of Landsat) of high (fine) resolution satellite, absence of thermal infrared sensor on IRS-series of satellites and non-availability of cloud-free images. TM thermal infrared data of 06.12.92, 24.02.93 and 31.05.93 have not revealed any thermal anomaly in the area, and the temperature variation observed in different periods was due to seasonal effect and changes in land use pattern. The study carried out in Central Asian Seismoactive region, Iran, Egypt, etc. using the National Oceanic and Atmospheric Administration (NOAA)-series satellite thermal images (10,000 numbers over a span of ten years) revealed positive infrared (IR) anomalies of few degree centigrade over large scale faults, and statistically significant correlation between the activity of IR anomalies and the seismic activity[16].

This study highlights the potential of satellite data for identifying thermal anomalies which may be used as precursors to earthquake. However, more intensive studies have to be carried out in other seismically active areas for establishing a relation between the appearance of the thermal anomalies and impending earthquakes.

1. Yamashita, T. and Ohnaka, M., *Tectonophysics*, 1992, **211**, 179–199.
2. Kozlov, V. I. *et al.*, pers. commun., 1996.
3. Ma Zongjin *et al.*, *Earthquake Prediction*, Seismological Press, Beijing and Springer Verlag, Berlin, 1990, 176–185.
4. Veber, K., Proceedings of 27th International Geological Congress, Moscow, 1984, Section C18, 18, 1681–1687.
5. Das, J. D. *et al.*, *Int. J. Remote Sensing*, 1996, **17**, 1433–1437.
6. Reddy, P. R. *et al.*, *GSI Spl. Publn.*, 1995, **27**, 199–204.
7. Gold, T. and Soter, S., *PAGEOPH*, 1984, **122**, 492–530.
8. Rastogi, B. K. and Rao, M. N., *Latur Earthquake*, Geol. Soc. India Publn., 1994, 139–149.
9. Scholz, C. H. *et al.*, *Science*, 1973, **181**, 803–810.
10. Sibson, R. H. *et al.*, *J. Geol. Soc. London*, 1975, **131**, 653–659.
11. Chandrasekharam, D., *GSI Spl. Publn.*, 1995, **27**, 229–233.
12. Gupta, H. K. *et al.*, *GSI Spl. Publn.*, 1995, **27**, 17–40.
13. Karve, A. K., *GSI Spl. Publn.*, 1995, **27**, 235–242.
14. Rao, B. S. *et al.*, *GSI Spl. Publn.*, 1995, **27**, 259–261.
15. Tilak, N. B. G. *et al.*, *GSI Spl. Publn.*, 1995, **27**, 251–258.
16. Tronin, A. A., *Int. J. Remote Sensing*, 1996, **17**, 1439–1455.

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Fission track dating of obsidian artefacts from Columbia

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The fission track technique is useful for dating young obsidian artefacts owing to their high uranium content. It is being used for obsidian source identification and provenance studies. Fission track age of Columbian obsidian from an archaeological site, Rio Hondo near Popayan, is found to be 3.83 Ma.

THE fission track technique is found to be most suitable for dating natural glasses[1–10], namely, obsidians and tektites owing to their high uranium content despite certain limitations. Volcanic glasses commonly present two particular problems to fission trackologists: they have microlites and gas bubbles which, after etching, are easily confused with fission tracks. Another limitation is the thermal heating of obsidian artefacts, which results in track fading, thus yielding reduced fission track ages of source material. Obsidian artefacts from archaeological sites around the world are dated for their source identification. The purpose of this study is to determine the fission track age of obsidian artefacts discovered at Rio Hondo, near Popayan in Columbia. The samples were analysed by coupling of PIXE and fission trace dating for trace element analysis and source identification at Grenoble[11]. Identifying the source of obsidians often directly provides evidence of pre-historic human activity, trade routes and cultural communication that took place between the archaeological site and the obsidian source area[12].

Experimental technique used for preparation, etching, irradiation and counting of obsidian samples is the standard one described elsewhere[9–10]. The obsidian artefact samples were broken, polished and etched in 6% HF for 8 min at room temperature to develop the fossil tracks. The counting of fossil tracks is a tedious job and the first two authors performed their independent counting after polishing and etching a freshly cleaved surface. The individual counting differs by as much as 10% which is also the range of statistical counting error. The samples were annealed in a furnace at 500°C for 1 h to remove fossil tracks before irradiation in CIRUS reactor at BARC, Trombay. Both the annealed obsidian samples and a standard glass wafer (NBS-SRM 962, U content 37.38 ± 0.08 ppm) were irradiated simultaneously in a thermal neutron fluence of 10^{15} n/cm^2. Irradiated samples were etched under identical conditions as used for original batch samples for fossil tracks. The track density for both fossil and induced tracks was determined using a calibrated graticule in the Carl Zeiss binocular

Table 1. Fission track ages of Rio Hondo obsidians from Columbia (Thermal neutron fluence $F = 3.512 \times 10^{15}$ n/cm^2)

Sample	Track density (per cm$^2 \times 10^4$)		Fission track age (Ma) $\pm 1\sigma$
	ρ_s (n_s)	ρ_i (n_i)	
RH-1	0.573 (85)	31.25 (821)	3.87 ± 0.42
RH-2	0.559 (79)	30.87 (736)	3.82 ± 0.42
RH-3	0.587 (90)	32.69 (756)	3.79 ± 0.40

Mean fission track age = 3.83 ± 0.42 Ma (Figures in parentheses show the number of tracks counted).

microscope. The track density in the standard glass dosimeter was used to estimate the neutron fluence.

