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Probable vertical and horizontal ground displacements due to Tehri reservoir load

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The load of the Tehri reservoir may cause maximum ground subsidence of the order of 5 cm and maximum horizontal displacement of about 0.5 cm towards the reservoir. These estimates are on the assumption that the local crustal material has a Young's modulus of 5×10^{10} Pa.

LOADS on the earth's surface range from atmospheric to those of mountain ranges. Each new addition or removal of load on the surface induces its own set of vertical and horizontal displacements of particles at and below the earth's surface because of the deformable nature of earth-forming materials. Ground subsidence due to the load of man-made lake Kariba in Central Africa had been measured geodetically. The observations were explained by Gough and Gough[1] using Boussinesq theory. They assumed that, unlike a mountain, the reservoir load was small enough to require no isostatic response from the earth's mantle. In the process they obtained averaged estimates of the elastic constants of the local crustal materials. Even in India, geodetic observations have been made before and after the impoundment of Sivaji Sagar behind the Koyna dam[2]. However observations after impoundment were subsequent to the Koyna earthquake of 10 December 1967. Thus the effects of the reservoir load and the earthquake were superimposed inextricably. Post-impoundment observations have been made for Gobind Sagar behind the Bhakra dam also[3]. They reveal possible movement of local ground particles in response to the rise and fall of the reservoir level in routine operation. If nothing else, these observations further show the sensitivity of particle positions to changes in nearby surface loads. They also underline the need for systematic geodetic observations around new reservoirs. We present here our simulated estimates of vertical and horizontal displacements of the surface particles due to the proposed Tehri reservoir (Figure 1).

Thick lines in Figures 1, 2 and 3 identify in map view the general location of an array of point loads used to simulate the load of the proposed Tehri reservoir. Details of the load simulation have been given by Chander and Kalpna[4] recently. Since the volume of water to be impounded at Tehri is less than that of Lake Kariba[5] we assume that no isostatic adjustments may occur in the mantle in this case also. Thus Boussinesq's formulae[6] for displacements due to a point load on the surface of an elastic solid half space may be used to superpose the estimated displacements due to individual point loads of the array. We assume values of 0.27 and 5×10^{10} Pa for Poisson's ratio and Young's modulus. The latter value is in the middle of the range of values measured in the laboratory for granite according to Birch[7]. Values of elastic constants measured for some surface rocks around Tehri reservoir site may be available with the project authorities. We have not sought them out for three reasons. Firstly, this is a preliminary stage as far as investigations of particle displacements due to proposed Tehri reservoir are concerned. More exact values may be considered when the reservoir is impounded and observations of actual particle displacements are at hand. Secondly, the movement of ground surface

