4. ———, R. E. Toya, Sr., *ibid.*, in press.
5. K. Y. Lee, W. Lijinsky, P. N. Magee, *ibid.* **32**, 65 (1964); P. N. Magee and K. Y. Lee, *Biochem. J.* **91**, 35 (1964).
6. P. Brookes and P. D. Lawley, *Biochem. J.* **89**, 138 (1963).
7. H. Jackson, B. W. Fox, A. W. Craig, *J. Reprod. Fertility* **2**, 447 (1961).
8. Synthesized in our laboratory. H. Jackson and A. W. Craig, *Ann. N.Y. Acad. Sci.*, in press.
9. A. W. Craig and H. Jackson, unpublished.
10. D. J. Pillinger, thesis, St. Andrew's University, Scotland (1961).
11. P. N. Magee, V. M. Craddock, P. F. Swann, in *Carcinogenesis, A Broad Critique* (Williams and Wilkins, Baltimore, 1967), pp. 421–39.
12. V. M. Craddock, *Biochem. J.* **94**, 323 (1965).
13. A. W. Craig, D. P. Pillinger, B. W. Fox, unpublished.
14. J. W. Conklin, A. C. Upton, K. W. Christenberry, T. P. McDonald, *Radiation Res.* **19**, 156 (1963).
15. A. C. Upton *et al.*, *Nat. Cancer Inst. Monograph 22* (1966), pp. 329–47.
16. A. C. Upton, F. F. Wolff, E. P. Sniffen, *Proc. Soc. Exp. Biol. Med.* **108**, 464 (1961).
17. Jointly sponsored under the NCI–AEC Carcinogenesis Program by PHS and AEC under contract with Union Carbide Corp.
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Migratory Animals as Dispersal Agents of Cultural Materials

Abstract. *Migratory animals (such as waterfowl, fish, whales, and seals) and large land animals (such as deer, elephant, bear, and cattle) that were hunted for food by aboriginal peoples may be struck, but not killed, by projectile weapons which remain imbedded in the body. Individuals which survive may be killed elsewhere, and the projectile weapon tips may be recovered. Numerous instances are cited. Such exotic artifacts can be mistakenly attributed to cultural contact between distant human groups unless archeologists are aware of this special kind of diffusion process.*

A possible means of noncultural diffusion of certain kinds of artifacts to distant areas is by migratory animals carrying such items imbedded in their bodies. A parallel in biology is the transport of viable algae and seeds by migratory water birds. Transport by floating objects (such as derelict boats, planks, or masts) with iron imbedded or attached, from which people with no experience working with metal secured iron, or dense stones used to make cutting tools and recovered by occupants of coral islands from the root net of drift trees (*1*), represent adventitious distributions which serve as a warning that the occurrence of all artifacts or materials of distant origin may not be taken as proof of contact through travel or trade between the areas and peoples concerned. Large mammals, not surprisingly, can receive a spear or dart which does not cause death and whose point (or at times the whole shaft) may remain imbedded and may be carried until the animal's death. Inferences on the migrations of oceanic whales and the existence of the Northeast Passage before it was traversed by Europeans were derived from harpoons found in whales' bodies in the 17th and 18th centuries by oceanic voyagers (*2*). Aboriginal harpoons found in whales' tissues were also recorded by 19th-century European sailors (*3*); in earlier times such spent weapon points recovered from killed or stranded whales could have served as models. The St. Lawrence Island Eskimos are reported to believe that weapon tips found in this way possess magical properties, and they keep the tips as charms of great value and potency (*4*). Harpoons are still being found in the bodies of stranded whales (*5*).

There have frequently been reported migratory waterfowl that carried weapons from the locality where they were hunted to distant places. A notable example is that of two honey buzzards (*Pernis apivorus*), shot in Finland in 1894 and 1900, each of which was found to have sticking in a wing a wooden arrow identifiable as having been made by the Pangwe tribe of southwestern Cameroon (*6*). Ducks, brants, and swans that carried Eskimo bone arrowheads have been killed in California, Indiana, North Carolina, and Nebraska (*7*). Eskimo toggle harpoons, such as the one found in an archeological site in Iowa (*8*), or some of the barbed bone projectile points from the exposed strands of the now-desiccating Pyramid Lake in Nevada (*9*) may have been introduced by migratory waterfowl wounded in Alaska.

