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The Composition of Fatty Materials from a Thule Eskimo Site on Herschel Island

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ABSTRACT. Analysis of midden material from a Thule Eskimo dwelling site on the shore of Herschel Island showed it to contain a high proportion of fatty material. Chemical analysis shows this to consist of a mixture of fatty acids from the fats and oils of marine animals which has been partially, but far from completely, converted to adipocere. The lack of complete conversion is attributed to anaerobic conditions, low ambient temperature, and lack of bacterial action. The results are consistent with, but not a proof that the debris is from a mixture of harbour, ringed, and bearded seal, which is the conclusion from the bone fragments found.

Key words: Thule dwelling, midden, fat and oil, adipocere, anaerobic decay, whale fat, seal fat

RÉSUMÉ. L'analyse du matériel provenant de l'amas d'une résidence inuit Thulé sur le rivage de l'île Herschel a signalé une concentration élevée de matière grasse. Selon une analyse chimique, cette matière consistait d'acides gras provenant du gras et des huiles d'animaux marines ayant été partiellement transformés en adipocire. Cette transformation non complétée est attribuée aux conditions d'anaérobie, à la basse température ambiente et au manque d'activité bactérienne. Ces résultats sont compatibles avec la conclusion tirée de l'étude des fragments d'os trouvés dans l'amas, selon laquelle les restes sont ceux de phoques communs, annelés et barbus, les résultats ne pouvant toutefois prouver cette conclusion.

Mots clés: résidence Thulé, amas d'ordures, gras et huile, adipocire, décomposition anaérobique, gras de baleine, gras de phoque

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INTRODUCTION

Erosion of the shoreline by wave action and local subsidence has exposed and partly destroyed an archaeological site north of Pauline (Thetis) Cove on Herschel Island, in northwestern Canada. Herschel Island, lying off the Yukon Coast west of the Mackenzie River mouth, provides one of the few natural harbours in that part of the western Arctic and as such has a long history of use by various peoples. The earliest evidence of human occupation there comes from a stretch of rapidly eroding shoreline on the northeast edge of the island. The Washout Site (NjVi-2) (Fig. 1) comprises three known manifestations of Thule occupation and potentially several more (Yorga, 1980).

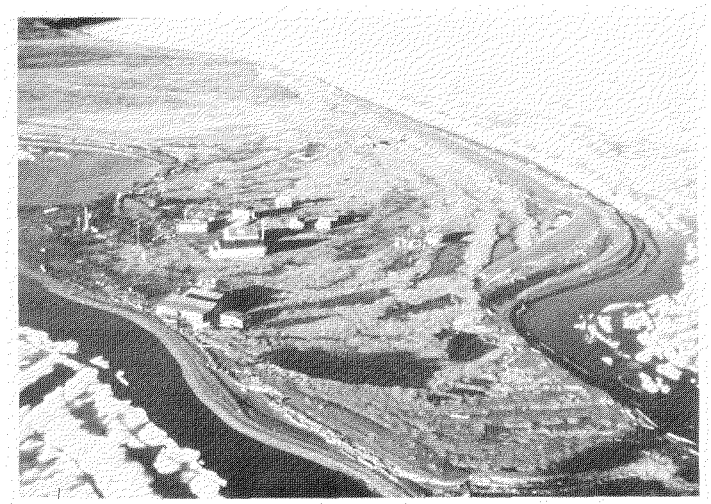

FIG. 1. The Washout Site, shown in the upper center of this photograph, lies on the seaward side of the Herschel Island sandspit. (Photo: B. Yorga)

Excavation in 1977 of a driftwood and sod structure (Fig. 2) yielded a wide range of artefactual and faunal materials on the basis of which the Western Thule assignment was made. Three radiocarbon assays were made on wood and charred midden material: S-1532 (1570 ± 60 B.P.), S-1533 (990 ± 95 B.P.), and S-1534 (1510 ± 90 B.P.). Specific corrections for reservoir effect and fractionation have not been made because necessary data are lacking on the area and on the materials concerned.

