tures resemble chlamydospores (asexual resting spores) produced in secondary mycelia of extant forms such as *Panus tigrinus* (Fig. 1, J and K). In the extant forms the spores are either homokaryotic or dikaryotic with simple septa.

The clamp connection, a structure which insures that sister nuclei from a conjugate division of a dikaryon become separated into daughter cells, is an integral part of the basidiomycete life cycle. Because of this special function, the clamp connection is direct evidence of the existence of a secondary stage, the dikaryotic stage, in the life cycle. Furthermore, the presence of clamp connections is now thought to be a structural characteristic confined to this class (*2*). The observation (*3*) of clamp connections in the mycelium of the ascomycete *Tuber lapiceum* is not substantiated (*4*).

Unfortunately, the fossil record has offered little specific information about the earliest occurrence and evolution of the Basidiomycetes. There are numerous reports of Mesozoic and Tertiary Basidomycetes, including one report of clamp connections preserved in wood from a Baltic amber sample (*5*). The exact age of this material has not been determined, but it is thought to range between the Late Eocene and Early Oligocene (*6*).

A recent review lists the oldest known occurrences of mycelial specimens ascribed to the Basidiomycetes (*7*). However, most specimens are poorly preserved remains from the Pennsylvanian and are of uncertain affinities. Some, such as *Excipulites* Geoppert, consist of structureless spots on various kinds of Paleozoic foliage (*8*). Others, such as *Pseudopolyporus carbonicus* Hollick (*9*) and *Dactyloporus archaeus* Herzer (*10*), although grossly resembling Basidiomycetes, lack pertinent cellular detail. Another possible basidiomycete, *Archagaricon bulbosum* Hancock & Atthey, is illustrated as a branching mycelium having intercalary swellings but lacking definitive basidiomycete features (*11*). *Polyporites bowmanni* Lindley and Hutton has been identified as a fish scale (*12*). *Teleutospora milloti* (*13*) is often cited as a rustlike basidiomycete from the Carboniferous. However, published illustrations do not convincingly demonstrate this. The best preserved rustlike material is *Anthracomyces cannallensis* Renault, which has branching mycelial strands with terminal conidia-like spheres (*14*). Poor preservation and absence of definitive structures in previously described Pennsylvanian forms makes it impossible to regard any of these as indisputable Basidiomycetes. Thus, the presence of the Basidiomycetes in the Paleozoic has remained an open question (*15*).

These fossil specimens provide the first convincing evidence of Basidiomycetes in the Paleozoic Era. The presence of clamp connections in the fossil material does not support recent suggestions that this structural feature indicates an advanced phyletic position and is of relatively recent origin among the Basidiomycetes. Apparently saprophytism arose among the Basidiomycetes much earlier than has been supposed. The presence of clamp connections and saprophytism are thought to be features of advanced Basidiomycetes (*15*). If one wished to support this supposition, the occurrence of these features in Middle Pennsylvanian time should place the origin of the Basidiomycetes considerably earlier.

ROBERT L. DENNIS
Department of Biological Sciences, University of Illinois at Chicago Circle, Chicago 60680

References and Notes

1. Pseudoclamps are identified in living hyphae by the presence of a nucleus which is trapped within the incomplete clamp connection. The structures present in the fossil specimens, although lacking nuclei, are best interpreted as pseudoclamps rather than immature normal clamp connections since production of these latter structures occurs in an extremely short time. It is highly improbable that intermediate stages of such a brief developmental process would be preserved.
2. C. Alexopoulous, *Introductory Mycology* (Wiley, New York, ed. 2, 1952), pp. 430–31.
3. O. Mattirolo, *Malpighia* **1**, 359 (1887).
4. E. Bessey, *Morphology and Taxonomy of Fungi* (Blakiston, Philadelphia, 1950), pp. 168, 307.
5. H. Conwentz, *Monographie der Baltischen Bernsteinbäume* (Engelmann, Danzig, 1890), Table 12, Figure 5.
6. J. Langenheim, *Harvard Univ. Bot. Mus. Leafl.* **20**, 225 (1964).
7. H. Banks, K. Chesters, N. Hughes, G. Johnson, L. Moore, in *The Fossil Record*, K. Chesters and N. Hughes, Eds. (Geological Society of London, London, 1967), pp. 173–180.
8. D. White, *U.S. Geol. Surv. Monogr.* **37**, 1 (1899).
9. A. Hollick, *Mycologia* **2**, 93 (1910).
10. H. Herzer, *Amer. Geologist* **12**, 289 (1893).
11. A. Hancock and T. Atthey, *Annu. Mag. Natur. Hist.* **4**, 221 (1869).
12. J. Lindley and W. Hutton, *The Fossil Flora of Great Britain* **2**, 1 (1833).
13. B. Renault, *Études des Gîtes Minéraux de la France* **4**, 80 (1896).
14. ———, *Bull. Mus. Hist. Natur.* **4**, 204 (1898).
15. D. Linder, *Mycologia* **32**, 419 (1940); G. Martin, *ibid.* **37**, 527 (1945); D. Savile, *Can. J. Bot.* **33**, 60 (1955); J. Furtado, *Persoonia (Leiden)* **4**, 125 (1966).
16. I thank D. A. Eggert, University of Illinois at Chicago Circle, for direction, and M. A. Rosinski, University of Iowa, for reading the manuscript. Supported in part by NSF grant GB-4126.

