trees taken from higher latitudes, e.g. Wisconsin (lat. ~45° N) trees have average $\delta^{18}O$ value of about 26‰ and British Columbia (lat. ~ 55° N) trees have average value of about 23‰ (ref. 13). Therefore the enriched value of $^{18}O/^{16}O$ ratio in air CO_2 from Ahmedabad can probably be ascribed to equilibration of CO_2 with enriched leaf water expected in the tropical part of India. The enrichment in CO_2 is less than that of the leaf water due to the rapid mixing of air on a global scale.

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Precambrian–Cambrian boundary in the Tal Formation of Garhwal Lesser Himalaya: Rb–Sr age evidence from black shales underlying phosphorites

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The recently reported faunal evidence for placing the Precambrian–Cambrian boundary within the main phosphorite unit of the Chert–Phosphorite Member of the Tal Formation, Garhwal Lesser Himalaya, is supported by the present report of 626 ± 13 myr for the whole-rock Rb–Sr isochron age of the black shales directly underlying the phosphorite band.

THERE is considerable international effort to recognize the Precambrian–Cambrian boundary in sedimentary records worldwide. The Working Group on Precambrian–Cambrian boundary of the International Commission on Stratigraphy has recommended that this boundary be placed in stratigraphic units showing the earliest appearance of diverse small shelly fossils[1] and selected three stratotype candidates for this boundary in present-day eastern Siberia (Aldan River), southern China (Meishucun) and eastern Newfoundland (Burin Peninsula). In this connection, the recent discovery of small shelly faunas close to the base of the Tal Formation in Garhwal Lesser Himalaya[2–6] has great significance for Lesser Himalayan stratigraphy and Precambrian–Cambrian boundary research. The candidate for the boundary stratotype in the Garhwal section is a 3-m-thick phosphorite band (Figure 1) from the Surkhet Block of the Maldeota phosphorite quarry, 14 km from Dehra Dun. The shelly faunas in this band include *Anabarites trisulcatus, Protohertzina anabarica, P. robusta, P. unguliformis, Fomitchella infundibuliformis, Mongolodus platybasalus, Hyolithellus* spp., *Spirellus columnaris*, etc. and are highly correlatable with those of zone I of Meishucunian stage in southern China, Pre-Tommotian Manykaian stage from the Siberian Platform and Yukon Territory of Canada[2,4]. According to the presently available palaeomagnetic reconstruction of the geography of the early Cambrian[7], faunal similarities between India and China are expected to be very strong.

The age of the Precambrian–Cambrian boundary has been inferred from isotopic dating of suitable sedimentary or igneous rocks temporally close to the boundary[8]. The

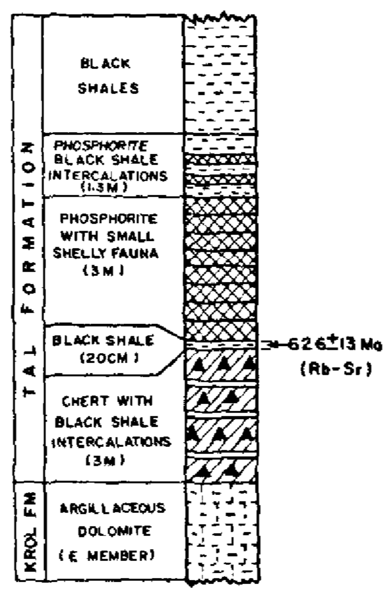

Figure 1. Vertical section across the Precambrian–Cambrian boundary at Surkhet Block, Maldeota Phosphorite Mine, Garhwal Lesser Himalaya.

available data show a large spread from 530 to 620 myr (million year) depending on geographical location, material dated and geochronological techniques used. Consistent ages for the Meishucunian boundary have been inferred from the whole-rock Rb–Sr dating of black shales deposited shortly after the boundary units[9]. We have therefore dated the black shales immediately underlying the phosphorite band of the lower Tal Formation to infer the age of this proposed boundary unit.

The basis for Rb–Sr dating fine-grained sedimentary rocks like black shales is that they were isotopically equilibrated with sea water during their sedimentation or early diagenesis and remained closed to Rb and Sr exchange since then[10,11]. The black shales in the present study consist primarily of illite, organic carbon, carbonates and some detrital quartz. A closer examination of the X-ray diffractogram of the separated fine fraction ~ 2 μm shows the illite to be sedimentary, 1 M polytype with sharpness ratio (SR) or Weaver index (WI) around 2 (refs. 12, 13). The presence of fresh pyrite in these shales argues against any secondary alteration due to permeating water, and thus provided a close system.