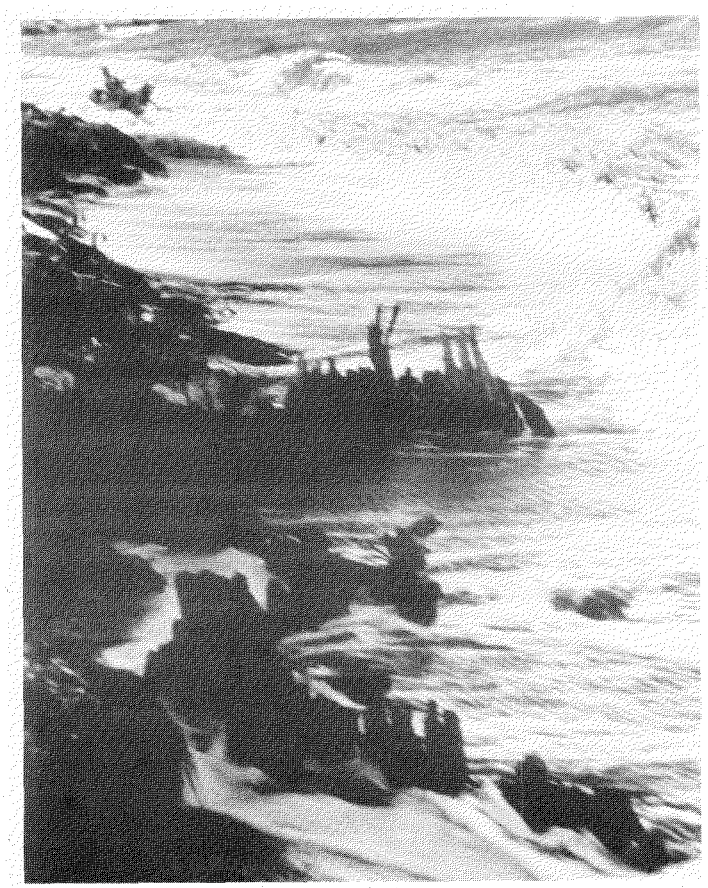

FIG. 2. Thule house structure eroding from the beach, 1978.

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During the summer of 1978 approximately 500 kg of midden material (Fig. 3) was salvaged from the site and transported south for future analysis. The midden was a degraded fatty material mixed with sand, silt, and gravel. Thanks to the anaerobic conditions provided by silt-capping, permafrost, and water-logging, preservation was excellent. In addition to the usual ground and chipped stone tools, pottery, and bone artefacts, a wide range of organics was preserved including bird and fish bone, scales, feathers, hair, hide, gut, sinew, coprolites, and large amounts of baleen.

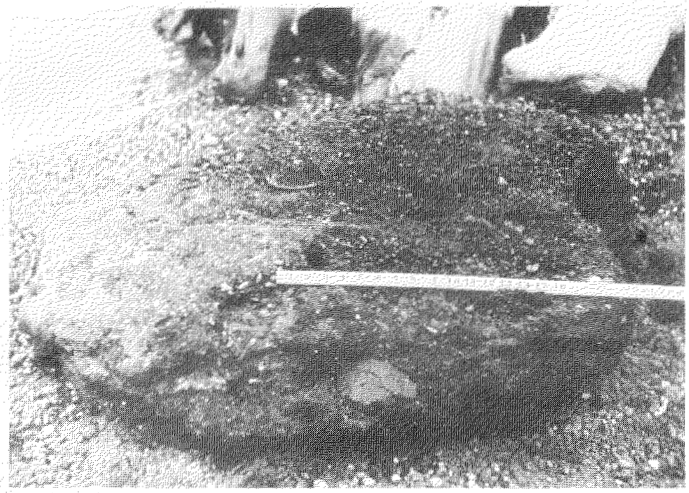

FIG. 3. Section of the midden recovered from site.

Fatty material of human, animal, or vegetable origin, when buried in soil or peat or immersed in water, undergoes a chemical change to a material first recognized by Robert Boyle and described by Fourcroy (1790) as adipocere (L *adeps* = fat, *cera* = wax). The extent of conversion of body fat to adipocere is helpful as an indicator of how long a body has been dead or immersed in water, as in forensic science (Mant, 1957). The role of anaerobic microorganisms in the conversion to adipocere was demonstrated by den Dooren de Jong (1961), as part of an investigation following reburial of people who had died during the German occupation of the Netherlands in 1944. Den Dooren de Jong was able to reproduce adipocere formation by showing that an oily material such as olive oil is completely converted to adipocere in a few months, when inoculated with soil bacteria, and sealed in water with nutrients at ambient temperature.

