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ALAN J. OSBORN

IÑUPIAT ESKIMO WHALERS are allowed to kill up to 50 bowhead whales every year in the arctic waters off Barrow, Alaska. Some of the older bowheads are more than 20 m in length and weigh more than 50 tons. Since 1981 the Iñupiat have found at least six lance and harpoon end blades embedded within the thick blubber that insulates these magnificent mammals (Raloff 2000). These archaeological weapon points included projectiles fashioned from chipped stone, ground slate, ivory, and iron. Wildlife biologists have suspected that whales may live to be quite old. One can only imagine their surprise, however, once they determined the ages of the whales based upon aspartic acid levels and amino acid racemization dating of the whales' eyes. Two of the adult bowheads were between 135 and 172 years old and the third whale was 211 years old. These bowheads had escaped the lethal hunting weapons of Eskimo whalers sometime during the past two centuries.

Technology has frequently been the focus of archaeological and ethnological studies of hunter-gatherer societies throughout the arctic and subarctic regions. This technological emphasis is readily understandable given the unusual archaeological preservation conditions, the numerous ethnohistorical descriptions and collections of material items, and the diversity and complexity of implements and facilities in this region. Technology has long been regarded as an essential "facilitator" of hunter-gatherer adaptations to harsh biophysical environments. Balikci (1964:1) states, for example, "This highly specialized technology was considered as the central factor explaining the secret of Eskimo adaptation to the Arctic environment."

The primary purpose of this chapter is to examine the systemic interrelationships between hunting weapon technology and the exploitation of aquatic food resources throughout the high latitude settings of the Northern Hemisphere or the circumpolar region (see Gjessing 1944). Artifact assemblages from numerous locations throughout the circumpolar region contain a diverse array of hunting weapons, implements, facilities, and "tools to make tools." This chapter focuses primarily upon slate projectile points (flaked, ground, and/or polished) as well as animal processing implements, such as "ulus" from high-latitude coastal areas. An explanatory argument will be proposed that will address the following questions: (1) What functional role did ground slate implements serve in prehistoric and historic adaptations? (2) Why did ground slate implements appear, persist, and disappear during a 6,000-year period? (3) How might archaeologists account for their variable geographical distribution? (4) How were ground slate implements integrated into a larger technological component of human adaptations involving marine resource exploitation?

Given the systemic nature of technology and its central role in human adaptation, this model must briefly allude to a number of seemingly diverse topics, such as circumpolar archaeology, hunter-gatherer technology, botany, phytotoxicology, marine ecology, paleoenvironments, and ethnohistory. As Levins (1966:430) states, however, "All models leave out a lot and are in that sense false, incomplete, inadequate. [Its] validation... is not that it is 'true' but that it generates good testable hypotheses relevant to important problems." This chapter offers a general explanation of the archaeological record in the circumpolar region that reflects aboriginal poison hunting strategies. It also challenges other investigators to evaluate this argument and to replace it with more robust, empirically testable interpretations of circumpolar technology and past human adaptations in maritime environments in this region.

PREVIOUS DISCUSSION AND INTERPRETATION OF GROUND SLATE TOOLS

In 1871, Oluf Rygh noted the pronounced similarities between ground and polished slate points and knives from many coastal locations in North America, Norway, and Sweden (Rygh 1871:113, in Gjessing 1944:21). Almost a half century later, Holmes (1919:25) stated that "the correspondence in shape, material, size, and method of manufacture [of ground slate tools] form[s] an unbroken chain of genetic, accultural, or fortuitous analogies entirely encircling the globe where the land areas are most continuous."

Numerous archaeologists have since described a recurrent, directional shift from chipped stone to ground slate–dominated lithic assemblages in the prehistoric record of North America, Scandinavia, Siberia, Kamchatka, Eastern Russia, and the Aleutian Islands (e.g., Borden 1962; Brøgger 1906; Clark 1980; Collins 1937; de Laguna 1946; Fitzhugh 1974, 1975; Gjessing 1944, 1948; McGhee 1980; Møllenhus 1958; Okladnikov 1965; Wintemberg 1940; Workman et al. 1980). This directional, technological pattern is more complex than has been generally appreciated. Collins (1956), McGhee (1980), and others have pointed out, for example, that chipped stone tools were never replaced or supplemented by ground slate implements on Southampton Island in northwest Hudson Bay. Also, archaeologists have described reversals in this seemingly directional, technological pattern (e.g., Workman et al. 1980:395). The differential appearance, use, and disappearance of ground slate implements may provide greater insights into the variable conditions under which past technological changes and the exploitation of aquatic resources occurred.

Ground Slate Tools: Spatial and Temporal Distribution

Detailed discussions of the spatio-temporal distribution of ground slate tools have been offered by Clark (1980), Dumond (1968), Fitzhugh (1974), Gjessing (1944), McGhee (1980) Møllenhus (1975), and Ritchie (1969). Ground and polished slate implements have been recovered from archaeological contexts throughout the circum-Pacific region from the Peoples Republic of China, Taiwan, Korea, Japan, eastern Russia, Kamchatka, Sakhalin, and Siberia to the Aleutian Islands, northern and southwestern Alaska, the Gulf of Georgia, and the San Juan Islands. Ground slate assemblages are also present in the Maritime Archaic sites across the northern Atlantic from Massachusetts, New York, the New England states, Newfoundland, Nova Scotia, portions of the St. Lawrence drainage, Labrador, Hudson Bay, Baffin Island, and Greenland to Finland, Sweden, Norway, and the Kola Peninsula (Figure 6.1, Table 6.1).

The earliest documented ground slate assemblages belong to the Suomusjärvi Complex ca. 5500 B.C. in southwestern Finland (Fitzhugh 1972), the Khin'skaya Stage ca. 5000 B.C. in the Ozero Baykal (Lake Baikal) region of the former Soviet Union, the Ta-p'en-k'eng Culture ca. 5000–3000 B.C. in northern Taiwan (Chang 1986:228–229), and the Shantung Lung-shan Culture (ca. 3000–1500 B.C.) in southeastern China (Chang 1986:245–252). Ground slate implements were used in a number of areas until the historic period (e.g., Point Barrow, Kodiak Island, the Pacific Northwest, the Kurile Islands, Sakhalin, and the Amur River region of eastern Russia).

Cultural Historical Interpretations

Archaeologists have relied extensively on cultural historical arguments to account for the appearance of ground slate tools in high-latitude settings.

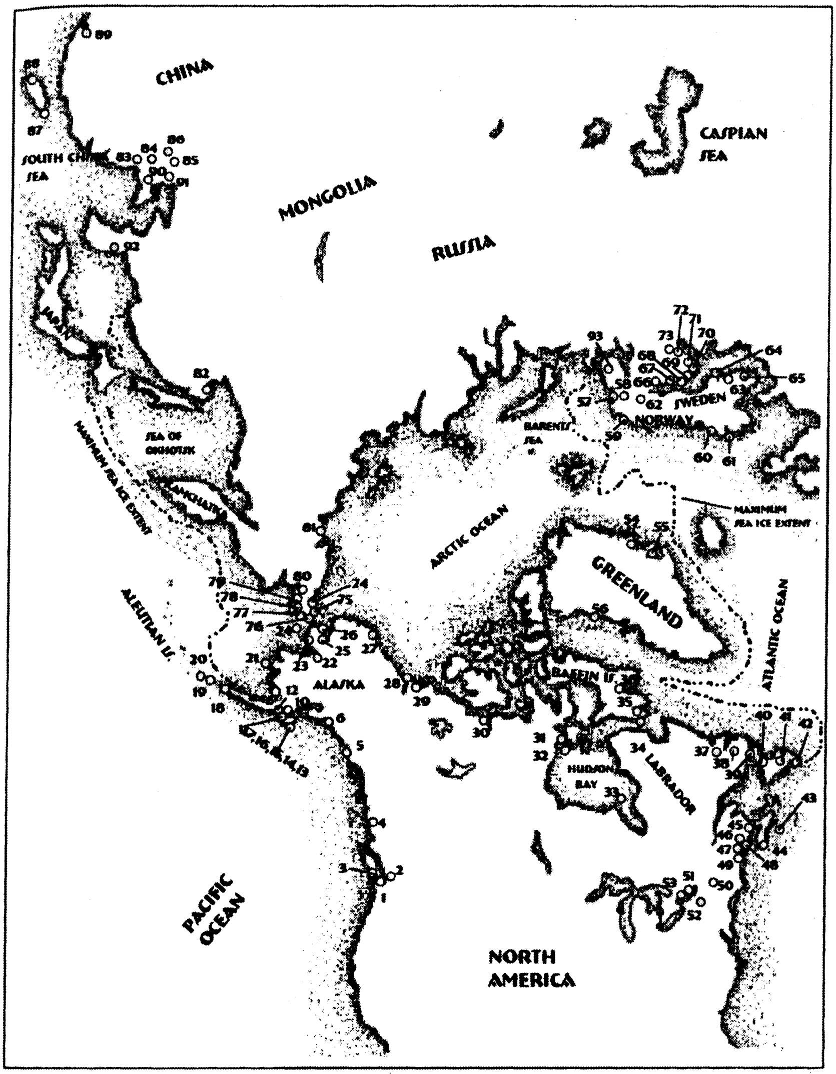

FIGURE 6.1 Geographical distribution of select archaeological sites containing ground slate implements (see Table 6.1).

Morphological and assemblage-level variability of ground slate tools has been interpreted as differential interaction with Eskimoan populations (e.g., Abbott 1881; Beaucamp 1897; Borden 1950, 1962; Chard 1960; Collins 1962; de Laguna 1946, 1947, 1956; Drucker 1955; Duff 1965; Dumond 1968, 1984, 1987; Gjessing 1944, 1948; Meldgaard 1960; Parker 1922; Spaulding

Table 6.1 Spatial and Temporal Distribution of Ground Slate Implements in the Circumpolar Region and Adjacent Areas

No.	Site/ Cultural Affiliation	Dates	References
1	Cattle Point, San Juan Island, Washington- Marpole Phase	400 B.C.-A.D. 400	(King 1950; Carlson 1960)
2	Glenrose Cannery/St. Mungo, Fraser River Delta, British Columbia- Locarno Beach Phase/ Marpole Phase	ca. 1000-400 B.C./ 400 B.C.-A.D. 400	(Burley 1980)
3	Shoemaker Bay, Alberli Inlet, Vancouver Island	910 B.C./ A.D. 500/ A.D. 820	(McMillan and St. Claire 1982)
4	Prince Rupert Harbour, British Columbia- Period II	ca. 1500 B.C.-A.D. 500	(MacDonald and Inglis 1981)
5	Old Town, Knight Island, Yakutat Bay, Alaska- Kachemak Bay sub-III and III	ca. 400 B.C.-A.D. 500	(De Laguna et al. 1964)
6	Palugvik, Prince William Sound, Alaska- Kachemak Bay sub-III and III	ca. 400 B.C.-A.D. 500	(De Laguna 1956; Workman 1980; Clark 1984)
7	Chugachik Island (SBL 0331), Kachemak Bay, Alaska- Kachemak II, Kachemak Sub-III- Kachemak III	790 B.C.- A.D. 475	(Workman, Lobdell, and Workman 1980)
8	Cottonwood Creek (SBL 0301) Kachemak Bay, Alaska- Kachemak III	A. D. 200-395	(Workman, Lobdell, and Workman 1980)
9	Fox Farad Bluff (SRL 041), Yukon Island, Kinchella Bay, Alaska	A.D. 625-860	(Workman, Lobdell, and Workman 1980)
10	Pedro Bay, Lake Iliaana, Alaska- Pedro Bay Culture	2580/2370 B.C.	(Clark 1984:143)
11	Takli Island Sites, Alaska - Takli Culture	ca. 2000 B.C.	(Clark 1984:137)
12	Brooks River Falls, Alaska	A.D. 125+!-130-A.D. 975+/-120	(Dumond 1984: 103)
13	Afognak, Kodiak Island, Alaska-Ocean Bay Phase I /Ocean Bay II	3800-2200 B.C./ 2550-1940 B.C.	(Clark 1984:143)
14	Crag Point, Kodiak Island- Koniag Phase	A. D. 850	(Clark 1984:184)
15	Three Saints, Kodiak Island- Three Saints Phase / Rolling Bay- Ceramic Koniag / Kiavik- Ceramic Koniag	A.D. 850/ A.D.1557-1597/ A.D. 1559-1670	(Clark 1984)
16	Uyak, Kodiak Island- Kachelak III Phase	400 B.C.-1 B.C.	(Clark 1984:139)
17	Chirikof Island, Alaska- Old Islander Culture	2100 B.C.	(Workman 1966, 1969)
18	Izembek Lagoon, Alaska- Izembek Phase	A.D. 1056	(McCartney 1974)
19	Chuluka, Akun Island	A.D. 780-1870	(Turner and Turner 1974)

Table 6.1 (Cont.)

20	Ashishik Point, Umnak Island	A.D. 1516+/-48	(Denniston 1972)
21	XNI-028, Nunivak Island, Alaska- Duchikmiut Phase	150 B.C.-A.D. 650	(Nowak 1982)
22	Iyatayet, Norton Sound, Alaska- Norton Tradition	ca. 500 B.C.- 1000 A.D.	(Dumond 1984)
23	Nome, Alaska- Cape Nome Phase	A.D. 1656+/-88	(Dumond 1984:104)
24	St. Lawrence Island, Alaska- Thule Phase	A.D. 800- 1200/1500	(Collins 1937; Ackerman 1984)
25	Krustenstern, Birnirk Phase	ca. A.D. 500	(Anderson 1984:91)
26	Kugzruk Island, Alaska- Norton Culture	600 -350 B.C.	(Larsen 1982)
27	Walakpa, Pt. Barrow, Alaska- Birnirk/Early Thule Phases	A.D. 980/1110	(Stanford 1976)
28	Washout, Herschel Island, Alaska	A.D. 380-960	(Yorga 1980)
29	Kittigazuit, Mackenzie Delta, Alaska	A.D. 1350-1650	(McGhee 1974)
30	Clachan and Naliqaq, Coronation Gulf, Northwest Territory- Proto-Historic Copper Eskimo	ca. A.D. 1200- 1500	(Morrison 1981)
31	Karaarvik, Northwestern Hudson Bay- Thule Eskimo		(McCartney 1977)
32	Silumiut, Northwestern Hudson Bay- Thule Eskimo	A.D. 1205/1260	(McCartney 1977)
33	Belcher Islands, Northwest Territory, Canada- Thule Culture		(Benmouyal 1978)
34	Morrison and Nanook, Lake Harbour, Baffin Island- Dorset Culture	ca. A.D. 500-800	(Maxwell 1980)
35	Crystal II, Frobisher Bay, Baffin Island- Dorset Culture	ca. A. D. 500- 800	(Maxwell 1980)
36	Cumberland Sound, Baffin Island- Thule Eskimo	A.D. 1370-1850	(Schledermann 1975)
37	Hamilton Inlet sites, Labrador- Sandy Cove Phase /Rattler's Bight Phase	4050-2750 B.C./ 2050-1850 B.C.	(Fitzhugh 1975; Tuck 1976:104)
38	Hopedale, Labrador- Maritime Archaic Tradition		(Bird 1945)
39	Forteau Bay (EiBf-2), Labrador- Maritime Archaic Tradition / L'Anse. Amour (EiBf-4), Labrador- Maritime Archaic Tradition	ca. 2040-1050 B.C./ 4250-2155 B.C.	(Harp 1964; Tuck and McGhee 1975).
40	Port au Choix. Newfoundland- Maritime Archaic Tradition	2340/1280 B.C.	(Tuck 1970)
41	Curtis, Twillingate Island, Newfoundland- Maritime Archaic Tradition	1770- 1250 B.C.	(Tuck 1976)
42	Beaches, Bonavista Bay,	2050 B.C.	(Tuck 1976)

(*continued*)

Table 6.1 (Cont.)

