revealed that when the noise is present, the efficacy of the scheme deteriorated for model II. In the case of model IV when $(\rho_2/\rho_1) < 1$, $\Delta\alpha\%$ for all the parameters is nearly the same as that obtained for the data not corrupted by random noise.

There appears to be a way out to invert the near zone CSAMT data which is a necessity to probe deeper layers. The scheme presented can be extended to multi-layer sections without much difficulty. However, the case of resistive substratum (two-layer or A-type three-layer model) appears to have poorer resolvability in view of large errors in $\Delta\alpha\%$ for depth factor (Tables 7 and 8).

1. Yamashita, M. and Hallof, P. G., CSAMT case histories with a multichannel CSAMT system and discussion of near field data correction, Phoenix Geophysics Limited, Markham, 1985.
2. Zonge, K. L. and Hughes, J. L., *CSAMT, E.M. Methods in Applied Geophysics* (eds Nabighian, M. N.), Society of Exploration Geophysicists, 1991, vol. 2, p. 713–809.
3. Rao, I. B. R., Ram Raj Mathur and Srinivas, S., *Curr. Sci.*, 1994, **67**, 446–453.
4. Sandberg, S. K. and Hohmann, G. W., *Geophysics*, 1982, **47**, 100.
5. Boerner, D. E., Wright, J. A., Thurlow, J. G. and Reed, L. E., *Geophysics*, 1993, **58**, 12–19.
6. Sasaki, Y., *Geophysics*, 1989, **54**, 254–262.
7. Sasaki, Y., Yoneda, Y. and Matsuo, K., *Geophysics*, 1992, **57**, 952–955.
8. Takakura, S., *Explor. Geophys.*, 1995, **26**, 172–178.
9. Ogawa, Y. and Takakura, S., *J. Geomagn. Geoelectr.*, 1990, **42**, 211–224.
10. Yamashita, M., Controlled Source Audio Magnetotellurics Field Survey Results, Phoenix Geophysics Limited, Markham, 1987.
11. Bromley, C., *J. Geomagn. Geoelectr.*, 1993, **45**, 887–896.
12. Pris, G. V. and Svetov, B. S., *Appl. Geophys.* (in Russian), 1970, **59**, 92–102.
13. Bartel, C. and Jacobson, R. D., *Geophysics*, 1987, **52**, 665–677.
14. Anderson, W. L., *Geophysics*, 1991, **56**, 1087–1092.
15. Wilt, M. and Strak, M., *Geophysics*, 1982, **47**, 1100–1105.
16. Spies, B. R. and Eggers, D. E., *Geophysics*, 1986, **51**, 1452–1471.
17. Basokur, A. T., *Geophys. Prospect.*, 1994, **42**, 141–147.
18. Szarka, L., *Geophys. Prospect.*, 1994, **42**, 987–988.
19. Das, U., *Geophysics*, 1995, **60**, 53–60.
20. Kaufman, A. A. and Keller, G. V., *Frequency and Transient Soundings*, Elsevier Science Publishers, Amsterdam, 1983.
21. Khmelovsky, G. V. and Bondarenko, V. M., *Electrical Prospecting, Hand Book of Geophysics*, Nedra, Moscow, 1989.
22. Cagniard, L., *Geophysics*, 1953, **18**, 605–635.
23. Gasanenko, L. B. and Sholpo, G. P., *Problems in Geophysics* (in Russian), Leningrad University Publications, 1959, p. 174–183.
24. Gasanenko, L. B., *Problems in Geophysics* (in Russian), Leningrad University Publications, 1960, p. 286.
25. Svetov, *Theory, Methodology and Interpretation of Low Frequency Inductive Electrical Prospecting Data* (in Russian), Nedra, Moscow, 1973.
26. Marquardt, D. W., *J. Soc. Ind. Appl. Math.*, 1963, **11**, 431–441.
27. Wiggins, R. A., *Rev. Geophys. Space Phys.*, 1972, **10**, 251–286.
28. Glenn, W. E., Ryu, Jisoo, Ward, S. H., Peoples, W. J. and Phillips, R. J., *Geophysics*, 1973, **38**, 1109–1129.
29. Marquardt, D. W., *Technometrics*, 1970, **12**, 591–612.
30. Daniels, J. J., Keller, G. V. and Jacobson, J. J., *Geophysics*, 1976, **41**, 752–765.
31. Anderson, W. L., USGS Open-file Report, 1979, **37**, 79–586.
32. Anderson, W. L., USGS Open-file Report, 1982, **65**, 68–82.
33. Goldtzman, F. M., *Izv. Earth Phys.*, 1975, **29**, 53.
34. Jenkins, G. M. and Watts, D. C., *Spectral Analysis and Its Applications*, Holden-day, Inc., 1968.
35. Press, W. H., Teukolsky, S. A., Vellerling, W. T. and Flannery, B. P., *Numerical Recipes in Fortran*, Cambridge University Press, Cambridge, UK, 1992.