Our interest was drawn to this phenomenon in connection with our analyses of "bog butter", lumps of white waxy material found during peat cutting in Scotland and Ireland (Thornton *et al.*, 1970). Our intention had been to use modern analytical methods to attempt to identify this archaeological material. Our analyses show that the butter or other fat has undergone a change to adipocere and its original state cannot be determined with confidence. In the laboratory we have been able to demonstrate this conversion of butter, mutton fat, and sheep's brain to adipocere over a period ranging from months to one or two years, using the method of den Dooren de Jong (Morgan *et al.*, 1973).

Thule economy is commonly regarded as centering upon caribou, seal, and whale with additional exploitation of fish, birds, small land mammals, walrus, bear, and muskoxen. The faunal analysis of the Washout Site shows that more than 90% of the excavated bone (excluding fish) is from ringed, bearded, and harbour seals. Fishing was next in importance, followed by the hunting of caribou and other land mammals, and fowling (Yorga, 1980). Evidence for either beluga or baleen whales is limited to a few artefacts made of beluga rib, and large amounts of baleen. No whale-hunting equipment has come to light from this site.

We have here an excellent opportunity to examine fatty material which has been subjected to prolonged anaerobic conditions in a cold environment. Our findings indicate that the transformation of this material to adipocere is far from complete in spite of its great age. Further, it is still possible to see that it is fat derived from cold-water animals of the type confirmed by the bone and other material present.

MATERIALS AND METHODS

The Washout Site midden material that we collected lay in 15-45 cm of water. In the cold room the midden material was judgmentally sampled for representative fatty material. Four samples were removed for analysis; I and II were fatty debris from beneath a small rock within the midden; III came from another part of the midden containing fibrous material, and IV was from the outer layer of the midden which had been exposed to wave action at the site.

Samples were stored dry in sealed glass bottles in a refrigerator. Care was taken to avoid contamination with oils and greases. Samples ranging from 1 to 5 g were continuously extracted in a Soxhlet apparatus with redistilled hexane.

The extracted fat was weighed and dissolved in boron trifluoride-methanol in the proportions of 4 mL for each 50 mg of fat. Antibumping granules were added and the mixture was heated under reflux for 6 min to convert acid and glycerides to methyl esters of the fatty acids. The mixture was cooled and partitioned with water, the hexane washed twice with water, dried over molecular sieves, and the hexane reduced to a small volume. Samples of 1 μL of the resulting solution of methyl esters were injected into the gas chromatograph.

Gas chromatography was carried out with a Pye 104 gas chromatograph fitted with flame ionization detectors, using a 1.5 m × 4 mm glass column packed with 10% Silar-10C on Gaschrom Q (Applied Sciences Inc., U.S.A.) operated at 150°C with a nitrogen flow of 60 mL·min^{-1}.

Individual fatty acids were identified by comparison with standards (Koch-Light, Colnbrook, England). The relative amounts of individual fatty acids were calculated from the peak areas of their esters on the chromatogram and expressed as percentages by weight of the total methyl esters measured.

Thin-layer chromatography was performed on 5 × 20 cm plates of Silica gel G and developed with light petroleum: ether:acetic acid (80:20:1). Pure fatty acids, monopalmitin, and cholesterol were used as standards for comparison, and the lipids on the plates were visualized by spraying with 60% sulphuric acid containing 1% chromic acid and then heated to 120°C for 2 hr.

RESULTS AND DISCUSSION

Samples I and II were soft, amber-coloured, waxy material, containing very little plant or soil debris. They contained 30% and 15% extractable fatty material, respectively. Sample III had a distinct fibrous structure, possibly induced by the freeze-thaw activity of contained water, and gave 28% extractable fat. This scatter of values is quite within that which might be expected in sampling heterogeneous material. Sample IV came from the exposed surface of the midden, was black and brittle, contained peat-like material, and gave only 9% fat on extraction. This lower value probably represents autoxidation to polymerized and insoluble material through contact with oxygen in the air at low tide. Therefore a portion of the fatty acids have been destroyed in this sample. It is omitted from the later discussion.

Thin-layer chromatography showed the fat in the samples to consist chiefly of free fatty acids with some sterols. The triacylglycerols of the fat had been hydrolyzed by contact with water, and the water-soluble glycerol was lost. This is not surprising and does not itself alter the composition of the fats for the analysis which follows.

