persons and left several others homeless in the Gona village, in the Tehri district of Uttaranchal Himalaya. Many landslides were observed in and around Gona village, which disturbed the transport network, electricity and also completely damaged the water supply system of the village. Heavy precipitation affected the slopes of Gongad stream of Balganga River, resulting in massive debris avalanches and other forms of slope failures, evidenced by a large number of deep and shallow scars on the slopes in the area.

A detailed survey of the area has revealed that about 4 sq. km of the area received very heavy precipitation on the above date and three villages viz. Gona, Saunp and Sitakot were affected out of these Gona was the worst hit. The losses assessed by the authors and the local governmental agencies are given in Table 1. A total number of 14 cloudburst scars are reported in the affected area. The debris flow along the gullies uprooted the trees and removed heavy boulders because of the high velocity and turbidity of the water. Along the narrow margins trees and big boulders temporarily dammed the streams (Fig. 1) particularly in the middle of village Gona and their subsequent breaching caused a devastating surge of water, leading to excessive mass movement along their courses, hitting the houses and causing widespread damage to life and property (Fig. 2). According to the villagers, similar devastating tragedy had also taken place in Bhatgaon village, situated on the opposite side of village Gona, about 80 years back.

This type of landslides and rockfalls are not at all an uncommon phenomenon in the Uttaranchal Himalaya and particularly in the Inner belt of the Himalaya. There are reports that, not only in the Garhwal region, but also all along the Himalayan terrain, landslides occur most frequently during intense rains, as water is an important catalyst for triggering landslides (Haigh et.al. 1989; Joshi, 1997). About 90 percent of the landslides in the Himalayan range occur during the three monsoon months and the rest take place during winter (Thakur, 1996). It is common knowledge that many other villages in the Uttaranchal Himalaya are also prone to landslides. The landslides and rockfalls are always in the zones of the active faults and are of predictable severity and proportion (Valdiya, 1998; Naithani, 2001).

Table 1. Survey details of the Gona August 2001 tragedy

1.	Total Number of Villages affected			:	03
2.	Total Population			:	1828
3.	Number of families affected			:	290
4.	Men	(i)	Fatalities	:	07
		(ii)	Injured	:	12
5.	Cattle	(i)	Fatalities	:	07
		(ii)	Injured	:	12
6.	Houses	(i)	Complete damage	:	11
		(ii)	Partial damage	:	17
7.	Agricultural land			:	16 ha
8.	Foot Path			:	9 km.
9.	Total losses			:	Rs. 50 Lakhs
10.	Total numbers of landslides (originated because of 31 August cloudburst in and around three villages)				More than 50

Geological and Physiographic Setting

This area come under the Deoban/ Garhwal tectonic unit and the Central Himalayan Crystalline Group of rocks, which are separated from each other by a thrust known as Main Central Thrust/ Mukhem Thrust (Saklani, 1972)/ Thayeli Thrust (Rao and Pati, 1982). In the Garhwal Group, quartzite is the main rock type, which is well bedded to massive, medium to coarse grained and shows varying colours e.g. white, purple and brown. It is gritty to arkosic

Fig.1. Trees and large boulders have dammed the stream in the upslope direction of the village Gona.

Fig.2. On the subsequent breaching of the dammed stream widespread damage was caused all along the stream due to debris flooding.

in nature and shows sedimentary structures like cross bedding and ripple marks. The quartzite is profusely jointed and slickensides, striations and thin encrustations of talcose material characterize the joint planes. Numerous basic intrusives exhibiting concordant relationship with the quartzite have been recorded. The quartzite occurs almost all along the thrust contact. The Central Himalayan Crystalline rocks of this area, comprise low to medium grade metamorphites with diaphthoretic gneisses at the base followed by coarse grained granite-gneisses, quartz-muscovite schist, sericite-schist, augen gneisses, porphyritic gneisses, tourmaline granite, amphibolite-schist and biotite schist (Fig. 3).

The MCT brings gneisses and low to high grade metamorphic rocks over the quartzite. The thrust plane dips towards northeast and north at varying angles from 30°-50°. The MCT zone is marked by intense shearing and diaphthoresis (Singh and Saklani, 1978). There are a number of N-S trending cross-faults, which affect the thrust planes. In Balganga valley, a steep angled fault designated as Balganga fault by Rao and Pati (1982), offsets the thrust contact plane far a distance of about 50 kms and is traced upto Belakhal from Ghansali. The rocks on either side near the thrust contact are sheared and crushed. The gneisses show elongated augen and bent mica flakes. Quartzite is pulverized and traversed by closely spaced fractures. Parallel to the thrust contact a number of sympathetic shear zones and fracture cleavages are seen.

