22. Singh, A. K. and Rembold, H., Maintenance of the cotton bollworm, *Heliothis armigera* Hubner (Lepidoptera: Noctuidae) in laboratory culture – I – Rearing on the semi-synthetic diet. *Insect Sci. Appl.*, 1992, **13**, 333–338.
23. Koul, O. and Isman, M. B., Effects of azadirachtin on the dietary utilization and development of the variegated cutworm *Peridroma saucia*. *J. Insect Physiol.*, 1991, **37**, 591–598.
24. Isman, M. B., Koul, O., Luczynski, A. and Kaminski, J., Insecticidal and antifeedant bioactivities of neem oils and their relationship to azadirachtin content. *J. Agric. Food Chem.*, 1990, **38**, 1406–1411.
25. Lowry, O. H., Rosebrough, N. J., Farr, A. L. and Randall, R. J., Protein measurments with folin–phenol reagent. *J. Biol. Chem.*, 1951, **193**, 265–275.
26. Laemmli, U. K., Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature*, 1970, **227**, 680–685.
27. Panse, V. G. and Sukhatme, P. V., *Statistical Methods for Agricultural Workers*, Indian Council of Agricultural Research, New Delhi, 1967, 2nd edn, p. 108.
28. Ayyanger, G. S. G. and Rao, P. J., Changes in haemolymph constituents of *S. litura* (Fabr.) under the influence of azadirachtin. *Indian J. Entomol.*, 1990, **52**, 69–83.
29. Qadri, S. S. H. and Narsaiah, J., Effects of azadirachtin on the moulting process of last instar nymphs of *Periplaneta americana* (Linn.). *Indian J. Exp. Biol.*, 1978, **16**, 1141–1143.
30. Subrahmanyam, B. and Rao, P. J., Azadirachtin effects on *Schistocerca gregaria* Forskal during ovarian development. *Curr. Sci.*, 1986, **55**, 534–538.
31. Ramdev, Y. P. and Rao, P. J., Biochemical changes in larval haemolymph of *Achaea janata* Linn. *Proc. Indian Natl. Sci. Acad. Sect. B*, 1984, **50**, 154–162.
32. Levenbook, L., Insect storage protein. In *Comprehensive Insect Physiology, Biochemistry and Pharmacology* (eds Kerkut, G. A. and Gilbert, L. I.), Pergamon Press, New York, 1985, pp. 307–346.
33. Ramdev, Y. P. and Rao, P. J., Effects of insecticides on *Achaea janata* Linn. I. Haemolymph volume, body moisture and cations. *Proc. Indian Natl. Sci. Acad. Sect. B*, 1986, **52**, 232–240.
34. Koul, O., Fate of azadirachtin in the variegated cutworm, *Peridroma saucia*. In World Neem Conference, India, 1993, pp. 307–313.
35. Garcia, E. S., Gonzalez, M. S., Azambuja, P. and Rembold, H., Chagas disease and its insect vector. Effects of azadirachtin A on the interaction of a triatomine host (*Rhodnius prolixus*) and its parasite (*Trypanosoma cruzi*). *Z. Naturforsch.*, 1989, **44**, 317–322.
36. Rembold, H., Secondary plant products in insect control with special reference to azadirachtin. In *Advances in Invertebrate Reproduction* (ed. Engles, W. E.), Elsevier, Amsterdam, 1984, vol. 3, pp. 481–491.
37. Schmutterer, H., Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. *Annu. Rev. Entomol.*, 1990, **33**, 271–297.

ACKNOWLEDGEMENTS. We thank Dr (Mrs) N. S. Sangwan for advice and Dr A. Singh for help in statistical analysis.

