Published as two separate articles in* American Antiquity*, Vol. 24, No. 1, pp. 1-23 and No. 2, pp. 131-47 (1958) with three other authors, C. W. Meighan, D. M. Pendergast, and M. D. Wissler. This article was written at a time when the term "ecology" was somewhat arcane and not yet widely applied to the field of archaeology. Only the text of the portions for which I was primarily responsible is included. I have incorporated revisions and updated the material. See, also, "Evidence for Pre-Columbian Animal Domestication in the New World," with a student of mine D. L. Johnson,* Lambda Alpha Journal*, Vol. 21, pp. 34-46 (1990).

ECOLOGICAL INTERPRETATION IN ARCHAEOLOGY

By B. K. Swartz, Jr. from selected writings

SETTLEMENT PATTERNS AND POPULATION

Valuable data on man's adaptation to environment may be derived from studying the density, distribution, and depth and configuration of archaeological sites. Several studies involving agricultural settlement patterns have been made (Willey 1956; Crawford 1953; Childe 1950; Ricketson and Ricketson 1937), but similar studies applied to hunting and gathering sites are still limited in number and extent.

An obvious technique used by several authors is simply to correlate the distribution of sites with the distribution of resources or natural features of the environment. For example, Clark (1952: 23) indicates the correlation between Magdalenian sites and the distribution of reindeer. The Sangoan culture of Africa seems to occur within areas now having over 40 inches of rainfall (Cole 1954: 153, Map 6, Nos. 3, 4). For hunting and gathering peoples, such correlations should be the rule rather than the exception, and we may expect to find relationships between site distribution and natural features in any case where a sufficiently large number of sites is known and plotted on a map.

Aerial photographs provide another technical aid for study of settlement patterns. Crawford (1953) and Solecki (1957) discuss types of evidence and methods of interpretation. Soil color differences are a very important guide to detection of midden areas which are frequently darker than the surrounding soil. In "crop sites," the site is revealed by a vegetation difference, due to some particular plant growing only on the site, or a more luxuriant or scantier growth of various plants where the soil has been altered by human occupation. In California, sites have been observed to have an abundance of such plants as thistles, mustard, buckeye trees, or cactus. Since midden sites differ chemically from the surrounding soil, almost any site should show as a crop site at one season or another.

Aerial photographs have been used in a limited way in this country, but their application could be greatly extended. However, there are some practical problems in the way of studying hunting-gathering sites from air photos. In the first place, the average hunting-gathering site is quite small and therefore may not be revealed in commercial air photos taken from high altitudes. In a spot check of a dozen sites on the west coast, none could be detected from the commercial air photos now available.

Whether or not aerial photographs of an entire district can be taken, ecological information of value can often be obtained from studying an air photo of a single site. Such photos may sometimes be taken from a kite or balloon (Bascom 1941; Roy 1954), but a low-level aerial photograph is usually easier to obtain. If topography permits, such a photo can be taken from the top of a nearby hill or cliff (Goodwin 1953). The picture is likely to reveal unsuspected drainage patterns as well as the exact borders of the site and the relationship of the site to the local vegetation zones (Crawford and Keiler 1928; DeLauwe 1951).

A final technique involves the calculation of site areas. Knowledge of area is important in such things as population estimates. The simplest method is to prepare the site map on graph paper and calculate the area from counting the squares, since the irregular shape of many sites makes it difficult to apply mathematical formulae to the computation of area.

The relationship between site distribution and food resources has already been mentioned. In arid regions, availability of water may be a primary consideration for location of a village, and location of sites along streams is common throughout the world. Other reasons for selecting a village location include defense, dryness, shelter from prevailing winds, exposure to morning sunlight, and elevation for unobstructed view of surrounding country.

INORGANIC REMAINS

During site excavation, not only artifacts and organic remains but also inorganic, nonartifactual materials should be collected. Column sampling can be used if the remains are abundant and fragmented. In this paper we are concerned with adaptation to the environment for survival; therefore materials selected for ornamental or luxury purposes will not be discussed.

A reconnaissance should be made of the site areas to determine inorganic resources. Specimens may be obtained of all materials which might be used for artifact manufacture, including rock from quarries and other sources, clay, if pottery is made in the area, and in certain cases, such as the Old Copper culture (Wittry and Ritzenthaler 1956), ores and minerals.

Ecological information can best be derived from inorganic materials if they are subjected to quantitative analysis. Archaeologists have made quantitative analyses of pottery (Shepard 1936, 1956), but primarily to obtain technological, not ecological, information. Studies of stone artifact materials are usually general and include a number of rocks and minerals (Holmes 1919; Heizer and Treganza 1944). Witthoft (1952) has studied variations of the same materials, while Boyer and Robinson (1956) have applied similar techniques to demonstrate that extensive trade took place in northwestern New Mexico by the wide dispersal of Jemez Mountain obsidian in that area. These same authors have made use of qualitative examination of obsidian by determination of indices of refraction of powdered material.