Other animals which when killed and butchered have been found to bear imbedded weapon points are deer, grizzly bears, hogs, cattle, and seals (*10*). Among the most ancient finds of this sort are the weapon tips penetrating reindeer bones in the Upper Paleolithic (Magdalenian) site of Stellmoor, Germany (*11*), and seal skeletons from the Mesolithic period found on raised beaches in Finland (*12*).

Fish may serve as disseminators of items such as spear tips and hooks in much the same way that large sea and land mammals do (*13*). It has been suggested and discussed at length that the unusual C-shaped shell fishhooks of the Santa Barbara region may have been introduced there by live tuna migrating from the western Pacific and arriving on the California coast with such hooks snagged in their mouths (*14*). Fish are also recorded as carrying artifacts such as a knife and scissors in the stomach (*15*). An instance of a South American rhea with three stone artifacts (two axes and a hammer) as gizzard stones that were swallowed at some distance from where it was killed is parallel (*16*).

Live elephants also carry imbedded weapons that are found when they are killed and butchered. (*17*). Since these animals live as long as 100 years and are migratory over distances of many hundreds of miles, one wonders whether the mammoths of terminal Pleistocene times, found in North America associated with flint projectile points, might not be late-surviving, repeatedly attacked individuals that were carrying weapon tips acquired over a span of several scores of years in quite different localities. Several mammoth skeletons have been associated with numbers of flint projectile points (*18*), and the pieces in each of these lots vary somewhat in size, form, and material. Krieger (*19*) has called attention to the use of nonlocal stone for projectile points in some Early Man kill sites, and he suggests that this may indicate far-ranging procurement of implement material by the hunting group. This may be true, but the alternative possibility, that points made of flints which occur at some distance away may have been acquired from the bodies of killed animals, may be worth considering.

Paleo-Indians (also called Big Game Hunters) in the New World (*20*) are usually assumed to have been free-ranging, nomadic hunters, but they may, for all we know, have been seasonally settled foragers occupying specific territories. Petrographical and typological examination of the weapon points found associated in kill sites of the Big Game Hunters could lead to some understanding of the nature of their social groups, if it could be demonstrated that some of these weapons were foreign to the area in which they were found.

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References and Notes

1. T. Rickard, *Geogr. Rev.* **24**, No. 4 (1934).
2. G. F. Muller, *Voyages from Asia to America* (London, 1761), p. xlii; J. Burney, *A Chronological History of North-Eastern Voyages of Discovery* (London, 1819), pp. 109–110; J. W. de Peyster, *The Dutch at the North Pole* (New York Historical Society, New York, 1857), p. 10; G. Steller, *Beschreibung von*