	Newfoundland- Maritime Archaic Tradition		
43	Cape Breton Island, Nova Scotia- Maritime Archaic Tradition		(Tuck 1976)
44	Tusket Falls, Nova Scotia- Maritime Archaic Tradition		(Sanger 1975)
45	Marble Cove, Saint John, New Brunswick- Maritime Archaic Tradition		(Sanger 1975)
46	Cow Point, New Brunswick- Late Maritime Archaic Tradition	1885 B.C./1680 B.C.	(Tuck 1975)
47	Hirundo, Maine- Maritime Archaic Tradition		(Snow 1980)
48	Ellsworth Falls, Maine- Maritime Archaic Tradition	2009 B.C./1400 B.C.	(Byers 1959)
49	Goddard, Brooklyn, Maine- Maritime Archaic Tradition	1960-1750 B.C.	(Bourque 1975)
50	Vergennes, Vermont- Vergennes Phase, Laurentian Culture	3500-3000 B.C.	(Mason 1981)
51	Morrison's Island-6t Quebec- Brewerton Phase, Laurentian Culture	2750 B.C.	(Mason 1981)
52	Frontenac Island, Cayuga County, New York-Frontenac Phase, Lalloka/Laurentian Cultures	2500-2000 B.C.	(Mason 1981)
53	Southern Ontario, Canada- Sites assigned to Northern Archaic Pattern		(Wright 1962)
54	Dodemandsbugten, Clavering Island, Greenland- Northeast Greenland Mixed Culture I / II	ca. A.D. 1500-1600	(Larsen 1934)
55	Kempe and King Oscar Fjord, Greenland- Northeast Greenland Mixed Culture/Eskimo		(Glob 1935)
56	Inugsuk, Upernivik District, Greenland- Inugsuk Period	ca. 1200/1750-1850	(Mathiassen 1930)
57	Skjavika, North Norway- Younger Stone Age	4550 B.C.-A.D. 150	(Gjessing 1938)
58	Nyelv Nedre Vest, Varangerfjord, North Norway- Younger Stone Age	4550 B.C.- 3500 B.C.	(Renouf 1986)
59	Storbathelleren, Lofoten Islands, Norway- West Norway Slate Complex	3300 B.C./2790 B.C.	(Bakka 1976)
60	Hitra/Vika/Vega Islands, Norway- West Norwegian Slate Complex	ca. 3000-1500 B.C.	(Fitzhugh 1974)
61	Straume, Norway- Pitted Ware Complex	ca. 3000 B.C.	(Fitzhugh 1974)
62	Rovaniemi, Finland- Pyheensilta Slate Complex	1800-1600 B.C.	(Fitzhugh 1974)

Table 6.1 (Cont.)

63	Overvada, Angerltanland, Sweden-North Sweden Slate Complex	4000-3000 B.C.	(Fitzhugh 1974)
64	Aland Islands, Sweden- Pyheensilta Slate Complex	4000-3000 B.C.	(Fitzhugh 1974)
65	Vasterbjers, Gotland, Sweden-Younger Stone Age		(Stenberger 1939)
66	Saraisnielli and Kestila, Finland-Suomusjärvi Complex	ca. 5500 B.C.	(Äyräpää 1951)
67	Haapajarvi, Pielavesi, Pihtipudas, Pyhajarvi, and Karttula, Finland-Suomusjärvi Complex	ca. 5500 B.C.	(Äyräpää 1951)
68	Alajarvi, Saarijärvi, Alavus, Jalasjarvi, Kaubajoki, and Honkojoki, Finland-Suomusjärvi Complex.	ca. 5500 B.C	(Äyräpää 1951)
69	Kangasala and Punkalaidun, Finland-Suomusjärvi Complex	ca. 5500 B.C.	(Äyräpää 1951)
70	Kiikala, Suomusjärvi (Laperla), Kisko, and Sallatti, Finland- Suomusjärvi Complex	ca. 5500 B.C.	(Äyräpää 1951)
71	Sjundea and Tuusula, Finland-Suomusjärvi Complex	ca. 5500 B.C.	(Äyräpää 1951)
72	Askolat Borgat and Lapptraskt Finland-Suomusjärvi Complex	ca. 5500 B.C.	(Äyräpää 1951)
73	Raisala and Kaukola, Finland-Suomusjärvi Complex	ca. 5500 B.C.	(Äyräpää 1951)
74	Uwelent Eastern Siberia-Old Bering Sea Stage	A.D. 1-700	(Rudenko 1961; Ackerman 1984)
75	Cape Deezhnev, Eastern Siberia- Old Bering Sea Stage		(Rudenko 1961)
76	Nuukant Eastern Siberia- Late Punuk Stage		(Rudenko 1961)
77	Cape Chaplin, Eastern Siberia- Late Punuk Stage		(Rudenko 1961)
78	Kiwak Eastern Siberia- Old Bering Sea Stage		(Rudenko 1961)
79	Sirhenik, Eastern Siberia- Old Bering Sea/Late Punuk Stages		(Rudenko 1961)
80	Enmylen, Eastern Siberia- Old Bering Sea/Early-Classic Punuk		(Rudenko 1961)
81	Cape Baranov area, Soviet Far East-Birnirk Phase	A.D. 300/400-800/900	(Ackerman 1984)
82	Maritime Province, Amur River- Shell Mound Culture	ca. 2000 B.C.-A.D. 1	(Andreyev 1964)
83	Hei-Ku-Tui, Honan, China- East Honan Phase Lung-shan Culture	ca. 2400 B.C.	(Chêng 1959; Chang 1986)

(*continued*)

Table 6.1 (Cont.)

84	Tsao Lu-T'ai, Honan, China		(Chêng 1959)
85	Yang-Shao-Ts'un, Honan, China-Neolithic Culture	5000-3000 B.C.	(Andersson 1947; Chang 1986)
86	Pao Chia Sha, Honan, China		(Andersson 1947)
87	Ta-P'en-K'eng, Taiwan- Ta-P'en-K'eng Culture	4450-4350 B.C.	(Chang 1969; 1986)
88	Feng-Pi-T'ou, Taiwan- Feng-Pi-T'ou Culture	ca. 4000 B.C.	(Chang 1969; 1986)
89	Shan Wan Bay, Southern Lamma Island, Hong Kong- Bronze Age		(Bard and Meacham 1972)
90	Chu-ch'teng, Shantung, China- Lung-shan Culture	ca. 2500-1500 B.C.	(Chang 1986)
91	Ch'eng-tzu, Shantung, China- Lung-shan Culture	ca. 2500-1500 B.C.	(Chang 1986)

1946; Strong 1930; Ritchie 1969; Rudenko 1961; Workman et al. 1980). Borden (1950:245) attributed the appearance of ground slate technology in the Pacific Northwest Coast region to "waves of migrations of Athapaskan-speaking peoples sweeping from northern regions southward along the Coast." Borden (1962) and Byers (1962) later proposed that ground slate technology originated in Asia and represented a "crosstie" or culture historical link between the Old World and North America. Drucker (1951) and Duff (1965) have suggested that Pacific Northwest coast slate assemblages resulted from direct immigration of high arctic peoples. And, Dumond (1987:46) attributed the archaeological appearance of ground slate implements in northern coastal Canada to a migration of Thule culture peoples and subsequent replacement of Dorset culture peoples. Finally, Bank (1977:30–31) proposed that aconite poison whaling represents a recent historical "cultural transfer" from Asia to North America in the context of the Russian fur trade.

Functional Interpretations

The first functional argument proposed for the emergence of ground slate technology involves prototypes. Brøgger (1906), Clark (1975), Fitzhugh (1972), Gjessing (1948), Ritchie (1969), and Turnbaugh (1977) have all suggested that ground slate technology is a logical development from "prototypic" cut and polished bone, antler, and ivory tools manufactured during the Upper Paleolithic period. This argument does not account for the observed temporal and spatial distribution of ground slate tools, nor does it enable us to understand the selective conditions under which aboriginal craftsmen would have transferred this process from bone to slate.

A second functional argument offered to explain the appearance of ground slate implements is based on raw material availability. Gjessing (1948:24) points out that peoples of the Komsa Culture of northern Norway could have made use of slate instead of several varieties of siliceous stone from coastal terraces once flint sources were exhausted. Similarly, McCartney (1974:79) suggests that slate tools are not found in western Alaska and the Aleutian Islands, where this raw material is scarce. Fitzhugh (1975:360–361) also observes for the Northwest Coast that "The distribution of slate technology does not appear to be a result of raw material availability since slate is equally present in the interior." Similarly, other archaeologists have found that slate was utilized in other regions despite the local availability of suitable cryptocrystalline materials (e.g., Collins 1937; Fitzhugh 1974; Maxwell 1973; Wintemberg 1940).

Third, Fitzhugh (1974:358) states, "Present distribution and typological evidence suggests the hypothesis that the development and spread of the slate complex occurs when this early slate technology becomes enmeshed with the requisites of a maritime economy with its time-consuming fish and sea mammal processing activities, tasks to which ground slate tools, with their large size and smooth, easily resharpened edges, are eminently suited."

It is important to point out that slate does occur in large slabs that can be fashioned into much larger tools than those that could be made from cryptocrystalline materials.

Clark (1975) has provided a fourth possible explanation for the adoption of ground slate points by maritime peoples. He states, "Use of slate weapons may, however, be more feasible for marine hunting than for hunting on land inasmuch as a cast that misses its mark and plunges into the water is less likely to result in a broken point than a deviant cast on land" (pp. 212–213). This proposal does not explain the effectiveness of these slate-tipped arrows, darts, and spears once they were implanted in the prey or the need to use slate at all given the availability of cryptocrystalline stone.

Fifth, McGhee (1980) presents an interpretation of change in prehistoric Eskimo technology that counters explanations of replacive change and relative functional efficiency. He (pp. 40, 46) suggests that archaeologists generally assume that new, functionally superior technological developments are gradually assimilated until they completely replace their predecessors.[1] Such change is seen by McGhee (1980:49) as an example of an "instinct of workmanship... similar to the unexplained but well documented and apparently inevitable process of change in artistic and technological style."

Invention, Technological Novelty, and Risk

Some archaeologists have chosen to focus greater attention on the more proximate aspects of technological innovation (e.g., Bamforth and Bleed 1997; Bleed 1997; Oswalt 1987; Van der Leeuw and Torrence 1989).

Fitzhugh (2001) has recently presented an "economic rational choice fitness-utility model" that is meant to explore the behavioral ecological contexts under which the benefits of innovative activities and inventions exceed the costs (time, energy, and raw materials). Unlike the evolutionary and selectionist archaeologists, Fitzhugh (2001) strives to move beyond the usual "mother-of-invention" and "random variation" models and utilize "optimal decision theory in evolutionary ecology" to assess the "changing opportunity costs related to technological tinkering or invention" (p. 127). He then applies this fitness-utility model to the archaeological record of the Kodiak Archipelago of southern Alaska. Fitzhugh (2001:151) describes the appearance of ground slate lance points, other projectile points, and double-edged knives in Ocean Bay II lithic assemblages on Kodiak Island around 4500 BP. He suggests that slate implements could be made using methods previously used to work bone such as sawing, grooving and snapping, and grinding. Slate can be resharpened more easily and economically than chert. In addition, slate points tend to shatter in the wounds of the prey. Ultimately, he states, "Slate bayonets, points, and processing tools may have been successful innovations brought about by resource depression" (p. 151) or the decline in sea mammal productivity.

GROUND SLATE IMPLEMENTS: AN ALTERNATIVE EXPLANATION

Archaeologists and anthropologists have recently begun to examine technology in relation to the dynamic, adaptive aspects of hunter-gatherer behavior (e.g., Balikci 1970; Binford 1979, 2001; Bleed 1986; Hames 1979; Shotts 1986; Torrence 1983). Based upon cross-cultural data from Oswalt (1976), Torrence (1983) demonstrates that subsistence-related tool assemblages of historic hunter-gatherers increase in diversity (numbers of subsistants or tools to directly acquire food) and complexity (numbers of component parts or techno-units in each subsistant) along a south-to-north latitudinal gradient. These interrelated shifts in subsistants and technounits ultimately result from increased time stress and a greater dependence on food storage found along this gradient. Osborn (1999) has recently proposed that marked increases in the complexity of subsistants in the arctic region are related to wood scarcity and the associated reliance upon a greater diversity of raw materials for individual technounits. Oswalt (1976) and Torrence (1983) both point out that weapons and facilities used to procure aquatic animals are more complex than terrestrial-oriented equivalents. Such subsistants are designed to decrease the high handling costs of marine mammals. These recent studies of hunter-gatherer technology, however, do not consider the use of poisons used in aboriginal fishing and hunting strategies.

Initial Shift to Marine Mammal Hunting

Anthropologists have continued to disagree about the productivity, renewability, and accessibility of marine food resources (see Erlandson 1994; Hildebrandt and Jones 1992; Jones 1991; Moseley 1975; Osborn 1977a, 1977b, 1977c; Pálsson 1988; Raymond 1981; Rick and Erlandson 2000; Schalk 1977, 1978, 1979; Yesner 1980, 1987). Yet, many anthropologists have failed to acknowledge that marine environments differ significantly from their terrestrial counterparts. For example, the oceans cover more than 70 percent of the biosphere, yet produce less than .21 percent of the total world's biomass (Whittaker 1975:224, Table 5.2). Primary or plant production in the world's oceans is restricted to the uppermost 1.5 percent of its volume. Primary production in the upper 100 meters of the ocean, or the euphotic zone, is governed by incident solar radiation and nutrient availability. Detritus and essential nutrients are lost from the euphotic zone due to sinking. Marine production is limited spatially and temporally in high-latitude oceans by additional factors (Nemoto and Harrison 1981).[2] Anomalous areas of higher marine productivity occur either along continental margins or within upwelling areas which, if combined, equal 8 percent of the oceans' surface area (Whittaker 1975). Consequently, human access to marine secondary biomass is greatly restricted.