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Clinopyroxenite xenoliths from the Deccan Trap lavas of Kutch and Mumbai

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Only a few occurrences of mantle xenoliths have been reported in the Deccan basalt province. These include the spinel peridotite and spinel lherzolite from Kutch and clinopyroxenite (with minor olivine) from Murud–Janjira coast. We now report hitherto unknown clinopyroxenite xenoliths from Kutch and Powai. The Kutch xenoliths are accidental and the Powai xenoliths are cognate. The Kutch clinopyroxenite xenoliths appear to have been formed due to the reaction between the mantle, containing olivine and orthopyroxene, and carbonated alkaline magma at about 1100°C and 17 kb pressure. The Powai xenolith represents cumulates of clinopyroxenes in the magma chamber which were picked up and brought up by a subsequent eruption.

IN the vast Deccan flood basalt province of India, mantle xenoliths are quite rare. However, a few occurrences of mantle xenoliths are known in the province[1–5]. The xenoliths in alkali olivine basalts from Kutch, Gujarat comprise dunites, spinel peridotites[4] and spinel lherzolites[3]. Xenoliths of clinopyroxenites (with minor olivine) are found in the lamprophyre dykes of Murud–Janjira along the western coast of India[1,5]. We report here, two hitherto unknown types of xenoliths, namely clinopyroxenite xenoliths from the alkali olivine basalts of Dhrubiya and Nana, Kutch (Figure 1 *a*) and also from the tholeiitic basalts of Powai, Mumbai (henceforth termed as 'campus xenoliths'; Figure 1 *b*) and discuss in detail their petrographic characteristics.

The alkali olivine basalts of Kutch containing the xenoliths have been dated at about 64 Ma (ref. 4). The

