Elastic properties of the elongated and normal pillows under uniaxial stress of 1.5 kb have been studied to understand the mechanical behaviour of lateral strain to axial strain (Figure 4). In undeformed pillows, the slope between lateral and axial strain remained nearly uniform, while in the elongated pillows the slope is distinctly different. The strain measurements indicate that the elongated pillows are brittle in their behaviour and the strain ratio is approximately 1:24, otherwise this ratio in case of undeformed pillows is 1:10 or 1:14. This change in the strain ratio appears to have been caused by the post-consolidation deformation during shearing and thrusting (Figure 4). Brittle deformation and development of fracture system almost at 90° to the schistosity is observed in most of the pillows.

Pillows are exposed in almost all late Archaean greenstone belts of Karnataka and other parts of the world[12] and the length/width measurements at other places such as Gadag and Ingaldhal in Chitradurga schist belt have confirmed that the length/width ratio of the normal undeformed pillows generally remains between 1 and 2. This increase in the length/width ratio along with change in the dip of the flows from 0 to 90°, almost vertical F_1 fold axis and the 20°–80° NE dip of the first generation axial plane schistosity are unequivocal evidence of horizontal compression and large-scale movement of the rock mass. Recently the 35 km thickness of the Sandur belt has been attributed to the thrust thickening[10].

Under the P–T conditions of regional metamorphism (confining pressure), elongation of pillows would not have taken place, as in the case of other parts of the belt (Spot B to E, Figure 1). This suggests that in addition to confining pressure the lavas of the western margin were subjected to a directional stress, which continued to produce post-consolidation brittle deformation. This may mean that the lavas of western margin were part of a subducting slab and compression continued till the closing of the proto-ocean. Therefore, it is argued that the western margin of the Sandur belt has been overridden by its eastern part. Furthermore, geometry and the wavelength (2–10 m) of the D_1 fold closures at the northern and southern termination of the belt[13] substantiate the inference that horizontal compression and crustal shortening have been a very significant and frequent aspect of tectonic evolution of this greenstone belt.

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Palaeotectonic implication of Lamayuru lake (Ladakh)

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The age of ancient Lamayuru lake in Ladakh, Trans-Himalaya, has been speculative due to non-availability of proper date at the base of its sediment profile. A date of 35,000 ± 600 yr B. P. was reported by earlier workers in the upper part of lower sedimentary profile but precise timing of the development of lacustrine conditions is all important to know the origin of the lake and the question whether it was formed by normal geomorphic processes of slope derived debris damming or tectonically induced slope instability leading to river impoundment. The present study shows that the lake developed around 45,000 years ago, which coincides with a regional tectonic event in the Trans-Himalaya. The geomorphic processes were but adjunct to the intrinsic process of earth shaking during this episode of tectonic activity in the region. Timing of initiation and closure of lacustrine sedimentation in the Himalayan river valleys could offer an important clue for determining the recurrence interval of major earthquakes in the Himalaya. This calls for extensive work both in space and time.

THE late Quaternary remnant lacustrine deposits lying at an altitude of 3600 m in Lamayuru, Ladakh (Figure 1), comprise mudstone, siltstone and sandy shale facies