dem Lande Kamtschatka (Frankfurt, 1774), p. 102; S. Pepys, *Diary*, H. B. Wheatley, Ed. (Random House, New York, 1946), vol. 1, p. 617; Pierre François Xavier de Charlevoix, *Histoire et Déscription Générale du Japon*, 6 (Paris, 1736), pp. 51–52, 398.
3. W. Scoresby, *An Account of the Arctic Regions with a History and Description of the Northern Whale-Fishery* (London, 1820), vol. 1, p. 8; O. T. Mason, *U.S. National Museum Annual Report for 1900*, pp. 189–304 (p. 264); H. H. Bodfish, *Chasing the Bowhead* (Harvard Univ. Press, Cambridge, Mass., 1936), p. 215; A. H. Clark, *The Fisheries and Fishery Industries of the United States* (Department of Commerce, Bureau of Fisheries, 1884–1887), 10, Sec. 5, part 6, p. 97; Anonymous, *Edinburgh Philosoph. J.* **4**, 216 (1821); D. Gray, *7th Annual Report, Fishery Board for Scotland for 1888* (1889), part 3, p. 365; R. W. Gray, *Scottish Naturalist* **199**, 6 (1933); *ibid.* **213**, 75 (1935); *The Naturalist* (London, 1940), p. 193; D. M. Lindsay, *A Voyage to the Arctic in the Whaler "Aurora"* (Estes, Boston, 1911), p. 87; R. F. Heizer, *Bur. Amer. Ethnol. Bull.* **133**, 415 (1943).
4. O. Murie, *Misc. Public. Univ. Alaska* **2**, 346 (1936).
5. Article, "Tweed: Rustic Cloth Goes to Night Clubs," *Life Magazine* **5** (No. 16), 58 (17 October 1938); Associated Press Wirephoto with article, "The Gull That Wouldn't Die," San Francisco *Chronicle*, 18 March 1968, p. 6; W. H. Dall, *Nat. Geogr. Mag.* **10**, 136 (1899).
6. G. Lindblom, *Ethnos* **3** (No. 1), 4 (1938).
7. A. Woodward, *Bull. S. Calif. Acad. Sci.* **40** (part 1), 13 (1941); J. A. Mason, *Amer. Anthropol.* **36**, 314 (1934); Editor, *Sci. News Lett.* (10 February 1934), 87; R. T. Orr, *The Condor* **48**, 280 (1946).
8. L. A. Brown, *Iowa Archaeol. Soc. Newslett.* **39**, 10 (April 1966).
9. P. C. Ting, *Nevada Archaeol. Survey Rep.* **2** (No. 3), 4 (1968).
10. G. Davidson, *Proc. Calif. Acad. Sci.* **4**, 132 (1873); J. Grinnell, J. S. Dixon, J. M. Linsdale, *Fur Bearing Mammals of California* (Univ. of California Press, Berkeley, 1937), vol. 1, p. 72; H. W. Elliott, *The Seal Islands of Alaska* (U.S. Dept. Interior, 1881), p. 66; J. Bidwell, *Out West* **20**, 182 (1904); A. Krieger, *Bull. Texas Archaeol. Soc. 27*, (1956), pl. 26; J. Baegert, *Observations in Lower California* (Univ. of California Press, Berkeley, 1952), p. 84.
11. A. Rust, *Die alt- und mittelsteinzeitlichen Funde von Stellmoor* (Wachholtz, Neumünster, Germany, 1943), p. 133.
12. M. Sauramo, *Quartär* **1**, 26 (1938); J. Leppäaho, M. Sauramo, V. A. Korvenkontio, *Suomen Museo* **43**, 1 (1936); E. Lonnberg, *Arkiv Zoologi* **4**, 1 (1908).
13. F. V. Pecino, *Comm. Fisheries Rev.* **22** (No. 9), 67 (1961); G. Clark, *Prehistoric Europe* (Methuen, London, 1952), p. 47. Compare to earliest postglacial finds of pike skeletons from Mesolithic lake deposits in Esthonia and southern Sweden: R. Indreko, *Abhandl. der Fischereikammer*, No. 2 (Tallinn, 1937); J. G. D. Clark, *Antiquaries J.* **28**, 45 (1948).
14. R. F. Heizer, in *Prehistoric Man in the New World*, J. D. Jennings and E. Norbeck, Eds. (Univ. of Chicago Press, Chicago, 1964), p. 124; L. Landberg, *Amer. Antiquity* **31**, 485 (1966); F. Reinman and L. Landberg, *ibid.* **33**, 95, 98 (1968).
15. E. W. Gudger, *Nat. Hist.* **22**, 452 (1922); G. T. Hellman, *New Yorker* **42**, 72 (10 December 1966).
16. R. Carneiro, *Amer. Antiquity* **24**, 192 (1958).
17. E. W. Gudger, *Sci. Mon.* **35**, 312 (1932); C. Combe, *Philosoph. Trans. Roy. Soc. for 1801*, 165; W. D. M. Bell, *The Wanderings of an Elephant Hunter* (Scribner, London, 1923), pp. 1–2.
18. See, for example, L. Aveleyra, *Amer. Antiquity* **22**, 12 (1956); E. W. Haury, *ibid.* **19**, 1 (1953); ———, E. B. Sayles, W. W. Wasley, *ibid.* **25**, 2 (1959); H. Gross, *Texas Archaeol. Paleol. Soc. Bull.* **22**, 101 (1951); A. J. Jelinek, *Papers Mich. Acad. Sci. Art Lett.* **42**, 225 (1957).
19. A. D. Krieger, *Amer. Antiquity* **19**, 275 (1954).
20. C. V. Haynes, *Science* **145**, 1408 (1964); G. R. Willey, *An Introduction to American Archaeology* (Prentice-Hall, Englewood Cliffs, N.J., 1966).