Received 13 June 2005; revised accepted 28 April 2006

Diagenetic talc of Jhiroli, Kumaun Himalaya

H. P. Sengupta* and R. N. Yadav

Department of Geology, Banaras Hindu University,
Varanasi 221 005, India

Talc/soapstone deposit of Kumaun Lesser Himalaya is mainly associated with magnesite. It occurs in small, irregular patches and pockets within the magnesite and sometimes with dolomite. Talc in the interstitial spaces of magnesite occurs as fillings of stylolitic veins, as well as in patches heavily corroding the magnesite grains lying in contact. Tremolite, chlorite and other low grade metamorphic minerals are absent while chalcedony is sometimes present in intimate association with talc in the stylolitic veins and in the patches. Talc is extremely fine-grained, sometimes scaly and at times fibrous. These features indicate that talc is neither hydrothermal in origin nor is produced by stresses acting on the carbonate rock. Presence of pyrite grains in talc and host magnesite is indicative of a reducing environment. X-ray diffraction and infrared studies reveal that there is no other metamorphic mineral present. Fluid-inclusion study of host magnesite suggests that the minimum temperature of homogenization (*Th*) ranges between 220 and 300°C. The antipathic relationship between silica and talc suggests that the latter is a product of diagenetic processes, being formed by reaction of magnesite and silica at temperature less than 300°C.

Keywords: Diagenetic processes, Kumaun Lesser Himalaya, metamorphic minerals, talc.

PROTEROZOIC talc/soapstone deposit of Deoban Formation in the Jhiroli area is a part of Kumaun Lesser Himalaya. It is situated between lat. 29°45′30″ and 29°47′30″ N, and long. 79°44′ and 79°46′ E. Talc is a hydrothermal or metamorphic mineral, characteristic of green schist facies and occurs in shear zones where it is considered as an alteration product. The genesis of talc/soapstone which revolves around the metamorphic/hydrothermal process, is still debated. Some workers suggest that talc is a product of hydrothermal replacement[1,2], while others contend that it represents a low-grade metamorphic reaction product of magnesite and silica[3–6].

The Deoban Formation consists of a thick pile of calcareous and siliceous metasedimentary rocks belonging to Kumaun Lesser Himalaya Upper Middle Riphean age[7]. It occurs in and around the study area, surrounded by three villages, i.e. Chaugaon Chhinna, Bilori and Kathpuria. The basement of the Deoban Formation is the Rautgara Formation that consists of predominantly pink, grey and

*For correspondence. (e-mail: sengupta_hari@yahoo.com)

white well-bedded, highly jointed arenites interbedded with subordinate brown, green and black argillites. This formation is best exposed along the motor road, southwest of Kathpuria Chhinna. The Deoban Formation occupies a major portion of the study area[8] (Figure 1). It consists of shale/slate, dolostone with cherty and argillaceous intercalations and magnesite.

Megascopically, talc varies from pure white colour to dark grey depending on the content of impurities. The mineral shows typical greasy lustre with development of perfect basal cleavage in some cases. It occurs both as massive bodies as well as in the form of foliated soapstone rock. Microscopically, it shows an extremely interesting relationship with magnesite. At times it contains euhedral to subhedral minute opaque pyrite grains (Figure 2 *a* and *b*). Talc also contains abundant relicts of magnesite crystals having the usual optical characters and showing all stages of corrosion and replacement of the latter (Figure 2 *b* and *c*). Relicts of quartz are rarely seen, which sometimes show corrosion effects by talc. In talc aggregates some interesting structures are developed, such as the presence of chert laminae (Figure 2 *d*). The fine talc developed at the contact of magnesite is somewhat coarser than the talc developed elsewhere and is also much later in origin. Scanning Electron Microscopic (SEM) study suggests that the contact of talc with magnesite is corrosional in which the former is seen to occur as finger-like offshoots or protrusions into the magnesite (Figure 3 *a* and *b*), indicating a diagenetic replacement origin for talc.