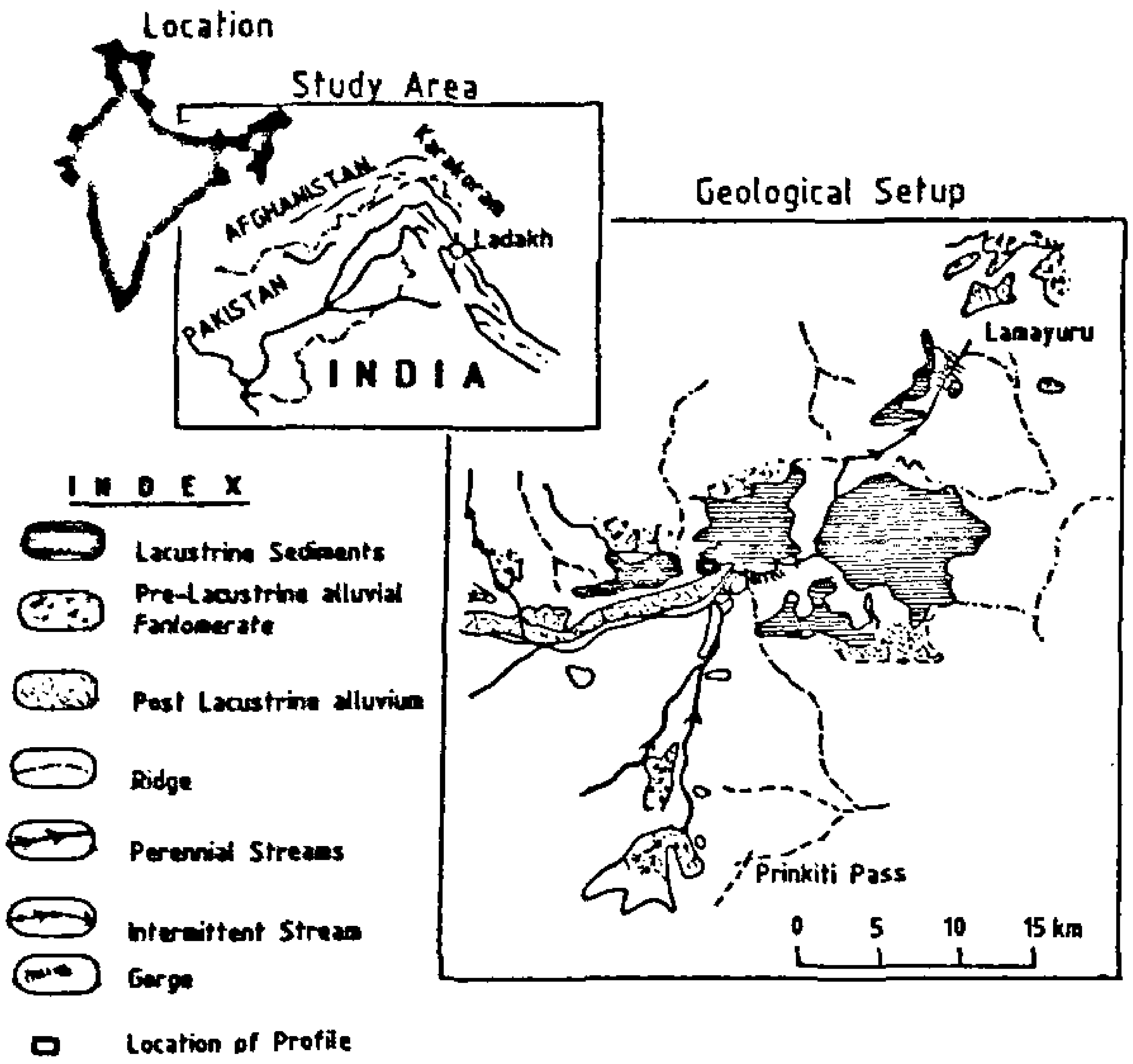

Figure 1. Geological map of the Lamayuru lacustrine sediments (Modified after Fort *et al.*[3]). The inset map shows location and the study area.

