

directed mutagenesis. Moreover, having the array of subunits will permit pharmacologists to develop drugs that modify the operation of specific subunit combinations, and this is the key both for unravelling the role of NMDA receptors in normal brain function and in disease, and also as a basis for developing useful drugs.

These races have gripped the attention of the neurobiological community. Now the longer process of using the clones to work out mechanisms, a process already

well under way for the non-NMDA receptors, can begin for the NMDA receptor subfamily. □

Charles F. Stevens is at the Salk Institute, La Jolla, California 92037, USA.

- Hollmann, M., O'Shea-Greenfield, A., Rogers, S. W. & Heinemann, S. *Nature* **342**, 643–648 (1989).
- Moriyoshi, K. *et al.* *Nature* **354**, 31–37 (1991).
- Monyer, H. *et al.* *Science* **256**, 1217–1221 (1992).
- Meguro, H. *et al.* *Nature* **357**, 70–74 (1992).
- Kutsuwada, T. *et al.* *Nature* **358**, 36–41 (1992).
- Chen, L. & Huang, L.-Y. M. *Nature* **356**, 521–523 (1992).

ARCHAEOLOGY

Under the skin of Nazca

Warwick Bray

WHY the Nazca lines were constructed remains a matter of conjecture^{1,2}. But the age of the lines has now been established more precisely by the application of a new technique^{3,4}, the upshot of a collaboration between an archaeologist (Persis Clarkson) and a geomorphologist (Ronald Dorn).

The Nazca lines, of south coastal Peru, are one of the world's largest and most spectacular archaeological monuments. Hundreds of square kilometres of the desert surface are covered with a palimpsest of immense geoglyphs, or ground-drawings, made by sweeping aside the dark, patinated stones to expose the lighter soil beneath. Designs include animals (quadrupeds, birds, spiders, killer whales) as well as spirals, triangles and trapezoids, spoke-like arrangements and straight lines several kilometres long.

Previous attempts to date the lines have given inconclusive results. It has long been realized that the animal designs can be matched with the painted motifs on Nazca pottery dating to about 200 BC – AD 600. But the linear and geometric ground-drawings offer no such stylistic clues and, as surface features, they have no stratigraphic context. Remains of wooden posts at the intersections of two different sets of lines have given (uncalibrated) radiocarbon dates of AD 525 ± 80 and 490 ± 80, but attempts to date the geoglyphs by means of the ancient pot sherds found on the cleared surfaces have produced contradictory information. Two investigations concluded that most of the pottery, though not all of it, belonged between 200 BC and AD 400; a third found evidence that the trapezoids, at least, may be much more recent (AD 600–1476)⁵.

All of these approaches are indirect and unsatisfactory. The posts could have

been reused or reset; the pottery fragments, assuming they have not been disturbed by later visitors, provide limiting dates but not the actual date of construction. What was needed was a method for dating the lines themselves. This is what Dorn's team has provided, by introducing a technique for determining the age of the rock varnish on stones disturbed by the building of the lines.

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

Condor-like figure on Pampa de San José, Peru.

Rock varnish is a dark coating, made up of clay minerals and manganese and iron oxides, that builds up on stone in dryland environments. Electron microscopy revealed that organic matter (lichens, cyanobacteria, fungi) adhering to the surfaces of the rock may become trapped beneath the varnish accretion, which begins to form whenever a fresh surface is exposed to the elements. Organic detritus of this kind sometimes occurs in quantities sufficient for accelerator mass spectrometry radiocarbon dating. Nine samples were taken from stones removed by the line-builders. After correction for tree-ring calibration, the carbon-14 dates ranged from about 190 BC to AD 600, an excellent fit with the 'traditional' dating for the geoglyphs. These carbon-14 determinations are minimum ages, however,

because the organic matter must be older (though probably not much older) than the varnish which covers it.

The same technique was applied to another long-standing problem of Nazca archaeology, the date of the filtration-galleries, or *puquios*. These are underground tunnels, analogous to the qanats of the Near East, which were cut into hillsides to tap subterranean aquifers for irrigation purposes. In the Old World qanats first appear in Assyrian times (8th century BC) in Iraq, and spread to the Mediterranean with the Roman and Arab conquests. There is sound historical evidence to show that the Spanish conquistadors transferred the technology to both Peru and Mexico⁶. The mass of documentary information from colonial Peru contradicts the popular belief that the filtration-galleries of the Nazca region are of pre-Spanish age and were linked with a group of settlements contemporary with the ground-drawings. At this stage, discussion had reached a stalemate — none of the colonial documents refers specifically to the Nazca galleries, and the archaeological case is at best circumstantial.

The matter has been partially resolved with the dating by Dorn and colleagues of the varnish on stone lintels from two of the Nazca *puquios*. They obtained calibrated ages of AD 552–644 and 591–698 (error margin 1 sigma). If these figures are confirmed with further samples, some of the Peruvian galleries, through clearly not all of them, must be precolumbian, and Peruvian Indians must be credited with an early and independent invention of qanat technology. For reasons unknown, the filtration-galleries of Nazca (like the drained fields of the Andes⁷) had already fallen into disuse by the time of the Inca expansion, and are not mentioned by the first European chronicles. As so often happens, the archaeologists seem to have found the answer to one question but created another. □

Warwick Bray is at the Institute of Archaeology, University College London, 31–34 Gordon Square, London WC1H 0PY, UK.

- Morrison, T. *Pathways to the Gods: The Mystery of the Andes Lines* (Michael Russell, Salisbury, 1978).
- Aveni, A. F. (ed.) *The Lines of Nazca* Mem. Am. Phil. Soc. Vol. 183 (American Philosophical Society, Philadelphia, 1990).
- Clarkson, P. B. & Dorn, R. I. *Boletín de Lima* **13**, 33–45 (1991).
- Dorn, R. I., Clarkson, P. B., Nobbs, M. F., Loendorf, L. L. & Whitley, D. S. *Ann. Ass. Am. Geogr.* **82**, 136–151 (1992).
- Silverman, H. & Browne, D. *Antiquity* **65**, 208–220 (1991).
- Barres, M. & Fleming, D. *Latin American Antiquity* **2**, 48–68 (1991).
- Bray, W. *Nature* **345**, 385 (1990).