diction for avalanche days is fairly good. The FAR of expert system was above 0.40 with both types of avalanche occurrence reports. The expert system over-predicts with both types of avalanche occurrence information. However, overforecast tendency of the expert system is found to be less with the actual avalanche occurrence reports available combined with the expert forecaster's assessment of the situation compared to the actual avalanche occurrence reports available (Table 4).

The performance of the expert system under different avalanche danger scales is given in Table 3. Under each avalanche danger scale, the performance of the expert system is expressed as percentage of avalanche days. Model performance is poor with actual avalanche occurrence reports and it improves for all the danger scales with the inclusion of expert forecaster's assessment of the situation (Table 3). This indicates that the model is in good agreement with the assessment of the expert forecasters. Significant improvement in model performance under high avalanche danger scale with the inclusion of the expert forecaster's assessment of the situation (Table 3) indicates that there is definite loss of avalanche occurrence information.

The expert system developed correctly predicts more than 80% days with both types of avalanche occurrence information. The performance of the expert system is fairly good for the prediction of avalanche days along the road axis with the available information. It performs poorly for identification of avalanche danger with the actual avalanche occurrence reports. However, it improves with the inclusion of the expert forecaster's assessment of the situation. This is mainly due to the lack of complete avalanche occurrence reports.

The situation-based rules can be developed according to time of winter and the expert system can be calibrated accordingly to propose decision. Further, it is necessary to integrate the latest avalanche occurrence reports in any avalanche prediction model for better assessment of the avalanche danger situation, which has not been included yet. The developed expert system needs to be tested on a large dataset with accurate avalanche occurrence information. This may help largely to improve the expert system.

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Discovery of trilobite trace fossils from the Nagaur Sandstone, the Marwar Supergroup, Dulmera area, Bikaner District, Rajasthan

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Well-preserved trace fossils produced by trilobites are reported from the upper part of the Nagaur Sandstone of the Nagaur Group, the youngest group of the Marwar Supergroup (Trans-Aravalli Vindhyans). The trace fossils are preserved as epirelief on the sole of the silty shale beds. The trace fossils are *Cruziana* isp., *Dimorphichnus* isp., *Rusophycus* isp. and *Aulichnites* isp. Except *Aulichnites*, the trace fossils are known to have been produced by trilobites. Indication of the presence of trilobites in the Nagaur Sandstone gives the trace fossil-bearing horizon a Lower Cambrian age. Thus the present finding supports a Lower Cambrian age to the upper part of the Marwar Supergroup.

Keywords: Marwar Supergroup, Nagaur Sandstone, trace fossils, trilobites.

THE Marwar Supergroup occupies a large area in northwestern Rajasthan and attains a thickness of more than 1000 m that unconformably overlies ca. 779–681 Ma old Malani Igneous suite[1]. As such the sediments of the Marwar Supergroup are considered younger than 680 Ma. No radiometric dates are available for the Marwar Super-

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Table 1. Lithostratigraphic succession of the Marwar Supergroup, Rajasthan (simplified after Pareek[2])

Supergroup	Group	Formation	Lithology
Marwar Supergroup	Nagaur Group (75–500 m)	Tunklian Sandstone	Sandstone, gritty and pebbly sandstone
		Nagaur Sandstone	Brick-red sandstone, siltstone, shale with greenish clayey bands
	Bilara Group (100–300 m)	Pondlo Dolomite Gotan Limestone Dhanapa Dolomite	
	Jodhpur Group (125–240 m)	Girbhakar Sandstone Sonia Sandstone	
		Pokaran Boulder Bed	
		Unconformity	
		Malani Igneous Suite	

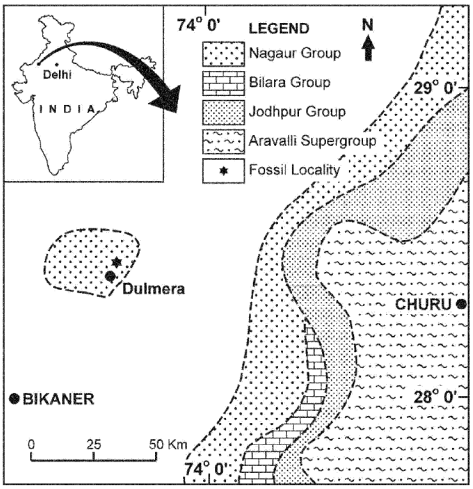

Figure 1. Geological and location map of the Dulmera area, Bikaner District, Rajasthan (after Pareek[2]).

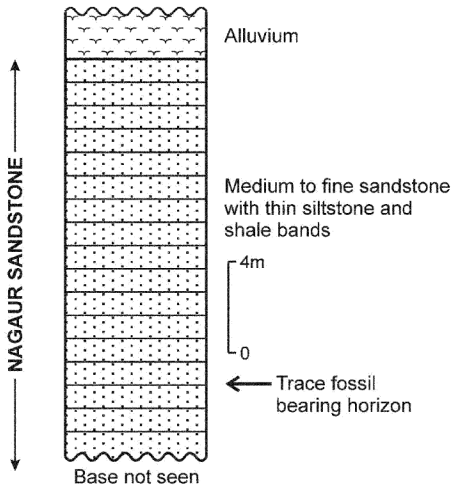

Figure 2. Litholog of the Nagaur Sandstone exposed in the Dulmera quarry, Bikaner District, Rajasthan, showing the position of trace fossils.

