TAPHONOMIC AND METHODOLOGICAL PROBLEMS IN RECONSTRUCTING PREHISTORIC DIET FROM ANCIENT HUMAN GUT AND FAECAL REMAINS.

By TIMOTHY G. HOLDEN.

Thesis submitted in fulfilment of the requirements for the degree of PhD. at the Institute of Archaeology, University College London. 1990.

"I went into another chamber, but was ready to hasten back, being almost overcome with a horrible stink. My conductor pressed me forward, conjuring me in a whisper to give no offence, which would be highly resented; and therefore I durst not so much as stop my nose. The project of this cell was the most ancient student of the academy. His face and beard were of a pale yellow; his hands and clothes dawbed over with filth. When I was presented to him he gave me a very close embrace, (a compliment which I could well have excused). His employment from his first coming into the academy, was an operation to reduce human excrement to its original food, by separating the several parts, removing the tincture which it receives from the gall, making the odour exhale, and scumming off the saliva. He had a weekly allowance from the society, of a vessel filled with human ordure, about the bigness of a Bristol barrel".

Jonathan Swift 1728 (Gulliver's Travels)

ABSTRACT.

The study of ancient human gut and faecal residues can provide some of the most reliable data relating to past diet. However, as with other forms of archaeological data it suffers from serious taphonomic bias, with some classes of food being well represented and others only poorly. This project attempts to identify more clearly where some of these biases lie, particularly with respect to the matter of differential digestion. In order to achieve this, a series of experiments relating to digestion in modern humans and the survival of different food items through the digestive tract, have been carried out.

The knowledge gained during this study of modern material has then been applied to three separate classes of ancient human gut and faecal remains:-

a) desiccated human gut contents from a number of locations in South America;

b) waterlogged human gut contents from a number of European bog bodies;

c) discrete, desiccated human palaeofaeces (coprolites) recovered from midden on the Northern Chilean site of Tulan 54.

The food debris from these samples have been accurately identified and quantified and interpretations made regarding past dietary practices. In the case of the coprolites from Tulan, North Chile, it has also proved

possible to compare and contrast the data recovered from coprolite material with both biological material recovered by flotation from the midden itself, and, the gut contents of two well preserved human bodies from an associated cemetery. It has therefore been possible to comment upon the advantages and deficiencies of each class of material which are more usually analysed in isolation.

CONTENTS

Chapter 2 - Methods of Coprolite and Gut Content Analysis.

Chapter 3 - Experimental Work to Identify the Effects of Digestion of Different Plant and Animal Tissues.

Chapter 4 - The Gut Contents of Ancient, Desiccated Human Bodies.

LIST OF DIAGRAMS.

LIST OF TABLES.

LIST OF PLATES.

ACKNOWLEDGEMENTS.

I would like to thank Don Brothwell Gordon Hillman, Prof. David Harris, Ann Butler, Jon Hather, Steve Carter, Stewart Laidlaw, Peter Dorell, Sue Colledge, Sarah Mason, Charlotte Herxheimer, Mike Charles, Delwyn Samuel and other members of the staff at the Institute of Archaeology, University College London for their help and support with various aspects of my work over the past five or six years. In particular I would like to thank Don, Sue, Charlotte, Gordon, Sarah and Dawn Holmes for their patient proof reading and useful suggestions. I would also like to add a special thankyou to Dawn and Sue who did more than anyone towards keeping me sane through the last tortuous months of this thesis.

Alwyne Wheeler, Ann Baker, John Taylor, and other members of the staff at the British Museum of Natural History, Prof. John Vaughan (Queen Elizabeth College, University of London), Camilla Dickson (Glasgow University), Gordon Hill (R.A.F. Wroughton), Tim Lawrence, Steve Renvoise and David Simpson (Royal Botanic Gardens, Kew), Tim Robinson (Dept. of Anatomy, University College London) for their help in identifying the diverse variety of ancient and modern material recovered during the course of this project.

Prof. Lautaro Nunez and Prof. Augustin Lagostera (Universidad del Norte, San Pedro de Atacama, Chile), Prof.

Marvin Allison (Universidad de Tarapaca, Arica), Chile, Prof. Enrique Gerszten (Virginia College University, Virgina), Ian Stead (British Museum) and David Liversage (National Museum Copenhagen), Elizabeth Carmichael and Tony Sheldon (British Museum - Museum of Mankind) and Dr. Van der Sanden (Drente museum, Assen) for allowing me the privilege of studying the various samples that they provided for this project.