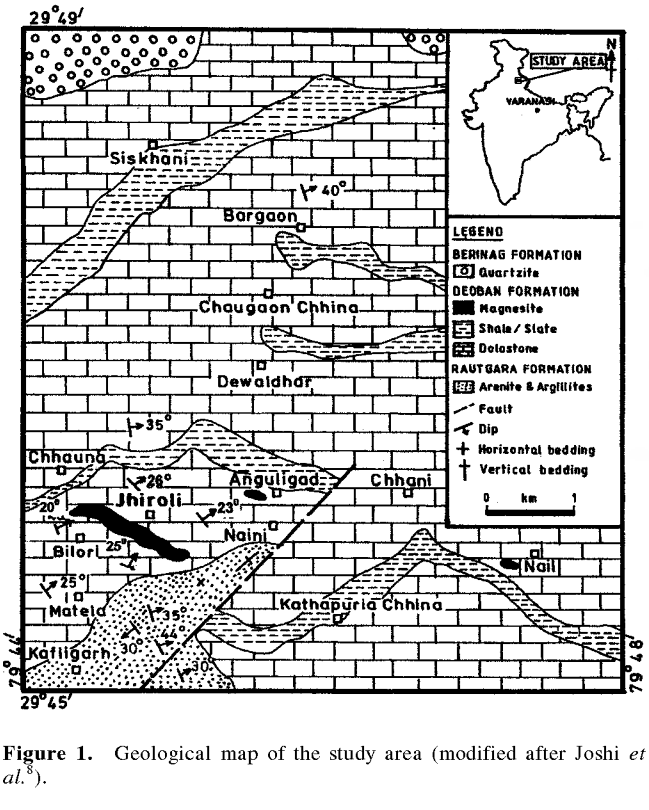

Figure 1. Geological map of the study area (modified after Joshi *et al.*[8]).

The major mineral phases of two representative samples of carbonate were identified by X-ray diffraction data, which reveal the presence of carbonate minerals such as magnesite, dolomite, calcite and siderite, apart from talc (Figure 4 *a* and *b*). Two more representative samples of carbonate with talc were analysed by infrared (IR) spectra (Figure 5), which exhibits the presence of magnesite, dolomite, talc, calcite and quartz.

Triphase inclusions (NaCl–H_2O + halite) are characterized by the presence of a solid phase, cubic in nature and identified as halite (Figure 6 *a*). The homogenization temperature of these triphase inclusions in talc with magnesite varies between 240 and 300°C, with temperature of homogenization (*Th*) maxima around 260 ± 10°C (Figure 7 *a*). The biphase, i.e. liquid–NaCl and vapour–H_2O (Figure 6 *b*)