By determining exact sources of supply of manufacturing materials **it** is possible to make certain ecological inferences. From the presence or absence of indigenous materials in a site one can infer cultural selection. At the Folsom site in northeastern New Mexico, local obsidian was not used; instead "Alibates flint," or dolomite, obtained from the quarries north of Amarillo, at least 150 miles away, was used. This would suggest a cultural bias against the use of obsidian by Folsom artificers (Krieger 1954: 275). If manufacturing materials not indigenous to a region are found in a site, trade or migration can be inferred. Witthoft (1952: 470-3, 493-4) infers that the producers of the Enterlene industry migrated from the north, since New York chert varieties are present in the Enterlene assemblage. It will be seen that in this and other areas analysis of inorganic materials plays an important role in providing ecological data.

ANIMAL DOMESTICATION

One way man can become a food producer is by domesticating animals. However, it **must** be stressed that domestication may be for other reasons, such as pack, draft, riding, or pets (Table 7).

Generally speaking, in this paper, we consider an animal domesticated if it fulfills the following 2 requirements: (1) it is of economic value, and (2) it breeds in captivity. Certain exceptions or partial exceptions included here are the elephant, dog, cat, and swan. Galton (1865) discusses various criteria of domestication. See Dyson (1953a) for a nearly complete list of domesticated animals.

Excluding the dog, whose domestication antedates that of other animals, 2 patterns of animal domestication developed. One pattern was associated with sedentary agriculturists. Here animals were domesticated primarily as an adjunct to the agricultural food supply. They were either raised in pens and/or were exploited as power for agricultural food production as draft animals. If bones from animals primarily used in this way are excavated, one can probably assume agriculture for the inhabitants of the site.

The second pattern of animal domestication is associated with pastoral nomads. Here animals were also eaten, but their primary uses were for packing and riding. Animals domesticated by nomads, particularly if not used for food, are quite sparse in the archaeological record and one must be on guard not to assume the absence of domestication from negative evidence. The sparseness of horse remains in the plains illustrates this problem.

Two types of interpretation can be made from the animal remains of food producing communities. (1) Are the remains from domesticated animals? (2) What effects did the domestication of animals have upon the ecology?

One method of determining whether animals are domesticated is by bony structure. This method is not applicable to dogs (White 1955:172). However, it can be used for animals exclusively kept by agriculturists, since extensive morphological changes occur due to increased feeding and immobility. Pioneer work was done along this line by Rütimeyer (1862) for the Swiss Lake Dwellings. A translation of his work (Anonymous 1862: 362-3) summarizes:

Critical comparison enabled science to distinguish the bones of wild from those of domestic animals. Those of the former exhibit a deep brown, almost black, color; a surface smooth and greasy to the touch, and in most cases a wonderfully increased specific gravity; more distinctly marked carinae; greater roughness, and more acutely cur muscle insertions — in short the greatest possible distinctness of all edges and protuberances, together with the least possible quantity of indifferent surfaces. On domestic animals the bony substance appears — if the expression may be allowed — more soft, spongy, and yielding to plastic impressions. We cannot doubt . . . that the new relations of life following the domestication of animals causes a weakening of all the energies of the system, by increased nourishment, and lessened exercise, and additional fattening. These are results, not of centuries, but of much shorter spaces of time.

Since Rütimeyer's time, almost no work has been done in qualitative bone study in regard to domestication. However, Cornwall (1957:102) points out differences between the dentition of wild pigs and domestic pigs.

Dyson (1953a) suggests that the above observations might be supplemented by quantitative methods. A rapid rise in the number of bones of a particular animal would suggest breeding instead of hunting.

Bone remains can also be used to extract information about the customs of the husbandryman. Clark (1952: 117) shows by counting bone remains from various excavation levels at Trundle, Sussex, that the pig lost favor in Iron Age times while sheep and goat increased in popularity. From this type of information past dietary patterns can be inferred.

Methods of slaughtering can also be inferred. Childe (1931: 200-1) shows that nearly 3/5 of the cattle at Skara Brae, Orkney, were slaughtered at less than 6 months and that less than 1/5 reached maturity. The remainder were killed off at between 12 and 18 or between 30 and 36 months, suggesting a seasonal slaughtering pattern.

Materials, particularly bone, from domesticated animals increased the supply of raw materials that could be used for manufacturing articles. Examples of the use of these materials are sheep metapodal for bobbins at the Glastonbury lake-villages, and the use of horn in Bronze Age Europe for making daggers, hilts, combs, ladles, drinking vessels, and trumpets (Clark 1952: 225). Not only can evidence of domesticated animals be obtained by recovery of their bony remains, but also by the recovery of paraphernalia that was specifically used by them (Table 8).

CONCLUSIONS ON DOMESTICATION

Our survey of archaeological knowledge relating to the domestication of plants and animals points to the following conclusions:

1. Present archaeological techniques provide no clear-cut methods for recognizing the incipient stages of either plant or animal domestication. There is a need for more intensive study of sites which combine hunting-gathering with plant and animal domestication, from the of view of developing more refined techniques for recognizing domestication when it occurs.