Duro Odwale and Keith Sales (E.S.R. dept. Queen Mary College, University of London) the staff at Geography and Chemistry departments at University College London, Reg Davis (X-ray dept. Royal Marsden Hospital, London), J. Boesen and other members of the staff in the C.T. scan dept. Rigshospitalet, Copenhagen, Rodney Resnek and Marian Hallett (C.T. scan department Bartholemews Hospital, London), Dr. Eddie Tapp (Preston Infirmary), Paul Thomas (Advance Visual Optics Ltd.) and Ken Wildsmith (Nikon Ltd.) for access to and help with the use of the specialised equipment, without which, much of this project would not have been possible.

Dawn Holmes for her patience and help during the compilation of this thesis, Pilar Allende for much appreciated help with the more difficult spanish translations, Penny Dransart for numerous helpful discussions and Enid Holden for her artistic and technical expertise!

Numerous members of the communities in the Cusichaca and

Patacancha valleys, Peru and San Pedro de Atacama, Chile for their help and hospitality during my field work in South America.

Prof. A.Aufderheide (Duluth Medical School, Minnesota) and Prof A.Steensburg (Royal Danish Academy of Sciences and Letters) for their enlightning correspondence some of which I have taken the liberty of reproducing in this thesis.

Filipe Cardenas for the loan and accompanying organisation of the two mummies from the Gold Museum in Bogota, Colombia and to British Airways for their financial and practical help regarding the transport of these bodies.

The Science and Engineering Research Council for their funding of the period of the work in this field at the Institute of Archaeology.

Finally, to Ann Kendall and the Instituto Nacional de Cultura, Peru for introducing me to the people and places of South America and the enormous potential for future study that exists there.

Chapter 1 - Introduction.

1.1.) The study of faecal material.

Human faeces are more often the subject of human disgust than of scientific interest, yet this disgust would, by all accounts (eg. Rosebury 1969), seem to be a relatively recent and somewhat irrational culturally-acquired trait. From works such as those by Bourke 1891, Mclaughlin 1971, Rosebury 1969, and Wright 1960 it is clear that human faeces have been regarded with widely differing attitudes by differing people: as gifts (Freud 1917-1919); religious relics; good luck charms (eg. Bourke 1891 and Rosebury 1969); manure/fertilizer; sources of disease or just plain filth. Science's interest has remained largely in the medical sector and has continued into the modern era through seminal works such as that of Cammidge (1914) "The faeces of children and adults". This continues to the present day as the link between health and diet is becoming more widely appreciated. Diseases such as diverticular disease, atherosclerosis and diabetes are recognised as being linked to diet and, in particular, to fibre intake. Researchers are therefore beginning to realise that little-understood organs such as the colon, and its symbiotic relationship with the bacterial flora is of more importance to human health

than originally thought.

Archaeological interest in human faeces followed later (see section 1.2). Unfortunately the medical profession and archaeologists interested in prehistoric subsistence have followed divergent paths when looking at diet as revealed by a study of faecal material. Generally, medical biologists and nutritionists have concentrated upon an essentially chemical approach (with the exception of works like that of Schel *et al.* 1980), defining food debris in terms of carbohydrates, proteins, fatty acids etc. Archaeologists have followed a more microscopic approach with identification of plant and animal debris being made on the basis of their anatomical characteristics. Although the emphasis of archaeological and medical work has been different it is likely that the two approaches will start to converge more, as the deficiencies of both approaches in isolation become apparent. Some preliminary work on chemical aspects of prehistoric faecal studies is already being undertaken (eg. Knights *et al.* 1983 and Wales *et al.* 1989), and should soon be able to complement the more usual data obtained by microscopic studies. It may therefore become possible to integrate data relating to macroscopic food remains with data relating to equally important food items that tend to leave little or no visible remains in faeces.

1.2.) Archaeological faeces.

