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Study of quartz grain surface texture by electron microscopy – a tool in evaluating palaeoglacial sediments in Uttarakhand†

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The scanning electron microscope (SEM) study of microtextures in quartz grains in India is still in infancy and restricted mostly to the placer or beach sediments. SEM study of micromorphology of quartz grains from Late Pleistocene–Holocene sediments in Uttarkashi district, Uttarakhand, has been taken up for understanding the depositional environment. In the Netal section the quartz grain micromorphological studies indicate basal part of a valley glacier environment or remnant glacial lake, as the quartz grains are angular with high silica deposition besides other imprints of glacial origin. In the Shiror section the sediment appears to be part of the glacial till. The present study provides a new approach to the much needed palaeoenvironmental evaluation of the Himalayan Quaternary sediments on a nanoscale.

Keywords: Palaeoglacial sediments, quartz grains, scanning electron microscope, surface texture.

DURING investigations for microfossils in the Quaternary of Uttarakhand for understanding the palaeoecological changes, Arcellaceans[1] and bugs[2,3] were found in two

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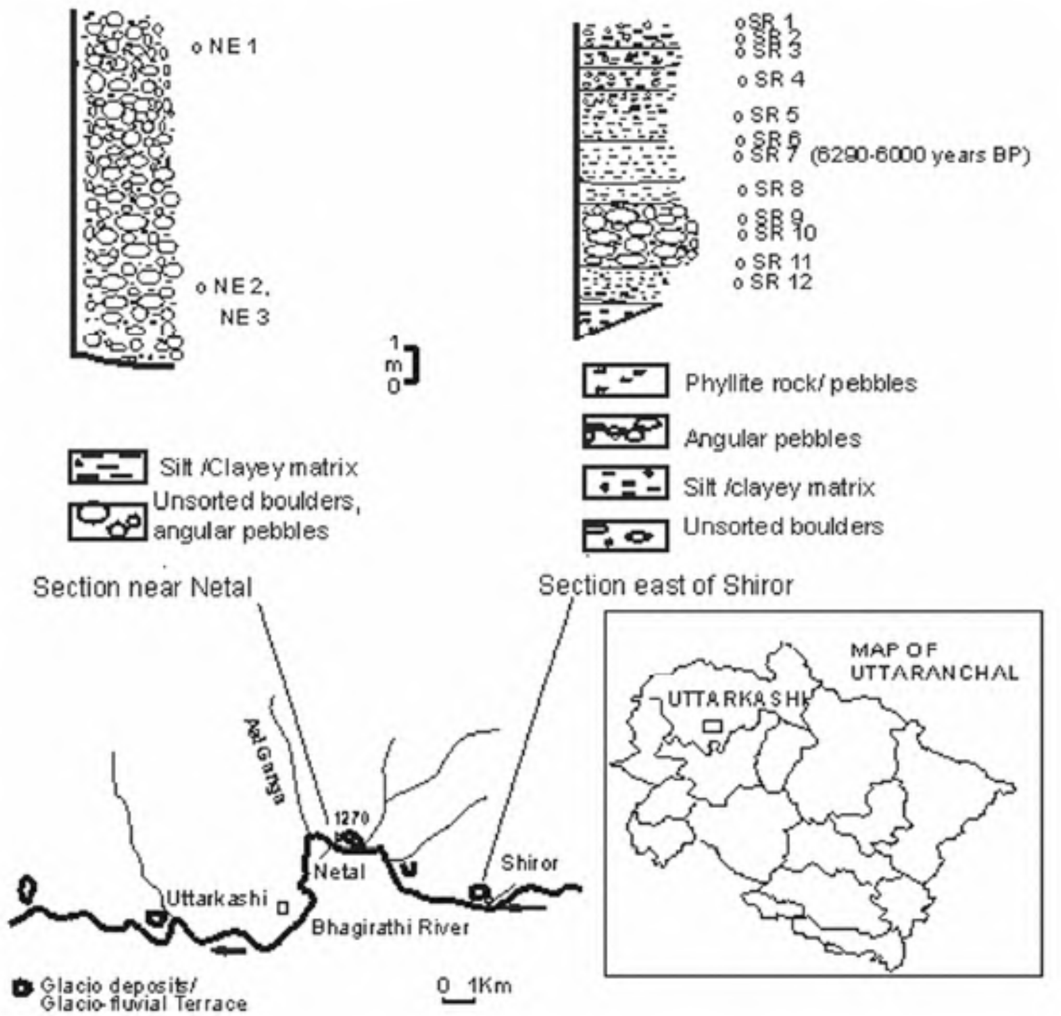