This area characterized by steep slopes of randomly trending hills and is dissected into narrow to wide open valleys by Balganga river. Both depositional and erosional terraces have been recognized in this area. Erosional terraces have convex sides facing towards valleys while the depositional terraces are semi-circular to elliptically outlined. Depositional terraces mostly comprise riverborne rounded to elliptical quartzites and gneissic boulders mixed with debris and sandy clay matrix. The development of depositional terraces at different levels provide an explanation for the successive changes in the course of Balganga and their occurrences possibly suggest that the area witnessed the effect of uplifting in Quaternary era. The transverse faults (N-S, NW-SE) play a significant role in determining the course of rivers.

Types of Mass Movement

Three types of slope failure were observed viz. debris slide, block slide or rock-cum debris slide, which are mainly due to wedge, translational and rotational failures. The joint planes play the vital role for landsliding. The presence of slickensides and striations along the joint-planes of quartzite imply that some movement has taken place along these planes. The intersection between the two joint-planes causes wedge sliding. Three sets of joints are prominent in quartzite (i) N30°E-S30°W dipping 75° in SSE direction. (ii) N15°W-S15°E dipping 60° in SSW direction. (iii) N30°E-S30°W dipping 68° in NNW direction. Since the planes i $\wedge$ ii and ii $\wedge$ iii are intersecting at acute angle, they are responsible for wedge sliding. The presence of talcose encrustation and the intercalations of chlorite-schist along joint-planes enhance the processes of sliding of these blocks. During rainy seasons, such intercalations when soaked with water, act as lubricant, hence facilitating the sliding process of these blocks.

Bedrocks having two or more sets of joints, possessing thin soil cover are usually ravaged by the translational slide. Debris flows are very common along high gradient channels. The rotational slips, generally triggered by the high porewater pressure, are developed along deeper slip-surfaces, where the thickness of the regolith is 10-40 m or more. Slumping is also reported, where the thickness of regolith is more and channels cut the basement. Majority of the debris slide are confined to the quartzite, due to the highly fractured and jointed nature of the bedrocks and the presence of shear zones etc.

Causes of Landslide

A combination of factors appear to have contributed to the present tragedy. This area is tectonically and seismically a very sensitive domain. Strong tectonised rocks and the fragile mountain slopes of this area are vulnerable to the onslaughts of rains and tremors of earthquakes. This area is very close to Main Central Thrust (MCT). The MCT zone was so vulnerable during last two decades in the Uttaranchal Himalaya, that many villages viz. Kauntha, Karmi, Belakuchi, Tawaghat, Jaggi, Paundar, Phata, Byung etc. situated in the vicinity of the MCT were wiped out (Anbalagan, 1998; Valdiya, 1998; Naithani, 2001, 2002).

According to the local inhabitants, this area receive maximum precipitation during the summer monsoon, therefore one can say that present area falls in the zone of maximum precipitation. In such a zone 200 to 500 mm of rainfall may be expected in a day, once in every 100 years (Dhar and Mandal, 1993). No meteorological observatory is in the Balganga valley of Garhwal Himalaya. Indian Meteorological Department recorded the rainfall data of Ghuttu (15 km. Aerial distance from the present area). The annual precipitation of this region is 285 cm and the maximum rainfall or presumed maximum precipitation (PMP) in one day prior to the present event in the last 100 years is 55 cm. The records available confirm that in the last one hundred years, there has not been any rainfall event of that area that has cause as much damage to life and property as the one from 31 August 2001 in Gona area. Some experts believed the PMP in this case was above 55 cm. There were incessant rains for about 6 hours before this incident. During a cloudburst, the runoff water is excessive and continuous, over- saturates the top layer of the soil or debris, leading to a shallow perched water table rising up to the surface. This reduces the grain-to-grain or block-to-block cohesion of the slope material below and increases the drainage density. Whenever the drainage density is high, the running water washes out the cohesive material from the soils and the rockmass. The water pressure not only pushes the slope forward but also generates