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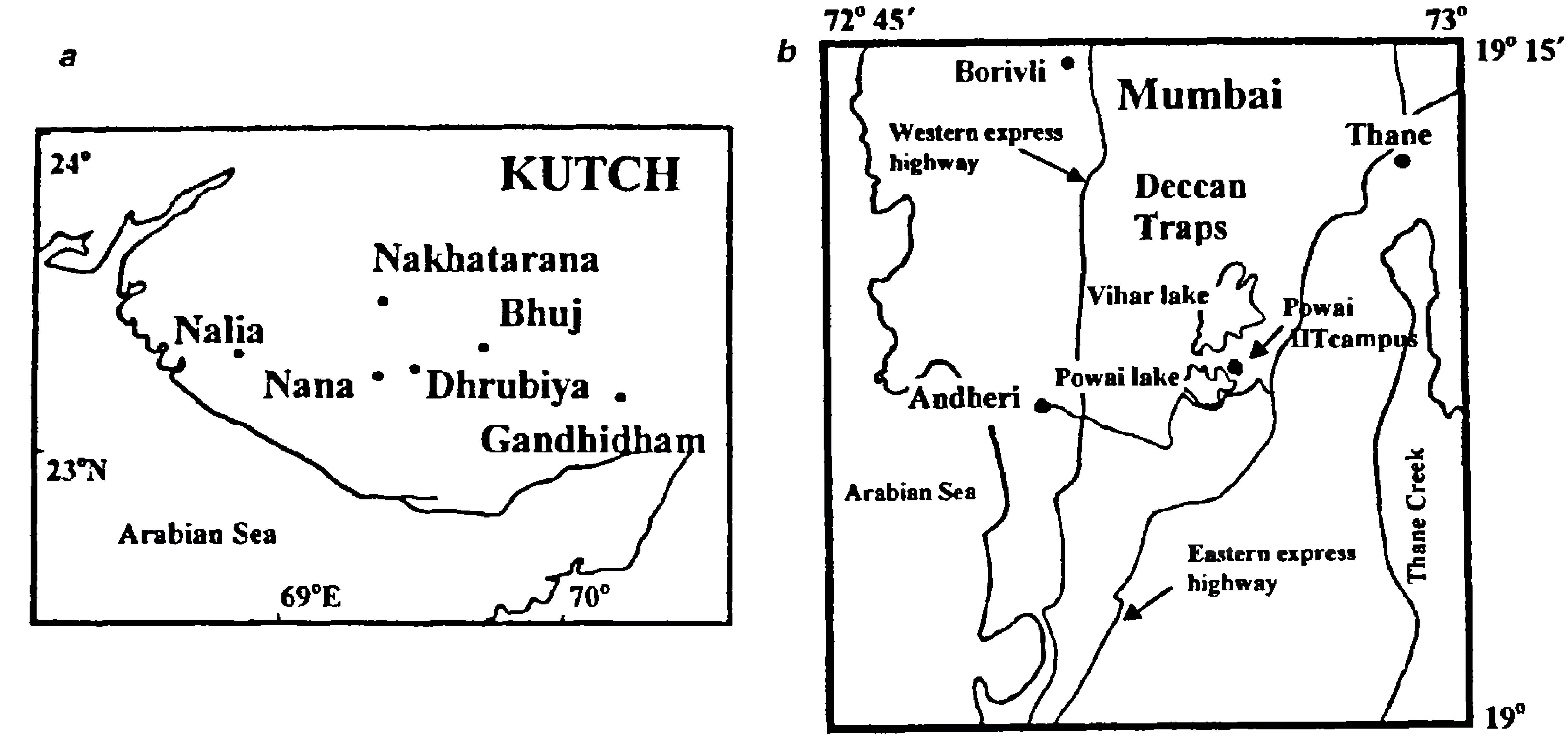

Figure 1. Map showing the occurrence of clinopyroxenite xenoliths in Kutch (*a*) and in Powai (*b*). Deccan flood basalt province.