Figure 1. Location of sections and glacial/glacigenic sediments along the Uttarkashi–Gangotri road.

sections near Uttarkashi. These indicated cold, aqueous ecology. Rawat and Gairola[4] have carried out Quaternary geological and geomorphological studies in parts of Bhagirathi valley, Uttarkashi District, Uttarakhand. They have classified the Quaternary sediments according to their mode of deposition into glacial, periglacial and fluvial. The Quaternary sediments unconformably overlie the Garhwal Group, and Saknidhar and Chandpur formations. The microfossil-bearing samples were collected from a section exposed in a U-shaped valley near Netal (30°44′35″N; 78°29′15″E) and laterally extending beds near Shiror (Figure 1). These sediments comprise heterogeneous, ill-sorted clasts which are angular to subangular and boulders of varying dimensions, some larger than 1 m in diameter in rock flour or clayey matrix.

The published data on microtextures of quartz grains is very limited[5–18]. Krinsley and Doornkamp[6] and Mahaney[10] have described and illustrated quartz grains with various micromorphological characters based on which glacial, eolian, fluvial, lacustrine and other processes can be identified. Van Hoesen and Orndorff[19], who have studied microtextures and surface characteristics of samples from quartzite, granite, limestone, basalt, chert, pillow basalt and quartz pebbles collected from a variety of depositional environments, suggest that it is possible to differentiate between glacial and nonglacial deposits based on frequency and morphology of diagnostic surface microfeatures. Further, they suggest that these features are best preserved and identified on competent and monomineralic samples such as quartz, chert and limestone.

Study of quartz grain surface texture from the Late Pliestocene–Holocene in Uttarkashi, was taken up for delineating the mode of deposition. The microtexture studies indicate that the basal part was deposited in valley glacier environment or remnant glacial lake in the Netal area. The sediments of the Shiror section might have been deposited as a part of the glacial till.

Samples were also taken from water body behind Kedarnath temple, Uttarakhand, which is a debris-blocked lake in the high-altitude temperate region of the Himalaya, locally named as Gandhi Sarovar, for comparison with the present environment.

