time variations in the structure of both quasars; in terms of the two-point-source model, the separation of the components of 3C 279 appears to have increased by about 10 percent in 4 months.

CURTIS A. KNIGHT
DOUGLAS S. ROBERTSON
ALAN E. E. ROGERS
IRWIN I. SHAPIRO, ALAN R. WHITNEY
Massachusetts Institute of Technology, Cambridge 02139
THOMAS A. CLARK
Goddard Space Flight Center, Greenbelt, Maryland 20771
RICHARD M. GOLDSTEIN
Jet Propulsion Laboratory, California Institute of Technology, Pasadena 91103
GERARD E. MARANDINO
NANCY R. VANDENBERG
University of Maryland, College Park 20740

References and Notes

1. Results from this aspect of the experiment will be published separately.
2. See, for example, B. G. Clark, K. I. Kellermann, C. C. Bare, M. H. Cohen, D. L. Jauncey, *Astrophys. J.* **153**, 705 (1968).
3. J. D. Kraus, *Radio Astronomy* (McGraw-Hill, New York, 1966), and references cited therein.
4. These numbers are based on an assumed spacing of ½ fringe between the two components at the times of the nulls of the fringe-amplitude curve. An assumed spacing of 1½ fringes yields somewhat poorer agreement with the observations. In either case, the resultant spacings do not reflect certain small corrections which are still under investigation, but which will not affect our conclusions.
5. Total fluxes of about 13 flux units have been reported at 3.75 cm by I. I. K. Pauliny-Toth and K. I. Kellermann [*Astrophys. J.* **146**, 634 (1966)]. A more recent discussion of flux measurements in this wavelength region is given by H. D. Aller [*Astrophys. J.* **161**, 114 (1970)]. Since 1966, observations at 1.55 cm have indicated a general increase in the emission from about 15 to 17 flux units with "outbursts" occurring sporadically [T. P. McCullough and J. A. Waak, *Astrophys. J.* **158**, 849 (1969)]; these latter "outbursts" may be associated with the small components to which our measurements are sensitive. Our two "point" sources may also be related to the quasar 3C 279C and 3C 279D sources reported for observations at a wavelength of 6 cm over a baseline, in wavelengths, approximately equal to ours [K. I. Kellermann *et al.*, *Astrophys. J.* **153**, L209 (1968)]. J. J. Broderick *et al.* [*Sov. Astron. AJ* **14**, 627 (1971)] note also that their 6-cm VLBI observations between Green Bank, West Virginia, and the Crimea show a complex structure for quasar 3C 279 with about 4 to 5 flux units belonging to an unresolved component less than 0.6×10^{-3} arc sec in extent.
6. C. R. Lynds, A. N. Stockton, W. C. Livingston, *Astrophys. J.* **142**, 1667 (1965); E. M. Burbidge and F. D. Rosenberg, *ibid.*, p. 1673.
7. Explosion and ejection models of quasars are fairly numerous; see, for examples, S. A. Colgate, *Astrophys. J.* **150**, 163 (1967); P. A. Sturrock, *Nature* **211**, 697 (1966); D. M. Mills and P. A. Sturrock, *Astrophys. Lett.* **5**, 105 (1970); M. J. Rees, *Mon. Notic. Roy. Astron. Soc.* **135**, 345 (1967).
8. Note that for $\beta^2 < 0.5$, v_a is a maximum for $\theta = \pi/2$. For $\beta^2 \geq 0.5$, v_a is a maximum for
$$\sin^2\theta = (1 - \beta^2)/\beta^2$$
whence
$$v_a = c/(1-\beta^2)^{1/2}$$
A discussion of corresponding formulas for the appearance of uniformly expanding shells was given by M. J. Rees [*Nature* **211**, 468 (1966)].
9. See, for example, G. L. Berge, *Radio Sci.* **69D**, 1552 (1965).
10. Coordinates were obtained from J. Kristian and A. Sandage [*Astrophys. J.* **162**, 391 (1970)]. See also: C. M. Wade, *ibid.*, p. 381; A. Sandage, J. Kristian, C. M. Wade, *ibid.*, p. 399.
11. We thank B. F. Burke, H. T. Howard, H. F. Hinteregger, G. Purcell, T. Sato, L. Skjerve, D. Spitzmesser, R. Sydnor, and the staffs of the Goldstone and Haystack facilities for vital assistance in the engineering and technical aspects of the experiment, and the Mathematics and Computing Branch of the Space and Earth Sciences Directorate and the Manned Space Flight Network Data Evaluation Branch of the Goddard Space Flight Center for support. We also thank D. L. Jauncey of the Arecibo Observatory and W. E. Howard III of the National Radio Astronomy Observatory for the use of their Mark I VLBI recording systems, the staff of the Pioneer Project of the Ames Research Center for cooperation in scheduling, and R. Vessot and M. Levine for assistance in the use of the Smithsonian Astrophysical Observatory's hydrogen-maser frequency standard which provided an independent check on the performance of Haystack's maser standard. The M.I.T. Haystack Observatory and the M.I.T. experimenters are supported in part by grants from the National Science Foundation; the Jet Propulsion Laboratory is sustained under NASA contract NAS 7-100.