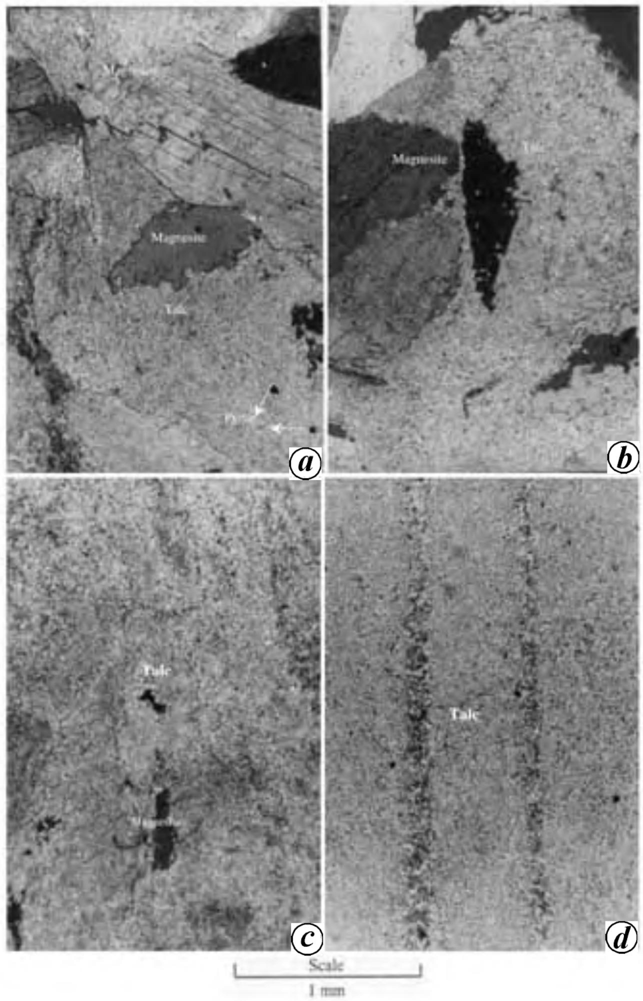

Figure 2. ***a***, Photograph showing rhomb of magnesite corroded by talc, which indicates diagenetic replacement of magnesite by fine-grained talc. Scattered grains of pyrite are also observed. ***b***, Photomicrograph showing corroded relict of magnesite surrounded by talc. ***c***, Photograph showing small relict of magnesite in talcose groundmass. ***d***, Photomicrograph showing faint development of chert laminae in talcose groundmass. Extremely fine grained pyrite is seen in chert laminae. These laminations are interpreted as being relict structure.

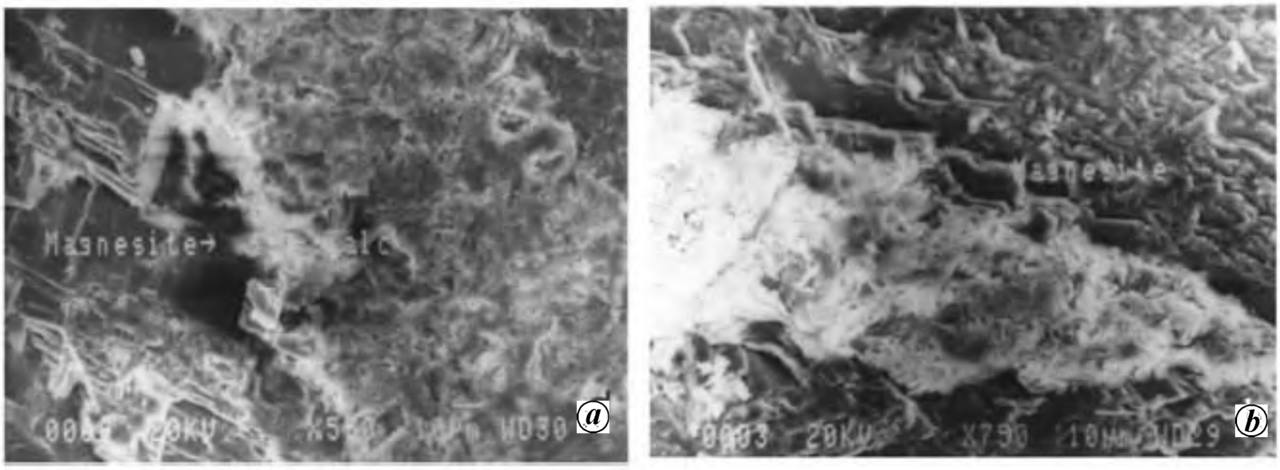

Figure 3. ***a***, Contact of magnesite and talc showing corrosion structure probably during late diagenesis. ***b***, Talc is seen to send finger-like offshoots or protrusions into the magnesite, indicating diagenetic replacement by talc.