It must also be pointed out that more than 97 percent of all marine life is phytoplankton and zooplankton that ranges in size from .010 mm to 5.0 mm in length. Large body–size animals, including crustaceans, fish, and marine mammals, constitute only 3 percent of the total animal biomass in the oceans. Marine ecosystems generally possess long, complex food webs that impose great limitations on the number and the density of these larger body–size animals. Given these dramatic ecological differences, mean biomass density is more than 1,230 times as dense in terrestrial versus marine ecosystems (Whittaker 1975:224, Table 5.2).

Since marine food webs are long and complex, larger fish and most marine mammals must be carnivorous. Therefore, human predators must become high-level carnivores in order to exploit larger and more accessible marine prey. Number of prey and the energy and nutrients that they provide decrease dramatically as human predators, in this case, move up the ecological pyramids. Hunter-gatherers may harvest 30 percent of terrestrial net primary production by consuming plants or 10 percent by consuming herbivorous mammals, but their energetic efficiencies are very low when aquatic food resources are consumed. As Whittaker (1975:217) points out, "Pyramid relations imply that if the meat of aquatic carnivores is used, the harvest efficiencies in relation to primary production will range downward from 1.0, 0.1, and 0.01 per cent for primary, secondary, and tertiary carnivores respectively."

Marine food resources frequently exhibit clumped or patchy distributions due to variation in incident solar radiation, nutrients, substrate, currents, upwelling, and the feeding and reproductive patterns of marine organisms (Schalk 1977, 1978, 1979). Marine mammals tend to exhibit more aggregated or clumped distributions in higher-latitude settings (Schalk 1978, 1979). Aggregation of such "low-density" marine animals would increase travel time required to move from patch to patch (Pianka 1983). Although search costs within a patch are reduced due to clumping, pursuit costs for marine mammals remain high as a function of effective escape behaviors, sinking due to seasonal fat depletion and dilution of seawater, and differential sea ice cover. The accessibility of such clumped and/or migratory resources became critical to aboriginal groups, particularly those dependent on anadromous fish, ringed seals, and whales.

Shellfish and gastropods occur as clumped resources within the dynamic intertidal zone. Storms may destroy beds of mussels and clams by scouring and/or alluviation (Meehan 1975). Salmon exhibit marked variation in species diversity, migration times, and the duration and size of runs. Optimal salmon habitats occur around 45 to 60 degrees north latitude (Schalk 1977, 1978, 1979). The patchy distribution and aggregation sizes for ringed seal have been causally linked to winter/summer sea ice conditions (e.g., Boas 1888; McLaren 1958, 1961; Steensby 1917). Crustaceans, shellfish, and anadromous fish represent aggregated resources, but exhibit very high processing costs (Osborn 1977a, 1977b, 1977c; Schalk 1977, 1978). Schalk (1979) also emphasizes the higher organizational costs, e.g., high logistical mobility, larger group sizes, and increased reliance on storage of processed resources associated with marine resource exploitation along the Pacific Northwest coast (Binford 1980, 1983, 2001; Torrence 1983, 1989). Demersal and pelagic fish represent high search and pursuit costs for aboriginal fishermen due to variable densities and their three-dimensional habitat.

Marine mammals should be added to the aboriginal diet as a function of the decreased availability and increased handling costs of lower-ranked terrestrial resources. Holocene occupants of the arctic should have initially exploited higher-ranked terrestrial resources such as caribou and musk ox. Later, increases in effective human population density and corresponding depression of higher-ranked prey would have necessitated an expansion of the diet to include lower-ranked shellfish, fish, and marine mammals. Short-termed declines in high-ranking caribou herds also triggered temporary shifts toward marine resource exploitation. Such changes occurred between 1890 and 1920 among the northern Alaskan Eskimo (Amsden 1979; Burch 1972; Damas 1972; Fitzhugh 1976).

Archaeological evidence for the initial, intensive utilization of aquatic resources suggests that humans avoided use of the oceans until late in prehistory (Binford 1968, 1983; Osborn 1977a, 1977b; Schalk 1977, 1978, 1979; Yesner 1980, 1987). Binford (2001:385) states:

> Exploitation of aquatic resources, other things being equal, appears to be a density-dependent response to terrestrial packing. It may result from the costs associated with maintaining high mobility in low-food yielding terrestrial habitats. In such situations, experimentation with aquatic resources could reduce mobility costs. Nevertheless, packing is a general characteristic of documented hunter-gatherers who are dependent upon aquatic resources.

Binford (2001:369) has stated, "The patches or access windows for the procurement of aquatic resources are largely determined by the nature of the habitat, as modified, of course, by the available technology for accessing food from the biome.... Add to these features of the environment the fact that a technological filter stands between many resources and the human ability to access or exploit the aquatic milieu." As a consequence of increased reliance upon aquatic food resources in high-latitude settings as well as wood scarcity, the diversity and complexity of implements and facilities in food-getting technology increases. Arrows, darts, lances, leisters, harpoons, hooks and lines, weirs, and nets become essential parts of the aquatically oriented tool kit. Various types of watercraft also become extremely important throughout the circumpolar zone. One very interesting addition to the hunting technology is poison that is used for debilitating and/or killing marine mammals.

Association of Marine Mammals, Ground Slate Implements, and Plant Alkaloid Hunting Poisons

Early ethnohistorical accounts by Eurasian explorers, hunters, naturalists, and missionaries who visited Kamchatka, the Aleutian Islands, and southwestern Alaska provide invaluable observations about marine mammal hunting strategies and ground slate projectile points. Ethnohistorical accounts described a number of aboriginal hunting episodes in which slate-tipped arrows, darts, spears, and/or lances were used to kill marine mammals including seals, sea otters, sea lions, walruses, and whales. Several of these accounts referred to the use of plant alkaloid poisons that were applied to ground slate, and in some cases chipped stone, projectile points. Such disparate historical accounts serve as possible clues to the underlying causal relationships between hunting implements manufactured from slate and a marine mammal hunting strategy based on phytotoxins.[3]

According to Krasheninnikov's (1755:209 in Rudenko 1964:273) accounts, the Koryak, Yukagir, and Chukchee of eastern Russia are said to have "smear[ed] their arrows with the crushed root of the cursed crowfoot... The largest whales and bearded seals, even if only slightly wounded... hurl themselves on to the shore and perish miserably."

European and Asian explorers and later ethnologists have described sea mammal hunting practices that made use of slate-tipped projectiles for the

Aleut (Dall 1877; Markoff 1856:99–100; Wrangell 1839:54), the Koniagmiut (Holmberg 1985:108–110; Lisiansky 1814:174, 202, 206; Osgood 1937:39; Pinart 1872:12–13; Sauer 1802:177; Steensby 1917:144), the Chugach (Birkett-Smith 1953:33–34, 209–210; de Laguna 1956), and the Tanaina of Cook Inlet (Steensby 1917:143). For example, Sauer (1802:177) found that the Koniag "use darts and lances headed with slate, with which they kill the sea mammals. They also use poison to their arrows, and the Aconite is the drug adopted for this purpose... [T]he men anoint the points of their arrows, or lances, which makes the wound that they inflict mortal."

Not all explorers, however, observed or mentioned aboriginal use of plant alkaloid poisons in conjunction with ground slate points in the context of sea mammal hunting. For example, Bisset (1976:108) states, "Neither Coxe [1787] nor [von] Langsdorff [1812, 1813] has any mention of poisoned weapons in connection with the Kodiak islanders." A number of firsthand accounts of aboriginal sea mammal hunting attributed the animals' deaths to seawater (Markoff 1856), body fat of deceased whalers (Lisiansky 1814; Veniaminov 1840; Pinart 1872:12–13), or to the "toxic" qualities of slate itself (Dall 1877, in Heizer 1938:359). Aboriginal use of both plant alkaloid poisons and ground slate points by the Koniag was mentioned by Sauer (1802:181), whereas Lisiansky (1814:174, 202, 206), Pinart (1872:12–13), Lantis (1938:441–443), and Osgood (1937:39) spoke of slate-tipped spears and lances dipped in "poisonous" human fat or grease. Heizer (1943:437) attributed the toxicity of specially treated ground slate points to "aconite, which was a carefully guarded secret. Additional 'poisons' in the form of fat rendered from corpses were used, but these were ceremonial and actually innocuous."

Many of the whale hunting methods employed by the Aleut and the Chugach were shrouded in ceremonial observances, secret practices, and taboos (Dall 1877; de Laguna 1956; Heizer 1938; Lantis 1938). Information concerning the actual ingredients of hunting poisons was restricted to certain individuals within aboriginal societies (Weyer 1932:309, in Heizer 1943:436, footnote 47). It is not surprising then that a number of Euro-Asian and American explorers, hunters, and military personnel either failed to mention aboriginal use of hunting poisons or attributed the deaths of struck sea mammals to various magico-religious causes.

Plant Alkaloid Hunting Poisons: Derivation, Composition, Effects, and Toxicity

The most significant writings regarding the use of plant alkaloid poisons in the circumpolar region were published more than 60 years ago. A number of archaeologists and anthropologists still seriously question the efficacy of aconite for hunting marine as well as terrestrial prey species. Heizer (1938, 1943) published several of the earliest anthropological studies of aconite poison and its use by prehistoric and historic hunters of the circum-Pacific region. Heizer's detailed accounts of poison hunting were meant to establish culture historical ties between the Old and the New World. Their greater significance was not realized in subsequent investigations of native technology in the arctic and subarctic regions (Bockstoce 1976; Manning 1944; McCartney 1980; Oswalt 1973, 1976; Sonnenfeld 1960; Suttles 1952; Torrence 1983, 1989; Wilson and Buck 1979).

These studies focused on aconite poison derived from several species of the genus *Aconitum* including *A. napellus* (wolfsbane), *A. delphinifolium* (larkspur), and *A. maximum* (Heizer 1943:443–445). Many archaeologists and anthropologists have overlooked the fact that Heizer (1943:444) spoke of two additional genera, that is, *Ranunculus* (cursed crowfoot) and *Anemone*, that contain alkaloid poisons used for sea mammal hunting. Furthermore, we must be aware of a number of additional phytotoxins that could have been used as an integral part of poison hunting strategies in the circumpolar region and beyond (Table 6.2). For example, Bisset (1976:91, 1979:334, 1981:254, footnote 9) points out that there are a variety of toxic plants in addition to *Aconitum* including *Actaea* (baneberry), *Apium* (celery), *Artemisia vulgaris* (mugwort), *Caltha palustris* (marsh marigold), *Cicuta* (water hemlock), *Euphorbia* (spurge), *Helleborus* (bear's foot), *Mandragora* (*Atropa*; mandrake or Satan's apple), and *Ranunculus* (crowfoot).

Spencer and Schaumburg (2000:122) point out, "The family Ranunculaceae contains a number of exceptionally toxic herbaceous perennials, such as *Aconitum napellus* L. (monkshood), *A. vulparis* Reichb. Ex Spreng (wolf's bane), and *Delphinium elatum* L. (larkspur)." The plant genus *Aconitum* has more than 300 species (and numerous varieties), and several of these are found throughout the circum-Pacific region (Bisset 1976). Aconite poison is derived from *Aconitum* species (monkshood or wolfsbane) that contain a combination of highly toxic diterpene alkaloids (Bisset 1976, 1979, 1981; Hesse 2002:84). These alkaloids are utilized by plants to provide protection against fungi, UV radiation, and herbivory (Hesse 2002: 284–293). Highly toxic ester-type alkaloids in *Aconitum* include hypaconitine, mesaconitine, jesaconitine, and aconitine. The crude or unprocessed alkaloid content of *A. maximum* and *A. sachalinense* is .19 and .26–.35 percent, respectively (Bisset 1976:113). The crude alkaloid content of *A. napellus* is .97–1.23 percent for the roots and .18–0.21 percent for the leaves (Mosto and de Landoni 1990). It is possible to extract 2–20 mg of aconite from 1 g of fresh *Aconitum* (Mofenson and Caraccio 2001).

Aconitine is the most significant toxic alkaloid in aconite poison (Bisset 1981:296). Aconitine activates sodium (Na+) channels in mammalian excitable membranes, including neurons, axons, and all types of muscle tissue (Hesse 2002:18–19). Spencer and Schaumburg (2000:3–4) state, "Neurotoxins have indirect or direct effects upon the nervous system function. The brain is one of the organs most frequently impacted in systemic toxic states." Since the central nervous system and the brain require tremendous quantities of oxygen, toxins that enter the bloodstream are channeled directly to the brain and the spinal column (Hesse 2002:10). Aconitine is both a neurotoxin and a cardiotoxin. Death occurs following cardiac arrest and

Table 6.2 Geographical Distribution of Alkaloid-Bearing Plants in the Circumpolar Region (Pammel 1911; Britton and Brown 1943; Hulten 1944, 1968; Polunin 1969)

Plant name	Kam.	Sib.	Aleu. Is.	Alas.	Yuk.	Lab.	Grnlnd.	Scan.
Family *Ranunculaceae*								
Aconitum delphinifolium ssp.	X	X	-	X	X	-	-	-
Aconitum maximum	X	-	X	-	-	-	-	-
Actaea spicata ssp.	X	X	X	X	X	X	X	X
Adonis vernalis	?	?	?	?	?	?	?	-
Anemone narcissiflora ssp.	X	X	X	X	-	X	-	-
Anemone patens multifida	-	-	-	X	X	-	-	X
Anemone pusatilla	-	-	-	X	X	-	-	-
Anemone richardsonii	X	-	-	X	X	X	X	X
Aquilegia vulgaris	-	-	-	-	-	-	-	X
Caltha palustris arctica	X	X	X	X	X	-	X	X
Consolida ambigua	-	-	-	-	-	-	-	X
Coptis groenlandica	-	-	X	X	-	-	X	X
Coptis trifolia	-	-	X	-	-	-	X	-
Delphinium brachycentrum	X	X	-	X	-		-	-
Delphinium glaucum	-	-	-	X	-		-	-
Ranunculus abortivus	-	-	-	X	X	X	-	-
Ranunculus acer (acris)	-	-	X	-	-	-	-	-
Ranunculus affinis	X	X	-	X	X	X	X	X
Ranunculus confervoides	-	X	X	X	X	-	X	X
Ranunculus cymbalaria	X	X	-	X	X	X	X	-
Ranunculus glacialis	-	X	-	X	-	-	X	X
Ranunculus gmelini	X	X	-	X	X	-	-	X
Ranunculus hyperboreus	X	X	X	X	X	X	X	X
Ranunculus lapponicus	X	X	-	X	X	X	-	X

Table 6.2 (Cont.)

