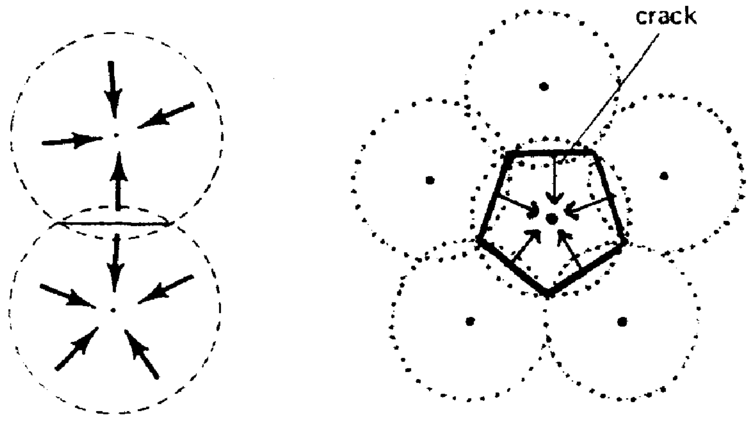

Figure 4. ***a***, Theory for the mechanism of formation of shrinkage; Polygonal cracks due to evaporation (after Brainerd Mears, Jr.[2]).

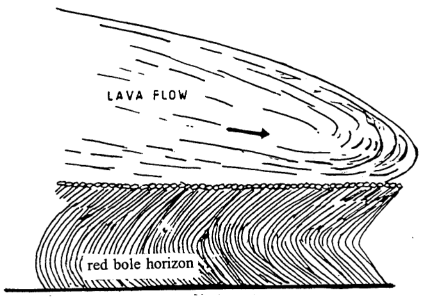

Figure 4. ***b***, Overloading pressure of the lava flow on the red bole bed causing buckling and dragging effects on the pencil joints.

fragments along with a frequent occurrence of fresh glass shards. Thus the petrographic characters clearly suggest that the red bole at Dighi is a typically weathered or altered product of pyroclastic rock as suggested by Wilkins *et al.*[1].

The heat provided by the younger lava flow which erupted onto this weathered, fine-grained pyroclastic material (which retained enough moisture) caused baking effects and the development of numerous evenly dispersed centres of shrinkage, similar to polygonal racks that develop when wet clayey sediments are subjected to evaporation (Figure 4 *a*).

According to Brainerd Mears, Jr.[2], although the causes for development differ, this shrinkage theory of cracking in mud applies far more spectacular forms, such as giant columns of basalt formed by contraction of freezing lavas. As the overloading pressure of the younger lava flow continued over the weathered, fine-grained matter has brought about a plastic deformation (buckling) of these pencil-jointed columns, the lateral movements of the younger lava flow caused the upper part of the pencil-jointed columns to be dragged tangentially in the direction of the movement of the younger lava flow (Figure 4 *b*). In the field this has also helped in determining the direction of the younger lava flow from west to east.

While the development of fine, perfect pencil joints has been explained, it is also pertinent to note that the plastic deformation (buckling) of the slender polygonal jointed red bole horizon and its dragging in a particular direction, helps to determine the direction of movement of the younger lava flow on its top.

1. Wilkins, A., Subbarao, K. V., Ingram. G., and Walsh, J. N., *Volcanism*, Radhakrishna Volume (ed. Subbarao, K. V.), Wiley Eastern Ltd, New Delhi, 1994, pp. 217–232.
2. Brainerd Mears, Jr., *The Changing Earth, Introduction to Geology*, D. Van Nostrand Comp, NY, 1970, 2nd edn, p. 575.

Received 1 May 2000; revised accepted 27 September 2000

P. K. SARKAR[†,**]
A. B. CHAKRANARAYAN[†]
A. K. DESHWANDIKAR*
M. R. FERNANDES*
S. D. RAUT[†]

[†]*Department of Geology, and*
**Department of Geography,*
Fergusson College,
Pune 411 004, India
***For correspondence*

Mapping of Indus ophiolites: Need for introspection

This concerns a research communication published recently in *Current Science* by Philip *et al.*[1] about the utility of high resolution IRS-IC/ID satellite data in 'mapping of ophiolites in the hostile and inaccessible mountainous terrains'. The objective of the study is to 'map the geological features in the Nidar Ophiolitic Complex' and thereby bring 'refinement of the existing geological maps'. It claims that satellite images from the area of study 'have helped not only in delineating the lithological boundaries more precisely but also in demarcation of a number of subunits within the already mapped litho-units'. It is unfortunate that the authors did not consult the published geological map from the specific area[2]; consequently, most of their claims became invalid and faulty.