The whole-rock samples were collected within a few metres along the strike of a 15–25-cm-thick black carbonaceous shale band. About 100 mg each of the powdered samples was dissolved in $HF+HNO_3$ and spiked with ^{84}Sr and ^{87}Rb tracers. The undissolved carbon was centrifuged to get a clear solution for ion-exchange separation of Rb and Sr. Rb and Sr isotopic compositions and abundances were measured on an automatic VG 354 thermal ionization mass spectrometer with the SRM 987 Sr standard giving a mean of 0.71025 ± 5. Processing contamination was negligible relative to the amount of Rb and Sr actually handled.

Rb–Sr analytical data for nine shale samples (Table 1) plotted on a Sr-evolution diagram (Figure 2) form a linear array with good mutual spread. The best-fit straight line (MSWD = 7) to the data has a slope corresponding to an age of 626 ± 13 myr and intercept on the ordinate corresponding to an initial Sr ratio of 0.7093 ± 1, the error in the age having been increased to allow for the MSWD being greater than unity. If the line is interpreted as an isochron, these results will imply that the samples have evolved from 626 myr as individually closed systems from a common initial Sr ratio of 0.7093 ± 1. This age most probably relates to the time of deposition or early diagenetic equilibration of Sr isotopes among the fine-grained silicate and carbonate components of the shale. The initial Sr ratio is quite close to that of sea water about 600 myr[10].

Since the proposed phosphorite boundary unit is immediately overlying the black shale, we believe that its time of deposition must be quite close to 626 myr. This agrees within error limits with the age of 610 ± 10 myr inferred for the Sinian (Precambrian)–Cambrian boundary in China[9,14,15]. Since the latter is a mean of several measurements on shales from different sections in the Yangtze platform, but not directly in contact with the boundary unit, its agreement with our result can be considered as only general. Further analysis of shale samples, preferably separated into various fractions, will be required to reach a firmer conclusion on the age of phosphorite band. But the present result does support the faunal evidence that the basal units of the Tal Formation in Garhwal Lesser Himalaya were deposited just prior to

Table 1. Rb/Sr data of black shales from the Chert–Phosphorite Member of Tal Formation, Surkhet Block, Maldeota Phosphorite Mine, Garhwal Lesser Himalaya

Sample No.	Rb (ppm)	Sr (ppm)	^{87}Rb/^{86}Sr*	^{87}Sr/^{86}Sr**
S-9/2	21.1	101.0	0.603	0.71398 ± 4
S-9/4	19.6	638.8	0.089	0.71016 ± 4
S-9/7	89.7	59.6	4.374	0.74837 ± 8
S-9/8	105.6	81.9	3.732	0.74337 ± 6
S-9/9	86.3	114.6	2.184	0.72937 ± 4
S-9/10	84.4	124.5	1.965	0.72700 ± 4
S-9/11	86.6	173.1	1.450	0.72279 ± 2
S-9/12	91.5	137.3	1.930	0.72653 ± 6
S-9/13	101.1	84.5	3.470	0.73962 ± 4

* Analytical error in ^{87}Rb/^{86}Sr is ± 2%.
** Errors are 2 standard deviations of the mean.