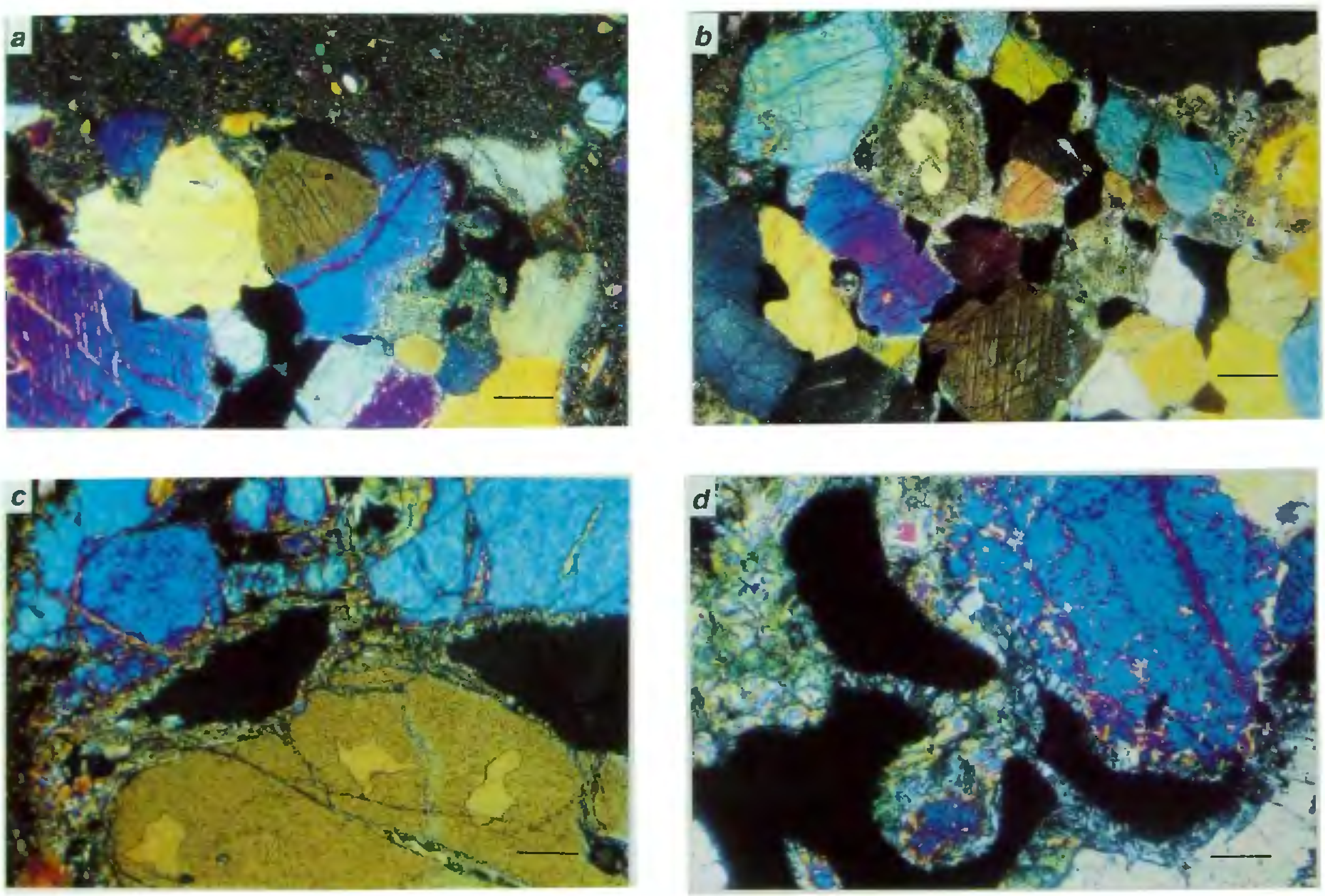

Figure 2. Photomicrographs of clinopyroxenite xenoliths from Kutch. Scale is shown as bar (= 0.15 mm) in the photographs. *a*, Fine-grained alkali olivine basalt enclosing clinopyroxenite xenolith. Small euhedral olivine grains are seen in the groundmass; *b*, Clinopyroxenes showing spongy border and enclosing exsolution lamellae; *c*, Pyrometamorphic texture around pyroxenes and spinels; *d*, Pyrometamorphic texture and reaction rims around clinopyroxenes enclosing tiny plagioclase laths and pyroxene grains. Spinels are seen as curvilinear bodies.

clinopyroxenite xenoliths occurring at Dhrubiya (lat. 23°8′N; long. 69°30′E) and Nana (lat. 23°17′N; long. 69°22′E) in Kutch, are rectangular in shape and vary in size from 1 × 0.5 cm to 0.5 × 0.3 cm.