Fission track ages are calculated using the simplified version of age equation[13]

$$T = \frac{\rho_s \sigma \, IF}{\rho_i \lambda_f}, \tag{1}$$

which reduces, on substitution of values of σ (582×10^{-24} cm^2), I(7.26×10^{-3}) and λ_f (7.03×10^{-17} yr^{-1})[14], to

$$T = 6.01 \times 10^{-8} \frac{\rho_s}{\rho_i} F, \tag{2}$$

where ρ_s and ρ_i denote recorded fossil and induced track densities respectively and F, thermal neutron fluence during irradiation.

Fission track ages of obsidian artefacts from Rio Hondo archaeological site near Popayan in Columbia are listed in Table 1. The statistical counting error, 1σ, calculated on the basis of fossil track counts is also given. The mean fission track age value of 3.83 Ma agrees well with the source age 3.70 Ma determined for this site[11]. It is obvious that the fission track technique combined with PIXE can prove useful for source identification and provenance studies of obsidian artefacts.

1. Fleischer, R. L. and Price, P. B., *Geochim. Cosmochim. Acta*, 1964, **28**, 755–760.
2. Fleischer, R. L., Price, P. B. and Walker, R. M., *Nuclear Tracks in Solids: Principles and Applications*, University of California Press, Berkeley, 1975.
3. Durrani, S. A., Khan, H. A., Taj, M. and Renfrew, C., *Nature*, 1971, **233**, 242–245.
4. Bigazzi, G. and Bonadonna, F., *Nature*, 1973, **242**, 322–323.
5. Storzer, D. and Poupeau, G., *C. R. Acad. Sci. Paris*, 1973, **276**, 137–139.
6. Miller, D. S. and Wagner, G. A., *Nucl. Tracks*, 1981, **5**, 147–155.
7. Yegingil, Z. and Goksu, Y., *Nucl. Tracks*, 1982, **6**, 43–48.
8. Virk, H. S., *Mineral. J. (Japan)*, 1986, **13**, 34–38.
9. Virk, H. S., Singh, G. and Kaur, S., *Nucl. Tracks Radiat. Meas.*, 1988, **15**, 719–722.
10. Virk, H. S., *Curr. Sci.*, 1977, **46**, 583–585.
11. Bellot-Gurlet, L., Calligaro, T., Dorighel, O., Dran, J-C., Poupeau, G. and Salomon, J., *Int. Assoc. Obsidian Studies Bull.*, 1996, **16**, 3–7.
12. Suzuki, M. and Tomura, K., *St. Paul's Rev. (Japan)*, 1983, **4**, 99–110.
13. Virk, H. S. and Koul, S. L., *J. Phys. Earth*, 1977, **25**, 177–186.
14. Roberts, J. H., Gold, R. and Armani, R. J., *Phys. Rev.*, 1968, **174**, 1482–1484.

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Asian elephants with longer tusks have lower parasite loads

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The Hamilton and Zuk hypothesis[1] that the intensity of male ornamentation allows females to assess a male's ability to resist parasites has been much debated recently[2–12]. Much of the empirical work to test this hypothesis has been with insect[2], fish[3,4], reptilian[5] or avian[6–9] hosts. In a southern Indian population, we show that the length of tusks of male Asian elephants (*Elephas maximus*), corrected for differences due to age, is significantly negatively correlated with intestinal parasite loads. The less aggregated distribution of parasites in this elephant population, as compared to other mammalian species, indicates that ivory poaching may have already selectively removed a significant proportion of parasite-resistant individuals. Ivory poaching which targets larger-tusked elephants may thus affect the health status of the population.

FREELAND[13] suggested that mate choice by females may be related to parasites and pathogens carried by males. Hamilton and Zuk[1] further developed the hypothesis that host-parasite coevolutionary cycles might drive the evolution of female preferences for extreme male displays. Males carrying genes for resistance to parasites will be healthier and in a better condition to develop expensive secondary sexual characters. By preferring such males, a female ensures 'good genes' for her offspring. Unlike other 'good gene' hypotheses, however, the resistance genes will be constantly changing since the parasites are also evolving, and thus the system remains dynamic maintaining the importance of female choice.