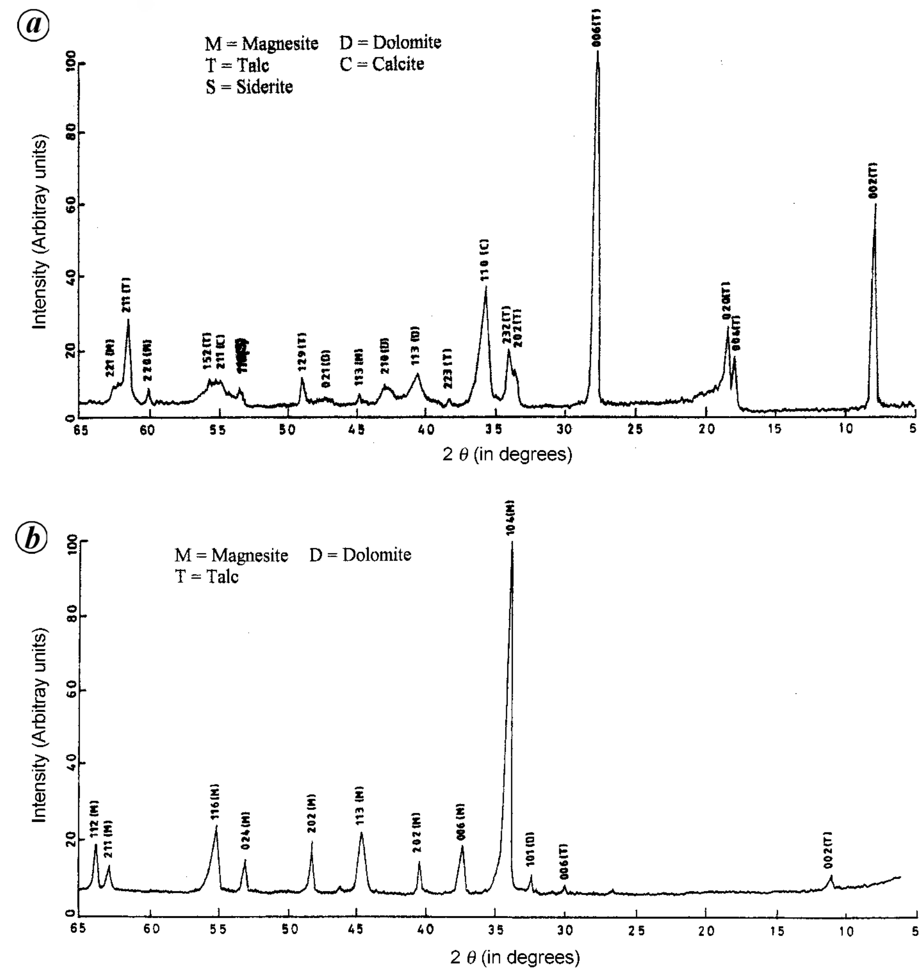

Figure 4. ***a, b.*** X-ray diffractogram of Jhiroli carbonate.

aqueous homogenization temperature in talc with magnesite ranges from 221 to 251°C with maximum fluid inclusion homogenized temperature around 220–230°C (Figure 7 *b*), whereas biphase inclusions in dolostone furnished a homogenization temperature range of 220–265°C with a pronounced peak at 220–230°C (Figure 7 *c*).

Talc is a common mineral intimately associated with the crystalline magnesite of Jhiroli. The quartz free talc–

magnesite assemblage is common in the Dewalthal area[3] and must have been formed at a temperature of 650°C and pressure 2 kbar in contact with solutions of nearly pure H_2O or mixture of H_2O and CO_2. This finding is based on the investigation of mineral equilibrium in the system $MgO–SiO_2–H_2O–CO_2$ in which it was pointed out that progressive enrichment of the fluid phase in CO_2 and later H_2O during the early stage of metamorphism of carbonate-bearing rocks led not only to recrystallization of the carbonate sediments but also promoted reaction of magnesite with quartz to produce talc at low temperatures[9]. Talc present in the calc zone of Chamoli area is of two generations. The early talc, present on the intergranular margins of magnesite, appears to have developed contemporaneously with magnesite. The other, occurring in the form of veins and cleavage filling in magnesite, occurred later than magnesite[10].