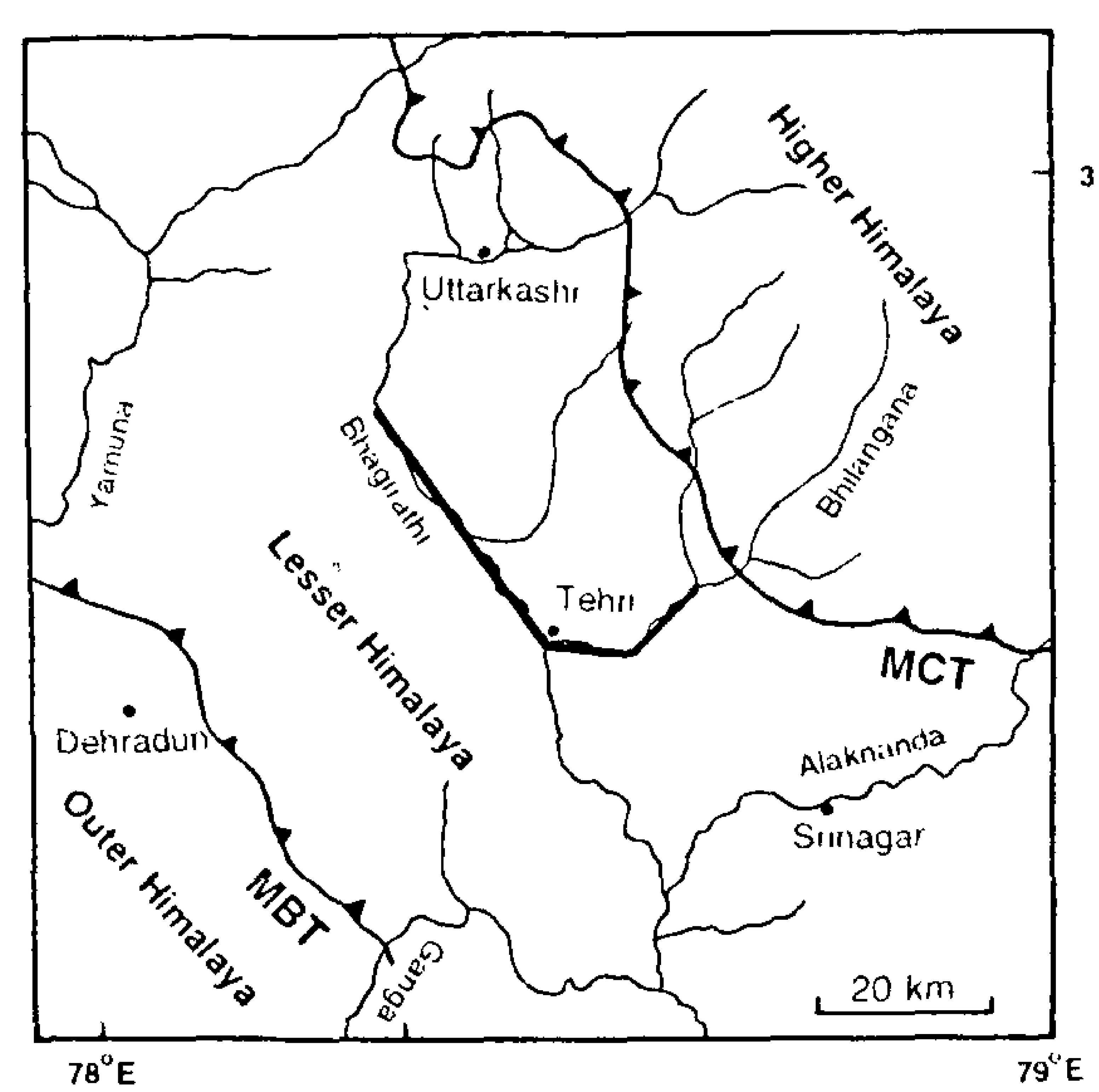

Figure 1. General location map. The thick straight lines represent the simulated axes of the proposed Tehri reservoir in the Bhilangana and Bhagirathi branches. The map and geological information are compiled from Valdiya. MCT and MBT stand for Main Central and Main Boundary Thrusts.