The most common and easily identified texture in peridotite and pyroxenite xenoliths is the pyrometamorphic texture developed due to local partial melting of the xenoliths[7,8]. Pyroxene grains develop spongy border zones at the beginning of melting. Clinopyroxene, due to partial melting produces plagioclase, augite and spinel. The Dhrubiya clinopyroxenite xenoliths (Figure 2 *a*) show pyrometamorphic texture characterized by the spongy appearance of pyroxene grains due to the solidification of partial melts (Figure 2 *b*). These melted portions of the pyroxene grains exhibit reaction rims enclosing tiny plagioclase laths and clinopyroxene grains (Figure 2 *c*). The large, curvilinear spinel formed due to partial melts, occupies the clinopyroxene grain boundaries (Figure 2 *c* and *d*). Further, stray grains of clinopyroxene xenocrysts exhibiting pyrometamorphic texture and exsolution lamellae are also present in the host basalt. The $2V_z$ and $Z\wedge c$ of the clinopyroxenes vary between 58–62° and 40–43°, respectively, designating them as diopsides.

The host alkali olivine basalts at Dhrubiya and Nana are holocrystalline, microphyric and contain plagioclases, clinopyroxenes and opaques. Two varieties of euhedral olivine phenocrysts with a maximum size of 1 mm also occur within these basalts. The first type has a sharp grain boundary and encloses minute opaques (Figure 3 *a*) while the second type shows reaction borders, encloses innumerable opaque, fluid and melt inclusions, and is zoned and twinned (Figure 3 *b*). The $2V_z$ of the first type varies from 88 to 90°, indicating their Fo content to be between 85 and 89%, while the $2V_z$ of the second type varies from 83 to 85°, indicating their Fo content to be greater than 90%. We consider the second type to be xenocrysts. Analcite often occurs as patches enclosing clusters of apatite needles.

Occurrence of basaltic xenoliths in the rhyodacites/ trachytes of Mumbai island has been reported earlier[9,10].