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An Early Center of Bovine Husbandry in Southeast Asia

Abstract. *Non Nok Tha is a prehistoric site in northeast Thailand. The radiocarbon dates suggest that it was first occupied by at least 3500 B.C., and possibly as early as 5000 B.C. The deepest levels contain unexpectedly early evidence for rice cultivation and bronze casting. Multivariate and cultural analyses of the bovine bones suggest that the first inhabitants raised domesticated cattle. This is among the earliest evidence for bovine domestication known.*

The potential importance of southeast Asia as a major center of economic innovation during the prehistoric period was suggested theoretically by Sauer but has only recently been recognized archeologically (*1*). Gorman (*2*) has discovered early evidence for horticulture at Spirit Cave (in northern Thailand), and excavations at Non Nok Tha in northeast Thailand have led to the recognition of a unique and indigenous bronze-working tradition by about 3500 B.C. (*3*). This date has been obtained from a carbon sample located in a 1966 grave typologically identical to a 1968 grave containing a socketed metal tool (5370 ± 320 years old, sample GaK 1034). Moreover, Bayard has recently discovered rice-chaff temper in the earliest pottery from Non Nok Tha (*4*). Although the age of the level in question is unknown, ^{14}C dates from overlying levels suggest an antiquity of at least 3500 B.C., and possibly as much as 5000 B.C. Non Nok Tha has thus produced the earliest known evidence for rice cultivation and the earliest cast bronze implements east of the Tigris-Euphrates Valley.

The early levels of Non Nok Tha contain human burials associated with animal bones. The animal bones have been studied at the Department of Anthropology, University of Otago (*5*). The presence of articulated limb bones of bovines, suids, and canids makes it essential to ascertain their economic and generic status. This report concentrates on the bovine bones for the following reasons: (i) it was possible to collect modern, sexed comparative bone samples of water buffalo (*Bubalus bubalis*) and zebu (*Bos indicus*); and (ii) bovines were of potential economic importance as sources of meat and traction (*6*). Although domestic cattle in southeast Asia can pull light wheeled vehicles, only the water buffalo has the strength necessary to draw a plow through wet paddy fields. The intimate connection between the water buffalo and wet rice agriculture in southeast Asia is well known (*7*).

The prehistoric bovine limb bones from Non Nok Tha may belong to any of the following, either singly or in combination: *Bubalus bubalis* (water buffalo), *Bibos gaurus* (gaur), *Bos sondaicus* (banteng), *Bos indicus* (zebu), or *Bos sauveli* (kouprey). Wild or domesticated animals, or animals undergoing domestication, could be present. Sexual di- or trimorphism, as in the case of castrated animals, are further complicating factors (*8*).

There is no known modern comparative collection of either *Bos sondaicus* or *Bos sauveli*. Moreover, both species are extremely rare. Select bone dimensions from three specimens of gaur have been collected, together with the metacarpals, magna, and first fore phalanges of 38 female water buffalo and of 18 adult female zebu from Thailand, and the same bones were collected from 40 cows of Aberdeen Angus (Australian specimens) and 38 cows of Red Danish breed (Danish specimens).

The magnum and first fore phalanx

have been selected for detailed study, because of their frequent survival in an unfragmented condition, the clear morphological differences that exist between *Bubalus* and *Bos* in the former, and the marked sexual dimorphism in the latter. The ten magna available derive from layers 21 to 9 (the initial settlement to 14th century A.D.). All but one are bovine, the exception being from a water buffalo, which dated to the 14th century A.D.