Figure 3. Field photograph of the Nagaur Sandstone exposed in the quarry at Dulmera village. Arrow marks the exposure of silty shale showing the presence of trace fossils.

group, which has given rise to speculation about its age. Earlier, the Marwar Supergroup was given a Cambrian age[2], but now it is considered either Neoproterozoic[1,3] or Neoproterozoic to early Cambrian[4–6]. Recently generated carbon, sulphur and strontium isotope data for the carbonates of the Bilara Group also point to a Late Neoproterozoic–Early Cambrian (Vendian–Tommotian) age[7–10]. The Nagaur Group, the youngest group of the Marwar Supergroup, has been correlated with the Purple Sandstone of the Salt Range, Pakistan, which has a well-established Early Cambrian age[11]. Thus, the Marwar Supergroup is either Neoproterozoic or extending up to Lower Cambrian, but its continuation in the Cambrian is a mere speculation considering the limitation for the interpretation of the isotope data and absence of Cambrian fossils. Discovery of a new genera *Marsonia* of Ediacaran affinity from the Jodhpur Sandstone (the lower part of the Marwar Supergroup) could not resolve this controversy[12]. Stromatolites have also been reported from the Bilara Group, but the reported forms are all long-ranging and cannot be used

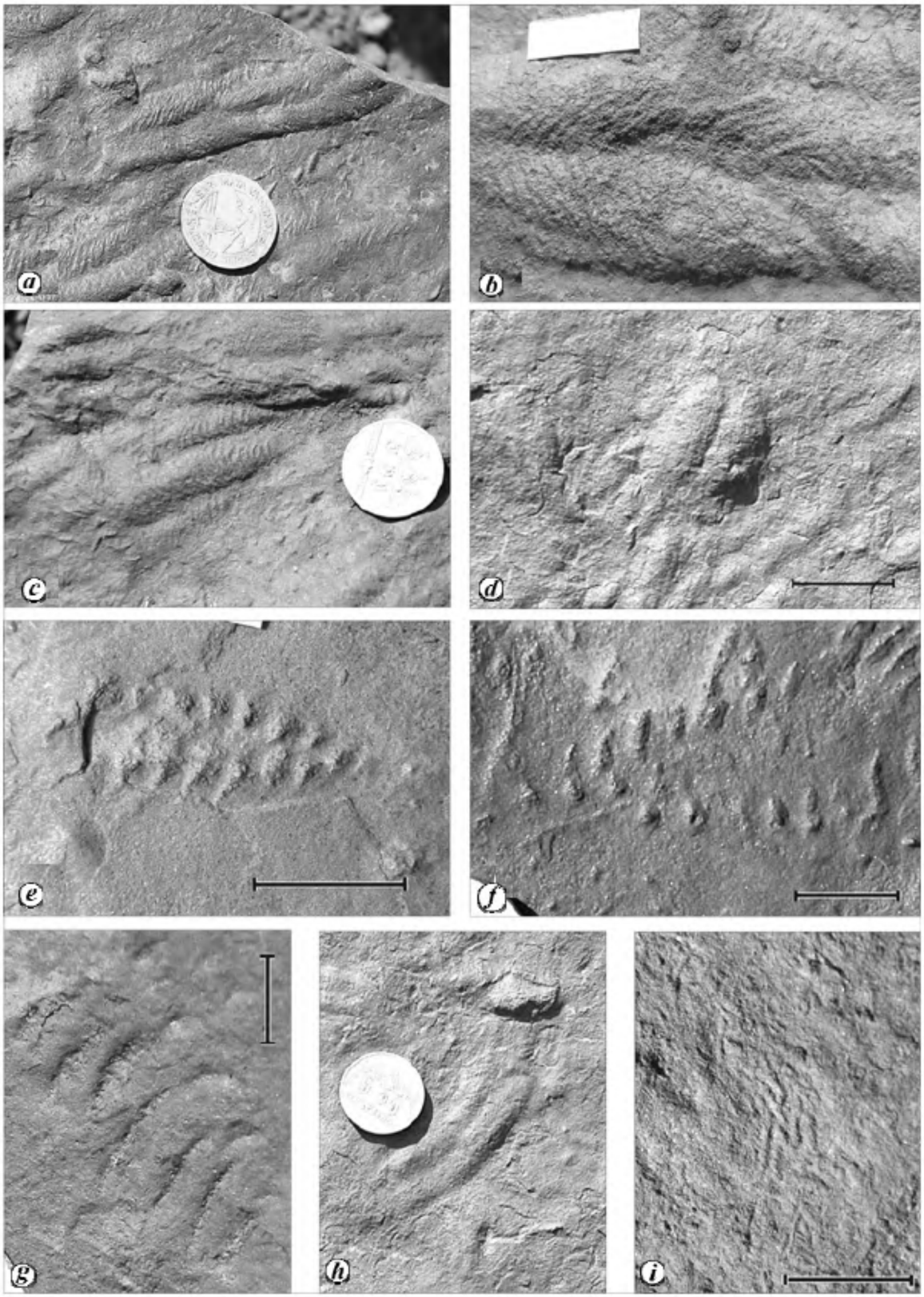

Figure 4. ***a***, ***b***, *Cruziana* isp. ***a***, Diameter of the coin = 2 cm. ***b***, Scale = 1 cm. ***c***, ***d***, *Rusophycus* isp. ***c***, Diameter of coin = 2 cm. ***d***, Scale = 2 cm. ***e–g***, *Dimorphichnus* isp. ***e***, ***f***, Scale = 1 cm. ***g***, Scale = 0.5 cm. ***h***, ***i***, *Aulichnites* isp. ***h***, Diameter of the coin = 2 cm. ***i***, Scale = 1 cm.

for suggesting the age[13–15]. The present communication records the presence of four trace fossils from the upper part of the Nagaur Sandstone belonging to the youngest group of the Marwar Supergroup. Three trace fossils are known to have been produced by the trilobites. Because of this reason their presence in the Nagaur Sandstone supports a Lower Cambrian age to the trace fossil-bearing horizon. These trace fossils have been reported from the Nagaur Sandstone exposed in the quarries around Dulmera village about 65 km from Bikaner on the Bikaner–Ganganagar road. Trace fossils have been recorded from the soles of the thin brownish-red coloured silty shale beds intercalated with the light coloured reddish-brown sandstones.

Developed west of the Aravalli Range, the Marwar Supergroup which unconformably overlies the Malani Igneous Suite in the northwestern part of Rajasthan, was earlier referred to as the Trans-Aravalli Vindhyans[16]. It is unconformably overlain by the Permo-Carboniferous Bap Beds[2]. The Marwar Supergroup has been lithostratigraphically subdivided into three groups; in stratigraphic order these are the Jodhpur Group, the Bilara Group and the Nagaur Group[2] (Table 1). The Nagaur Group has been subdivided into the Nagaur Sandstone and the Tunklian Sandstone formations (Table 1). Trace fossils have been recorded from the upper part of the Nagaur