Ranunculus macounii	-	-	-	X	X	X	-	-
Ranunculus nivalis	X	X	-	X	X	X	X	X
Ranunculus occidentalis	-	-	X	X	X	-	-	-
Ranunculus pallasii	X	X	-	X	X	-	-	X
Ranunculus pygmaeus	-	X	-	X	X	X	X	X
Ranunuculus repens	X	X	-	X	-	-	X	X
Ranunculus reptans	X	X	X	X	X	X	X	X
Ranunculus sceleratus ssp.	X	-	-	X	-	X	-	X
Ranunculus sulphureus	-	X	X	X	X	X	X	X
Thalictrum alpinum	X	X	-	X	-	-	X	X
Thalictrum minus	X	X	X	X	-	-	X	X
Thalictrum sparsiflorum	X	X	-	X	X	-	-	-
Family *Scrophulariaceae*								
Digitalis purpurea	-	-	-	-	-	-	-	X
Family *Umbelliferae*								
Conium maculatum	-	-	-	-	-	-	-	X

paralysis of the respiratory system (Mosto and de Landoni 1990). Also, aconitine slows the heart rate and lowers blood pressure. Consequently, it is quite possible that mammalian metabolism is lowered and detoxification is slowed (Bisset 1976; Polson and Tatersall 1969; Stern 1954:278).

As Polson and Tatersall (1969) pointed out, all parts of the *Aconitum* plant contain toxic alkaloids. In general, the pharmacological activity and toxicity of this plant increases in the following order: stems > leaves > flowers > tubers (Bisset 1981:296). Yakazu (1958), Bisset (1976, 1979, 1981), and others have discussed the seasonal variation in alkaloid content for various species of *Aconitum* in Japan, China, and Central Asia. Yakazu (1958:3727) points out, "The content of the alkaloids... in the aconite roots varied with time of harvesting, place of cultivation, period of preservation, and also the mode of processing after harvesting." Bisset (1981:297), for example, states that the alkaloid content of *Aconitum* sp. in Japan, China, and Europe increases in the tubers of the parent plant throughout the first months of the year until spring and then begins to decline as the toxicity of the daughter plant's tubers increase through late summer and early autumn.

Some scholars have referred both to the scarcity of poisonous plants and/or the low alkaloid content of arctic varieties of *Aconitum* (e.g., Bank 1977; Black 1987; Heizer 1943). Heizer (1943:444), for example, pointed out that poisons used in hunting were less important in the higher latitudes for two major reasons: use of phytotoxins did not diffuse into some areas, and phytogeography—higher-latitude plants are not as poisonous. Bisset (1976:112) suggests that this may well be the case since there is less diversity of plant species in higher latitudes.

There are reasons to believe that such an assumption is unfounded. For example, plant and animal life in high-latitude settings tends to reflect patterns of life that are found at high altitudes in more mid-latitude settings. Consequently, we might note that the alkaloid content of a number of varieties of *Aconitum* found at higher elevations in the mountains of China can be considerable. *Aconitum nagaum* was used in China to manufacture arrow poison. It grows between 1,800 and 4,200 m in the mountains of Yunnan, Upper Burma, and in Nagaland of India (Bisset 1981:251). Similarly, *A. ouvradianum* was also used for arrow poison; it is found between 3,000 and 4,000 m above sea level in northwest Yunnan and southeast Tibet (Bisset 1981:251). *Aconitum stylosum* that is harvested between 2,700 and 4,100 m was used in eastern Tibet for the same purpose (Bisset 1981:251).

Bisset (1976, 1979, 1981) and others have pointed out that aboriginal peoples frequently combined primary plant poisons with various poisonous and nonpoisonous adjuvants such as spiders, insects, leaves, pine resin, puffer fish oil, and the fat of deceased Aleut whalers. On Hokkaido, the Ainu combined aconite with adjuvants including toxic marsh marigold and mugwort to produce *surku*, a very toxic arrow poison (Bisset 1976:90–91). Such adjuvants may have served to enhance the binding and storage properties and to increase the toxicity of the hunting poisons. Hunting poisons may have included two or more plant phytotoxins in regions where plants reportedly contained low alkaloid levels.

Data regarding the toxicity of aconite for several different body-sized mammals is provided in Tables 6.3 and 6.4. Both intravenous and subcutaneous lethal dosages are noticeably lower than the required oral dosage. Also, aconite poison injected into prey animals by means of poisoned arrows, darts, lances, or harpoons would not be subject to regurgitation (Bisset 1976:116). Since aconite poison arrows were used in warfare by the Chinese, it is interesting to note that the lethal dosage of aconite for adult humans is approximately 5 mg (Mosto and de Landoni 1990).

Lethal dosages of aconite poison for various marine mammals are provided in Table 6.4. These calculations are based on Heizer's (1943:440) lethal dosage of .13 mg/kg live body weight. This lethal dosage is an average value required to kill "warm-blooded" animals, such as rabbits and domesticated cats cited in experiments by Cash and Dunstan (Allen 1929: 260–262). This value agrees well with the data provided by Kuroda (1951 in Ishikawa 1962) for maximum subcutaneous injections required to kill dogs (Table 6.3). Fatal dosages for humans are 5 mL of aconite tincture, 2–6 mg of pure aconite, and 2–4 g of *Aconitum* root (Mofenson and Caraccio 2001). Given a mean lethal dosage of .13 mg/kg live body weight, we find

Table 6.3 Lethal Dosages of Aconite Derivatives for Small Mammals and Humans (from Bisset 1979: 298–300, Table 5; Mitchell 1929: 260–261, Human Data)

Aconite Preparation- **Aconitum sczukinii:**	Test Animal	Subcutaneous, s.c. (mg/kg)*	Intravenous, i.v. (mg/kg)*	Mean s.c and i.v. (mg/kg)
10% alcohol tincture	rabbit	-	15-20(17.5)	17.5
10% alcohol tincture	cat	-	30	30.0
Hypacinitine	mouse	1.19	0.47	0.83
Benzoylhpaconine	mouse	130	23	76.5
Mesaconitine	mouse	0.20-0.26(0.23)	0.10-0.13(0.12.5)	0.18
Benzoylmesaconitine	mouse	230	21	125.5
Aconitine	mouse	0.27-0.31(0.29)	0.31	0.30
Aconine	human	0.5 (oral)	0.15	
Aconitine triacetate	mouse	-	125	125.0
Benzoylaconine	mouse	-	23	23.0
Aconifine	mouse	1.15	0.22	0.68
Aconifine	dog	-	0.04	0.04
Yunaconitine	mouse	0.26	0.05	0.155
Yunaconitine	dog	-	0.03	0.03
Talatizamine	mouse	-	115.5	115.5
Lappaconine	mouse	-	6.1-11.5(8.8)	8.8
Lappacinitine triacetate	mouse	-	145	145.0
Lappaconine	mouse	-	142-144(143)	143
Songorine	mouse	630	142.5	386.2
Songorine acetate	mouse	-	132	132
Songorine acetate	rabbit	-	50	50.0
Songorine acetate	dog	-	35	35
Napelline	mouse	-	87.5	87.5
Delavaconitine	mouse	106	28	67.0
Delavaconitine	rabbit	112	5-10(7.5)	59.7
Delavaconitine	dog	-	10-12(11)	11.0
Higenamine	mouse	-	58.9	58.9

(*continued*)

Table 6.3 (Cont.)

Magnoflorine	mouse	138	19.6	78.8
Mean	All	122.65	45.82	65.86
Mean	mouse	123.71	56.525	90.12
Mean	rabbit	112.0	25.0	68.5
Mean	cat	-	30.0	-
Mean	dog	-	2.85	-

* Mean for toxicity range in parentheses.

that a humpback whale weighing more than 34 metric tons may be killed with approximately one-seventh of an ounce of aconite poison.

Investigators have questioned the efficacy of aconite as a hunting poison for sea mammals, especially whales. Bisset (1976:116–117) seriously questions the potency of aconite for killing adult whales. He bases his argument on several assumptions including: (1) an average lethal dosage of aconitine equal to .1 mg/kg live body weight, and (2) an active principle in the poison equal to 5 percent. Bisset (1976:116) then suggests that 4–5 g of aconite would be needed to kill an adult whale. The hunting poison discussed by Bisset includes only one alkaloid, (i.e., aconitine), and it is

Table 6.4 Estimated Lethal Dosage of Aconite Poison Required for Select Marine Mammals

Marine Mammal	**Live Body Weight (kg)**	**Lethal Poison Dosage (g) ***
Whale, bowhead (adult)	45,000	5.580
Whale, humpback (adult)	34,000	4.420
Walrus	1,363	0.177
Sea lion (adult male)	1,010	0.132
White whale	454	0.059
Sea lion (adult female)	273	0.035
Seal, bearded (adult)	227	0.030
Seal, harp (adult)	181	0.024
Seal, harbor (adult)	150	0.020
Seal, ringed (adult)	90	0.012

* Lethal dosage calculated on the basis of Allen's (1929:260–262) figure equal to .13 mg/kg live body weight (in Heizer 1943).

administered subcutaneously or intravenously via one strike or hit with an arrow, spear, or lance. Black (1987:26) states, for example, "Assuming that the alkaloids constitute 5% of the poison, a total of 100 grams is needed. This quantity is obviously too large to apply to a [harpoon] blade."

Several factors should be reconsidered concerning the arguments made by Bisset (1976) and Black (1987). First, hunting poisons may have been administered by way of multiple hits in the flukes and tail with projectile points of various sizes. Nelson (1899) described aboriginal hunting of seal and walrus in the Kuskokwim and Norton Sound area of Alaska that involved the use of multiple, detachable lance heads. Property marks were "cut" into each lance point "so that, when the animal is secured each [hunter] is enabled to reclaim his own [prey animal]" (Nelson 1899:147). Holmberg (1985:48) states that Koniag whale hunters traveled in a pair of *baidarkas*. It is quite possible then to assume that whales were struck by more than one projectile thrown by more than one hunter. Although Nelson did not discuss hunting poison for the Kuskokwim/Norton Sound area, Heizer (1943:440) compared this account to Kodiak whaling lance hunting that made use of barbed slate points, property marks, and aconite poison. Workman (1978:67) suggests that the incised designs on Ocean Bay II slate points may have been ownership marks that were characteristic of historic poison lance whaling. He also comments, "One wonders if some of the 'ornamental' grooves and pits might not have served to retain aconite poison" (p. 67).

Second, many hunting poisons contained two or more adjuvants including other toxic and/or haemolytic alkaloids. For example, the Ainu on Hokkaido utilized five or six different poisons that included aconite. As mentioned, *Surku* contained *Aconitum* (aconite) as well as *Caltha palustris* (marsh marigold) and/or *Artemisia vulgaris* (mugwort). Spencer (2000:5) states, "Exposure to two or more chemicals may have interactive biological effects [additive, synergistic, or antagonistic] that may modify the toxic potency of the agents."

Third, previous estimates for the amount of active principle in *Aconitum* plants has been based either upon percent dry weight of the plant or upon the content of an alcohol tincture in which aconitine had been dissolved. Tinctures have been a common pharmacological method for preparing and administering drugs and medicines. Calculations were not based upon the toxicity of crystalline aconitine that can be prepared from the dry, powdered root of the monkshood plant. Crystalline aconitine is very concentrated and is "almost insoluble in water" (Mitchell 1929:233).

There is now very good reason to believe that lethal dosages for aconite (aconitine) have been miscalculated. Heizer (1943), Bisset (1976), and Black (1987) all made use of Allen's (1929:260–261) average lethal dosage of aconite for "warm-blooded animals" equal to .13 mg/kg live prey weight. In order to calculate the lethal dosage for larger marine prey animals, they then extrapolated from this average for small mammals. Calculations of toxicity in this case should be based upon "physiologically based pharmacokinetic models" (Travis et al. 1990:285). Such pharmacokinetic models recognize the interrelationships between mammalian body size, basal metabolic rate, and the toxic effects of chemicals and/or drugs (Table 6.5). These lethal dosages for small body–size animals were plotted, and an exponential equation was fit to the data (Figure 6.2). This equation was then utilized to calculate the relationship(s) between marine mammal basal metabolic rates and corresponding lethal dosages of aconitine (Figures 6.3a, 6.3b). The Kleiber curve "indicates that the basal metabolic rate of a mammal decreases as the mammal becomes larger" (Eisenberg 1981:233; McNab 1988). If we make use of the interrelationship between body weight and basal metabolism, we can estimate the basal metabolic rate for various sea mammals, including whales. Given this information, we can then calculate the lethal dosages of aconite (aconitine) for a range of sea mammals. These physiologically based calculations reveal that previous estimates for lethal dosages of aconite were grossly overestimated (Figure 6.2). For example, if we use Heizer's lethal dosage of .13 mg/kg live body weight, the amount of aconite required to kill an adult bowhead whale equals 5.580 g. However, a revised lethal dosage based upon the basal metabolic rate for

Table 6.5 Recalculated Lethal Dosage of Aconite Poison Required for Select Marine Mammals Based upon BMR Equations

Marine Mammal	**Live Body Weight (kg)**	**Estimated Basal Metabolic Rate (cm^{3}O$_2$/g.h)**	**Lethal Poison Dosage (mg/kg)**	**Required Lethal Poison Dosage (total mg)**
Whale, bowhead (adult)	45,000	0.021946	0.0422765	1,902.44
Whale, humpback (adult)	34,000	0.023784	0.0422913	1,437.90
Walrus	1,363	0.059871	0.0425832	43.01
Sea lion (adult male)	1,010	0.065250	0.0426269	43.05
White whale	454	0.082081	0.0422765	19.19
Sea lion (adult female)	273	0.094982	0.0428692	11.70
Seal, bearded (adult)	227	0.100147	0.0429114	9.74
Seal, harp (adult)	181	0.106872	0.0429665	7.78
Seal, harbor (adult)	150	0.112793	0.0430149	6.45
Seal, ringed (adult)	90	0.130602	0.0431612	3.88

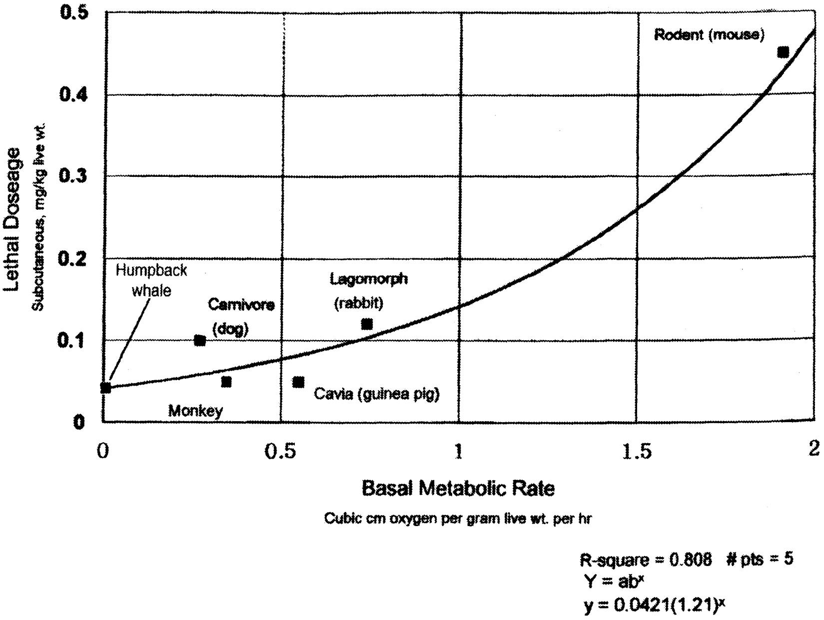

FIGURE 6.2 Pharmacokinetic model of lethal dosages of aconitine for small body-size mammals and humpback whale.

the bowhead whale equals 1.905 g. Previous estimates appear to be 2.5 to 3.0 times the lethal dosages that were calculated on the basis of basal metabolic rates.