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Ice on Venus: Can It Exist?

Libby (*1*) has suggested that the similarity between the amount of CO_2 in the atmosphere of Venus and the total amount of this gas evolved by Earth raises a serious question about the absence of terrestrial amounts of water on Venus. His solution to this dilemma postulates that the water is present in the form of polar ice caps. It is the purpose of this note to call attention to some weaknesses in Libby's arguments.

In order to have extensive ice caps at the poles of Venus, the temperature there must be well below freezing. The available observations do not support this condition. Clark and Kuz'min (*2*) have reported interferometric radiometer measures at 10.6 cm, which indicate temperatures above 420°K at the poles. Libby (*1*) argues that these results are probably invalid because of the large amount of attenuation caused by the intervening atmosphere. However, the attenuation would act to decrease the observed limb temperature from its true value; this implies that the poles are even warmer than the values suggested by Clark and Kuz'min. Furthermore, these authors found an increase in temperature toward the equatorial limb, where the atmospheric attenuation would be just as large as at the poles.

As a second counterargument to the radio measurements, Libby (*1*) notes that the Soviet space probe Venera 4 recorded a surface temperature of only 550°K, which is considerably lower than the 630° ± 70°K deduced (*2*) for the antisolar point; a temperature of 273°K at the poles might then be within the range of possibility. However, the maximum temperature difference between equator and pole permitted by the interferometric measurements is only 31 percent. This would give a T_{pole} of 380°K if T_{equator} is 500°K. If the full range of uncertainty is allowed, T_{pole} does not fall below 300°K. Furthermore, if the ice caps are to survive over long periods of time, the temperature must be well below freezing over most of the ice-covered region, not just at the poles.

This requirement leads to another contradiction. A large number of measurements at many wavelengths are consistent with the requirement of a mean planetary temperature above 550°K (*3*). If a substantial fraction of Venus is covered by ice caps [Libby (*1*) mentions 30° latitude as a possibility for the extent of the caps], the equatorial region would have to be very hot indeed for such high temperatures to be observed. The rather serious discrepancy between the radius of Venus implied by the Venera 4 results and the radius determined by ground-based radar (*4*) may mean that Venera 4 did not reach the planet's surface. If this is the case, the argument against polar ice caps of any size is virtually irrefutable.

Where then is the water? Any acceptable explanation must account for the absence of large amounts of water on Venus and the present existence of the terrestrial oceans. Mars also appears to possess an atmosphere that can be understood by analogy with the outgassing that has taken place on Earth, again with the exception that water is grossly underabundant (*5*). There are also large differences in the amounts of water present in meteorites. It is very unlikely that the same process for the fractionation of water operated in all of these cases. Nevertheless, it is clear that Earth is really the anomalous planet in the inner solar system in this respect.

It is not yet possible to decide whether water was initially underabundant in the material that ultimately formed Venus or whether the water subsequently escaped from the planet's atmosphere. However, the present existence of large amounts of water on the surface of Venus, in liquid or solid form, does not appear to be consistent with the evidence that we have at our disposal.

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References

1. W. F. Libby, *Science* **159**, 1097 (1968).
2. B. G. Clark and A. D. Kuz'min, *Astrophys. J.* **142**, 23 (1965).
3. W. Ho, I. A. Kaufman, P. Thaddeus, *J. Geophys. Res.* **71**, 5091 (1966).
4. A. Kliore, G. S. Levy, D. L. Cain, G. Fjeldbo, S. I. Rasool, *Science* **158**, 1683 (1967); M. E. Ash *et al.*, *ibid.*, **160**, 985 (1968).
5. T. Owen, *Astrophys. J.* **146**, 257 (1966).
6. Supported in part by NASA under contract NASr-65(19).

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The report by Libby (*1*) at first sight promises a challenging and provocative new idea concerning Venus and has been treated as such by the press (*2*). However, Libby's model inevitably implies either an absurdly large horizontal pressure gradient, or an untenable vertical temperature structure. If we assume that melting at the edges of the ice caps is balanced by snowfall over the caps, then the temperature near the poles must be below freezing through much of the depth of the atmosphere