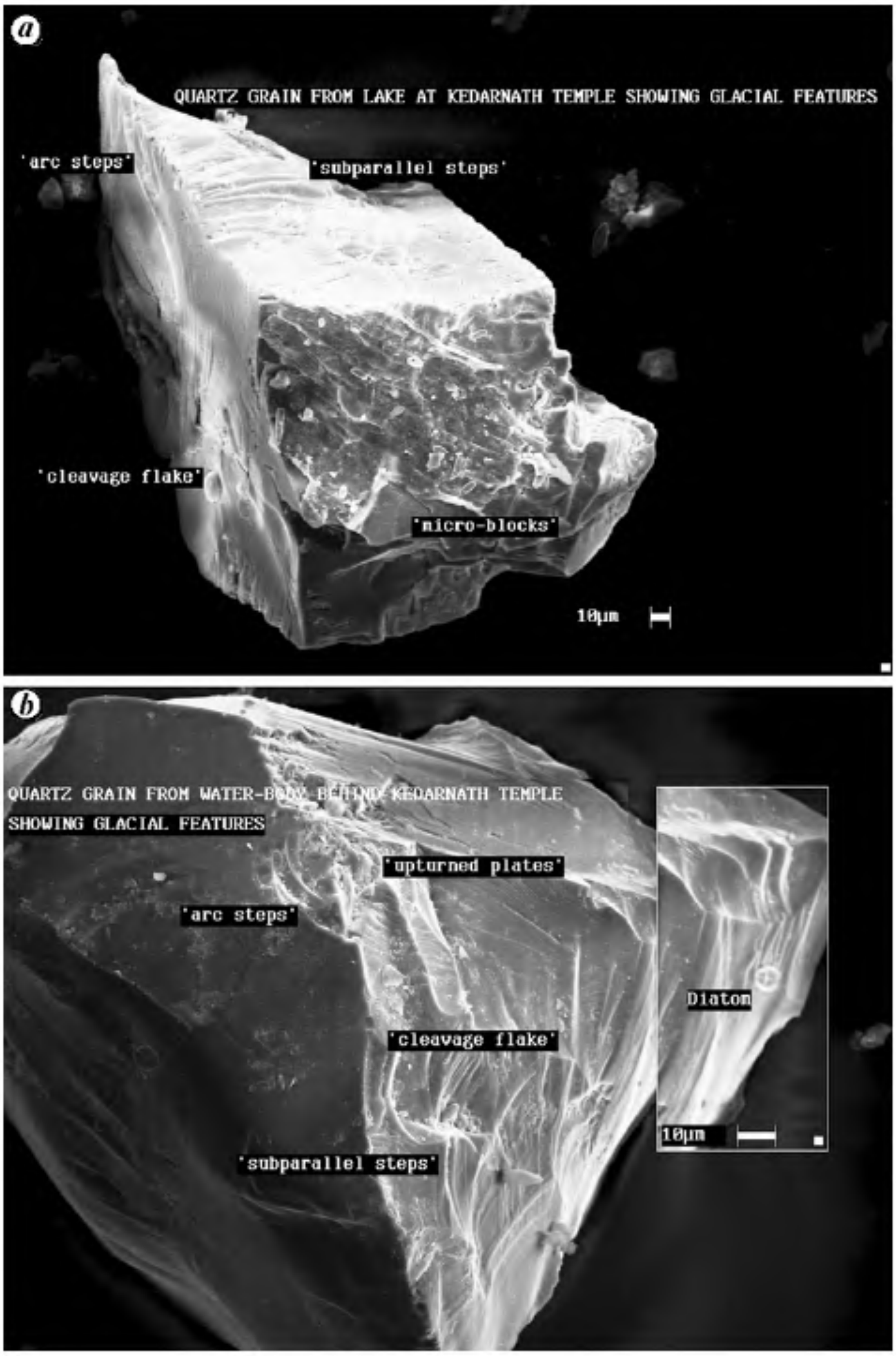

Figure 2. ***a***, ***b***, SEM image of fresh quartz grains from remnant glacial lake behind Kedarnath temple with labelled micromorphological characters.

In order to record the morphological variations and effects of mechanical and chemical weathering on fresh quartz grains released from the source rock, the samples were subjected to treatment with concentrated hydrochloric acid (HCl) to remove any carbonate coating over quartz grains and washed several times to remove excess HCl. No iron coating was observed on the grains and therefore, the samples were not treated with stannous chloride. From an aliquot of 1 g sediment of each sample, 40 to 45 fresh quartz grains were randomly selected and kept on an assemblage slide. These were then examined under light microscope, Leica MZ12, for general morphological characters. Micromorphological characters of these selected fresh quartz grains were studied under SEM Leo 440 following Helland *et al.*[7], who distinguished 26 micromorphological characters to identify the effects of mechanical and chemical weathering on them, in order to interpret the process or mode of deposition.

In order to understand the characters imparted due to the depositional regime to the quartz grains released from the rock, the sediment collected from the debris-blocked lake behind Kedarnath temple was studied. The quartz grains were examined under a scanning electron microscope (SEM) for their micromorphological characters (Figure 2). The three samples studied from the Netal–Shiror area are NE 1, NE 2 and SR 8. A quantitative analysis of the micromorphological characters of quartz grain populations is summarized in Table 1 and their graphic representation is shown in Figure 3.