Extremely fine-grained, scaly and fibrous talc and absence of tremolite and chlorite may indicate that it is formed during diagenesis. Presence of euhedral to subhedral minute opaque pyrite grain in talc is indicative of reducing environment during diagenesis. Talc is seen to send finger-like offshoots into the magnesite and its contact with the latter is corrosional as indicated by SEM observations. Jhiroli talc appears to have been formed around 300°C, which has led to widespread diagenetic replacement. Evidences of formation of other metamorphic minerals like chlorite and tremolite are entirely lacking. The higher temperature of 480°C is possible only at XCO_2 of nearly one (1.00), the fluid pressure being 1 kbar[11]. However, a temperature of 650°C appears improbable, as at that temperature and with the moderate XCO_2 (0.50), diopside would have formed at 1.5 kbar fluid pressure[3]. Irregular pockets of very fine-grained white talc in metadolomites are not affected by shear[12]. In this case, transition from metadolomite to talc is gradual and the original layering is preserved, suggesting diagenetic transformation without significant volume change. This type of deposit has no clear relation to shear zones or to igneous intrusions. The possibility of talc being of diagenetic origin is supported by several workers who have suggested a diagenetic origin for talc in the evaporitic sediments[13,14]. It is also noted that talc and other minerals in the Zechstein (upper Permian) sediments are diagenetic in non-evaporitic rocks[15]. Talc from a dolomitic limestone has also been reported[16]. These authors favour a sedimentary (diagenetic) origin for talc

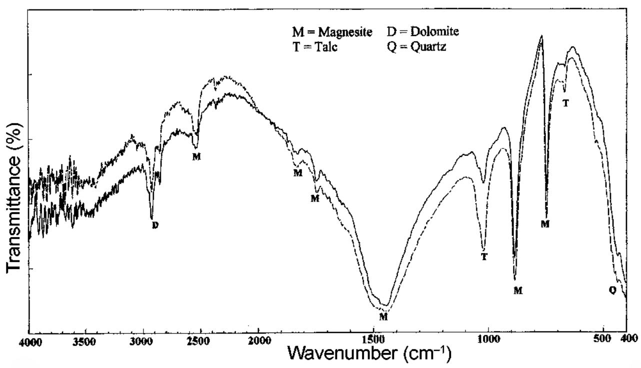

Figure 5. Infrared spectra of Jhiroli carbonate.

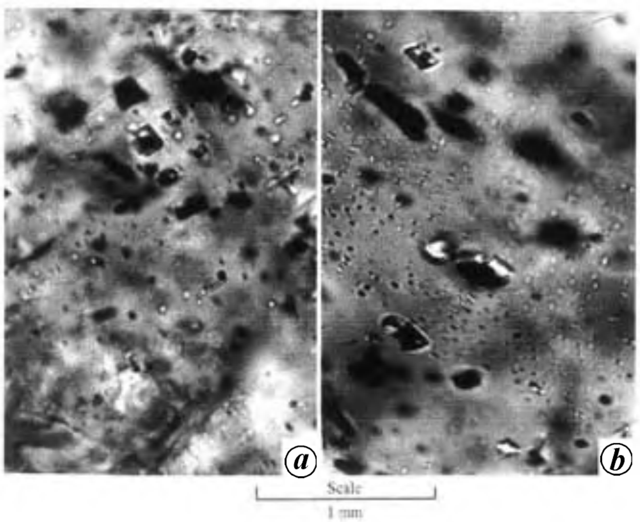

Figure 6. *a*, Photomicrograph showing three-phase primary fluid inclusion in talc with magnesite, i.e. solid–halite, liquid–NaCl and vapour–H_2O. *b*, Photomicrograph showing two-phase primary fluid inclusion in talc with magnesite, i.e. liquid–NaCl and vapour–H_2O.