Geographical and Environmental Distribution of Marine Mammals and Ground Slate Implements

In most instances, ground slate implements are found in archaeological contexts along coastal areas between 35 and 70 degrees north latitude. The geographical distribution of ground slate implements coincides closely with the polar (ice cap and tundra) and humid microthermal (subarctic and warm/cool summer humid continental) climatic regions of the Northern Hemisphere (Trewartha 1957 in Espenshade and Morrison 1975:10–11).

These specialized stone implements are always found in coastal, riverine, or lacustrine environments inhabited or visited by marine mammals (see Fitzhugh 1975; Turnbaugh 1977). Ground slate implements can be found in archaeological contexts that are located some distances from the oceans. If ground slate projectile points and ulus are found in the interior, they are from sites located on streams and lakes, like those found in Ontario

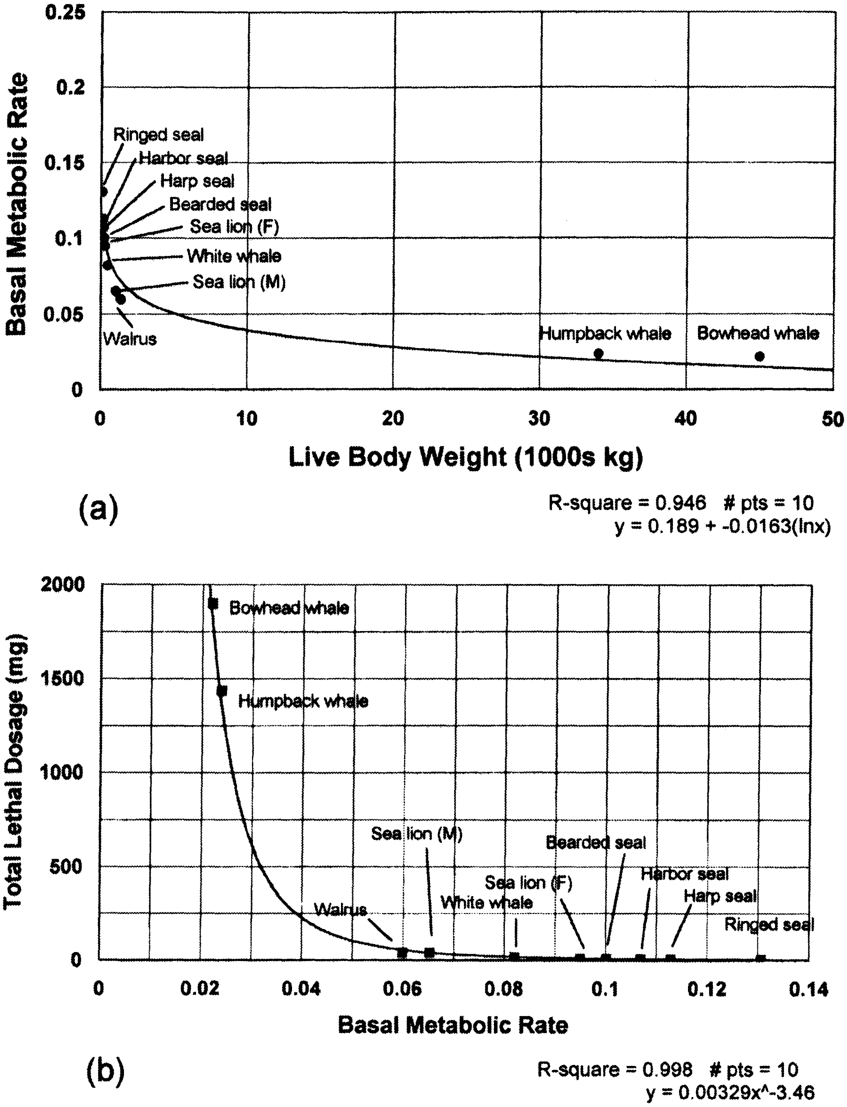

FIGURE 6.3 Pharmacokinetic model of lethal aconitine dosages for select marine mammals: (a) relationship between body weight and basal metabolic rate (cm^3 O$_2$/g live wt/h); and (b) relationship between basal metabolic rate (cm^3 O$_2$/g live wt/h) and lethal dosage (subcutaneous, mg/kg live wt).

for example, that are connected to marine environments. It is well known that seals and other small marine mammals follow migratory fish up freshwater streams (see Rudenko 1964:277). In fact, the geographical distribution of ground slate projectile points and knives is primarily coincident with the saltwater and freshwater habitat of *Phocinae* or northern seals (Davies 1958:487, Figure 7). Some of the most "anomalous" archaeological occurrences of ground slate points are located in lowland China along the courses of the Huang Ho and Yangtze Rivers. Such archaeological cases are perhaps indicative of the exploitation of seals, Southeast Asiatic porpoises, and Chinese white dolphins.[4]

In addition, the archaeological occurrences of ground slate implements coincide with major coastal areas in portions of the subarctic that remain ice-free throughout much of the year. In addition, a number of smaller areas of the Arctic remain relatively ice-free during a portion of the winter. These ice-free areas or polynas are generally associated with deep ocean currents, wind currents, unique coastline configurations, and/or freshwater drainages (Schledermann 1980). Schledermann (1980:293, Figure 1) provides a map of twelve such polynas in the Canadian high arctic near Bathurst, Cornwallis, and Devon islands and between Ellesmere Island and Greenland. In addition, deep channel currents in Gray Strait and south of Diggs Island in Hudson Bay prevent formation of winter sea ice (Hare and Montgomery 1949). Landfast ice generally does not form along the coast of western Greenland south of Disko Bay nor along the eastern coast of Baffin Island south of Cape Dyer due to the Canadian and West Greenland currents. Recurring primary and/or secondary polynas may have made it possible for aboriginal hunters to procure sea mammals, e.g., ringed seals, bearded seals, and walruses, during the winter season (see Morrison 1983:67). Loss rates would have been high, however, due to escape beneath any nearby winter sea ice.

Sea ice distribution in the circumpolar region has varied on a temporal basis as well. Such long-term shifts in sea ice conditions have significantly affected sea mammal distribution and abundance (Figure 6.1). Schledermann (1976) outlines changes in climate and the amount and duration of winter sea ice over the past 11 centuries in the arctic. During the Neo-Atlantic Period (A.D. 800–1200), temperatures were warmer than at present and sea ice was more limited. Pagophilic ringed seals were smaller and fewer in number due to decreased winter ice. Correspondingly, harp seals, bearded seals, and walrus exhibited a more northern distribution. White whale, narwhal, and the bowhead occupied the northern and central arctic waters. Schledermann (1975, 1976) suggests that it was during the latter portion of this climatic period that the eastern "Thule expansion" in the arctic occurred.

A cooling trend during the Pacific Period (A.D. 1200–1550) brought temperatures closer to present-day normals, and ringed seals increased in size and number. Larger marine mammals, including walrus, harp seal, bearded seal, white whale, narwhal, and the bowhead whale, were forced southward from the northern and central arctic.

The Neo-Boreal Period or "Little Ice Age" (A.D. 1550–1850) brought colder temperatures and more extensive winter sea ice. Ringed seals experienced periodic difficulty in maintaining open breathing holes in the thick winter ice, and their populations may have declined significantly. Large sea mammals migrated into the southernmost extremes of their distribution (Schledermann 1976). During this period, whale migration routes shifted away from the areas of increased landfast ice, making these animals relatively inaccessible to aboriginal hunters.

Schledermann (1976) also suggests that terrestrial prey animals, including caribou and musk ox, vary in numbers as a function of these same climatic shifts. Cold temperatures were associated with lower precipitation. Lack of snow cover and ice on land was more favorable for terrestrial mammals. Therefore, cold periods characterized by greater ice cover, fewer large sea mammals, and increased ringed seal populations were favorable for caribou and musk ox population growth. During warmer conditions, ringed seal populations would decline, whales and walrus would return, and terrestrial game would diminish.

McGhee (1970) describes the differentiation of Thule culture after A.D. 1200 as the arctic climate cooled and sea ice became more widespread. Whales could no longer move into the high arctic. Aboriginal peoples shifted hunting strategies away from whaling and began to hunt caribou in summer and ringed and bearded seals in winter. Morrison (1983) suggests that the historic Eskimo strategy of breathing hole sealing achieved its most specialized forms during the late Neo-Boreal/Little Ice Age period.

Such shifts in climate and sea ice conditions, winter severity, and faunal distributions played a significant and dynamic role in technological change in the arctic. Periods of increased winter sea ice cover were also characterized by short summer periods of open water. Poison hunting strategies could not have been successfully employed during cooler climatic periods in the high latitudes. Ground slate technology should vary in the archaeological record as an inverse function of winter temperature and sea ice cover.

Southern Greenland, on the other hand, would have provided very suitable conditions for the use of poison hunting strategies. Wilson and Buck (1979:36) point out that the ice-free southwestern coast of Greenland enabled the "Subarctic Eskimos . . . [to develop] . . . refined use of kayaks and umiaks for sea hunting [in open waters year round]."

Patterns of Within- and Between-Site Variability

Binford (1982:5) suggests "that if archaeologists are to be successful in understanding the organization of past cultural systems they must understand the organizational relationships among places which were differentially used during the operation of past systems." He (p. 6) points out that both intrasite and intersite content variability may be generated by human behavior at the local level (i.e., economic zonation) as well as at a regional level resulting from residential and/or logistical mobility strategies. Intersite content and structural variability can be expected to increase along a continuum of hunter-gatherer adaptations from foragers to collectors (Binford 1980). Binford (1982:20) argues that decreased residential mobility associated with a shift from foraging to collecting adaptations would be reflected by patterns of between- and within-site variability. Collectors would exhibit collapsed home range sizes, decreased distances between residential sites, increased between-site (ancillary sites) variability, and decreased within-site variability. Given decreased residential mobility, ancillary sites would be expected to exhibit greater content redundancy resulting from repetitive, specialized use. On the other hand, residential sites "are more flexible in their location and more variable in their content" (Binford 1978:487).

Binford's (1980, 1982) arguments are extremely relevant to the discussion of circumpolar patterns involving the supposed replacement of chipped stone assemblages by ground slate assemblages. Traditionally, we have seen that archaeologists have accounted for such technological shifts (if they, in fact, occurred) through references to diffusion, migration/invasion, or environmental change. However, shifts within artifactual assemblages at a given location may reflect changes in the "economic potential of the place" or a significant organizational shift in prehistoric patterns of terrestrial and aquatic habitat use. For example, Bockstoce (1976:44) states, "Fluctuations between warmer and cooler climatic periods would then have caused certain points of land to have varied in their usefulness as whaling sites." Many of the previous discussions of circumpolar technological change have not considered the dynamic implications of such terrestrial and aquatic exploitation patterns.

Additional Technological Considerations

This section seeks to describe additional interrelated aspects of technological systems in the circumpolar region. The production and use of ground stone implements cannot be adequately understood unless we also examine the apparent systemic linkages between circumpolar tool assemblages used for hunting and fishing; butchering prey animals; processing animal skins for clothing, shelter, and watercraft; tools used to make tools; woodworking; and boatbuilding.

GROUND SLATE PROJECTILE POINTS. Projectile points were initially manufactured from slate because this raw material provides a hard and brittle tip for hunting arrows, darts used with throwing boards, lances, and harpoon end blades. These projectile points include a wide range of morphological shapes including tanged, barbed, serrated, and notched lanceolate, triangular, and bayonet-shaped points (Figures 6.4, 6.5). Slate may have been used to manufacture large weapon points and knives that could not have been produced from cryptocrystalline stone, which occurred in small nodules or tabular pieces. Initially in this study it was thought that slate exhibited

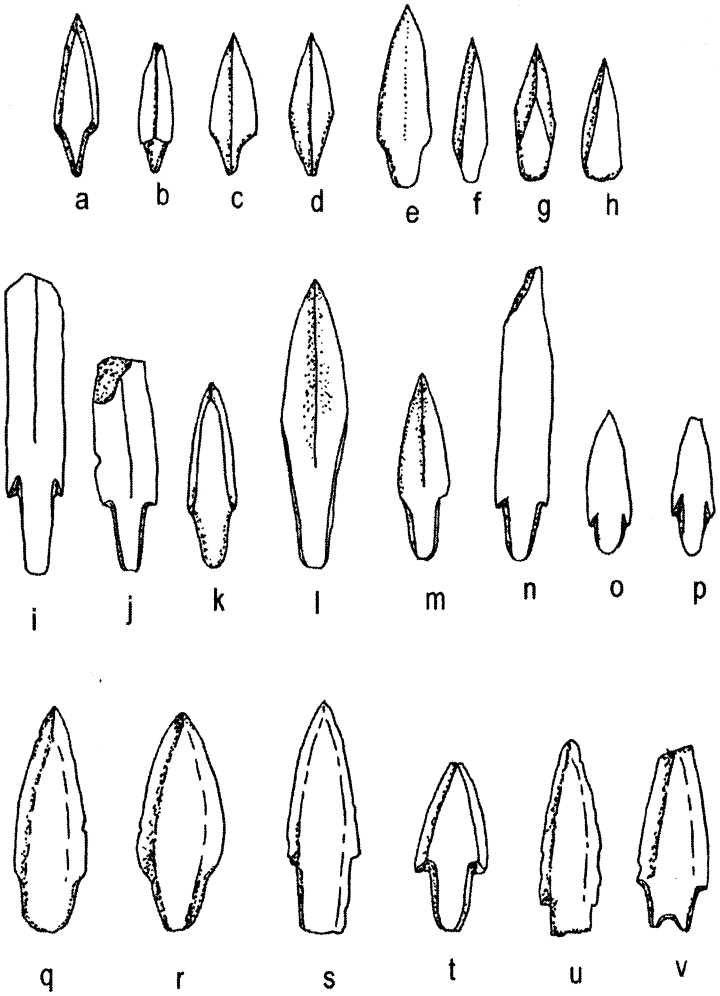

FIGURE 6.4 Stemmed ground slate projectile points: (a) Hei-ku-tui, Honan, China; (b–d) Ch'ao-ch'ia, Honan, China; (e–h) Yang-Shao-Ts'un and Pu-Chao-Cha, Honan, China; (i–l) Bellsås, Ångermanland, Sweden (5.8–8.5 cm l.); (m–p) Overeda, Ångermanland, Sweden (4.0–8.0 cm l.); (q–v) Uyak, Kodiak I., Alaska.