The Geological Survey of India had been engaged in the study and systematic geological mapping of Indus Ophiolite belt and Indus Suture Zone for many years[3,4]. Neither these early nor later studies from the selected area[2] by this premier organization has been referred[1]. It is a fact that maps in none of the referred studies[5,6] involving the authors provide much details on the ophiolitic

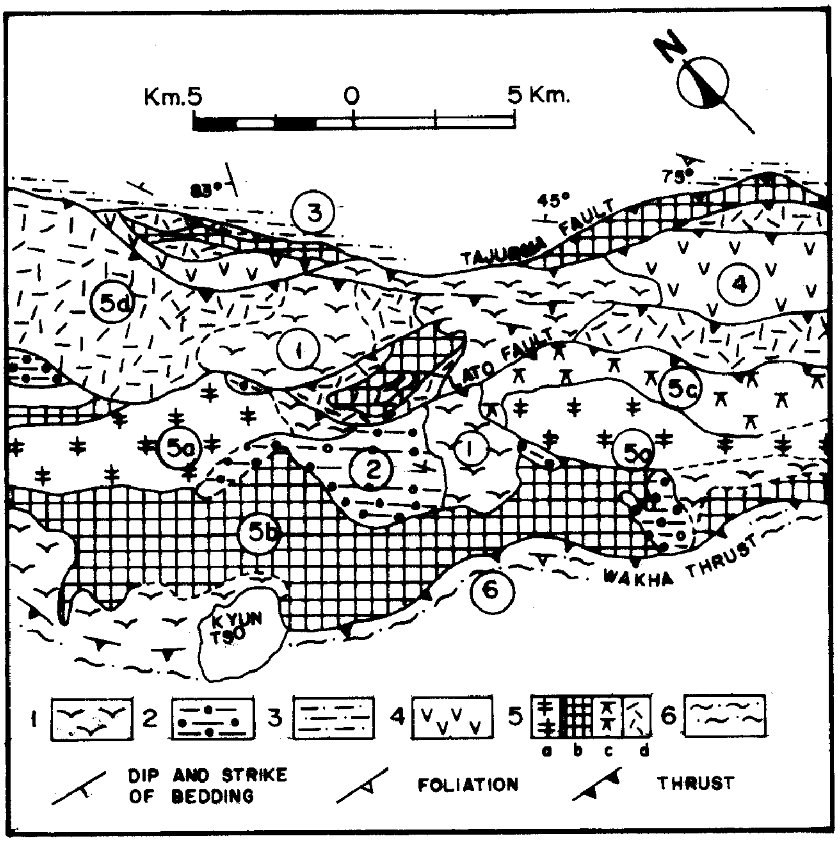

Figure 1. Geological map of Kyun Tso–Nidar–Shrok Sumdo area. 1, Quaternary; 2, Liyan Fm; 3, Nindam Fm; 4, Volcanics; 5, (a-Dunite, b-Peridotite, c-Pyroxinite, d-Diorite-gabbro); 6, Permo-Trias rocks; 7, 8, Dip and strike of bedding/foliation; 9, Thrust/fault (after Wangdus and Tikku[2]).

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.
3. Shanker Ravi, Padhi, R. N., Prakash, G., Thussu, J. L. and Wangdus, C., *Geol. Surv. India, Misc. Publ.*, 1976, **34**, 41–58.
4. Srikantia, S. V. and Razdan, M. L., *J. Geol. Soc. India*, 1980, **21**, 523–545.
5. Thakur, V. C. and Virdi, N. S., *Himalayan Geol.*, 1979, **9**, 63–78.
6. Thakur, V. C. and Mishra, D. K., *Tectonophysics*, 1984, **101**, 207–220.

Received 12 August 2000; accepted 3 October 2000

S. K. ACHARYYA

Geological Survey of India,
27, J. L. Nehru Road,
Calcutta 700 016, India

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