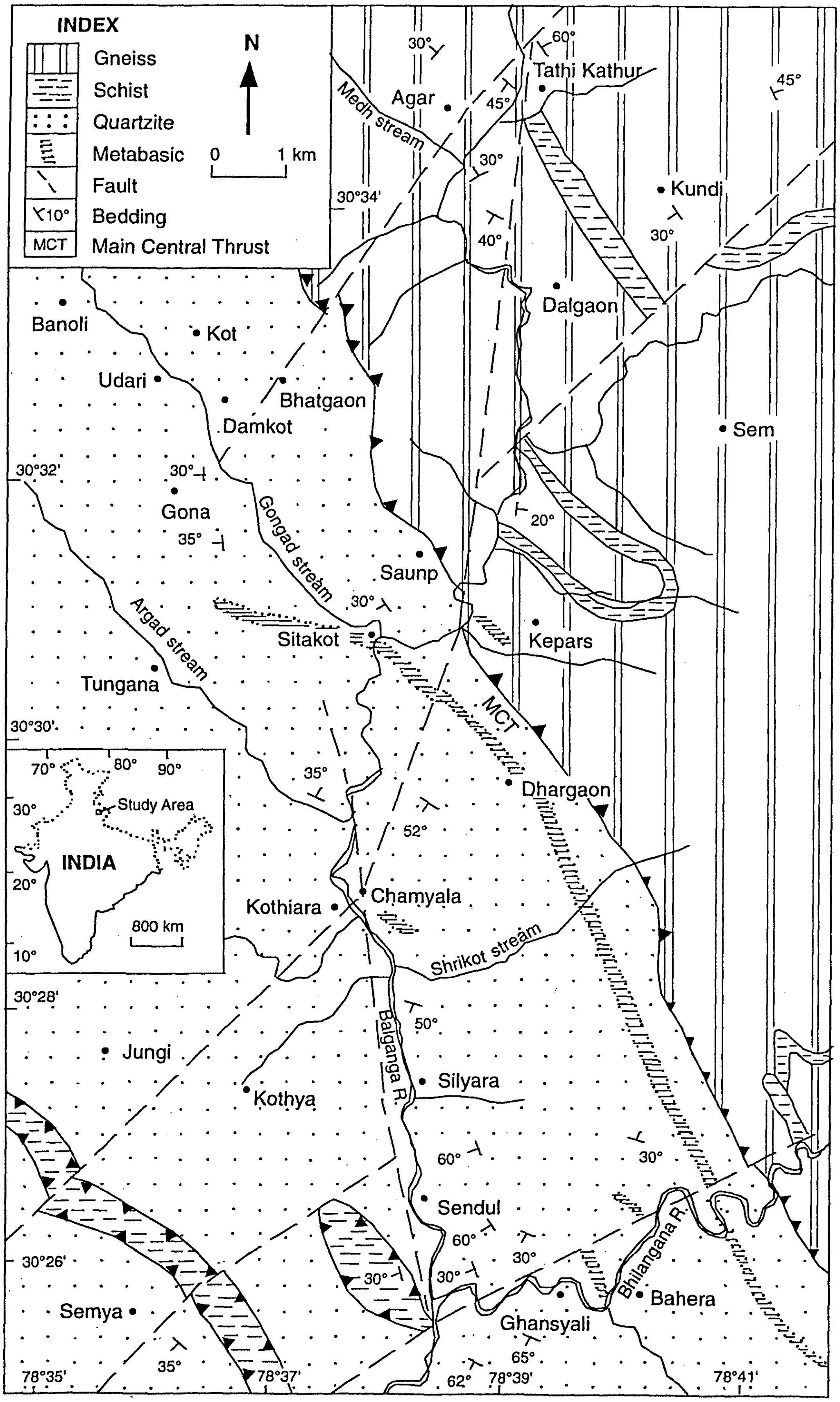

Fig.3. Geological map of the study area (*after* Saklani, 1972; Rao and Pati, 1982).

porewater pressure along joints and bedding planes. As the failure starts, the opening of a rough joint is enlarged on dilation (Deoja et.al. 1991). Thus the plane of sliding acts as natural channel for the flow of water. The secondary structural weakness zones present in the host rocks and pre-existing slip-surfaces in old landslide areas are also reactivated. Because of adverse hydrological conditions at higher reaches, active creep and subsidence are also observed.

Most of the superficial deposits viz. soils are related to the solifluction lobes of Pleistocene are usually loose and unconsolidated. As there is a dominance of clay in such debris cones, which becomes impermeable due to increase in pore water pressure whenever water infiltrate cross a critical limit. The water forces its way through the weak planes onto the slope carrying hundred of tons of soil, rock fragments and trees etc. Secondly, the height of embanking wall and outwards slopping of the terraces add to the problem. These terraces are in a destabilized position due to the heavy mass of the soil and prolonged rains.

A combination of factors like tectonically disturbed state, fractured lithology, seismic events, loose soil cover on steep slopes and prominent seepage zones are responsible for this tragedy, but the action of water during the torrential rain appears to be the main triggering factor.

In the past, landslides and related phenomenon have played severe havoc in this region, where there has been a phenomenal increase in population density and also development activity. In every year, two to three villages of Uttaranchal Himalaya come under the grip of incessant rain causing heavy damages to life and property but even today we do not have any well formulated plan for tackling such disasters. More than 300 villages alone in the Garhwal Himalaya are prone to landslides and road blockades every year during monsoon season but hardly any preventive steps are taken. We must not embark on any developmental activity without a proper understanding of the tectonic setup and other factors of the Himalayan terrain. There is an immediate need for the new State of Uttaranchal to formulate a policy by involving the geologists, hydrologists and civil engineers in the management of landslides and related disasters. It is important that the hazards be assessed realistically in order to provide a sound basis for natural hazard mitigation by planners and administrators.

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