Sandstone. The Nagaur Sandstone is exposed in the quarries around Dulmera village (Figure 1). The beds are more or less horizontal and represented by a succession of whitish-grey to reddish-brown sandstone, brick-red to red shale and siltstone. Pockets of greenish clay with red shale are also present. These are unmetamorphosed and undeformed. About 16 m thick succession can be seen in these quarries (Figures 2 and 3). Large and small-scale cross-bedding, parallel bedding, ripple marks and mud cracks have been abundantly recorded.

Four trace fossils have been reported from the soles of the brown-coloured silty shales, which are intercalated with thick-bedded, medium to fine-grained cross-bedded sandstones (Figure 3). These are *Cruziana* isp., *Rusophycus* isp., *Dimorphichnus* isp. and *Aulichnites* isp. Ichnogenus *Cruziana* isp. D'Orbigny 1842 is represented[17] by elongate band-like furrow with side ridges showing curved scratch markings (Figure 4 *a* and *b*). The width is 1.5 cm and can be traced for a distance of 7 cm. A number of such traces are present on the sole of the bed. At places, the traces overlap each other.

Ichnogenus *Rusophycus* isp., Hall 1852 is seen[17] as bilobate buck-like form (Figure 4 *c* and *d*). Lobes show transverse marking or striae, but in some cases these markings are not seen. It is believed to be a resting trace of trilobite.

Ichnogenus *Dimorphichnus* isp. Seilacher 1955 is marked[17] by asymmetrical trails with two different types of impressions arranged in series oblique to the direction of movement (Figure 4 *e–g*). These are formed by the grazing action of trilobites.

Ichnogenus *Aulichnites* isp. Fenton and Fenton 1937 occur[17] as trails consisting of two convex ridges separated by a deep median groove in epirelief (Figure 4 *h* and *i*). It is considered as a crawling and/or grazing trail, most probably made by gastropods.

In general, the trace fossils are poor time markers and have long time ranges[18]. However, in the case of the *Cruziana* species, their moving and resting tracks are valuable index fossils as they are produced by the trilobites[18]. Discovery of *Cruziana*, *Dimorphichnus* and *Rusophycus* from the Nagaur Sandstone suggests the presence of trilobite traces at the time of deposition of these sandstones, thereby confirming at least an Early Cambrian age for the Nagaur Sandstone. This is a direct evidence for suggesting an age to the upper part of the Marwar Supergroup.

The confirmation of Cambrian deposits in the upper part of the Marwar Supergroup supports its correlation with the Krol–Tal succession of the Kumaon–Himachal Lesser Himalaya, which also shows similar trace fossils along with the presence of trilobite and brachiopods[19–22]. This also justifies the correlation of the trace fossil-bearing Nagaur Group with the Cambrian succession of the Salt Range of Pakistan[23]. It opens up the possibility of establishing the Precambrian–Cambrian boundary within the Marwar Supergroup. This is a preliminary account and detailed work is under progress.

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