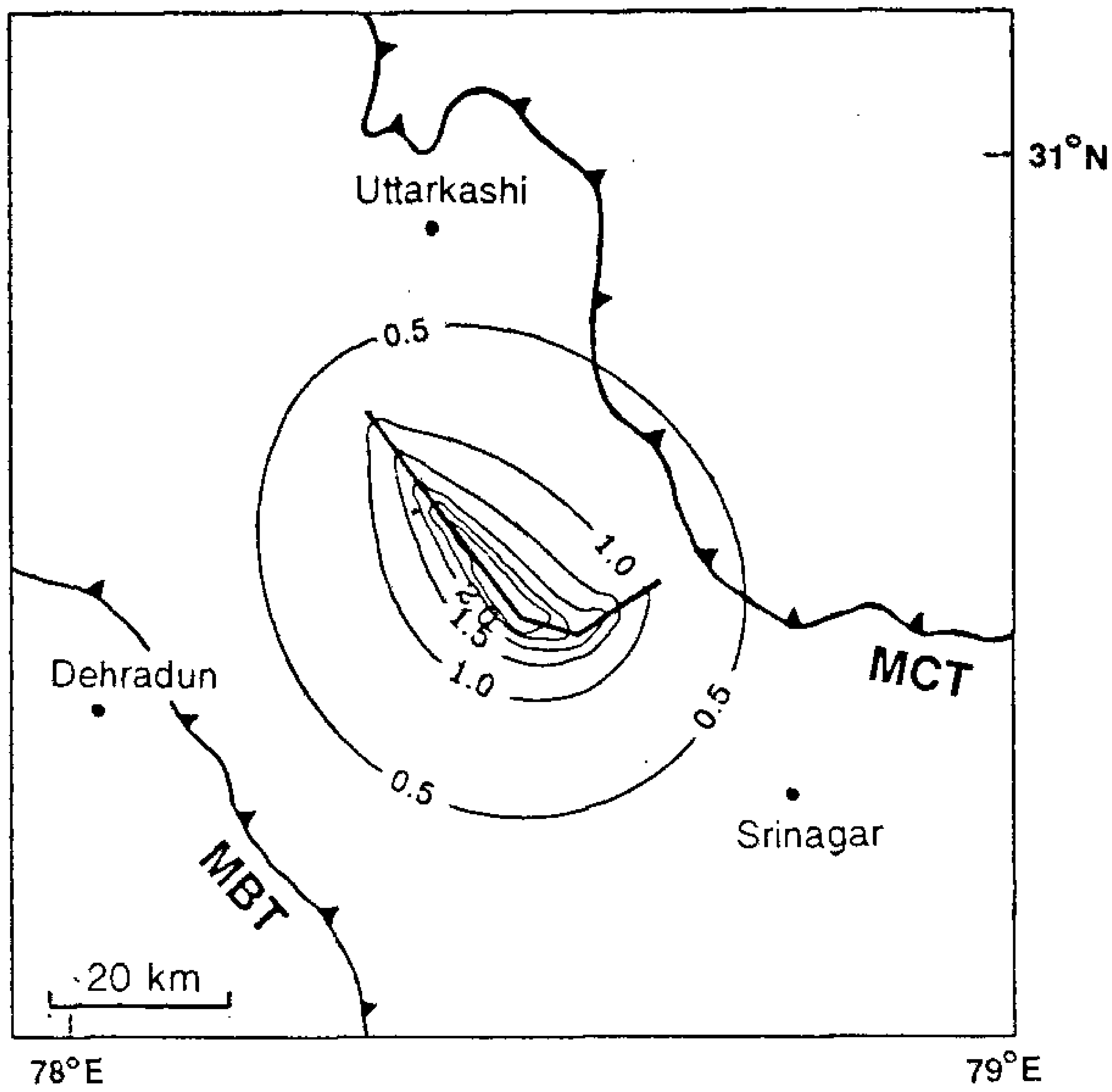

Figure 2. Contours of surface vertical displacements (in cm) due to the proposed Tehri reservoir load.

