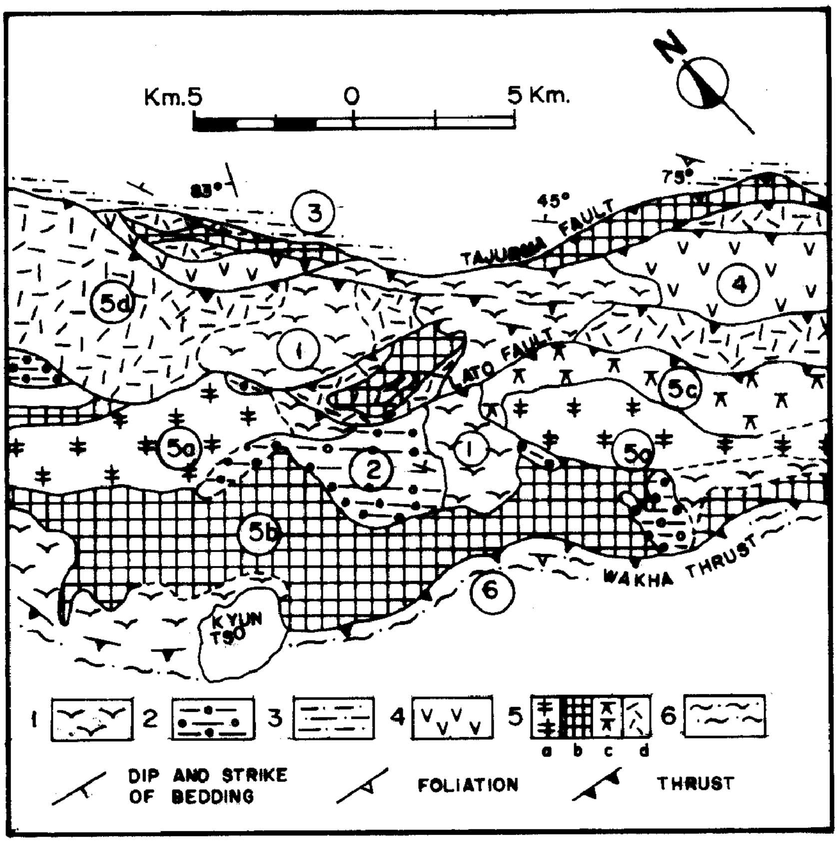

Figure 1. Geological map of Kyun Tso–Nidar–Shrok Sumdo area. 1, Quaternary; 2, Liyan Fm; 3, Nindam Fm; 4, Volcanics; 5, (a-Dunite, b-Peridotite, c-Pyroxinite, d-Diorite-gabbro); 6, Permo-Trias rocks; 7, 8, Dip and strike of bedding/foliation; 9, Thrust/fault (after Wangdus and Tikku[2]).

rocks from the area under reference. The published geological map[2] covering major parts of the selected area clearly brings out complex dismembered nature of several litho-units and a number of tectonic discontinuities (Figure 1), many of which have not been picked up in the lithological outcrop map (figure 5 in the ref. 1) prepared from IRC-1C-LISS III and PAN data[1]. The Lian unit has been mapped[2] contrary to claims otherwise[1] and the main outcrop mapped matches well in shape with the digital image (figure 6 *b* in ref. 1). But there are several examples of lithological mismatches. The location of image figure 6 *a* (ref. 1) is not shown in figure 5 (ref. 1), however, it possibly corresponds to central part of figure 5 flanking the Indus river. It is not clear which feature of figure 6 *a* (ref. 1) depicts the 'depositional contact of chert, jaspar of (and) clastics with Indus Formation (IF)'. The contact appears to be tectonic and not depositional. The strikes of beds within the 'Indus Formation' (≡ Nindam Fm[2]) clearly continue uninterrupted from the green-toned area to the brown-toned area of figure 6 *a* (ref. 1). Both of these tones represent the same unit. If this is the Indus *Fm*, then what happens to a small isolated outcrop of so-called 'chert, jasper' unit shown on the left bank of the Indus in figure 5 (ref. 1)? Further, the main outcrop of so-called 'chert, jasper and clastics' unit in the left bottom part of figure 6 *a* (ref. 1) lacks litho contact clarity or structural details. There is mismatch between inferred lithology and that depicted in the published map[2].

The 'chert, jaspar and clastics' assemblage has been grouped into a single package in the digitally enhanced images of figures 5 and 6 *a* (ref. 1). In the Nidar nala section, however, the chert, jasper and cherty argillite sequence representing the oceanic pelagic sediments overlies the top section of the volcanics. Conglomerate beds, containing pebbles of chert, volcanic and ultramafic rocks, and representing the base of the overlying shallow marine clastic sediment, unconformably overlie the chert-bearing sequence. The oceanic pelagic sequence is often structurally imbricated with the clastic sequence. These litho-units are very well exposed in and around Nidar village. But all these remain unresolved and have been included within the 'volcanics' in figure 5 (ref. 1), whereas peridotites and diorite-gabbros mapped[2] to the east of Nidar and abutting against the Nindam Fm (≡Indus Fm[1]) have been shown as chert, jasper in figure 5 (ref. 1). Thus in actual situation even enhanced digital images from the study area have provided far less lithological details than the published geological map[2] – a reverse of what has been claimed and emphasized.

From the foregoing analysis it may be reemphasized that satellite imageries with or without digital enhancing are very important *modern aids* in mapping of geological units, particularly the coloured ophiolite melange and associated rocks from the cold-arid, unvegitated Ladakh terrain. These products would greatly help the field geologist. But they become acceptable geological maps only after validation and field checks by a geologist.