The realisation that archaeological faecal material can potentially illuminate aspects of past human life not normally accessible from other classes of remains is not a recent one. As early as 1896 Harshberger (1896:150) pointed out the potential of studying ancient faecal material while in the following two decades a number of studies of different types of human faecal material were made by various researchers. Young, for example (1910:324 cited by Wilke and Hall 1975), made a study of desiccated coprolites from Lovelock Cave, Nevada; Warren (1911) studied material taken from the abdominal areas of a skeleton from Walton-on-the-Naze; while Jones (1908, 1910) and Netolitsky (1911 & 1912 cited by Wilke and Hall 1975) made studies of the desiccated gut contents of some Egyptian mummies. Good reviews of the history of coprolite studies, concentrating mainly upon desiccated remains, have been presented by Bryant (1974b), Callen (1967b), Fry (1970) and Wilke and Hall (1975). In view of this, rather than present a chronological review of previous work the following sections concentrate on the three major classes of human excrement available to archaeologists and the potential that they represent for study.

1.2.1.) The different classes of ancient faecal material.

1.2.1.1.) Cesspits, latrines and sewers.

This category of material, commonly referred to as sewage (see Greig 1984:49), is by far the most common source of human faecal material in temperate climates. It represents large, mixed assemblages of faecal and other debris and is most often recovered from urban settings where the concentration of human population has necessitated the formation of specialised areas for waste deposition. This is as opposed to more rural areas where faecal material, even if collected initially, would be spread over the fields as a fertiliser or consumed by scavengers in much the same way as it is in many parts of the Third World today (see for example Gade 1975:128). These often large urban deposits, even though periodically cleaned out, were frequently abandoned, and, where suitable conditions prevailed, have been preserved to the present day. In most cases (though not exclusively), this preservation is by waterlogging and under such conditions a whole variety of faecal and household refuse can be recovered (see Greig 1981 as an example of this). Individual items can also be preserved by a process of mineralisation (Green 1979).

Sewage describes a mixed assemblage derived from a number of sources. These will include: faecal material (both human and possibly animal); household waste (food debris, packaging, ashes, floor sweepings etc.); ancient

equivalents of toilet paper and sanitary towels (moss and cloth fragments); remains of the flora and fauna living in and around the deposit itself (beetles, fly pupae, other insects, weeds growing around the site etc.); materials added to reduce the smell or faunal infestations (lime, ashes, straw, earth); material from the surrounding environment that had washed, dropped or blown into the assemblage (seeds, earth, leaves, construction material etc.), and items lost and not retrieved while using the facilities. A certain amount of mixing may also occur by bioturbation, human activity and water flow. The resulting mixture of organic and inorganic material can therefore provide substantial data relating to many aspects of the more basic aspects of life. It is, however, of only limited value when it comes to looking at more specific details of diet. For this reason sewage has not been considered further in this thesis.

Notable publications on the composition of sewage in its various forms, include: Buckland (1976); Dennell (1970); Dickson (1988, 1989); Dickson *et al.* (1979); Greig (1976, 1981, 1984); Hall *et al.* (1983); Knights *et al.*, (1983); Knorzer (1983); O'Connor (1986); Paap (1983) and Wilson (1975).

1.2.1.2.) Individual stools (Coprolites).

This type of faecal material is frequently referred to as a coprolite, a term that according to Murray's New English dictionary was first used by the Rev. W.Buckland

in a treatise on the dung of *Icthyosaurus* from lias at Lyme Regis (Buckland 1929). In this case it was used to describe the fossilised faecal material and *in situ* gut contents of these ancient reptiles. In the field of archaeology it is more widely used to describe discrete ancient stools or scats of either humans or animals, whether fossilised (ie. mineralised) or not. Throughout this thesis therefore, this broader definition is used, although in no cases are the samples strictly speaking mineralised.

These archaeological stools, or coprolites, can be preserved in a number of ways. Most commonly, they are preserved by desiccation and it is upon such material that most work relating to prehistoric diet has been undertaken. In the arid areas of Southwestern North America and Mexico, cave and other protected sites such as at: Danger and Hogup Caves, Utah, (Fry 1970); Clyde's Cavern, Utah, (Hall 1972, Winter and Wylie 1974); Glen Canyon, Utah (Callen and Martin 1969); Hidden Cave, Nevada (Roust 1967); Lovelock Cave, Nevada (Ambro 1967, Cowen 1967, Heizer,1967, 1969, Heizer & Napton 1970, Napton 1969 and Roust 1967); Dirty Shame rock shelter, Oregon (Hall 1977); Tamaulipas and Tehuacan, Mexico (Callen, 1963, 1969), and a number of sites from Texas (Bryant 1974a, Bryant and Williams-Dean, Hall 1979, Stock 1983) have yielded considerable data.