2. A number of indirect methods may be applied to the question of plant and animal domestication (such thing as storage structures reflecting agriculture or sudden increase of a particular species reflecting animal domestication). Such indirect methods could be expanded and codified, but the conclusions derived there from must be stated in terms of probabilities rather than as facts.

3. The fact that agriculture and animal-breeding are so difficult to demonstrate in their incipient stages argues strongly for a long and gradual transition from hunting-gathering societies. This has both chronological implications (agriculture older than now believed) and theoretical implications (the "revolution" theory not an accurate reflection of culture history).

TABLE 7. ANIMALS DOMESTICATED BY MAN. CRITERION: BRED IN CAPTIVITY PRIOR TO THE INDUSTRIAL REVOLUTION.

Common Name	***Taxonomic Name***	***Primary Uses***	***Probable Origin***
1. Dog	*Canis familiaris*	Pet, Hunting, Herding, Watching	Cen. Asia
2. Dog	*Canis familiaris*	Transport	Circum-Polar
3. Dog	*Canis familiaris*	Meat	New World
4. Cat	*Felis domesticus*	Pet	Egypt
5. Ox (Cattle)	*Bos taurus*	Draft, Dairy, Meat	[Balkans,AsiaMinor][1]
6. [Cattle	*Bos* spp?	Draft, Dairy, Blood	East Africa]
7 Zebu (Brahman)	*Bos indicus*	Draft, Dairy	India
8. Yak	[*Bos*] *grunnieus*	Draft, Dairy	Tibet
9. Bali Cattle [(Banteng)]	[*Bos javanicus*]	Draft	SE Asia
10. [Mithan (Gayal)	*Bos frontalis*	Draft	SE Asia]
11 Water Buffalo	*Bubalus bubalus*	Draft [incl. Mud Plowing, Dairy]	SE Asia
12. Camel	*Camelus dromedarius*	Pack [Ride; Dairy - E. Sudan]	So. Arabia
13. Camel	*Camelus bactrianus*	Pack [Draft]	Cen. Asia

14. Llama	*Lama glama*	Pack, Meat, Wool	Andes
15. Alpaca	*Lama pacos*	Wool, Meat	Andes
16. Reindeer	*Rangifer tarandus*	Pack, Dairy, Ride	Siberia
17. Sheep	*Ovis aries* and *vignei*	Meat, Wool	Near East
18. Goat	*Capra hircus*	Meat, Dairy	Near East
19. [Indian] Elephant[2]	*Elephas indicus*	Pack, Ride	India
20. Horse	*Equus caballus*	[Meat?] Pack [Draft]	[Pontic Plain]
21. Horse	*Equus caballus*	Ride	Near East
22. Ass	*Equus asinus*	Pack, Draft	[Upper Nile]
23. Onager	*Equus hemionus*	Pack, Draft	Cen. Asia
24. Swine	*Sus scrofa*	Scavange	Near East
25. Swine	*Sus cristatus*	Scavange, Meat	SE Asia
26. Rabbit	*Oryctolagus cuniculus*	Meat	[Iberia]
27. Cavy (Guinea Pig)	*Cavia porcellus*	Meat	Andes
28. [Jungle Fowl] (Chicken)	*Gallus domesticus*	Sacrifice, Fighting	SE Asia
29. [Domestic Fowl] (Chicken)	*Gallus domesticus*	Poultry, Feathers	Europe
30. Turkey	*Meleagris gallopavo*	Poultry, Feathers	Mesoam.
31. Goose	*Anser anser*	Poultry, Feathers	Egypt
32. Goose	*Cynopsis cygnoid*	Poultry, Feathers	China
33. Goose	*Alopochen aegyptiaca*	Poultry, Feathers	Egypt
34. Duck	*Anas platyrhnchos*	Poultry, Feathers	Egypt, China
35. Muscovy Duck	*Cairina moschata*	Poultry	So. Amer.
36. Pigeon	*Columbia livia*	Poultry	Egypt
37. Guinea Fowl	*Numida melegris*	Poultry	Sahara
38. Peacock	*Pavo cristalis*	Poultry, Decoration	India
39. Swan	*Cygnus olor*	Decoration	Eurasia
40. Honeybee	*Apis mellifera*	Honey, Wax	Eurasia
38. Stingless Bee	*Melipona beechii*	Honey, Wax	Mesoam.
39. Silkworm	*Bombyx mori*	Silk fiber	China
40. Cochineal	*Dactylopius coccus*	Dye	Mesoam.
41. Lac Insect	*Lacciffer lacca*	Lacquer	No. India
42. Antelope[3] [?]	[2, or 3 if incl. Gazelle, spp.	Ritual]	Egypt
43. Mouse[3]	*Mus musculus*	Meat, Pet	China

1 - Brackets indicate modification or updating from original article.
2 - Not bred in captivity.
3 - Dobzahnsky, 1955, pp. 192-93.

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