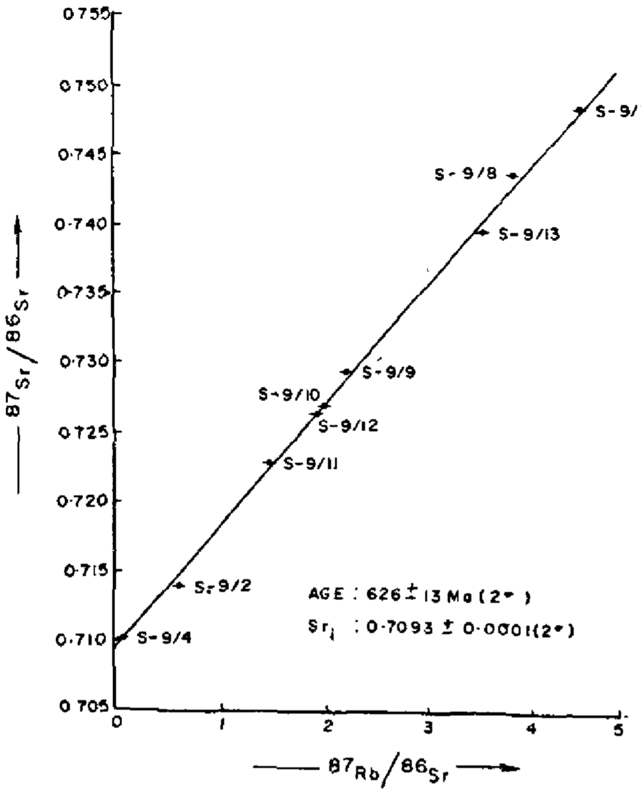

Figure 2. Rb/Sr isochron for black shales from the Chert Phosphorite Member, Tal Formation, Garhwal Lesser Himalaya.

and during the dramatic transition from the Precambrian to the Cambrain and hence can be used to reconstruct the events during this important phase in earth history.

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Geodynamic significance of Algal-oncolites reported from Dras and Lamayuru area of the Indus–Tsangpo collision zone of Ladakh Himalaya, India

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Olistoliths, the enigmatic blocks of limestone, which for long have puzzled geoscientists, occupy the northern margin of Zanskar shelf sediments. They are observed within different tectonic zones of western Ladakh Himalaya, constituting a major part of Indus–Tsangpo Suture Zone. These olistoliths, which are often associated with fossiliferous and organosedimentary structures, i.e. spherical to elliptical oncolites, provide important clues for deciphering both the pre-collision sedimentation history of the Zanskar shelf and the collision-related tectonics of the Indus–Tsangpo Suture Zone.

THE Indus–Tsangpo Suture Zone in the NW sector of the Ladakh Himalaya decipher a complete N–S cross-section of the suture zone-related rocks and their tectonic set up. Studies[1] have demonstrated that the NW sector of the Ladakh Himalaya is sandwiched between the backthrusted Tethys Himalaya zone of the Spiti and Zanskar (Zanskar Supergroup) to the south and the Karakoram zone (Karakoram Thrust) to the north. We report here the presence of oncolite-bearing limestone olistoliths ('exotic blocks' of limestone) around Lamochun peak, south of Dras village. The limestone olistoliths are tectonically incorporated in the Dras Volcanic Formation of Cretaceous age[2–5], which is underlain by Zanskar Thrust to the south (Figure 1). These limestones, occurring as tooth-like projections, are 50–100 m thick, associated with oncolites along with fragmentary molluscan remains with it.

The limestone olistolith within the Lamayuru Formation of Triassic–Palaeogene age[6–9] also exhibits oncolite association near the village Saraks, north of Namikla pass. The limestone olistoliths are tectonically juxtaposed with the Lamayuru Formation of distal turbidites of the basin plain setting[5,6]. Macroscopic study reveals flattened spherical to ellipsoidal geometry of oncolite. They are often fragmented. Sometimes they show a mosaic-like pattern and often reflect the shape of the intraclastic nuclei (Figures 2,3). Their size ranges from 0.2 cm to 4 cm (Figures 4,5). Microscopic studies reveal that the grain supported fabric and the dolomitized sparry calcite cement occupy the inter-particle pore spaces. Some of the sections, however, show that the grains are supported by algal encrustations. Algal intraclast form the oncolitic nuclei, molluscan fragments and other skeletal particles are

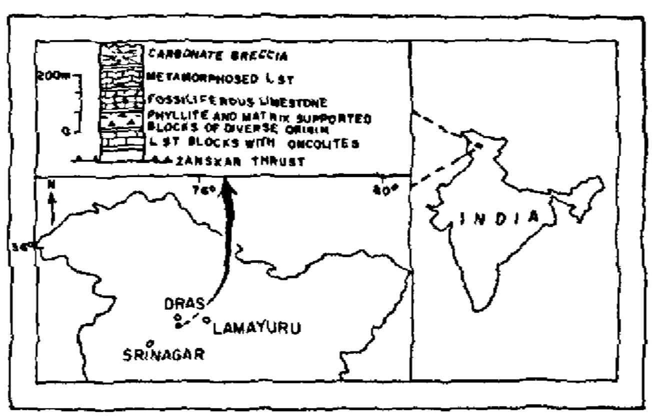

Figure 1. Location and index map with lithocolumn and oncolite locality.