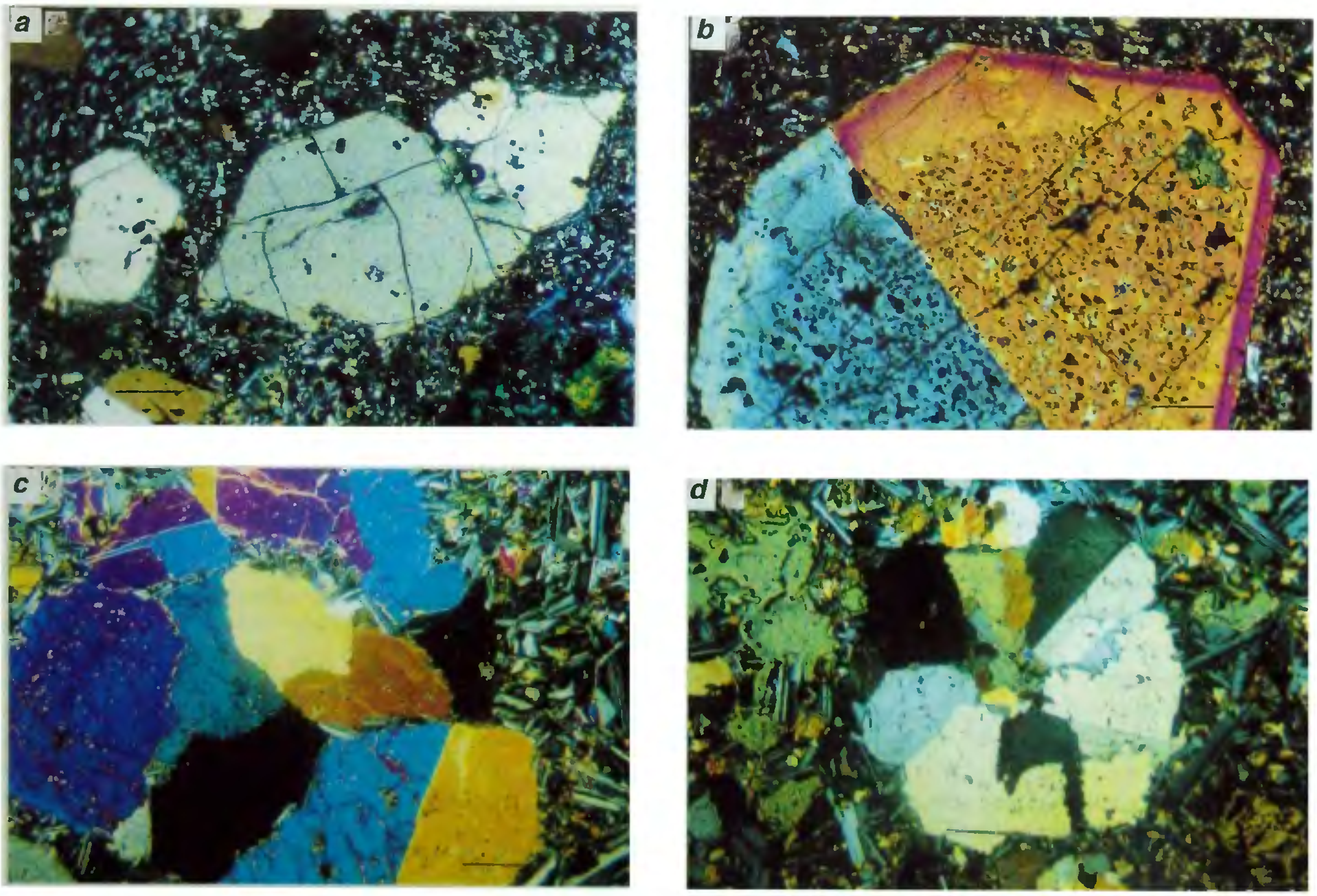

Figure 3. Photomicrographs of clinopyroxenite xenoliths from Kutch (*a, b*), and Powai (*c, d*). Scale is shown as bar (= 0.15 mm) in the photographs. ***a***, Euhedral olivine phenocryst in alkali olivine basalt of Kutch; ***b***, Euhedral zoned olivine xenocryst from Kutch, exhibiting simple twinning on (100). Note innumerable fluid and melt inclusions in the grain; ***c***, Polygonal campus xenolith showing sharp contact with the host aphyric basalt. The dark patches are clinopyroxenes in extinction position. Note the absence of pyrometamorphic texture around the clinopyroxenes; ***d***, Nodular-shaped campus xenolith with radiating sheaths of twinned clinopyroxenes. Dark patches are clinopyroxenes in extinction position. Note the opaques arranged in concentric circles, within the pyroxene grains in *c* and *d*.

However, a large number of circular patches of clinopyroxenite xenoliths varying in size from < 1 mm to 5 mm in a tholeiitic basalt flow are now reported from Mumbai. These 'campus xenoliths' occur in a basalt flow seen within the campus premises of the Indian Institute of Technology (IIT), Powai (lat. 19°8′N; long. 72°56′E; Figure 1 *b*). These xenoliths comprise clinopyroxenites with polygonal, rounded or nodular outlines (Figure 3 *c* and *d*). Pyrometamorphic texture, which is conspicuous in Kutch xenoliths, is not observed in the campus xenoliths where their contact with the host basalt is sharper. In some cases the pyroxenes are arranged in a radiating pattern (Figure 3 *d*). Innumerable minute opaque inclusions, arranged in concentric circles, are seen in the pyroxene grains (Figure 3 *d*). Spinels, which are very conspicuous in Kutch xenoliths, are totally absent in the campus xenoliths. Twinning is quite common in the pyroxenes of these xenoliths (Figure 3 *c* and *d*) but absent in those of Kutch. The $2V_z$ and $Z \wedge c$ of the clinopyroxenes vary between 32–60° and 38–40°, respectively, which correspond to augites and ferroaugites. Though kink bands have been reported in several xenoliths[1,11,12], such bands are not observed in either the Kutch or the campus xenoliths.