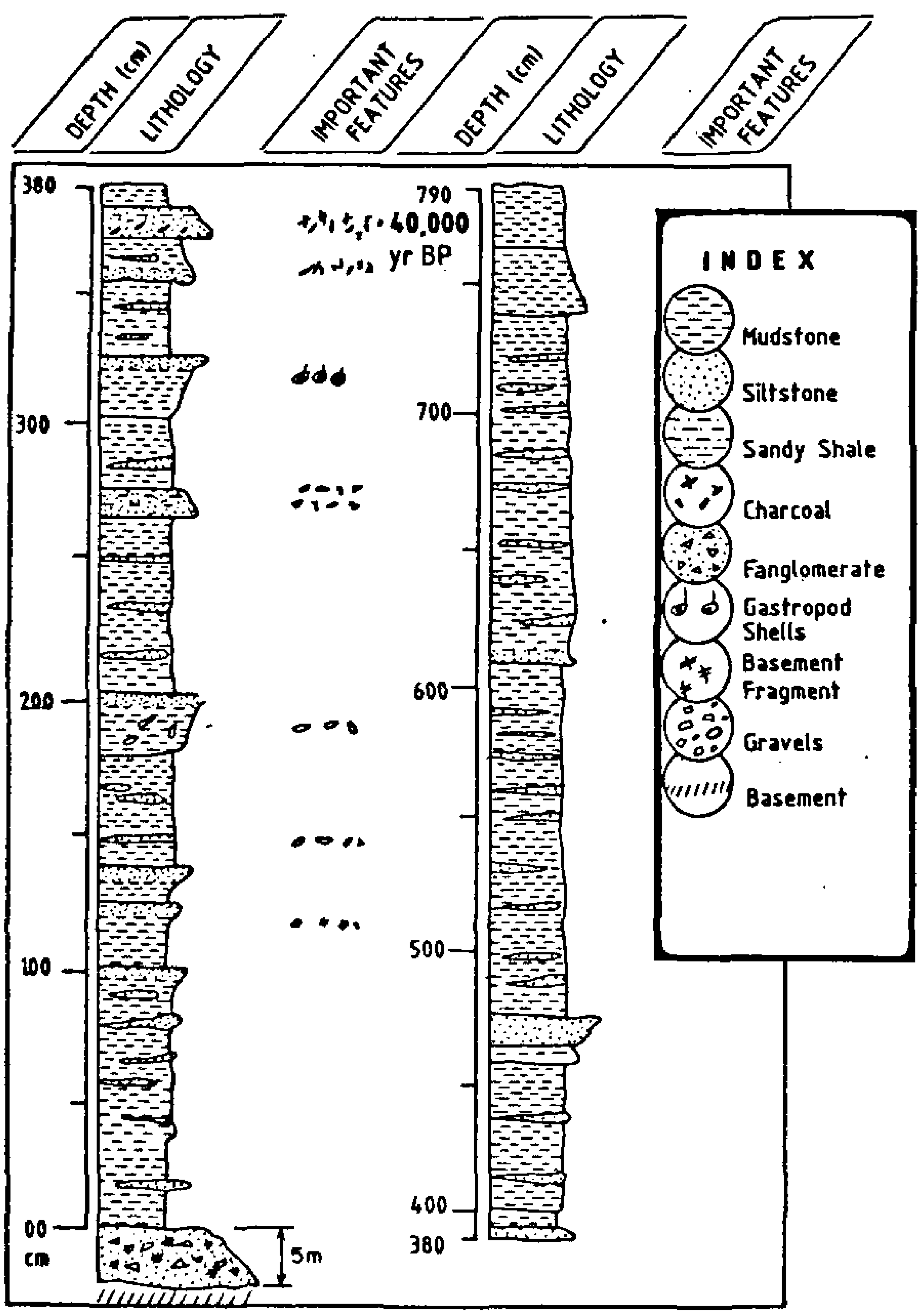

Figure 2. Lithosequence of Lamayuru lacustrine sediments at Rong-Gongkha.

resting over the prelacustrine fanglomerate. The sediments in the central part are rarely preserved due to extensive erosion and slumped blocks. The basement rocks are composed of argillaceous and calcareous Lamayuru flysch in the north, east and west of the basin, while the Tethyan carbonates are exposed in the south of the basin. The clay and silt contents of flysch have favoured post-lacustrine mass wasting processes including debris and rock slides in the proximal part of this ancient lake body. At present the climate of Lamayuru area is cold and dry and devoid of any vegetation except some scrubs.

In the present study, a 7.9 m profile of lacustrine sediments in the central part of the basin at Rong Gongkha has been investigated in detail (Figure 2). The base of the lacustrine fill lies on top of about 5 m thick fanglomerate which rests on the flyschoid basement rocks. The same profile was worked in detail by Sangode and Bagati[1] for palaeoclimatic studies using magnetic susceptibility and sedimentological parameters. The profile under investigation consists of five facies. These are: i) mudstone–siltstone, ii) mudstone–siltstone with charcoal, iii) mudstone–siltstone with small clasts, iv) sandy shale, and v) mudstone.