The first fore phalanges have been subjected to a series of multivariate analyses to determine their degree of affinity with the available modern samples. The three dimensions employed are maximum length, maximum distal width, and maximum proximal width. All 11 specimens come from human inhumation burials, 4 of which are among the earliest in the site. In the first stage of the statistical analysis, linear discriminant functions based on the generalized Mahalanobis D_3^2 statistic were calculated for the five samples of modern specimens. A reapplication of these functions to the individual members of these modern groups demonstrated, in general, considerable group divergence. When applied to the Non Nok Tha specimens, the functions located 7 of the 11 bones into the *Bos indicus* sample, demonstrating their similarity with this group. Significances were uniformly greater than 0.5, and three were as high as 0.999. Caution should be exercised in accepting these significance levels too literally, because this method is relatively crude and because both allocation and significance are markedly affected by changes in the size of the universe under consideration (*9*). Nevertheless, with small samples this method possesses several advantages over others.

Of the four remaining bones, three are most similar to Red Danish cows, and one to Aberdeen Angus cows. Owing to a high plane of nutrition, these breeds have more robust phalanges than the zebu, and close analysis of the four specimens under consideration suggests strongly that at least three come from male animals equivalent to the females whose affinities lie with *Bos indicus*.

In terms of a canonical analysis, the Non Nok Tha group, with or without the putative male specimens, is closer to female *Bos indicus* than to any other group (Fig. 1). It could be argued on theoretical grounds that a direct application of the D^2 statistic to those data might prove the most reliable, and therefore this application was undertaken with use of the generalized form of D_3^2. This may appear to be a small number of variables, but the canonical variates were highly significant, a fact that demonstrates the discriminative power of the three metrical dimensions in question. The results show that Non Nok Tha specimens could be confused, at varying levels of significance, with all other groups (Table 1). Once again, however, the *Bos indicus* sample is the most similar. Each of the three analyses reinforces the others insofar as they all point to an extremely close morphological similarity between the phalanges of *Bos indicus* and those from Non Nok Tha.

The bovine remains from Non Nok Tha come from a bovine that is osteologically very similar to *Bos indicus*. Naturally, it does not necessarily follow that the Non Nok Tha bovines themselves were domesticated. The as-

Table 1. Values of D_3^2, F, and associated significance levels (*P.L.*) on comparing six samples of bovine phalanges. D^2, value of the Mahalanobis D^2 statistic in question; F, variance ratio obtained in order to test the significance of the value of D^2; *P.L.*, the level of probability at which F is significant. [For full explanation of these terms, see Rao (*10*).]

Samples	Statistic value	2	3	4	5	6
1. *Bubalus bubalis*	D^2	5.4	10.5	12.1	15.5	3.7
	F	20.0	27.1	69.7	89.0	20.7
	P.L.	0.025	0.025	0.005	0.005	0.025
2. *Bos indicus*	D^2		1.4	18.1	7.6	4.2
	F		3.0	72.3	30.2	16.3
	P.L.		0.25	0.005	0.025	0.025
3. Non Nok Tha	D^2			3.9	2.6	1.9
	F			10.7	7.1	5.1
	P.L.			0.1	0.1	0.25
4. Aberdeen Angus (male)	D^2				3.0	2.1
	F				19.7	13.3
	P.L.				0.025	0.1
5. Aberdeen Angus (female)	D^2					1.6
	F					10.0
	P.L.					0.1
6. Red Danish (female)						