8 November 1968; revised 17 December 1968

Hoabinhian: A Pebble-Tool Complex with Early Plant Associations in Southeast Asia

Abstract. *The term "Hoabinhian" has been applied to "mesolithic" assemblages from all parts of mainland Southeast Asia. Recent excavation in north Thailand has yielded the first associated carbon-14 dates and provided evidence for the early (about 7000 B.C.) domestication of plants in Southeast Asia.*

The term "mesolithic" has been applied (*1*) to a number of prehistoric, Southeast Asian assemblages thought to be artifacts of post-Pleistocene food collectors. On mainland Southeast Asia the term "Hoabinhian" is almost synonymous with mesolithic. Until recently Hoabinhian assemblages have been ill defined and undated (*2*).

In attempting a local sequence which would bracket the transition between the Hoabinhian and early food-producing in at least one area (*3*), I located Spirit Cave (*4*), a small limestone rockshelter (20°N by 98°E) approximately 60 km north of the Thai provincial center of Mae Hongson, northwest Thailand.

The central shelter, located 600 m up the face of a limestone cliff overlooking a part of the Salween drainage system, has a floor area of approximately 25 m^2. Surface and subsurface animal disturbances were encountered. The general stratigraphic layers, however, formed distinct horizons over the total excavated area. A 1.5-meter grid was constructed over the shelter floor; 1-meter squares were excavated, with natural strata as units of vertical control. Balks (50 cm) were left in place until all squares had been excavated; they were then lifted to provide intersecting profiles across the deposit. Owing to internally complex stratigraphy and local ash lensing several squares were excavated in 8 to 12 layer units. All "excavation layers" were then correlated across the site (Fig. 1).

Five general layers are represented in the Spirit Cave deposit, and we may speak of this overall layer stratigraphy and soil horizons together. Each layer in Fig. 1 has differing soil characteristics. Layers 2 to 4 may represent one cultural group with the different soil horizons representing varying occupational patterns. The interface between layer 2 and layer 1, and layer 1 itself, both evidence a culture contact situation.