TABLE 1. Fatty acid analysis of four samples of midden material, percentage by weight composition

		SAMPLES			
Acid	Symbol	I	II	III	IV
Undifferentiated low-molecular-weight components		—	—	—	12.7
Myristic	C14:0	2.7	5.7	3.0	10.3
Myristoleic	C14:1	0.9	1.0	1.1	1.1
Palmitic	C16:0	21.8	25.8	39.2	36.2
Palmitoleic	C16:1	15.6	17.3	7.5	12.1
Stearic	C18:0	3.1	2.6	3.7	4.2
Oleic	C18:1	29.5	25.8	24.0	13.2
Arachidic	C20:0	4.2	2.5	0.5	trace
Gadoleic	C20:1	14.1	12.3	14.4	10.1
Behenic	C22:0	3.4	2.8	1.2	trace
Cetoleic	C22:1	2.9	2.2	3.2	
Lignoceric	C24:0	1.6	2.0	2.1	

The fatty acid composition of the samples is given in Table 1. The acids are identified by their common names and also by the number of double bonds present. Thus oleic acid, which contains a straight chain of 18 carbon atoms and one double bond, is represented by C18:1. Stearic acid which has the same chain length but no double bonds is C18:0. A summary of the acids and their general occurrence is given in Table 2.

The fatty acid composition of fats and oils is not fixed, but falls within a range of values dependent upon many factors, including nutrition, season, maturity, and part of the body from which the fat is taken. Common animal fats (e.g. beef tallow, lard, mutton fat) consist chiefly of C14:0, C16:0, C18:0, and some C18:1 fatty acids. Vegetable oils are more unsaturated and contain more C18:1 together with C18:2 and C18:3. Even more highly unsaturated fatty acids occur in fish, seal, whale, and other marine animal fats. These fats are distinguished by the presence of polyunsaturated fatty acids containing 20 or more carbon atoms. Thus the presence of significant quantities of gadoleic acid (C20:1) immediately places the midden samples among the last group as would be expected. Fish oils contain much larger amounts of the longer-chain unsaturated fatty acids, such as C22:1, (cf. for example Malins and Wekell, 1970) than are found in the samples we have analyzed or in seal and whale oils. Fish oils do not therefore appear to make a large contribution to the midden materials.

Some recent analyses of the fat from northern mammals that could have provided food for the Thule inhabitants are listed in Table 3. It is apparent that there is variation in composition between the species. Further, as in the case of seals where analyses are given for males and females separately, there is even variation between the sexes. Similarly, samples taken from individuals of the same species at other times or places, or of different state of maturity or breeding cycle, would show variations from these values.

TABLE 2. Notes on the occurrence of the common natural fatty acids

Name	Symbol	
Myristic	C14:0	1-5% of most animal and vegetable fats; 8-12% in milk, 15% in head oil of sperm whale, 20% in palm seed fats
Myristoleic	C14:1	Traces only in depot fat of land animals; almost 1% in most marine animal oils; up to 14% in sperm whale head oil
Palmitic	C16:0	Ubiquitous, less than 5% in majority of fats; in oils, e.g. peanut, soybean, corn, and many fish and marine oils, up to 10%
Palmitoleic	C16:1	Occurs widely, the characteristic acid of cold-blooded animals as oleic is of warm-blooded animals. In variable amounts in head and blubber oil of whales, seals, cod liver oil, and fish generally; marine animals 15 to 20%; mammals and birds 6-8%
Stearic	C18:0	Occurs along with palmitic acid, but often in smaller amounts, as in seed fats and marine oils, and up to 5-15% in milk fat. Predominant component of body fat of practically all animals (except marine); comprises 10-30% of fatty acids of lard and tallow
Oleic	C18:1	In practically every plant and animal in some proportion; dominant in natural fats, frequently 50% or more, rarely as little as 10%
Linoleic	C18:2	In significant quantities in seed oils and marine oils; absent in most marine animal oils. Essentially absent from the midden samples
Arachidic	C20:0	Widely distributed as a minor component in most fats; more noticeable minor constituent of marine oils
Gadoleic	C20:1	In cod liver, herring, sardine, whale, seal, and other fish and marine animal oils in widely varying proportions, usually 5-10%
Eicosapentaenoic	C20:5	Major component of most fish oils
Behenic	C22:0	Minor component of marine oils and butterfat
Cetoleic	C22:1	Found only in marine oils; absent from freshwater fish
Clupanodonic	C22:5	Fish and marine animal oils
Docosahexaenoic	C22:6	All marine animal oils
Lignoceric	C24:0	Not normally found in marine oils — decay product here?