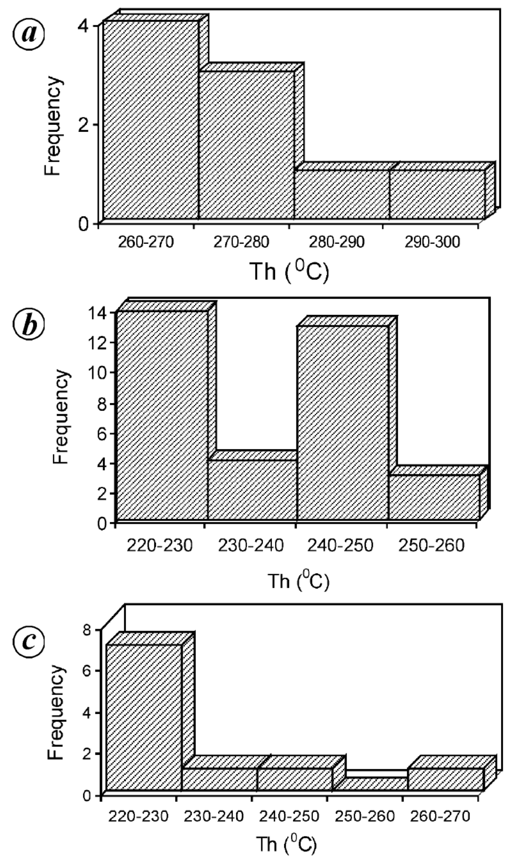

Figure 7. Histogram of homogenization temperatures and their frequencies for triphase inclusion in magnesite with talc (*a*), biphase inclusions in magnesite with talc (*b*) and biphase inclusions in dolostone (*c*).

in limestone. The occurrence of talc as a clay mineral in sedimentary rocks is also suggested[17]. Field, petrographic and SEM studies, as well as XRD, IR observations and fluid inclusions studies reveal that the antipathic relations of silica and talc are indicative of the fact that the latter is a product of diagenetic sedimentary environment, being formed by the reaction of magnesite and silica ($3MgCO_3 + 4SiO_2 + H_2O + MgSi_4O_{10}(OH)_2 + 3CO_2$) at a temperature less than 300°C.

1. Nautiyal, S. P., General report for the year, 1947. *Rec. Geol. Surv. India*, 1953, **79**, 375.
2. Muktinath and Wakhaloo, G. L., A note on the magnesite deposit of Almora district, UP. *Indian Miner.*, 1962, **16**, 116–123.
3. Valdiya, K. S., Origin of the magnesite deposits of Southern Pithoragarh, Kumaon Himalaya. *Econ. Geol.*, 1968, **63**, 924–934.
4. Bhattacharya, A. K., Sengupta, H. P. and Mukherjee, A., Origin of the Upper Precambrian talc/soapstone deposit at Chandak, District Pithoragarh. *Curr. Trends Geol.*, 1985, **7**, 291–300.
5. Sengupta, H. P. and Yadav, R. N., Origin of Jhiroli magnesite deposit, Almora district, UP: A geochemical approach. *J. Indian Acad. Geosci.*, 1998, **41**, 1–6.
6. Sengupta, H. P. and Yadav, R. N., Genesis of Jhiroli magnesite, District Almora, Uttaranchal: Petrological and scanning electron microscope (SEM) approach. *Indian J. Geol.*, 2002, **74**, 261–274.
7. Valdiya, K. S., *Geology of Kumaun Lesser Himalaya*, Himachal Times Press, Dehradun, 1980, p. 291.
8. Joshi, M. N., Bhattacharya, A. K. and Anantharam, M. S., Origin of sparry magnesite deposits around Bauri, Almora district, UP (India). *Miner. Deposita*, 1993, **28**, 146–153.
9. Greenwood, H. J., Minerological equilibrium in the system MgO–SiO_2–H_2O–CO_2. *Res. Geoch.*, 1967, **2**, 542–567.
10. Gaur, C. G. S., Dave, V. K. S. and Mittal, R. S., Stratigraphy, structure and tectonics of the carbonate suite of Chamoli, Garhwal Himalaya. *Himalayan Geol.*, 1977, **7**, 416–455.
11. Winkler, H. G. F., *Petrogenesis of Metamorphic Rocks* (*4th edn*), 1976, p. 334.
12. Szabo, G. A. J., Andrade, F. R. D., Guimaraes, G. B., Moya, F. A. and Carvalho, F. M. S., Genesis of talk deposits and the metamorphic history of the Itaiacoca Group metadolomites, Southern Brazil. In *Applied Minerology* (eds Pecchio *et al.*), 2004, pp. 759–761.
13. Stewart, F. H., The petrology of the evaporates of the Eskdale no. 2 boring, Yorkshire (Part I – The lower evaporite bed). *Mineral. Mag.*, 1949, **28**, 621–675.
14. Rraymond, L. R., The petrology of the lower magnesium limestone of north-east Yorkshire and southeast Durham. *Q. J. Geol. Soc. London*, 1962, **118**, 39.
15. Dreizler, I., Mineralogische Undersuchungen an Zwei Gipvorkommen du Werraserie (Zechstein). *Mineral. Petrogr. Acta*, 1962, **8**, 323–338.
16. Milliot, G. and Palausi, G., Sur un talc d'origine sedimentaire. *C. R. Somm. Seances Soc., Geol. Fr.*, 1959, **45**, 45–46.
17. Friedman, G. M., Occurrence of talc as a clay mineral in sedimentary rocks. *Nature*, 1965, **207**, 283–284.