The mudstone–siltstone is the dominant facies occurring at various stratigraphic levels. In this facies mudstone is grey and shows parallel laminations. The thickness of laminae varies from 0.5 to 1 cm but increases in up section. The mudstone–siltstone with charcoal facies occurs at four stratigraphic levels. At places the charcoal is associated with mud pellets and is aligned parallel to the bedding. The mudstone is yellowish grey to ash-coloured and is generally laminated. The charcoal is generally associated with thick siltstone layers and shows grading. Some plant impressions were also observed in this facies. The charcoal fragments lying at 350–370 cm level were radiocarbon dated. The mudstone–siltstone with small clasts facies is present at two levels and shows grading. The clasts are generally associated with mudstone and oriented parallel to the bedding. Both intraclasts and extraclasts are present in this facies and represent turbidity deposits. The sandy shale facies is present at one level only in the upper part of the sediment profile. The laminae in this facies are 3–5 cm thick. It is yellowish grey and fine grained. The mudstone facies occupies the topmost part of the profile and shows parallel lamination.

In the central part of the basin the facies assemblage with charcoal and sedimentary structures indicate that density flows were responsible for deposition of silty turbidites. They are associated with sediments deposited under calm conditions and the deposition took place in a progressively deeper water body. The source for silty turbidites and sandy shale mudflows was probably from the Fotu La as indicated by the presence of large charcoal fragments within the lacustrine sediments exposed

Figure 3. Siltstone–mudstone containing charcoal fragments (dark patches).