TABLE 3. Analysis of some fresh marine fats by % composition

Fatty Acid	Whales				Seals						Walrus[6]
	Fin[1]	Black right[2]	Beluga[3]	Bowhead[4]	Harbour[5] m	Harbour[5] f	Ringed[5] m	Ringed[5] f	Bearded[5] m	Bearded[5] f	
C14:0	5.4	6.2	6.8	5.8	1.9	2.5	3.4	1.7	1.8	2.8	2.7
C14:1	1.0	1.1	1.5	1.3	0.4	0.4	0.8	0.6	0.3	0.3	0.5
C16:0	8.9	6.8	8.4	8.4	6.8	8.0	5.3	3.2	7.3	10.0	7.3
C16:1	7.2	5.6	20.1	21.2	11.0	10.6	19.0	9.5	12.5	14.1	17.2
C18:0	1.9	1.5	1.5	1.7	0.9	1.1	0.7	0.7	1.7	2.3	2.8
C18:1	28.3	19.3	15.6	18.4	29.8	24.2	15.8	16.2	21.3	21.7	18.3
C20:0	0.1	1.7	trace	—	0.1	0.1	trace	0.1	trace	0.2	0.3
C20:1	18.0	20.7	9.3	12.2	13.8	8.9	5.0	8.2	3.9	9.0	6.0
C20:5	2.3	17.1	3.9	8.5	6.5	10.6	12.0	10.6	14.0	9.3	14.2
C22:1	15.7	1.2	4.4	7.0	2.7	2.4	0.7	1.6	0.8	3.3	—
C22:5	1.2	1.7	1.9	3.2	7.8	7.7	11.6	14.6	9.8	4.8	10.8
C22:6	2.8	3.7	4.1	5.2	12.6	16.7	17.8	26.2	12.1	13.4	6.7
C24:1	0.7	—	0.2	—	0.4	0.4	1.1	0.8	0.6	0.6	trace

[1]Ackman *et al.* (1965)
[2]Tsuyuki and Itoh (1970)
[3]Litchfield *et al.* (1971)
[4]Wo (1973)
[5]West *et al.* (1979a)
[6]West *et al.* (1979b)

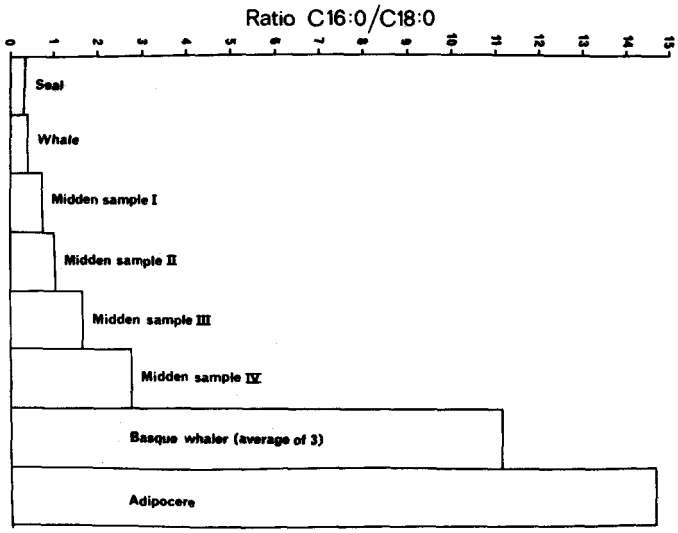

FIG. 4. Histogram showing ratio of palmitic acid (C16:0) to oleic acid (C18:1) for various substances, including unpublished results of fatty material from a Basque whaling station excavated at Red Bay, Labrador.

It has been demonstrated that in the transformation of fats to adipocere, the unsaturated fatty acids tend to disappear and are replaced by saturated fatty acids of two fewer carbon atoms (den Dooren de Jong, 1961; Morgan *et al.*, 1973). For example, oleic acid (C18:1) is replaced by palmitic acid (C16:0) and C16:1 by C14:0. Figure 4 shows the ratio of C16:0 to C18:1 in several materials, including adipocere and three samples of fat taken from a sixteenth-century Basque whaling site in the warmer waters of southern Labrador (Morgan and Edwards, unpublished results). From this, one would conclude that the fats from the Thule site are somewhat altered towards adipocere, but by no means completely, nor as much as the samples from the Basque site.