Layers 4, 3, 2a, and 2 may be

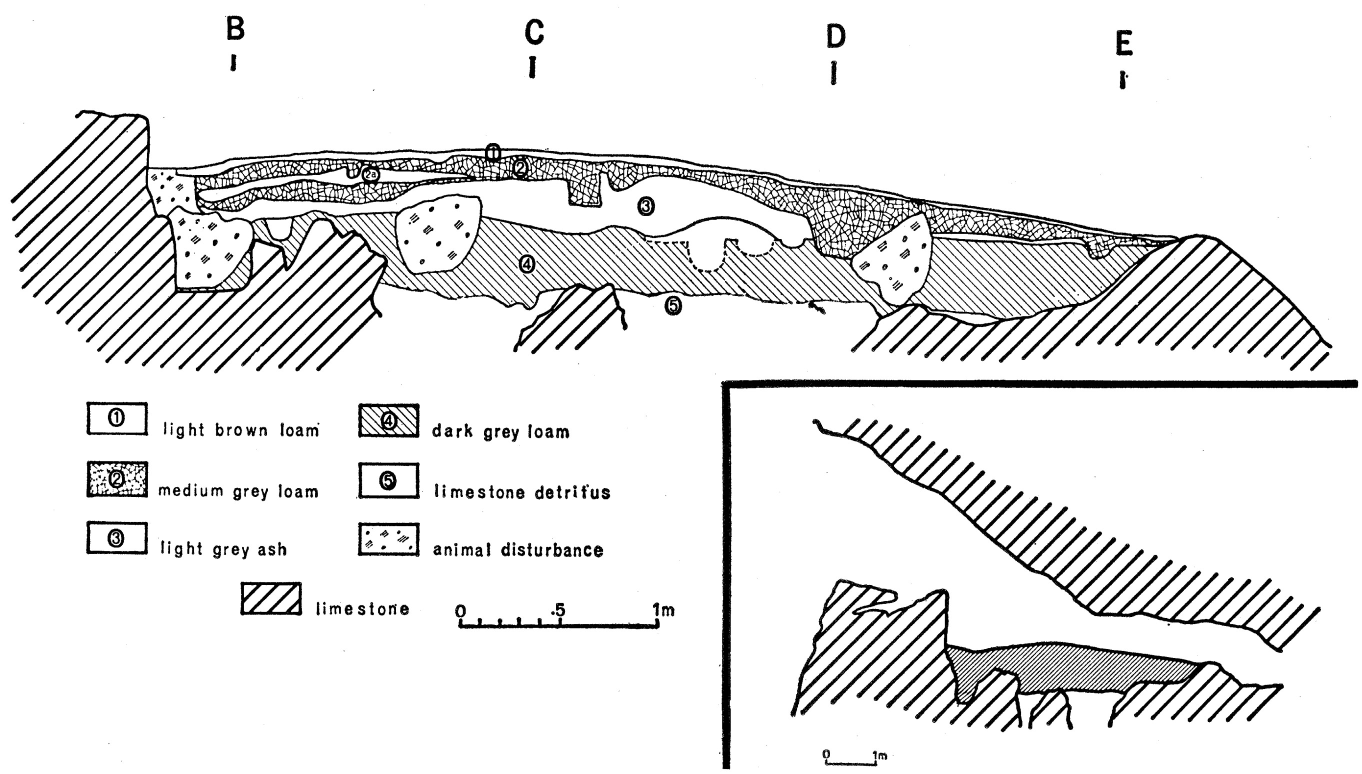

Fig. 1. Longitudinal section from the opening to the rear of Spirit Cave, drawn through the middle of the deposit. (Inset) Section showing relation of cultural deposit to geologic formation (reduced 4 ×).

grouped into a general Cultural Level I which is best described from its lithic component as "Hoabinhian." A recent attribute-oriented statistical analysis of a Hoabinhian assemblage (*5*) has shown the difficulty in establishing definite types within this flake-core assemblage. However, "Sumatra-type cores," ochre-covered grinding stones, unifacially worked quartzite pebbles, and utilized flakes, all representative of Hoabinhian facies are present in the Spirit Cave deposits. The extensive use of rolled, quartzite pebbles provides specimens well suited for edge-damage analysis (*6*).

In addition to the lithic and faunal material a number of botanical macrofossils have been tentatively identified from Cultural Level I (*7*). Layer 4: Species of *Prunus* (almond), *Terminalia, Areca* (betel), *Vicia* (bean) or *Phaseolus* (bean), *Pisum* (pea) or *Raphia, Lagenaria* (bottle gourd), and *Trapa* (Chinese water chestnut). Layer 4/3 interface: *Piper* (pepper tree), *Madhuca* (butternut), *Canarium, Aleurites* (candle nut), and *Areca.* Layer 3: *Canarium, Lagenaria,* and *Cucumis* (cucumber). Layer 2: *Piper, Areca,* and *Canarium.*

The pattern of plant consumption indicated by these remains and the ethnographic information on use of such plants in modern indigenous contexts (*8*) for the area is one of exploitation of wild or tended nuts for food, butternut (*Madhuca*), *Canarium,* and *Terminalia*; for lighting and possibly consumption, candlenut (*Aleurites*); pepper (*Piper*) as a condiment; and the betel nut (*Areca*) as a stimulant. The use of the bottle gourd (*Lagenaria*) and *Cucumis,* a cucumber type, with Chinese water chestnut (*Trapa*), the leguminous beans (*Phaseolus, Vicia*), and possibly the pea (*Pisum*), however, form a group of food plants which suggests economic development beyond simple food-gathering. The leguminous plants in particular point to a very early use of domesticated plants.