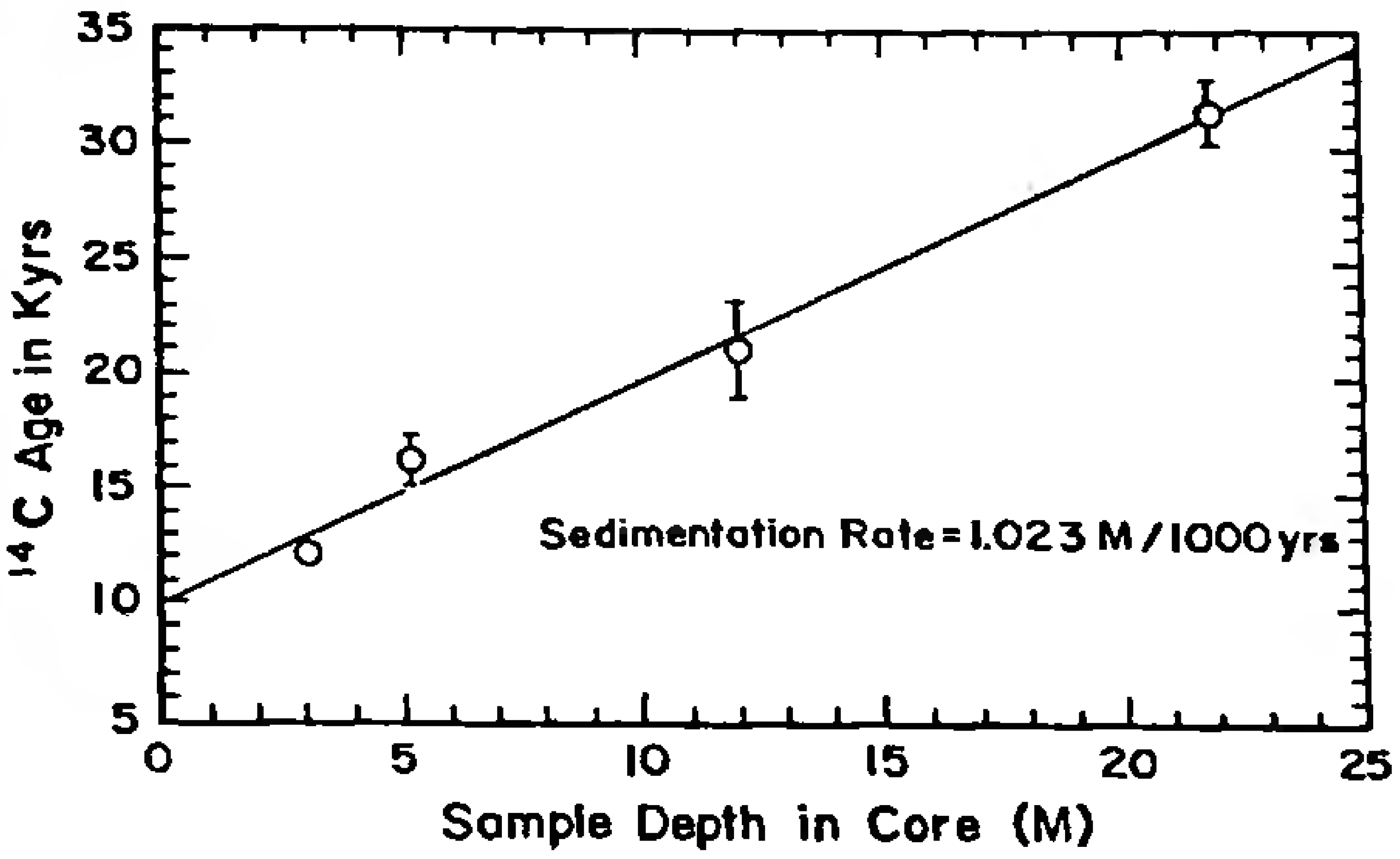

Figure 4. ^{14}C age vs depth of the sediment profile TP-6 from Tsokar lake. The rate of sedimentation, 1 m/1000 yr, is based on the linear regression line drawn through the data points (after Rajagopalan *et al.*[4]).

in upper reaches of the main Lamayuru channel. The presence of charcoal with plant impressions (Figure 3) indicates that the source was very close to the site of deposition. Bagati and Thakur[2] are of the opinion that during this period the climate was warm and forests grew luxuriously. Hence forest fires were common in the catchment. The warm phase is further supported by magnetic susceptibility study of the sediments[1].

The charcoal fragments recovered from siltstone–mudstone facies at 350–370 cm level were dated by the ^{14}C method (BS-879). The sample has yielded a date of 40,000 yr B. P., the maximum range provided by ^{14}C method. In essence, the sample could be much older. There is no other date available in the profile, hence the timing of lacustrine sedimentation could not be worked out directly. A date of 35,000 ± 600 yr B. P. given by Fort *et al.*[3] does not correspond with the present profile at its equivalent height and level since their profile lies far away from our site of investigation. Thus, the only method that could be applied for determining the commencement of lacustrine condition is the rate of sedimentation, but again there are limitations posed by non-availability of another radiometric date in the profile. Since this is significant for many reasons, we have used average rate of sedimentation calculated for the Tsokar lacustrine sediments on the basis of radiocarbon dates for core TP-6 (Figure 4) (ref. 4). The basis being that Tsokar and Lamayuru fall in the same geographical entity or geomorphological domain, which permits logical application of known sedimentation rate of the former to the latter where such data do not exist. Such an approach is based on a work where empirical equation of sediment yield in relation to catchment characteristics has been used to estimate the distribution of sediment yield in adjoining catchments of similar morphology[5]. Thus by applying the sedimentation rate of Tsokar lake (approx. 1 m/1000 yr) to our profile from average point of 360 cm level where charcoal sample was recovered, we get a time frame of 3600 years to the base of the lacustrine sedimentation. Adding this figure to 40,000 yr B. P., we get a date of 43,600 yr B. P. for the commencement of the lacustrine phase. As Fort *et al.*[3] postulate that the filling of the Lamayuru basin may have taken anywhere between 1000 and 10,000 years, we believe that attaining of full lacustrine conditions may have taken anywhere up to 2000 years or so. From this work we estimate that the initial damming of the erstwhile Lamayuru river took place probably somewhat prior to or near about 45,000 yr B. P. Due to the obliterated top sequence there is difficulty in calculating the closure of the lacustrine condition based on the rate of sedimentation. Hence more detailed work is required to answer this question. Assumptions based on discrete evidences, at this stage, have the risk of committing gross error.