In sample NE 1, there is a very high frquency of angular quartz grains in the population with high frequency of small conchoidal fractures, arcuate steps and edge abrasion in them. Silica precipitation is also high in some grains (Figure 4 *a* and *b*). This indicates that quartz grains released from the rock in cold weather conditions have stagnated in cold water, where extensive deposition of silica has taken place. This sample could thus represent glacial lake environment.

In sample NE 2, again there is a high frequency of angular quartz grains of medium relief, with high frequency of both large and small conchoidal fractures, straight and arcuate steps, imbricated blocks and upturned plates (Figure 4 *c* and *d*). There is a high frequency of grains with adhering particles and also extensive silica precipitation. These appear to indicate some transportation and stagnation for a long time, which can be due to transportation with the ice flow and deposition in a cold-water lake.

In sample SR 8, the frequency of angular quartz grains is again very high, which have low to medium relief with high frequency of small conchoidal fractures, arcuate steps, fractured plates and upturned plates but low frequency of straight steps, imbricated and large breakage blocks (Figure 4 *e* and *f*). There is a relatively low percentage of adhering particles and silica deposition. This could be attributed to the relatively less time for chemical changes due to stagnation or high rate of deposition.

Van Hoesen and Orndorff[19] have summarized the observations of various workers in the field of quartz grain microtextural studies. According to them subparallel and linear fractures, directional curved troughs in multiple sets, crescentic gouges, crushing features and arc-shaped steps are indicative of glacial environments. Further, deeply entrenched and consistency in preferred orientation of fractures and striations on grains are affected by glacial processes. In the above-described three samples (NE 1,

Table 1. Micromorphological characters present in different sample populations of quartz grains (%)

Character/sample no.	NE 1	NE 2	SR 8
Angular outline	100	100	100
Rounded outline	0	0	0
Low relief	45	58	38
Medium relief	37	41	50
High relief	16	0	11
Small conchoidal fracture	61	94	73
Large conchoidal fracture	50	94	9
Straight steps	43	88	14
Arcuate steps	58	76	47
Imbricated blocks	37	88	28
Large breakage blocks	41	73	28
Fractured plates	50	76	45
Striations	25	14	11
Edge abrasion	43	76	30
Mechanical V-shaped pits	12	0	7
Straight grooves	0	0	14
Curved grooves	0	0	19
Meandering ridges	4	0	14
Irregular depressions	16	0	33
Upturned plates	52	64	52
Solution pits	29	70	35
Chemical V-shaped pits	0	0	2
Adhering particles	81	73	50
Limited silica precipitation	43	32	42
Extensive silica precipitation	56	64	54
Euhedral crystal growth	0	0	0