The layer 2/layer 1 interface separates Cultural Level I from Cultural Level II. Impressed into the surface of layer 2 were several concentrations of pottery. A small hearth dug into the surface of layer 2 had in direct association two, simple, quadrangular adzes. In addition, one unfinished adze blank and two small bifacially ground "knives" were recovered from layer 1. The ceramic material, characteristically cord-marked, also included a smooth, burnished ware. The cord-marked sherds were a uniform dark reddish brown (5YR 3/4 to 10YR 3/3 Munsell) averaging 3 to 6 mm in thickness. The cord-marked surface was occasionally incised with a multipronged tool; sand grains, both waterworn and angular, appear as temper inclusions. The Hoabinhian lithic material characteristic of the lower layers continued in use through layer 1.

Fourteen charcoal samples have been submitted for C^{14} analysis; three have now been completed. An age of 9180 ± 360 before present (GaK 1845) was obtained from a charcoal deposit just below the surface of layer 4. Charcoal from layer 2a was dated at 8750 ± 140 before present (TF 802). The hearth (mentioned above in association with the adzes) in the surface of layer 2 has yielded an age of 8550 ± 200 before present (GaK 1846). All samples were composed primarily of bamboo charcoal, and seem reliable. The elapsed time between these dates is compatible with the stratigraphic sequence.

The earliest inhabitants of Spirit Cave apparently utilized a "typical Hoabinhian" lithic assemblage. Associated plant remains indicate that by about 7000 B.C. plant domestication had occurred in mainland Southeast Asia. Numerous species of plants which are either cultivated or tended in modern Southeast Asia were also in use. The associated C^{14} date places this stratum just post-Pleistocene; contemporary with, or earlier than the earliest evidence of food production in the Middle East. An agricultural complex of root and fruit crops has been attributed to a similar, early "Corded Ware" stratum on Taiwan hypothetically dated between 11,000 and 4200 before present (*9*). The data from Spirit Cave appear to support this early date, and evidences an early agricultural stage before the use of cereals in Southeast Asia. Just prior to 6000 B.C. the quadrangular adze, small slate knives, and cord-marked pottery appeared as intrusive elements in the continuing local Hoabinhian expression.

This evidence for early plant domestication in Southeast Asia combined with evidence for a similar early metallurgical development (*10*) both indicate that prehistoric Southeast Asia was not a culturally backward cul-de-sac. Benedict's recent work (*11*) suggests that a number of major cultural advances (agriculture, plant and animal domestication, metallurgy, and others) originated in areas occupied by Austro-Thai speakers, and from there diffused unidirectionally into areas occupied by Chinese speakers. New archeological and linguistic data suggest that Southeast Asia was a progressive emanating center of early cultural development.

CHESTER F. GORMAN
Department of Anthropology,
University of Hawaii, Honolulu 96822

References and Notes

1. The concept of a major post-glacial cultural readaptation in the humid tropics is becoming less acceptable. See K. Flannery, *Amer. Antiquity* **31**, 800 (1966) and R. MacNeish, *Science* **143**, 531 (1964) for similar views from New World archeology.
2. M. Colani, *Mem. Serv. Geol. Indochine (Hanoi)* **14**, 86 (1927); H. van Heekeren and E. Knuth, *Archaeological Excavations in Thailand, Sai-Yok* (Munksgaard, Copenhagen, 1967); J. Mathews, *Asian Perspectives* **9**, 86 (1966).
3. It now appears that domesticated plants were in use during the Hoabinhian period.
4. Spirit Cave is a translation of the local Thai Yai or Shan name for the shelter complex.
5. J. Matthews, thesis, Australian National University, Canberra (1964).
6. G. F. MacDonald and D. Sanger, *Amer. Antiquity* **33**, 237 (1968).
7. Botanical materials, mostly carbonized, were identified by D. Yen (ethnobotanist) and P. van Royen (botanist) at the Bishop Museum, Honolulu. Tree genera were identified from fragmentary remains of seed pericarp. *Cucumis* was represented by one seed, and *Lagenaria* by several fragments of fruit exocarp. The bean identifications were made on two whole carbonized seeds. The individual structure which first suggested a seed of *Pisum* might equally be representative of a form of Palmae. Although common names have been used to describe the remains, the tentative nature of the identifications and the allowance for genetic changes in species in time have obviated the use of binomials.
8. I. H. Burkhill, *Economic Products of the Malay Peninsula* (Governments of the Straits Settlements and Federated Malay States by the Crown Agents for the Colonies, London, 1935).
9. K. C. Chang and M. Stuiver, *Proc. Nat. Acad. Sci. U.S.* **55**, 539 (1966); K. C. Chang, *Asian Perspectives* **9**, 140 (1966).
10. W. G. Solheim II, *Curr. Anthropol.* **9**, 59 (1968); also see D. T. Bayard, The Bangkok *Post Sunday Magazine* **22**, No. 229 (18 Aug. 1968), for a report of excavation of early (about 3000 B.C.) bronze from northeast Thailand.
11. P. K. Benedict, *Behavior Science Notes* **1**, 227 (1966); *ibid.* **2**, 203 (1967); *ibid.* p. 275.
12. This research was supported by an NSF predoctoral research grant GS-861, and the Mosher Fund for Southeast Asian Archaeology. In Thailand the work was sponsored by the Fine Arts Department of the Thai government. I thank D. Yen, W. G. Solheim II, P. van Royen, and R. Green for their help in the preparation of this material.