The origin of the lake is attributed to tectonically induced slope instability in the basin, a sudden pulse of which mobilized large quantities of slope debris to dam the Lamayuru river. The episodic active nature of the lineament running parallel to the Lamayuru river is amply revealed in the narrow and deep cross profile developed after the depletion of the lake. The principal cause of blockade by periglacially derived debris as held by Fort *et al.*[3] in this light appears substantially unconvincing. There are evidences where lake basins like Sumdo in lower Spiti valley were developed by high seismic activity in the region resulting in blocking of the river around 45,000 yr B. P. (ref. 6). Reactivation of the Nainital Fault around the same time[7], though in a different tectonic domain, could be taken as an indirect clue for a major tectonic episode in the Himalaya. By analogy of timing it is possible that the same event was responsible for the development of discrete lake basins in the Spiti valley[8].

In conclusion it may be said that the Himalaya which registered its maximum uplift during Pleistocene experienced periodic regional tectonic impulses to account for impoundment of rivers, thereby leaving imprint of such evidences for posterity. The depletion of such lake basins could be either due to normal processes of erosion or triggering of post-blockade major tectonic impulses. Given this thesis, the timing of the depletion of lake basins on a larger regional scale assumes importance in determining the recurrence interval of catastrophic earthquakes in the Himalaya. Such an objective calls for extensive field work and dating of river valley lacustrine deposits along the length and breadth of the Himalaya.

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Chemical age of detrital zircons from the basal quartz–pebble conglomerate of Dhanjori Group, Singhbhum craton, Eastern India

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Chemical ages of detrital zircon concentrates from the uranium-bearing basal quartz–pebble conglomerate of Dhanjori Group from six localities have been determined based on high precision analysis of U, Th and Pb. Three of the zircons gave concordant ages of 3044–3090 Ma, which represent the minimum age of the provenance rock and older age limit of Dhanjori sedimentation. The Singhbhum Granite Complex dating between 3.3 Ga (Phases I & II) and 3.12 Ga (Phase III) are the likely provenance rocks. Chemical ages, coupled with evidences from field relations and temporal nature of uranium-bearing QPCs suggest that the sedimentary members of Dhanjori Group are likely to be older than the presently assigned age of 2300 Ma.

THE Singhbhum–Orissa craton, eastern India, comprises of a complex geological assemblage of Archaean and Proterozoic age. Chronostratigraphic status of many of the lithogroups in this craton, especially the Dhanjori Group and Iron Ore Group (IOG) are still debatable[1,2], mainly because of inadequate radiogenic ages. The occurrences of uranium-bearing basal quartz–pebble conglomerates (QPC) in both Dhanjori Group[3] and IOG[4] are important in this context. Detrital U-bearing QPCs the world over have distinct temporal and stratigraphic positions[5,6] and are generally confined to Archaean–Proterozoic transition period. Among the detrital heavy minerals in such conglomerates, zircons, because of their highly refractory nature, are considered provenance diagnostic. The ages of detrital zircon in QPCs correspond to the age of the parent rock and thereby aid in establishing provenance and stratigraphic position of the QPCs. In this communication, we report U, Th and Pb contents of detrital zircons from some QPC horizons at the base of Dhanjori Group and their chemical ages.

The volcano-sedimentary sequence of Dhanjori Group began with a basal quartz-pebble conglomerate, followed by a thick sequence of fuchsite-quartzite and an occasional phyllite. Upper part of the sequence is an extensive basic volcanic sequence. Basal QPC is exposed intermittently along the south, east and western margins of the Dhanjori basin. Conglomerate samples for the present study have been collected from six localities; Butgora in the western margin; Phuljari, Jawardih and Asthakaoli in the southern margin; and Tirioburu and Chakri in the eastern margin of the basin (Figure 1).

Zircon, chromite, rutile, monazite, pyrite, etc. are the prominent detrital heavy minerals found in all the QPC samples. Zircons recovered from these samples are characterized by their coarse (mostly 200–250 μm), stubby, unzoned nature and pink colour (Figure 2). Systematic morphometric analyses of zircon grains