ACKNOWLEDGEMENTS. We are grateful to Prof. A. K. Bhattacharya for critical and valuable suggestions. We would like to thank Director and Dr H. K. Sachan, Wadia Institute of Himalayan Geology, Dehdradun for extending fluid inclusion facilities, and Prof. R. N. Tiwari, Head, Department of Geology, BHU, Varanasi for encouragement. We also thank Prof. W. Pohl, Institute of Environmental Geology, Technical University, Braunschweig, Germany for valuable comments and suggestions.

Received 7 January 2006; revised accepted 4 June 2006

Shoreline changes during the last 2000 years on the Saurashtra coast of India: Study based on archaeological evidences

A. S. Gaur*, K. H. Vora and Sundaresh

National Institute of Oceanography, Goa 403 004, India

Shoreline shift coupled with sea-level change have always remained intriguing aspects due to wider ramifications for the populations living on the coast. Different methods are employed to understand and explain their causes and quantum. In this communication an attempt is made to study shoreline and sea-level changes during the last 2000 years on the basis of archaeological evidence. Archaeological excavations undertaken at Bet Dwarka (western most part of India) revealed an interesting cultural sequence commencing from protohistoric period (3800 yrs BP) to historical period (1600 yrs BP). Excavation was undertaken in six trenches up to the lowest level of archaeological findings. The results from these trenches suggest that the oldest habitation was situated below the present high water line. This is an indication of a lower sea level during that period of settlement. ^{14}C ages and archaeological data suggest a time bracket for these habitations between 2050 and 1650 yrs BP (calibrated). Analysis of sea level versus ancient settlement suggests that around the Christian era sea level was lower by 2 m than the present. The remains from the excavation also suggest that one of the attractions for early settlers was the availability of marine resources around the island. Data from early historical period and other archaeological sites situated along the Indian coast confirm this finding.

Keywords: Archaeological evidence, Bet Dwarka, Saurashtra coast, shoreline and sea level.

THE fluctuations of sea level played a prominent role in the emergence and decline of cultures during Pleistocene and Holocene periods. Several authors have updated sea-level studies along the west coast of India[1–7]. There are well-defined observational data on Quaternary sea-level oscillations based on geological proxies like coral, limestone, foraminifera and other marine organisms. Focusing on long time-frames involves a high degree of error due to various reasons like paucity of data, methods of measurement, instrumental errors, etc. In comparison, archaeological evidences, when available, provide foolproof manifestation of the event that has taken place in one particular geographical entity. Ancient settlements also preserve each event, whether it be environmental, political, cultural diffusion, etc. that occurred in the course of time.

*For correspondence. (e-mail: asgaur@nio.org)