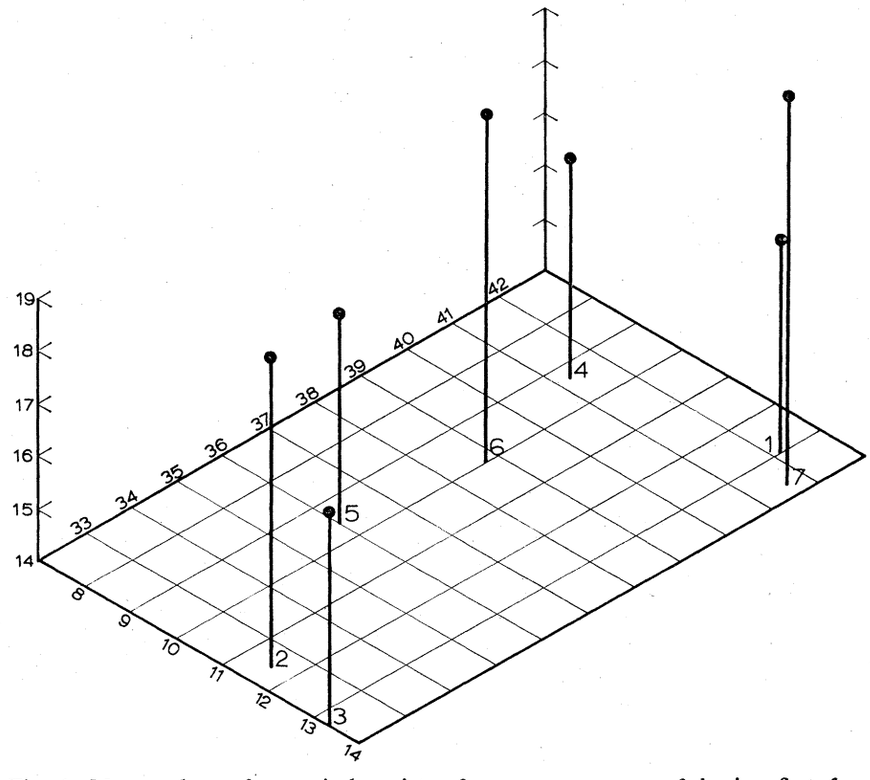

Fig. 1. Mean values of canonical variates from seven groups of bovine first fore phalanges. Group 1, *Bubalus bubalis*; group 2, *Bos indicus*; group 3, Non Nok Tha; group 4, Aberdeen Angus (male); group 5, Aberdeen Angus (female); group 6, Red Danish (female); group 7, *Bibos gaurus*.

sociation of complete, articulating limbs of young female bovines with human inhumations suggests, however, an intimate association with the cattle herd. Indeed, a combination of osteometric and cultural evidence supports the conclusion that the Non Nok Tha rice farmers possessed domestic bovines of both economic and spiritual importance.

Although the origins of a trend to bovine domestication in southeast Asia cannot be determined without further fieldwork, there can be little doubt that northeast Thailand was occupied by an innovative agricultural and herding society far earlier than previously believed. The early development of bronze technology and farming in northeast Thailand, unlike that in southwest Asia and Mesoamerica, appears to have been followed by a period of cultural conservatism lasting at least two and possibly four millennia until the adoption of iron, the domestic water buffalo, and wet rice farming probably during the first millennium A.D.

C. F. W. HIGHAM
B. F. LEACH
Anthropology Department, University of Otago, Dunedin, New Zealand

References and Notes

1. C. Sauer, *Agricultural Origins and Dispersals*, (American Geographical Society, New York, 1952).
2. C. F. Gorman, *Science* **163**, 671 (1969).
3. W. Solheim, R. H. Parker, D. Bayard, "Preliminary Reports on Excavations at Ban Nadi, Ban Sao Lao, Pimai No. 1, Honolulu" (Social Science Research Institute, University of Hawaii, Honolulu, 19(→ W. Solheim, II, *Curr. Anthropol.* **9**, 59 (1968). Ten additional radiocarbon samples have been dated from the 1968 excavations [see (*4*)].
4. D. Bayard, *Asian Perspect.*, in press.
5. C. Higham and M. Jurisich, "The Faunal Remains from Non Nok Tha, Changwat Khon Kaen, Thailand," in preparation.
6. C. Higham and R. H. Parker, "Prehistoric Investigations in Northeast Thailand, 1969–70" (Anthropology Department, University of Otago, New Zealand, 1970).
→ I. Adams, *Amer. Anthropol.* **50**, 256 (1948); R. Pendleton, *Thailand: Aspects of Landscape and Life* (Duell, Sloan & Pearce, New York, 1962).
8. C. Higham, *J. Zool. Soc. London* **157**, 63 (1969).
9. C. R. Rao, *Advanced Statistical Methods in Biometric Research* (Wiley, New York, 1952).
10. ———, *Linear Statistical Inference and Its Applications* (Wiley, New York, 1965).
11. We thank W. G. Solheim, II, for permitting us to analyze the prehistoric material and for his encouragement and advice; D. Bayard and R. H. Parker (University of Otago), who criticized this report during its preparation; and Khun Noom Yoonaidham (Thai Fine Arts Department) and Khun Chin You-di (Thai National Museum), who made possible the research work in Thailand. Supported by the New Zealand University Grants Committee, the Wenner Gren Foundation, and NSF grant GS 1877.