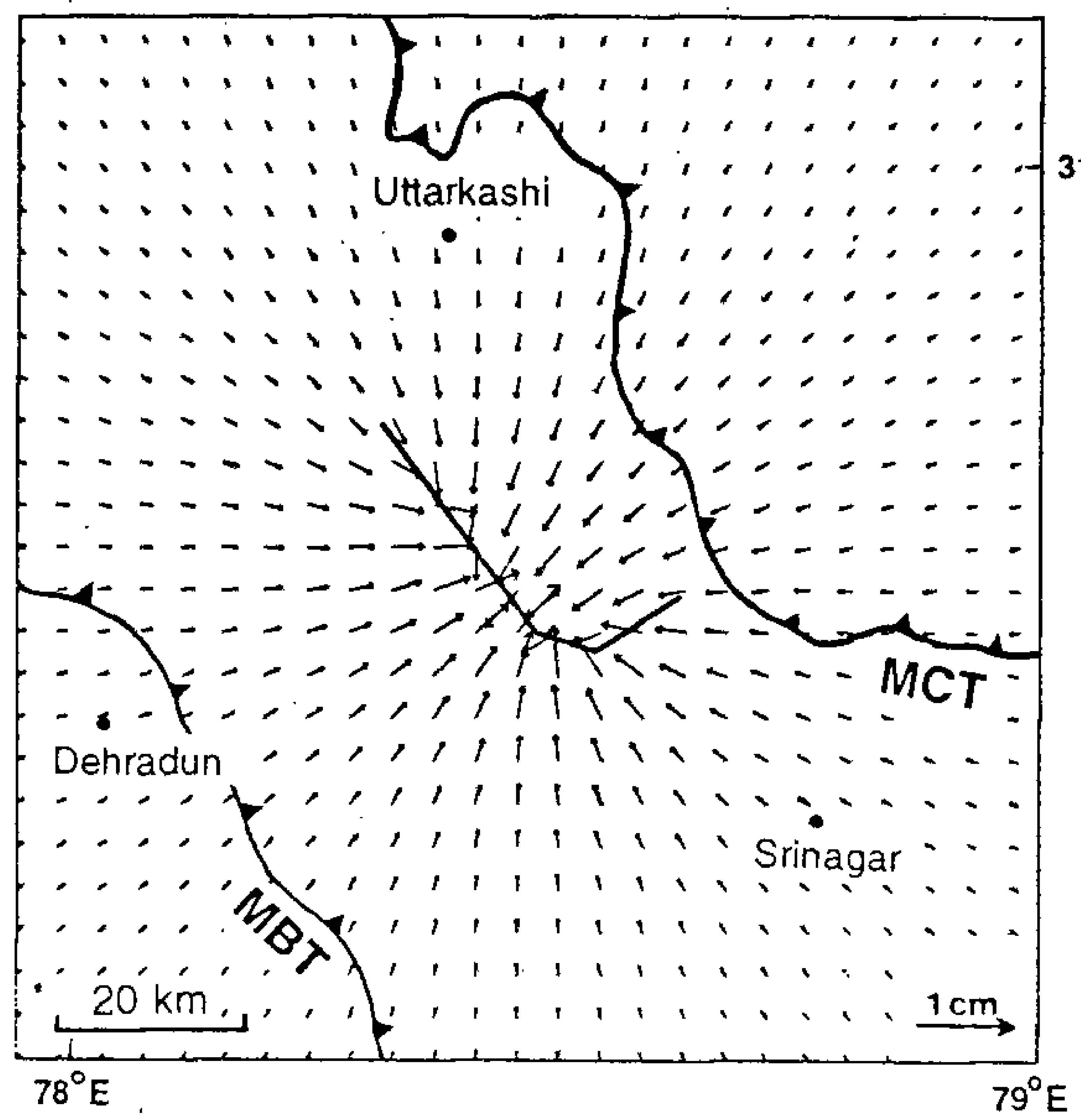

Figure 3. Load-induced horizontal surface displacement due to the proposed Tehri reservoir. The tail of an arrow indicates the point at which the displacement is calculated. Direction of an arrow denotes the movement of the particle at that point. The scale of magnitude of displacement is indicated at the right bottom.

particles under reservoir load should be governed by elastic properties of the local crustal material up to some substantial depth in the crust. It is not obvious at this stage as to how representative are the surface rocks of the materials up to these crustal depths below Tehri. It is customary in geophysical studies of the upper crust to use data for granite when specific information to the contrary is not at hand. Thirdly, the values used should give good first order estimates of the load-induced displacements. Finally, since Young's modulus appears as a linear multiplying factor in Boussinesq's formulae, the estimated displacements may be scaled proportionately for other values of this parameter.

Results of our simulations of vertical and horizontal displacements of particles due to Tehri reservoir are shown in Figures 2 and 3. Displacements are maximum near the deepest part of the reservoir and decrease outward with increasing distance in map view. All estimates of vertical displacements imply load-induced subsidence and horizontal displacements are directed inward toward the reservoir.

Tehri reservoir will be an important national resource whose safety and stability is a matter of concern to many. As in the case of the Bhakra project, pre- and post-impoundment geodetic observations close to Tehri reservoir could serve as checks on the stability of the reservoir and the dam under routine operation. Also, geodetic observations have been recommended to assess seismic hazards in the Tehri region. Additional geodetic observations as suggested here, would ensure that the ongoing geodetic observations in the region are not jeopardized because the reservoir-induced particle displacements are not duly accounted for. The simulations reported here could assist in a proper design and implementation of the scheme for additional geodetic observations around the Tehri reservoir site.

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