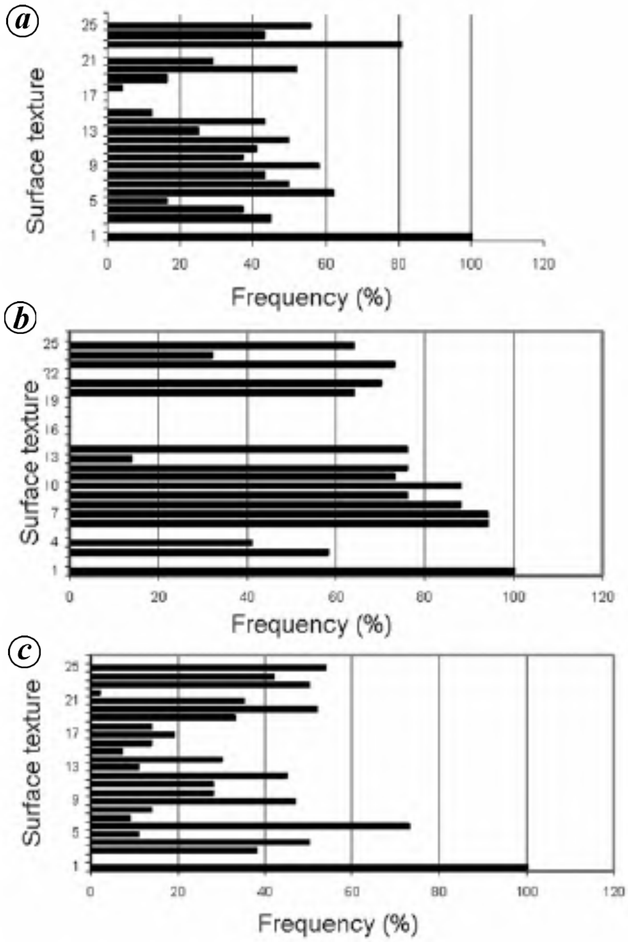

Figure 3. Graphic representation of the micromorphological characters of quartz grain population in samples (***a***) NE 1, (***b***) NE 2 and (***c***) SR 8.