The second point to notice in comparing the composition is that the relatively unstable polyunsaturated fatty acids with five or six double bonds are absent in the midden samples. They may have been oxidized by the air soon after they were thrown on the midden or since removal from the site. Their absence makes identification of species still more difficult.

In order to aid comparisons, results have been recalculated in Table 4. The proportions of the principal fatty acids present in both the midden and fresh oils have been compared by recalculating to omit the polyunsaturated fatty acids which are absent from the midden samples. The Thule people are supposed to have exploited the bowhead whale, for which only one report is available (Wo, 1973). The fin and black right whales are its closest relatives for which we also have data. Values for the saturated and mono-unsaturated fatty acids of these three whales have been averaged. There is no strong correspondence with the midden samples because of the generally higher proportion of saturated acids and lower proportion of mono-unsaturated fatty acids in the midden material.

TABLE 4. Comparison of average relative proportions of some fatty acids in midden fat, whales, seals, and eight mammal species combined, omitting polyunsaturated fatty acids*

Fatty Acid	Samples I, II, III	Whales	Seals	8 Mammals
C14:0	3.9	8.3	4.4	6.0
C14:1	1.0	1.6	0.9	1.3
C16:0	29.5	11.0	12.4	11.8
C16:1	13.7	18.3	24.5	21.7
C18:0	3.2	2.3	2.2	2.4
C18:1	27.0	27.7	38.4	33.7
C20:0	2.5	0.7	trace	0.3
C20:1	13.9	20.5	14.3	17.0
C22:0	2.6	—	—	—
C22:1	2.9	9.6	2.9	5.8

*Data recalculated from Table 3.

In the fourth column the average values for the seal species of Table 3 are displayed. These average values are similar to those for whales and do not correspond any better with the midden samples. Again the ratio of C16:0 to C18:1 is quite different, and this difference is attributed to partial conversion of the midden samples to adipocere. The closest comparison of the average midden sample is probably with the harbour seal data of Table 3, except for the amount of C16:0. In Figure 5

the cumulative percentage compositions are plotted from Table 4. Fresh seal fat resembles the midden material somewhat more closely by this method of presentation than does whale fat.

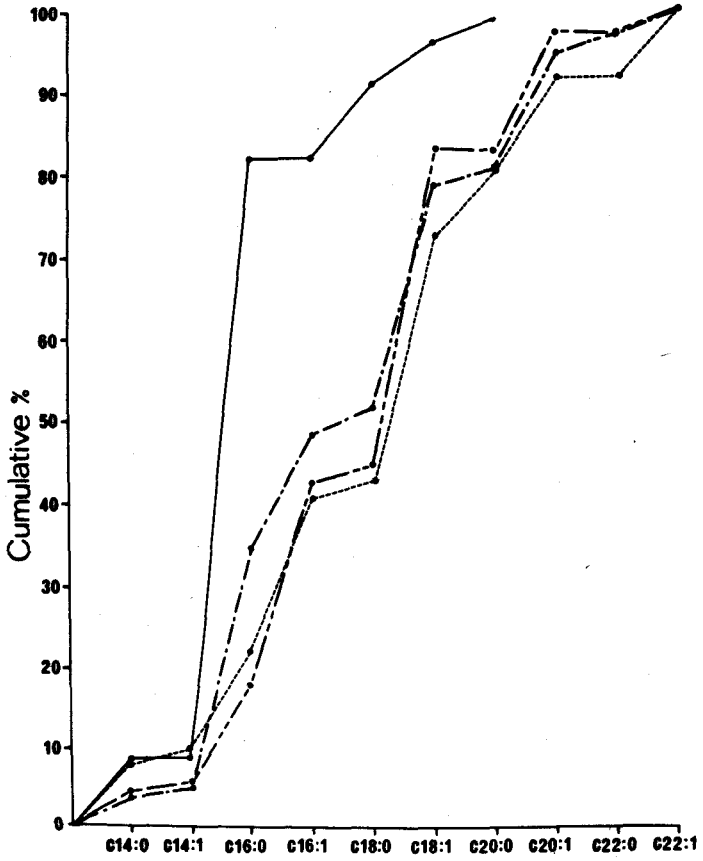

FIG. 5. Cumulative percentage fatty acid composition plots of various materials, showing apparent similarity of midden samples (means of samples I, II, and III of this study) to average for three seal species and average for whales (data taken from Table 4). Adipocere ——, midden samples I, II, III —·—, average seals — — —, average whales ----.