1. Philip, G., Ravindran, K. V. and Thakur, V. C., *Curr. Sci.*, 2000, **78**, 1014–1019.
2. Wangdus, C. and Tikku, V. K., *Rec. Geol. Surv. India*, 1994, **127**, 23–24.
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5. Thakur, V. C. and Virdi, N. S., *Himalayan Geol.*, 1979, **9**, 63–78.
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Response:

We appreciate the interest of S. K. Acharyya in our article[1] on ophiolites. The objective of our article was to give an opportunity to appreciate the potential of remote sensing techniques in high altitude and arduous terrain of Trans Himalaya, while keeping in mind the limitations of the technique. In our study, we have delineated independent lithological units based on the outcrops as seen in the satellite data. The technique advocated is based solely on the identification of spectral reflectance features common to many rock types. As vegetation cover is minimum in this terrain, the histograms have reflected the spectral properties of rocks and soils. Hence, remote sensing is proved to be one of the potentially rich sources of information for lithological and structural mapping in Himalaya. This study also demonstrates that valuable and systematic lithological and structural inferences can be made from the high resolution Indian Remote Sensing Satellite (IRS) data covering arid and inaccessible terrain of the Ladakh and Karakoram Range of Trans NW Himalaya.

In our present study we did not refer to the published geological map[2] claimed to be 'covering major parts of selected area' for various reasons. Firstly, the published geological map[2] is an abstract of a 'reconnoitory traverse mapping'[2] which is sketchy and pertains only to less than one-third (305 km^2)[2] of our study area (940 km^2)[1]. Secondly, the map[2] is merely part of an extended abstract of the field progress report of the Geological Survey of India (GSI) printed as an in-house publication. Thirdly, this map[2] is wrongly oriented (north direction) and does not provide any locality name or drainage features (except Kyun Tso) for location and comparison (interestingly, the redrawn map of the same area given by Acharyya in his rejoinder note shows an entirely different north direction!). Fourthly, the geological maps prepared by different group of scientists at GSI[2–4] show different interpretations of lithological units, structural features and stratigraphic nomenclature for this zone. In fact the map contained in the rejoinder note by Acharyya does not give stratigraphic nomenclature for all the units probably because of this reason. We have considered as a reference a map covering our whole study area, that has been published in an internationally reputed scientific journal[5]. The map has been widely cited by various workers in Himalaya as far as the Indus Suture Zone is concerned.

As far as Lian Molasse is concerned, we have observed that the digitally processed image shows distinct spectral signature of the molasse outcrop (figure 6 *b*)[1] compared to the unprocessed image (figure 3)[1]. However in the figure of Acharyya's rejoinder note, the Lian Molasse (Unit-2) does not match in size, shape and expression of the outcrop of the Lian Molasse as seen on the enhanced satellite image[1] (see Figure 1). This is a clear-cut example where the size and shape of the outcrop of a litho-unit is more distinct on the image and therefore closer to the ground truth than the map prepared by ground traverses where extrapolations are involved in extending the litho-boundaries by a 'reconnoitory traverse mapping'[2]. Therefore the field geologists need to appreciate the advantage of digitally enhanced satellite data in improving their observations.

Acharyya may appreciate that the satellite data we have used cannot discriminate units like 'peridotites and diorite-gabbro', therefore, we do not claim a high resolution mapping on this aspect. We have followed the standard photo-interpretation keys in vogue, apart from the spectral response curve of different rock types, for the interpretation of satellite images. The main objective of this study remains to enhance the discrimination between lithologically dissimilar rock and soil units compared to single band images or composites and to map the units with high confidence level. This study surely helps a field geologist to map the area more accurately and with high degree of confidence. Also, we do not find any lithological mismatches with our reference map[1] as mentioned by Acharyya.

Most of the area was checked in the field by one of the authors (V.C.T.) to corroborate our interpretation.

We heartily welcome Acharyya's suggestion of 'off and on scientific interaction of workers from different institutions engaged in the study on the evolution of the Indus Suture Zone'. Towards this, the paper[1] itself is the outcome of scientific interaction of like-minded scientists of multi-institutions in the study on the evolution of the Indus Suture Zone.

While we appreciate that Acharyya has accepted remote sensing technique as *one of the modern aids* to facilitate geological mapping, one may also note the comments about this paper[1] by K. S. Valdiya, a veteran Himalayan geologist[6].

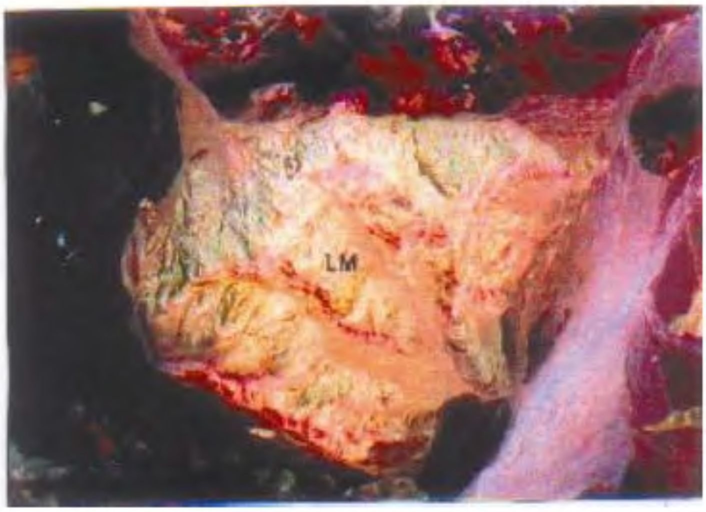

Figure 1. Closeup view of Lian Molasse (LM) as observed on digitally processed satellite image.

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