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Conductance Changes Produced by Acetylcholine in Lipidic Membranes Containing a Proteolipid from Electrophorus

Abstract. *Ultrathin lipidic membranes containing one ten-thousandth of a special proteolipid from electric organ of* Electrophorus *reacted to the addition of acetylcholine by a rapid and transient increase in conductance. Such a change was not induced by choline and is greatly reduced by a previous application of* d-*tubocurarine. These properties, resembling those from chemically excitable membranes, were not observed with another proteolipid from the same tissue.*

The mechanism of action of synaptic receptors involves (i) a molecular interaction of the transmitter with the receptor site, which is followed by (ii) a change in the postsynaptic membrane conductance resulting in the physiological response. Studies on the isolation of receptors are beset with the difficulty that only the first step may be experimentally approached. Previous studies from this laboratory have shown that special proteolipids (that is, hydrophobic lipoproteins) extracted from the nerve-ending membranes of the cerebral cortex had the property of interacting with dimethyl-*d*-tubocurarine (*1*), serotonin (*2*), and atropine (*3*); while proteolipids from electric organs of *Torpedo* and *Electrophorus* showed high affinity binding for acetylcholine and other cholinergic agents (*4*).

We now describe some experiments in which the second step—that of eliciting a response—has been explored by the use of ultrathin black artificial lipidic membranes separating two aqueous phases (*5*). Control membranes were made with a solution of chloroform, methanol, and tetradecane (1.0 : 0.8 : 0.4) containing, per milliliter, 10 mg of synthetic cholesterol (Sigma, 99 percent) and 10 mg of total phospholipds from bovine cerebral cortex. After extraction (*6*) the phospholipids were evaporated several times, to precipitate the contaminating proteolipids, and then they were purified through a column of silicic acid. Experimental membranes were made as indicated, but with addition of proteolipids from *Electrophorus* in a proportion of protein to phospholipids of 1 : 10,000. The proteolipids were extracted and purified as described (*4*). Two proteolipid peaks separated by column chromatography on Sephadex LH-20 from a total lipid extract of the electric organ were used. Peak 1 has no binding capacity for acetylcholine and peak 3, the so-called "receptor" peak, is the one that binds the cholinergic agents (*4*). The membranes were made across a hole 1 mm in diameter in a Teflon septum separating two chambers containing 100 m*M* NaCl and 50 m*M* tris(hydroxymethyl)aminomethane (*p*H 7).

The instrumental arrangement was similar to that of Ehrenstein *et al.* (*7*). A potential difference across the membrane was maintained constant by a voltage source, and it was measured via calomel electrodes with a Keithley d-c voltmeter 200B. The current was determined with a Keithley 150A microammeter and recorded with a Heat EUW servo-recorder. In most cases the drugs were added in 50-μl portions, by means of a fine polyethylene tube ending at 2 mm from the positive side of the membrane.

In the control membranes (without proteolipid) the current voltage (I/V) curves showed an ohmic relation between 0 ± 100 mv, and the resistance thus calculated was $4.2 \pm 0.6 \times 10^5$ ohm cm^2 (mean $\pm$ S.E.; $n = 10$); this value is similar to that reported (*8*). When the membranes were made by adding to the original mixtures proteolipids from peak 1 or 3, the resistance became nonlinear in the voltage range mentioned, and their values were about ten times smaller. At 100 mv the mean value was $5.0 \pm 0.9 \times 10^4$ ohm cm^2 ($n = 12$).

The injection of acetylcholine ($10^{-2}M$ in the pipette) upon the membrane containing the proteolipid of peak 3 produces a rapid five- to tenfold increase in d-c current intensity, which is of a transient nature (Fig. 1A). This result was obtained on 20 different membranes and in some cases it was elicited with only 5 μl of the acetylcholine solution. Since the applied voltage is maintained constant the d-c effect reflects an increase in the conductance of the membrane. Choline applied in a similar way and concen-