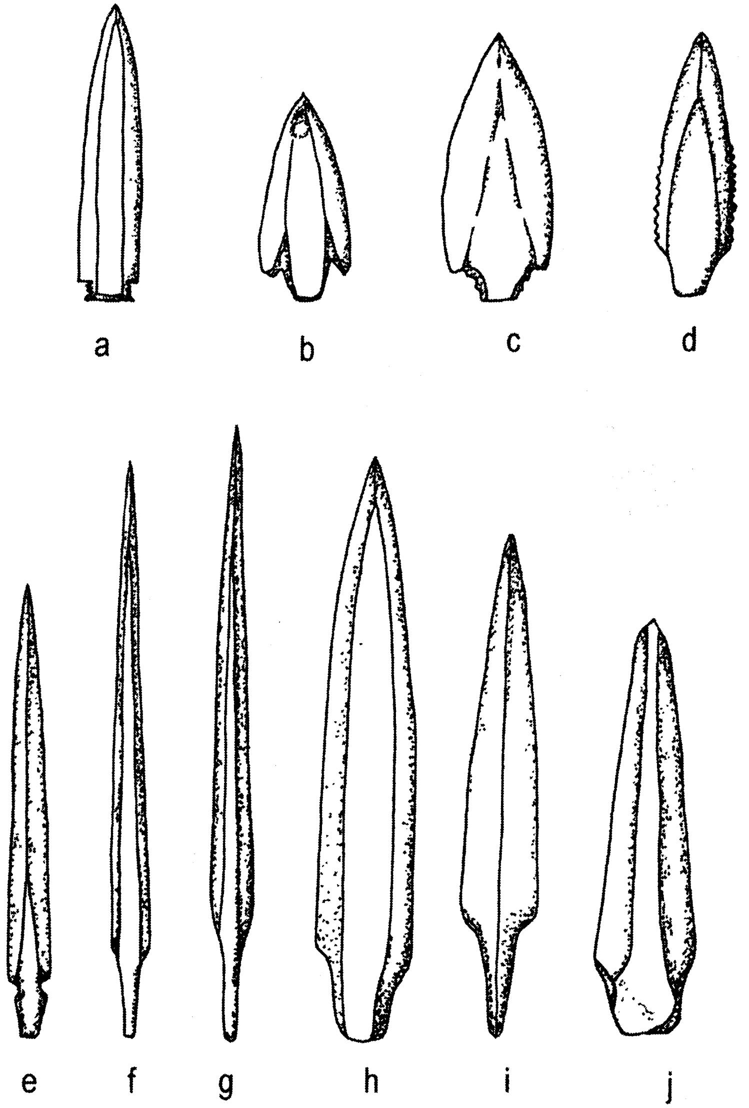

FIGURE 6.5 Stemmed ground slate projectile points: (a) Fraser River delta, British Columbia; (b–c) Champlain Valley, Vermont; (d) Sebec Lake, Maine; (e) Montague Harbor I., British Columbia; (f) Korea; (g) Port Au Choix, Newfoundland; (h) Ellsworth Falls, Maine; (i) Maine; (j) Blue Hill, Maine.

greater porosity and/or effective permeability than siliceous lithic materials. Experimental evidence suggests, however, that this is probably not the case.[5]

It is suggested here that hunting poisons could bond more readily to a ground slate surface than to cryptocrystalline materials (i.e., obsidian, chert, or chalcedony).[6] Several methods may have been used by aboriginal hunters to ensure that phytotoxins adhered to projectile points and foreshafts. For example, Bisset (1979:357) states that the Li-su, a Tibeto-Burman group in Yunnan Province, China, mixed aconite poison with resin or vegetable gum prior to applying it to crossbow arrows. In addition, the points of Chinese crossbow arrows were dipped in aconite, wrapped with cotton thread, and coated with carbon black over a straw fire (Bisset 1979:341).

Many ground slate projectile points exhibit contracting stems or hafting elements (e.g., Clark 1974:152, Plate 12J–M; 171, Plate 21A, B). This bayonet-like design allowed the hunter to quickly replace broken or "spent" slate points. Fragile ground and polished slate projectile points were kept in harpoon-head boxes made from blocks of soft wood (Murdoch 1892:247, 249, Figure 251). It must be pointed out, however, that Murdoch does not mention if such points were coated with poisons. Lisiansky (1814:174) states that Koniag whale hunters used spears "made of slatestone, and so fixed into the handle, as to detach itself when the whale is struck." Sea mammal hunters were thus able to implant several poisoned slate points in a prey animal before it managed to escape. De Laguna (1934:183) states, however, that Koniagmiut hunters were able to strike large whales only once before they sounded.

Slate projectile points may also exhibit notched or grooved blades to facilitate breakage and exposure to poison once implanted within a prey animal (Clark 1974:131, Plate 1B). Osgood (1937:39) may be alluding to this process when he states, "These people (Kaniagmiut) they describe as hunting the whale with spears having heads of slate-like stone about 8 inches long and 1 inch wide which break off in the body causing death." One might also suggest here that differential projectile point size may reflect variable lethal dosage levels required for marine mammals.

Ground slate points were also utilized as harpoon end blades (Murdoch 1892: Figure 213; Schledermann 1975:155, Plate 8a). Poison could have been applied to harpoon end blades to increase the efficacy of this hunting method. Heizer (1943:438), Holmberg (1985:49), and Steensby (1917:144) refer to several examples of aboriginal preferences for ground slate points and taboos against the adoption of iron harpoon points. It is quite possible that alkaloid poisons would not bond to the surfaces of siliceous stone or metal.

Holmberg (1985:49) states, "They [the Koniag] also tried replacing the stone points of the spears with iron, but found these unsuitable, for no whale wounded with such weapon ever drifted ashore. They thus believe that the iron point does not cause a deadly wound, and this suspicion is reinforced since whales with healed wounds are often killed later."

GROUND SLATE KNIVES. Ground slate blades were used in an array of cutting, slicing, and flensing implements throughout the circumpolar region (Figure 6.6). Ground slate men's knives and women's ulus played a crucial role in the exploitation of marine mammals (Fitzhugh 1974, 1975; Gustavson 1970) and fish (Burley 1980; Frink et al. 2002; Mitchell 1971).

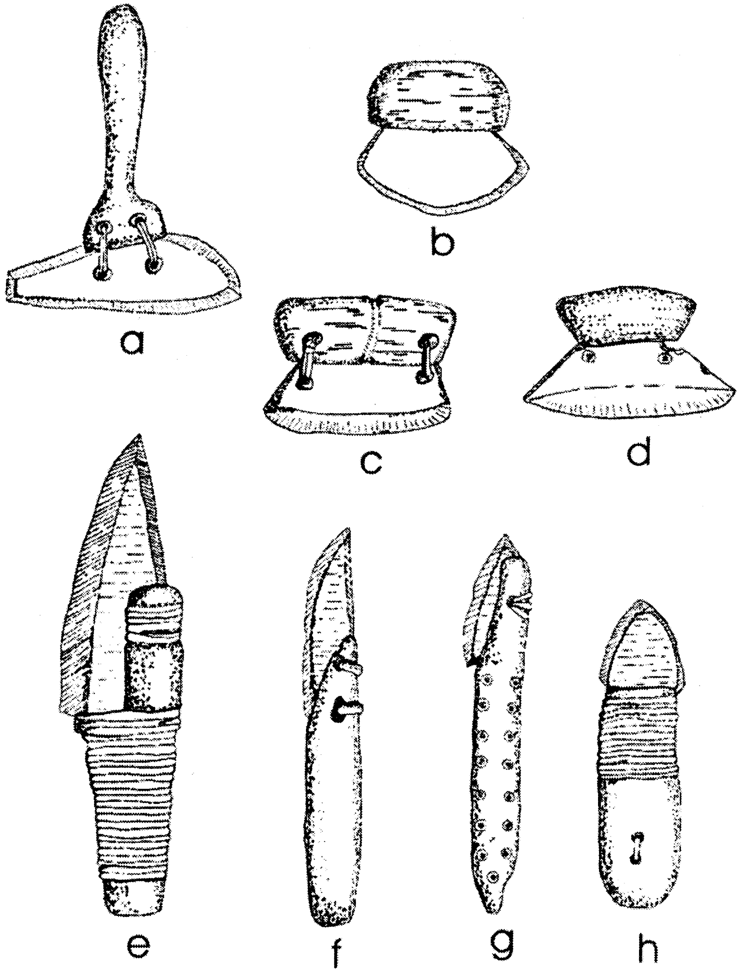

FIGURE 6.6 Ground slate ulus and men's knives: (a) Ulu, Davis Strait, Baffin I.; (b) ulu, Pt. Barrow; (c) ulu, Clavering I., Greenland (blade w. 7.8 cm); (d) ulu, Oscar Fjord, Greenland (blade w. 11.8 cm); (e) men's knife, Bering Strait (total l. 17.3 cm); (f) men's knife, Pt. Barrow, Alaska (total l. 15.6 cm); (g) men's knife, Pt. Barrow, Alaska (total l. 16.3 cm); (h) men's knife, Pt. Barrow, Alaska (total l. 13 cm).

Fitzhugh (1974:53) states, for example, "Smooth, sharp cutting edges of ground slate knives and ulus ... are functionally superior to chipped stone edges in cutting the flesh of fish and blubber-rich sea mammals; chipped stone edges quickly become fouled with animal fibre and require frequent resharpening and cleaning."

Burley (1980:70–71) suggests that the initial appearance of thin slate knives in the Gulf of Georgia circa 400 B.C. to A.D. 400 indicates intensive processing of salmon for storage. Thin ground slate fillet knives are reported in the ethnographic literature for processing salmon for wind drying (Stewart 1977:138, in Burley 1980:71).

The ulu or semilunar woman's knife is particularly well suited for processing marine mammal skins to be used for kayak, *baidarka*, and umiak covers (Balicki 1970:8–15; Boas 1888:108–115; Fitzhugh 1975; Murdoch 1892:294–301; Nelson 1899:116–118; also see Rankin and Labrèche 1991). Fitzhugh (1974:53) states that slate ulus function well in both dehairing and flensing blubber and that they do not perforate or damage sea mammal skins. Many ulus illustrated in the archaeological literature are irregular or subrectangular and not semilunar in shape. Turnbaugh (1977:90) has proposed that slate ulus developed from "prototypic semi-lunar knives" fashioned from deer scapulae, bone crescents, or mollusk shells. Many ground slate ulus may in fact be recycled hunting blades. Worn or broken slate lance/spear points could have easily been modified and hafted in several different ways to produce women's ulus (Boas 1888:110, Figure 73; Larsen 1934: Plate 3, No. 23, 24; Murdoch 1892:Figure 120–122, 124; Nelson 1899, Plate XLVII, Figure 1, 4, 5, 7) and men's knives (Larsen 1934, Figure 28; Murdoch 1892: Figs. 101, 103, 118a, 118b; Nelson 1899: Plate XLVII, Figure 9).

WOODWORKING IMPLEMENTS. Aboriginal peoples of the circumpolar region manufactured various forms of watercraft including skin-covered kayaks, *baidarkas*, and umiaks as well as bark canoes, dugouts, and large plank canoes. Increased dependence on watercraft in this region is reflected in the woodworking technology. Aboriginal woodworking in areas beyond the tree line and/or within ice-free or drift ice regions included compound hafted planing adzes, chisels, crooked knives, saws (historic), and bow drill kits designed to shape intricate, complex frames for kayaks, *baidarkas*, and umiaks (Arima 1964; Freeman 1964; Guemple 1967; Nelson 1899: Plates XXXVI–XXXIX).

In the subarctic region below the tree line, woodworking technology related to the construction of bark canoes, dugouts, and large oceangoing plank canoes was dominated by hollow ground gouges, celts, shell adze blades, large splitting adzes, stone hammers and mauls, antler wedges, and abrasive stones (Gjessing 1944; Hebda and Mathews 1984; Mitchell 1971; see Figure 6.7).

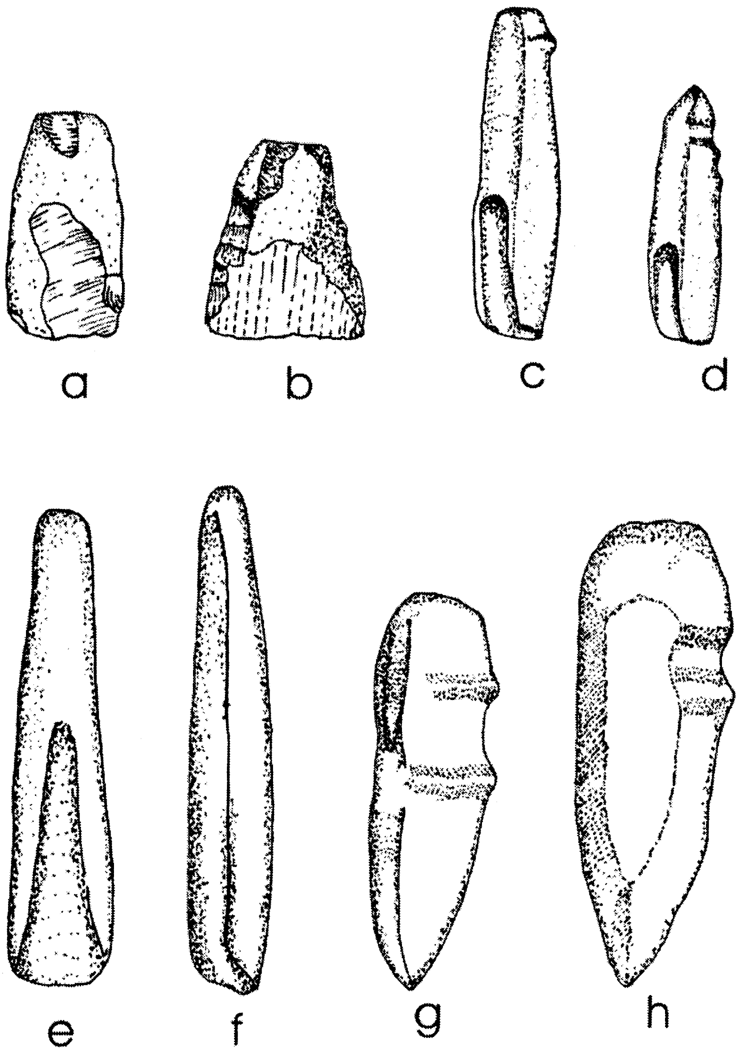

FIGURE 6.7 Planing adzes, curved-back or hollow-ground gouges, and splitting adzes: (a) Kodiak Island, Alaska (8.0 cm l.); (b) Point Barrow, Alaska (7.4 cm l.); (c) Massachusetts (18.6 cm l.); (d) New Hampshire (15 cm l.); (e) northern Norway (18 cm l.); (f) Billerica Falls, Massachusetts (28.5 cm l.); (g) Massachusetts (28.5 cm l.); (h) Kodiak Island, Alaska (20.0 cm l.).