17 October 1968

Environmental Temperatures of Tertiary Penguins

Abstract. *Marine paleotemperatures, determined by oxygen isotope measurement, show that Australasian Tertiary penguins, including giant forms, lived in warm to tropical environments. Evolution from smaller species also occurred in warm environments. Mid-Tertiary fluctuations of sea temperature were controlled by alternating uplift and erosion of "Tasmantis," an unstable meridional landmass occupying and extending beyond the present position of New Zealand.*

Tertiary fossil penguin material from New Zealand, Australia, Patagonia, and Seymour Island has been described and reviewed (*1–8*). Clayton and Stevens (*9*) and Devereux (*10*) have estimated environmental temperatures of Cretaceous belemnites and mid-Eocene to Pliocene benthic deposits in New Zealand, respectively, using the oxygen isotope method of paleotemperature determination. Dorman (*11*) has produced comparable values for Tertiary deposits in southern Australia. Environmental temperatures are therefore known for a period in the evolution of penguins when they were widespread, diverse in size, and generally larger than present forms.

The occurrence of specimens representing eight genera of Australasian fossil penguins, together with curves of Devereux and Clayton and Stevens, is shown in Fig. 1; Dorman's curve (not shown) agrees substantially with Devereaux's except for slightly higher temperatures. Material from South Island (New Zealand) sites is likely to have been deposited at temperatures within ± 2°C of the curve; the single North Island specimen (*4*) and the Australian material seem to have been deposited within ± 3°C.

Fluctuations in sea temperature during the Tertiary in the New Zealand area can be explained if a regional pattern of temperature zonation and circulation similar to or slightly warmer than contemporary systems is assumed, with uplift and erosion of land controlling the local movements of water masses. New Zealand's present orientation deflects part of the warm Pacific Trade Wind Drift southward along its eastern seaboard. Subtropical waters also wash the northern and western shores of the North Island, and mix with cooler western water in the Tasman Sea. Simultaneously, the southern end of New Zealand diverts westerly flowing water from the Tasman Sea southward to blend with water from the West Wind Drift, bathing the southwestern, southern, and eastern shores of the South Island in mixed cool temperate waters (*12*). From Upper Cretaceous to early Miocene times, a long narrow landmass ("Tasmantis") extended over the New Zealand region from New Caledonia to a latitude south of the present position of Campbell Island (Fig. 2); earth movements and marine transgressions intermittently converted Tasmantis into an archipelago throughout the early Tertiary (*13*). A shallow sea lay to the east, its shores advancing westward through the late Cretaceous to deposit limestone and mudstone, and later greensand and calcareous inshore materials were deposited along the present flank of the South Island.

As a meridional barrier extending beyond the present limits of New Zealand, Tasmantis would have diverted more of the tropical counterclockwise circulation southward along the east coast, reduced the warm component of the Tasman Sea current, and shielded its own eastern flank from the cooling effects of mixed Tasman and West Wind Drift waters from the south. Such a barrier existed during the Middle and early Upper Cretaceous (Fig. 2a), breaking down with marine transgressions in the late Upper Cretaceous, Paleocene, and early Eocene, and reforming through the late Oligocene and Lower Miocene (*13*). During periods