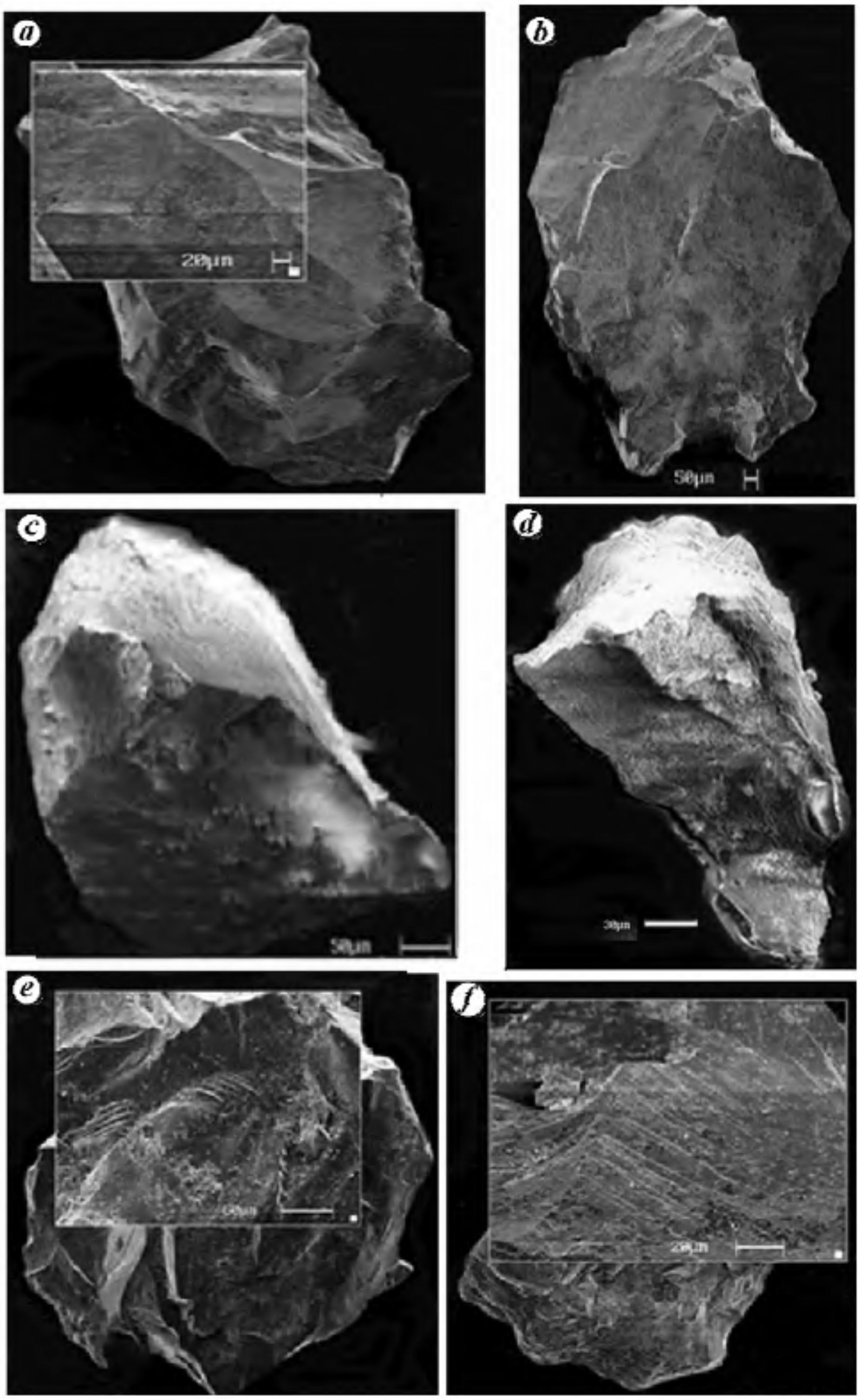

Figure 4. Scanning electron micrographs showing surface texture of quartz grains. ***a***, Quartz grain from sample NE 1 showing angular outline, high relief, large and small arcuate conchoidal fractures with parallel steps and large breakage blocks characterstic of glacial environment. ***b***, Another grain from sample NE 1 showing angular outline, high releif, large conchoidal fractures, small conchoidal fractures with parallel and arcuate steps. Large breakage blocks are also present which indicates glacial environment. ***c***, Quartz grain from sample NE 2 showing angular outline, large conchoidal fractures, breakage blocks, surface showing striations and deposition of silica indicating dragging along bottom and subsequent stagnations in the glacial lake. ***d***, Quartz grain from sample NE 2 showing angular outline, large breakage blocks, conchoidal fractures, small conchoidal fractures with parallel and arcuate steps and deposition of silica on quartz grains indicating long stagnation in glacial lake. ***e***, Quartz grain from sample SR 8 showing angular outline with large conchoidal fractures having dominance of parallel arcuate steps. Large breakage blocks, mild silica precipitation and adhering particles indicate characterizing deposition as glacial till. ***f***, Quartz grain from sample SR 8 showing angular outline, large and small conchoidal fractures, breakage blocks with upturned plates and parallel steps characterizing primary glacial origin with transportation and deposition as glacial till.

NE 2 and SR 8), there is predominance of angular quartz grains of high to medium relief having high frequency of arc-steps and small and large conchoidal fracture faces. These are characteristic primarily of glacial origin grains[19]. These features can be observed on the quartz grains from the remnant glacial lake at Kedarnath Temple (Figure 2). The precipitation of silica on grains is also considered a glacial character. The abrasion of quartz can produce local enrichment of silica[20] and result in its precipitation in suitable environment on grain surfaces. As the particle size decreases, there is an increase in rate of solutioning, which can result in smoothening of the surfaces. The dominanace of grains with extensive silica precipitation in samples NE 1 and NE 2 could be due to their being at the bottom of the glacial lake, where silica taken into solution at higher levels has resulted in the enrichment of silica at the bottom[6]. The grains in sample SR 8 have relatively higher frequncy of upturned plates and large breakage blocks – features which indicate minimal effect of diagenesis and characteristic of grains released from the source rock under glacial environment. The lower precipitation of silica also indicates minimal stagnation. Rai *et al.*[21] have recorded glacial terraces in Sarju valley at low altitudes such as Bilkhet (1180 m) and Semdevta (1060 m).

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A special core liner for sub-sampling of aqueous sediments

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A portable and reusable special core liner (spcl) has been developed to accomplish real-time sub-sampling of aqueous sediments. Besides being revolutionary, inexpensive and user-friendly, the spcl is capable of collecting undisturbed sediment sub-sections. The spcl also facilitates rapid sub-sampling of sediments onboard with remote possibility of core shortening, sample outflow, contamination or mixing. The proposed method of sub-sampling by spcl saves time, money and manpower, without inducing changes in the physical and biogeochemical properties of the sediments.

Keywords: Aqueous sediments, gravity corer, special core liner, sub-sampling.

AQUEOUS sediment samples from the seabed can be obtained by various methods and the choice of a particular

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