Temporal variation in woodworking technology throughout the circumpolar region has been observed by a number of archaeologists. Workman (1980:69) has observed a marked increase in frequencies of stone adzes, large bone wedges, and splitting adzes during the Koniag Phase (A.D. 1100–1763) on Kodiak Island. The appearance of these heavy adzes and associated tools reflects increased reliance upon large plank canoes. De Laguna (1956:263) suggested that the splitting adze had replaced the planing adze of earlier developmental periods in the Chugash and Prince William Sound region. Similarly, Borden (1962) remarked that gouges were replaced by splitting adzes and that frequencies of stone mauls and hammers increased during the Late Period (A.D. 1200–1800) in the lower Fraser River area of British Columbia (Mitchell 1971). Snow (1972) suggested that the replacement of the hollow-ground gouge by the planing adze in the Maritime Archaic Period in the Northeast represented a shift from dugouts to bark canoes.

HARPOON-BASED HUNTING GEAR. Harpoon-based hunting strategies in the circumpolar region probably replaced earlier poison hunting methods as a response to depressed local or regional marine mammal densities. Harpoon-based hunting strategies reflect increased labor costs (e.g., larger watercraft, increased crew size, and greater technological diversity/complexity; see Hildebrandt 1981; Hildebrandt and Jones 1992). Yet, prey losses would be minimized. Archaeologists should expect to observe shifts away from whale hunting based on poisoned slate points toward increased dependence on harpoon technology as the probability of successful strikes and recovery diminish. Material items associated with this form of whale hunting technology would include lines, inflator valves and plugs, drags, sealskin floats, harpoon shafts/foreshafts, toggle heads, end blades, harpoon crotches or rests, and whaling lances (Murdoch 1892; Nelson 1899).

Winter breathing hole seal hunting and poison hunting would be almost mutually exclusive strategies. Breathing hole sealing necessitated the development of a specialized technology. A number of specially designed implements were required in order to locate breathing holes, to monitor prey movement, and to procure the prey animal from beneath the landfast ice. These items would include: snow probe, snow knife, breathing hole probe, sealing harpoon and ice pick, harpoon rests, harpoon lines, ice scoop, seal indicator, wound pins and plugs, draglines and handles, sealing stool, and sealer's ear-trumpet.

CHIPPED STONE IMPLEMENTS. Circumpolar tool assemblages also contain various forms of chipped stone implements. A number of these forms made their initial appearance during the American Paleo-Arctic (9000–6000 B.C.), Northern Archaic tradition (4600–2200 B.C.), and the Arctic Small Tool (2000–800 B.C.) traditions (Anderson 1984). These chipped stone tools included dart and arrow points, crescent-shaped sideblades, endscrapers, thin bifaces/knives, microblades, burins, gravers, and perforators. Chipped stone points as well as slotted bone and antler points with chipped stone insets are thought to represent terrestrial hunting strategies. Chipped stone burins, gravers, and perforators probably played a key role in the manufacture of bone and antler implements, including projectile points.

Fitzhugh (1975:376) describes the apparent mutually exclusive archaeological distribution of chipped stone burins and ground slate tools in the Northern Maritime sites. Such tools would be used to make component parts (e.g., projectile points of bone/antler/ivory, wooden dart/arrow/harpoon shafts. He suggests that chipped stone and ground slate tools represent an "interior" versus a "coastal" adaptation. We might also expect seasonal variation in lithic technology. For example, Binford (1979:263) suggests that chipped stone arrow points cannot be utilized during arctic winters for terrestrial hunting because they fracture easily due to extremely low temperatures. Arrow points of bone and antler are used instead.

Stone scrapers used for the processing of caribou skins were manufactured from high-quality, durable stone including jasper, flint, chert, or jadite (Murdoch 1892; Nelson 1899). Caribou hides were important to all circumpolar peoples both in the interior and on the coasts for clothing, bedding, and—in many cases—shelter.[7] Since terrestrial mammals lack thick subcutaneous fat or blubber, they can be more readily skinned and the hide can be set aside for later processing. Murdoch (1892:300) states that caribou hides were first rough-dried in the open air before fatty tissue was removed and the grain was broken with a stone scraper.

Dynamic Aspects of Marine Mammal Hunting and Technological Change

SEASONAL PATTERNS OF PREY LOSS RATES. In the arctic, many potential prey animals are lost by marine hunters due to sinkage. High loss rates due to sinkage are a function of seasonal fluctuations in marine mammal body fat and seawater salinity levels (McLaren 1958). In late spring and summer, salinity levels decrease in arctic waters due to melting sea ice. At the same time, the specific gravity of sea mammals increases relative to that of seawater due to marked declines in body fat (Lockyer 1981).

McLaren (1961:170) states, "The blubber of an average ringed seal drops from a winter peak of about 40 percent of the animal's weight to a summer low of about 23 percent... [resulting] in decreased buoyance and a much greater proportion of seals killed... are lost." Marine hunting losses in the circumpolar region vary seasonally in response to changes in prey fat content, sea ice cover, and seawater salinity levels.

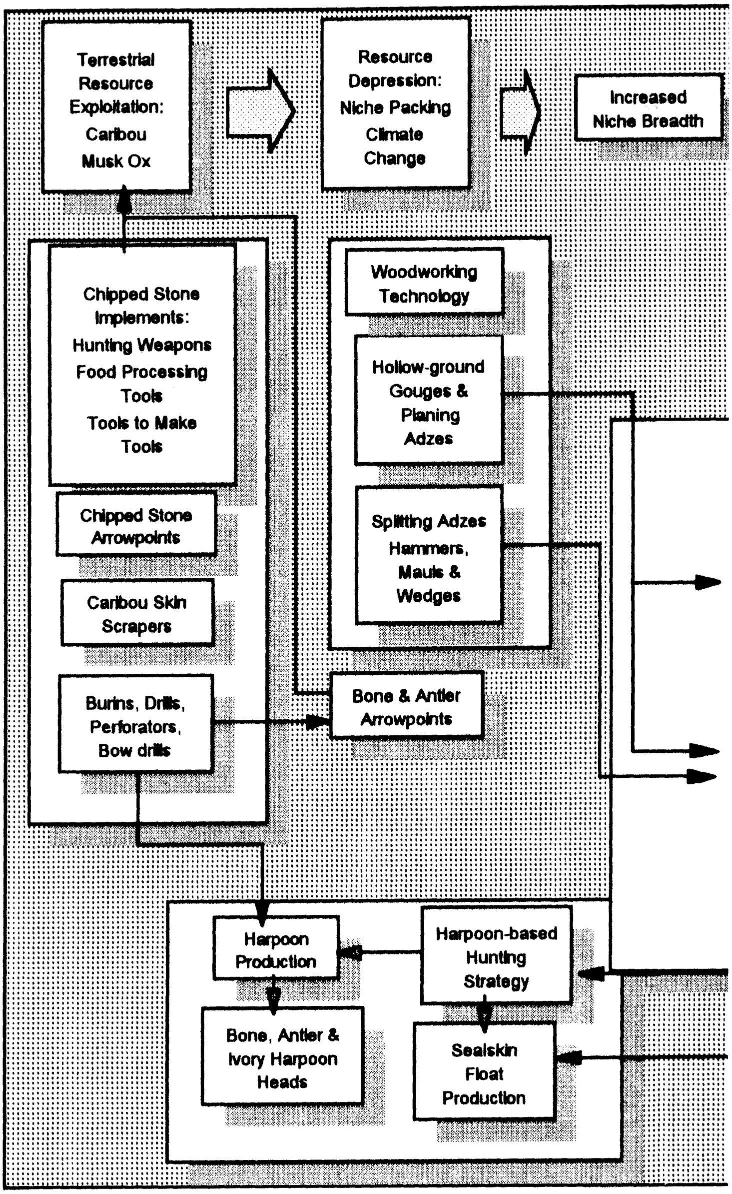

FIGURE 6.8 Interrelationships between the components of circumpolar terrestrial and marine-based food-getting and technological subsystems.

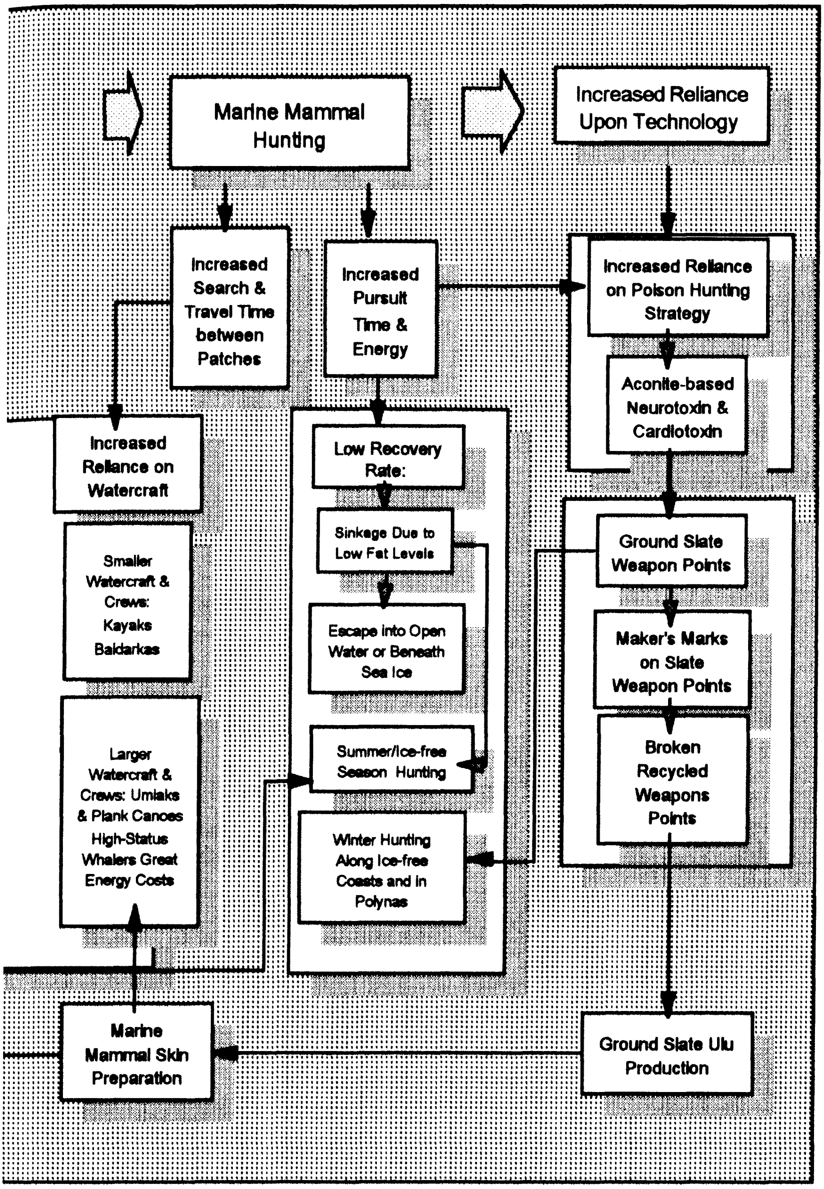

FIGURE 6.8 (continued)

SUMMARY OF TECHNOLOGICAL INTERRELATIONSHIPS. The adoption of ground slate implements must be viewed within a broader systemic framework (Figure 6.8). Early human adaptations in this region should be characterized by terrestrial hunting based primarily on musk ox and caribou and limited fishing. As a result of regional population packing and/or periodic declines in caribou and musk ox, aboriginal peoples began to depend increasingly on marine food resources. In areas characterized by landfast ice suitable for pagophilic marine mammals, we would expect to observe the adoption of breathing hole sealing as an overwintering subsistence strategy. Marine resources exhibit clumped distributions. Lower absolute densities and clumping would increase interpatch travel costs for northern hunter-gatherers using marine resources. Technological changes (e.g., watercraft and dogsleds) can be understood as adaptive responses to such increased travel costs in the arctic and subarctic. Adoption of aconite poison and ground slate dart and lance points can also be viewed as a technological response to increased pursuit costs associated with marine mammals.

Initially, poison hunting techniques required limited labor expenditures. One or two hunters searched for and pursued marine mammals in small skin-covered boats (i.e., kayaks and *baidarkas*). Local prey populations were depressed as aboriginal populations increased their dependence on marine fauna. Considerable numbers of marine mammals were lost due to sinking. Loss rates were quite high if poison hunting techniques were employed during late spring, summer, and early autumn. Prey losses were further exacerbated by the presence of landfast ice and drift ice. Aconite poison and ground slate-tipped implements would have been used during winter in areas free of landfast ice, such as the coastal areas of Scandinavia, southwestern Greenland, southwestern Alaska, Kodiak Island, and Cook Inlet. Longer term changes in temperature and precipitation in the circumpolar region affected both marine and terrestrial food resources. Warm climatic conditions generally meant that precipitation increased. The distribution and abundance of ice-loving sea mammals was adversely affected at such times. Reduced sea ice cover, however, was favorable for the northern expansion of harp seals, bearded seals, walrus, and bowhead whales. Terrestrial game animals (i.e., caribou and musk ox) decreased in many areas due to more severe snow and ice conditions. These interrelationships between temperature, sea ice cover, and marine versus terrestrial mammals were reversed during colder, drier periods (e.g., the Neo-Boreal Period, A.D. 1550–1850). It was during this extremely cold period that the historically observed breathing hole sealing developed in its most specialized form.