The basalt flow hosting the campus xenoliths is medium-grained, holocrystalline, aphyric, subophitic and contains plagioclase laths, pyroxenes and opaques. Olivine occurs occasionally as subhedral grains and is altered to iddingsite. Thus based on the texture and mineralogy, it is apparent that the Kutch xenoliths are accidental while the campus xenoliths are cognate.

The occurrence of three compositionally different types of xenoliths (spinel peridotites, spinel lherzolites and clinopyroxenites) implies that either the mantle below Kutch is zoned or layered and contains these types of rocks which were picked up by the alkali olivine basalt extrusive or the clinopyroxenites are the products of reaction between peridotite (olivine and orthopyroxene) and carbonated alkaline magma at temperatures between 1050 and 1100°C and 17 kb pressure[13]. Considering the proximity of the xenolith-bearing flows to the carbonatite province of Gujarat, it is quite likely that the Kutch clinopyroxenite xenoliths got formed due to the later process. The campus xenoliths, on the contrary, seem to represent cumulates of clinopyroxenes in the magma chamber which were picked up and brought up by a post-pyroxenite pulse of eruption. Detailed investigation on the mineral chemistry and whole rock isotope geochemistry of the Kutch and campus xenoliths is presently going on in order to decipher their petrogenesis.

1. Dessai, A. G., *J. Geol. Soc. India*, 1987, **30**, 61–71.
2. De, A., Report of the 22nd Session of International Geological Congress, 1964, pp. 126–138.
3. Karmalkar, N. R., Duraiswami, R. A., Griffin, W. L. and O'Reilly, S. Y., *Curr. Sci.*, 1999, **76**, 687–692.
4. Krishnamurthy, P., Pande, K., Gopalan, K. and Macdougall, J. I *Geol. Soc. India, Mem. 10*, 1988, 53–67.
5. Dessai, A. G., Knight, K. and Vaselli, O., *J. Geol. Soc. Ind.* 1999, **54**, 585–598.
6. Pande, K., Venkatesan, T. R., Gopalan, K., Krishnamurthy, P. a Macdougall, J. D., *Geol. Soc. India Mem. 10*, 1988, 145–150.
7. Pike, J. E. N. and Schwarzman, E. C., *J. Geol.*, 1977, **85**, 49–61.
8. Irving, A. J., *Am. J. Sci.*, 1980, **280**, 389–426.
9. Sukheswala, R. N. and Poldervaart, A., *Geol. Soc. Am. Bu* 1958, **69**, 1475–1494.
10. Sethna, S. F. and Battiwala, H. K., *Geol. Min Metall. Soc. Ind* Golden Jubilee Volume, 1974, pp. 337–346.
11. Ninomiya, A. and Arai, S., Science Report, Kanazawa Uni Japan, 1993, vol. 38, pp. 25–49.
12. Mercier, J. C. C. and Nicolas, A., *J. Petrol.*, 1975, **16**, 454–487.
13. Meen. J. K., Ayers, J. C. and Fregeau, E. J., in *Carbonati* (ed. Bell, K.). Unwin Hyman Publ., 1989, pp. 464–499.

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Cloning and characterization of the *Plasmodium falciparum* adenylosuccinate synthetase gene

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Parasitic protozoa lack the *de novo* purine biosynthet pathway and rely exclusively on the salvage pathwa for their purine nucleotide requirements[1]. Purine sa vage enzymes are therefore potential chemotherape tic targets. This paper reports the cloning and deduce amino acid sequence of *Plasmodium falciparu* adenylosuccinate synthetase (PfADSS), an enzyn involved in purine salvage. PfADSS exhibits 67 homology with that of the human enzyme. On expr ssion in *E. coli*, enzymatically active ADSS was pr duced as deduced by functional complementatic analysis. The PfADSS activity was shown to be inh bited by hadacidin, a known competitive inhibitor this enzyme.

ALMOST all protozoan parasites lack the biosynthet machinery required for the *de novo* synthesis of purines

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Nucleotide sequence reported in this paper is available in the Ge Bank™ data base under the accession number AF095282.