In the last column of Table 4 average values for the eight mammal species of Table 3 (beluga, bowhead, fin, and black right whales, harbour, ringed, and bearded seals, and walrus) are presented. The various species have not been weighted according to their population or likely importance to the Thule hunter.

While the results are unclear as to the particular species involved in the Washout Site midden, it is clear that the samples are derived from seal or whale or a mixture of these with even some fish oil, and that the composition has been altered over time. A principal-components analysis of the data provided no further clarification and so has not been included in this paper. At this stage it is more reliable to make conclusions on the Thule diet from the bone material found on the site and then to decide how much the fats have been altered.

What is astonishing about the midden material from this site is that the fats have changed so little. Similar fat in an anaerobic environment at laboratory temperatures would undergo sufficient bacterial change in a year or two to reduce the content of palmitoleic and oleic acids almost to zero.

The finding is very promising for the study of fatty debris from other arctic sites. While in many cases the material can be expected to consist of a mixture of fats from various food sources, nevertheless samples may be found which can be related to a single food source. Indeed, a food source may be represented at a site by fatty debris while the bone material of the source may never have been deposited in that site. Accumulation of data from different sites, comparison of results, more accurate analyses, and more careful handling of samples may well increase the accuracy of our conclusions. Many Eskimo midden sites in the Arctic are known from the black, greasy nature of the soil. These will repay chemical examination as, for example, in the possible documentation of subsistence patterns in a comparison of contemporaneous inland and coastal sites. Sampling of fatty material could be improved if the samples could be immediately stored under nitrogen to prevent autoxidation by the air, and either dried or refrigerated to prevent bacterial action.

REFERENCES

ACKMAN, R.G., EATON, C.A. and JANGAARD, P.M. 1965. Lipids of the fin whale. Canadian Journal of Biochemistry 43:1513-1530.

DEN DOOREN DE JONG, L.E. 1961. On the formation of Adipocere from fats. Antonie van Leuwenhoek Journal of Microbiology and Serology 27:337-361.

FOURCROY, A.F. 1790. Mémoire sur les différens états des cadavres, trouvé dans les fouilles du Cimetière des Innocens en 1786 et 1787. Annales de Chimie 5:154-185.

LITCHFIELD, C., ACKMAN, R.G., SIPOS, J.C. and EATON, C.A. 1971. Isovaleroyl triglycerides from the blubber and Melon oils of the Beluga Whale (*Delphinapterus leucas*). Lipids 6:674-681.

MALINS, D.C. and WEKELL, J.C. 1970. The lipid biochemistry of marine organisms. Progress in the Chemistry of Fats and other Lipids 10:339-363.

MANT, A.K. 1957. Adipocere — a review. Journal of Forensic Medicine 4:18-35.

MORGAN, E.D., CORNFORD, C., POLLOCK, D.R.J. and ISAACSON, P. 1973. The transformation of fatty material buried in soil. Science and Archaeology 10:9-10.

MORGAN, E.D. and EDWARDS, C. (Unpublished). MSS on file at Department of Chemistry, University of Keele, Keele, Staffordshire, ST5 5BG, England.

THORNTON, M.D., MORGAN, E.D. and CELORIA, F. 1970. The composition of bog butter. Science and Archaeology 2 and 3:20-25.

TSUYUKI, H. and ITOH, S. 1970. Fatty acid components of black right whale oil by gas chromatography. Scientific Reports of Whales Research Institute of Tokyo 22:165-170.

WEST, G.C., BURNS, J.J. and MODAFFERI, M. 1979a. Fatty acid composition of blubber from four species of Bering Sea phocid seals. Canadian Journal of Zoology 57:189-195.

———. 1979b. Fatty acid composition of Pacific walrus skin and blubber fats. Canadian Journal of Zoology 57:1249-1255.

WO, C.K. 1973. The nutritional status of Alaskan Eskimos with respect to fatty acids, Vitamin A and Vitamin E. Ph.D. thesis, University of Illinois at Urbana-Champaign.

YORGA, B. 1980. Washout: A western Thule site on Herschel Island, Yukon Territory. Ottawa: National Museums of Canada, Mercury Series No. 98. 219 p.