Local and regional depression of marine mammals required increased investments in technology and labor organization. Lower prey densities meant that the search radius for sea mammals had to be increased. Such increased search and travel costs necessitated significant commitments to the design, manufacture, and maintenance of diverse, highly specialized hunting implements and facilities, including watercraft. Hunting technology became more complex in order to reduce both pursuit time and the risks of losing prey animals. Considerable equipment was required for such specialized, long-distance hunts. For example, Drucker (1955) mentions that historic Nootka whaling required rigged harpoons, four sealskin floats with plugs and inflator valves, harpoons lines, spare lines and floats, baling buckets, spare harpoon shafts and points, whaling lance, spade, whaler's tackle boxes, food, and water. Larger watercraft, such as umiaks, dugouts, and plank canoes, were necessary to transport greater quantities of gear, supplies, and a larger crew.

Poison-tipped darts and lances were replaced by toggle-headed harpoons to decrease the risk of losing prey animals that had been successfully struck. Ground slate end blades soaked in aconite were probably retained following adoption of the harpoon. Phytotoxins would have impaired motor coordination and would have induced respiratory and cardiac failure in larger marine prey animals.

Ground slate hunting implements disappear in the archaeological record due to expansion of landfast ice during the Little Ice Age throughout the high arctic. Aboriginal hunters like the Inuit became more dependent on breathing hole sealing during the winter (McGhee 1980). Ground slate implements were abandoned differentially throughout the circumpolar region during a series of economic adaptive responses to the advent of Eurasian whaling and trapping, the establishment of missions and trading posts, and the introduction of the gun and metal traps (Balicki 1964; McGhee 1980).

In other regions of the world, ground slate implements decrease in frequency following the adoption of farming and animal husbandry. There is archaeological evidence for such shifts from marine mammal hunting to the consumption of domesticated plants and animals in Neolithic Scandinavia (Broadbent 1978), Eastern Russia (Okladnikov 1965; Rudenko 1961), and China (Andersson 1947).

ARCHAEOLOGICAL EXPECTATIONS AND EMPIRICAL TESTS

Given this explanatory argument, archaeologists might expect to observe the following temporal and spatial patterns in the archaeological record for the circumpolar region:

1. If ground slate implements did in fact replace chipped stone implements as is traditionally assumed, then these two tool assemblage types should exhibit negative or inverse correlations.
2. Woodworking tools, for example, hollow-ground gouges and planing adzes associated with the manufacture of smaller skin boats, should be

positively or directly correlated with ground slate tools, such as ground slate points and knives.

3. Woodworking tools (e.g., splitting adzes, stone hammers and mauls, and splitting wedges associated with the manufacture of larger watercraft) should be negatively or inversely correlated with ground slate points.
4. Bone/antler/ivory harpoon points used for breathing hole sealing or for marine mammal hunting associated with landfast or drift ice should not be correlated with ground slate points.
5. Ground slate points should be negatively or inversely correlated with harpoons used to hunt sea mammals in any region devoid of landfast ice.
6. Harpoon-based whaling technology reflected by whale toggle harpoon points, sealskin floats, inflator valves and plugs, and drags should be negatively or inversely correlated with ground slate points—particularly contracting stemmed, bayonet-like points and/or points bearing maker's marks. Harpoon end blades of ground slate might vary independently of this winter, open-water hunting pattern.
7. The archaeological distribution of ground slate implements in general should correspond with former or present-day coastlines and associated riverine/lacustrine drainages as a function of marine mammal distribution.
8. The archaeological distribution of ground slate implements, including contracting stemmed points, ulus, and men's knives, should coincide with regions devoid of landfast ice, (e.g., Kodiak Island, the southern shores of the Aleutian Islands, the Pacific Northwest coast, southwestern Greenland, and Scandinavia).
9. Ground slate points, (e.g., contracting stemmed, bayonet-like points and associated woodworking tools used to manufacture skin boats) should vary negatively or inversely with breathing hole sealing implements including sealing harpoons, harpoon points, seal indicators, antler probes, snow knives, ice scratchers, ice scoops, sealing stools, and wound plugs (see Birkett-Smith 1953).

Several of these expectations were chosen for empirical tests. Archaeological data concerning tool assemblages in the circumpolar region was collected from a number of published sources. Linear regression analyses were then used to measure the strength of correlations between the variables outlined in the expectations cited above.

First, given the traditional argument concerning replacive patterning, we would expect to observe an inverse or negative relationship between chipped stone and ground slate tools. A regression analysis using data from 41 archaeological assemblages from throughout the North American arctic and adjacent areas of the Pacific Northwest coast revealed that this generally accepted pattern does not occur. Instead, chipped stone tools and ground slate tools are directly or positively correlated ($r = .54$; $R = .29$; $df = 39$; $p > .01$). Little more than 29 percent of the variability exhibited by chipped stone tool frequencies can be accounted for by ground slate tools. More significantly, the observed relationship is the reverse of the expected pattern. In fact, unlike the simple replacive pattern of technological change expected, the interrelationship between chipped stone and ground slate assemblages appears to be quite complex. For example, an analysis of 20 lithic assemblages from 20 sites in the Lake Harbour District of Baffin Island (Maxwell 1973) produced a very high positive correlation between chipped stone tools and ground slate tools ($r = .96$; $R = .92$; $df = 18$; $p > .01$). This result suggests that more than 90 percent of the variation in chipped stone frequencies is accounted for by ground slate tool frequencies. On the other hand, regression analyses of Kodiak Island data produced quite varied results ranging from correlation coefficients equal to $-.77$ (Afognak sites Afo-136, 110, 108, 107) to $+.79$ (Chert Site, Afo-106). It is interesting to note that all Kodiak Island sites included in this analysis produced negative or inverse relationships with the exception of the Chert Site. Interestingly, Clark (1979) suggests that boulder flakes were used to manufacture slate tools. Regression analyses demonstrate that boulder flakes at Afo-109 vary directly as expected with ground slate tools and debitage ($r = .89$; $R = .79$; $df = 9$; $p > .005$). Chert tools and debitage on the other hand are inversely related to ground slate tools and debitage ($r = -.32$; $R = .10$; $df = 9$; $p < .05$). Finally, a regression analysis of the Walakpa Site assemblages reveals that chipped stone and ground slate exhibit no correlation ($r = .086$; $R = .007$; $df = 1$; $p < .05$). These analyses suggest that traditional assumptions based on technological replacement are too simplistic and do not accommodate the empirical evidence.

Second, several analyses were conducted in order to evaluate our expectations regarding interrelationships between ground slate tools and woodworking tools. Planing adzes were associated with the manufacture of complex frames for skin-covered boats. They should be directly or positively correlated with ground slate points. An analysis of 40 archaeological assemblages from the circumpolar region revealed a positive relationship ($r = .64$; $R = .41$; $df = 38$; $p > .01$). Splitting adzes, on the other hand, were associated with the manufacture of plank canoes like those of the Northwest Pacific coast used for open-ocean whaling. They should not be related to ground slate technology since they were used by large whale hunting crews dependent on harpoon and line technology. They do not appear to be correlated ($r = .029$; $R = .0008$; $df = 22$; $p < .01$). Furthermore, we would also not expect to observe a direct relationship between ground slate points and stone mauls (hafted and handheld) used in woodworking and plank canoe construction on the Northwest Pacific coast. An analysis of data from Drucker (1943:120–121, Table 8) produced a correlation coefficient equal to $-.16$ ($R = .027$; $df = 4$; $p < .05$). This supports our expectations.

Third, harpoon points of bone, antler, and ivory should vary inversely or negatively with ground slate points if we assume that aboriginal whale hunters shifted exclusively from poison to harpoon-based hunting strategies. An analysis of 35 circumpolar assemblages produced a low positive correlation ($r = .19$; $R = .04$; $df = 33$; $p < .01$). An analysis of Drucker's (1943) data for the Northwest Pacific coast also produced a very low positive correlation ($r = .037$; $R = .001$; $df = 4$; $p < .05$). Low positive correlations suggest that perhaps both marine mammal hunting strategies were practiced contemporaneously. Both hunting methods could have been employed on a seasonal basis throughout the year with poison being used in summer and harpoons during the winter in ice-free waters.

CONCLUSION

My interest in marine mammal hunting strategies and ground slate tool assemblages developed during the course of my dissertation research at the University of New Mexico more than 28 years ago. During this time, I read several classic monographs like Robert Heizer's (1943) *Aconite Poison Whaling in Asia and America: An Aleutian Transfer to the New World* and Gutorum Gjessing's (1944) "Circumpolar Stone Age." Marine ecology as well as optimal foraging theory suggested that marine resources were in many cases lower ranked and exploited intensively only after higher-ranked terrestrial foods became limited. Archaeologists repeatedly referred to long-term temporal shifts from chipped stone implements to ground slate implements throughout the arctic region as well as the circumpolar zone in general. These observations led me to think that variation in lithic assemblages may correspond to increased reliance upon aquatic resources—particularly marine mammals such as seals, sea lions, walruses, and whales.

I must say that my contribution to Lew Binford's graduate seminar that dealt with theory-building in archaeology ultimately was met with varied reactions. Once the resulting volume *For Theory Building in Archaeology* (Binford 1978) was published, I received a great deal of positive response as well as criticism for my explanatory arguments dealing with marine resource exploitation. Interest in aquatic resource use and coastal adaptations increased markedly during the late 1970s and early 1980s. I vividly remember presenting a preliminary version of this study at the eleventh International Congress of Anthropological and Ethnological Sciences (ICAES) in Vancouver, British Columbia, in 1983. It was at these meetings that I had the opportunity to meet a number of distinguished arctic archaeologists including Lydia Black, Donald Clark, Don Dumond, Allen McCartney, James Savelle, and others. Several of these investigators provided much of the "positive" and "negative" stimulus that encouraged me to continue my research dealing with aconite poison whaling and ground slate tools.

This current study accomplishes several things. First, it reviews the history of the ideas regarding slate projectile points, ulus, and related lithic technology. Second, it summarizes information regarding slate implements in the archaeological record of the circumpolar region. Third, considerable attention is devoted to phytotoxins including the genera *Aconitum*, *Ranunculus*, and *Anemone*, and the geographical distribution of additional toxic plants throughout the arctic. Fourth, data concerning the toxicity of aconitine is summarized and several calculations are made regarding the lethal dosages that might be required to kill various marine mammals. More recent thinking regarding pharmacokinetic relationships suggests that lethal dosages for aconitine have continually been overestimated. This reevaluation of the relationships between basal metabolic rates of marine mammals and toxic levels of aconitine indicate that hunters could have indeed disabled and/or killed very large marine mammals with poisoned slate projectile points. Finally, a series of regression analyses of circumpolar assemblages reveal empirical support for a number of these hypothesized relationships. Analyses demonstrate that the tool assemblages in this region are quite complex. Simple technological replacement reflected by inverse relationships between chipped stone versus ground slate assemblages does not occur. Such complex interrelationships between environment, food-getting, and technology represent the varied, alternative causal linkages that will enable archaeologists to understand better a range of hunter-gatherer adaptations throughout the circumpolar region.

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NOTES

1. Yet functional efficiency does not explain the persistence of chipped stone tools from Norton culture through the historic Eskimos following the appearance of ground slate implements in northern Alaska (McGhee 1980:42). Furthermore, chipped stone tools predominated throughout the entire prehistoric/historic sequence on Southampton Island. Ipiutak assemblages do not contain ground slate artifacts even though these peoples are supposed to have been in contact with North Alaskan groups that made use of ground slate implements (McGhee 1980:44, 47).

2. Production in arctic marine ecosystems is limited by three primary factors: (a) limited solar radiation, (b) sea ice cover, and (c) water column stability. At low sun angles, approximately 40 to 50 percent of incoming solar radiation may be reflected from the ocean's surface (Nemoto and Harrison 1981:96). Arctic sea ice cover fluctuates from 80 percent in winter to 60 percent in the summer (Nemoto and Harrison 1981:96). And, water column stability and associated near-surface nutrient depletion contribute to the low overall productivity in the arctic.

3. Aconite derived from *Aconitum* tubers has been used in medicine and arrow poisons in China for at least two millennia (Bisset 1979, 1981). The earliest use of aconite poison can be traced to the middle of the seventh century B.C. in China (Bisset 1979:330, footnote 5). Aconite-producing plants, i.e., *Aconitum carmichaelli*, were grown in northern Szechuan Province for 1,300 years (Bisset 1981:320).

4. A number of ground slate projectile points and knives have been found in archaeological sites far removed from the oceans. Examples can be cited from the Pacific Northwest; interior streams and lakes within the province of Ontario as well as along the shores of Lake Ontario (Wright 1962); along streams and lakes in Sweden and Finland (Renouf 1986); and along the Huang Ho and Yangtze Rivers in China (Andersson 1947). Suttles (1952:10) and Smith (1947:266) described the movement of seals along the Fraser and Skeena rivers and into related interior lakes. Fisher (1952:12, 56) described seal "migrations" that took them more than 200 miles along the Skeena River and upstream in the Fraser River to the first major rapids at Alexandria in British Columbia.

It is quite possible that ground slate points and phytotoxins were used in prehistoric/historic China to hunt marine animals. Sites with ground slate tools occur along coastal and inland waters that were inhabited by seals (e.g., larga seals, the smallest of the North Pacific harbor seals) and river dolphins (e.g., Sousa sp.; King 1983:85–86; Anderson and Knox Jones 1967:314–353). Inland rivers and lake systems in the lowlands of eastern China contained these aquatic mammals that could have been hunted using poison arrows, darts, and spears.

5. A fragment of slate (origin unknown) was cut into two samples using the "groove and snap" method. Three parallel diagonal grooves approximately one millimeter wide were cut into the surface of one sample. Both the grooved and the ungrooved samples were dehydrated and weighed; their weights equaled 10.7 and 7.9 g, respectively. The samples were soaked in water for five days. Weight change due to absorption in both samples was negligible. The grooved specimen was also boiled in water for 20 minutes; there was no weight gain attributable to water absorption.

6. It is possible that slate exhibits several chemical properties that enhance chemical bonding of aconitine as well as other alkaloids to the surface of ground

slate weapon points. First, it is possible that the organic carbon found in gray and black slates may serve as a hemoabsorbent that would more effectively transfer the aconitine into the mammalian blood stream. It is interesting in this regard that Bisset (1979:342) describes the application of aconite to Chinese cross-bow arrows during the sixteenth century. Aconite was smeared on the arrow heads, dried in the sun, and then smoked over a burning straw fire. The arrow points became coated with carbon black. It is possible that the carbon black not only coated the points but also chemically bonded to the carbon. Second, oxygen atoms within aconitine would bond to the surface of slate points as a function of cation exchange. Such an exchange would not occur for silica-based tool stones such as flint, chert, quartzite, or obsidian.

7. Balikci (1970:9) comments, "Preparing caribou skins for use was a long and tedious job.... After she scraped and stretched it, she slightly moistened the hide and put it out in the cold to freeze for a day or two. In the last phase of curing she removed the subcutaneous tissues by using a sharp scraper.... As a final softening process, the men thinned the skin by vigorous scraping, arduous work that only the men could do successfully."

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