On open sites, preservation is less common and more

reliant on persisting aridity, but samples from sites such as: Huaca Prieta, Peru (Callen 1963, 1969, Callan & Cameron 1960); Tarapaca, Chile (Williams 1970, 1980, Kautz 1980); Azapa, Chile (Rivera 1980); Tiliviche, Chile (Nunez and Hall 1982), and also at La Quinta and Myoma Dunes, California (Farrell 1988 and Wilke 1978) have yielded good results. Preservation by desiccation, however, is not restricted to extremely arid areas, as the large number of preserved coprolites from dry caves in the Mammoth Cave National Park, Kentucky, show (Bryant 1974; Marquardt 1974; Schoenwetter 1974; Stewart 1974; Watson and Yarnell 1966; Yarnell 1969, 1974).

Specimens preserved by phosphatisation are occasionally recovered from more temperate climates such as the examples from Viking York show (Jones 1983, O'Connor 1986). It is also possible to get partial replacement of organic constituents by fine mineral material where suitable alternating phases of arid and wet conditions have occurred (see section 6.3.4.).

Finally, a rarely recognised form of preservation of coprolites is by charring. Hillman *et al.* (1989:164, 1989:228), for example, have recovered what they suggest are charred fragments of human faecal material from late palaeolithic Wadi Kubbaniya in Upper Egypt and from Tell Abu Hureyra, an epipalaeolithic site in Syria. This particular class of remains causes a number of analytical problems and chemical techniques may yet prove to be the

most valuable sources of information regarding their composition.

Postdepositional contamination of coprolites and the identification of human as opposed to animal faeces have, in some cases, caused problems for interpretation (see section 2.1). Nevertheless, their value to archaeology has been demonstrated, and, as more reliable methods of identifying human coprolites are developed, this will cease to be a problem.

1.2.1.3.) The gut contents of ancient well-preserved humans.

Well preserved human bodies with remaining sections of their gut and its contents are not commonly recovered from archaeological sites. Their value to archaeology is, however, considerable, as is their potential for analysis of aspects of diet and subsistence by the standard techniques used in coprolite research. It is also often possible to complement this with medical, chemical and physical analyses of the surrounding body tissues so adding a further dimension to the study. As with other classes of faecal debris, whole human bodies can be preserved in a variety of different ways. The most common method of preservation is by desiccation and in areas such as the Pacific coast of Chile and Peru, whole cemeteries of buried individuals are frequently recovered (eg. Allison 1974, Allison *et al.* 1984, Reiss and Stubel 1880-87, Santaro 1980). The gut contents of one such example from

Huaca Prieta, Peru has been studied by Callen (1963:189, Callen and Cameron 1960:39), while Paredes and Aspillaga (1984), have made a brief study from Caserones, Northern Chile. Other desiccated bodies from the New World have also provided samples of gut contents for analysis. Wakefield and Dellinger (1936) studied material from a cave in the Ozark mountains and Yarnell (1974) and Robbins (1971) have studied the gut contents of a body recovered from Salts cave Kentucky. This latter example was particularly interesting since it proved possible to compare the contents of the gut with both other coprolites and samples of organic debris recovered from the cave floor by flotation.

These "mummified" bodies (here used to include all well preserved ancient bodies irrespective of whether this is the result of deliberate or fortuitous means) are not confined to the New World. Many classical Egyptian mummies were eviscerated as part of the deliberate mummification procedure but others (see for example Brothwell 1986:plate V), were buried intact. Such bodies can survive in a state of preservation comparable with that found on the occidental South American coast. No recent attempts at analysis of the gut contents of these have been published, but earlier work by Netolitzky (1911, 1912 cited by Wilke and Hall 1975) and Jones (1908, 1910) give some idea of the potential.

Some bodies preserved by smoking or artificial drying

such as those from the Aleutian Islands (Zimmerman 1983:125), or from cave sites in Boyaca, Colombia (Felipe Cardenas 1989 pers. comm., Dawson 1928) would also fall into the class of bodies preserved by desiccation.

Rarely, human corpses are preserved by waterlogging. Most commonly, this preservation occurs in the acidic, anaerobic environments of peat bogs and a number of analyses of the gut contents of such bodies have proved successful (Brandt 1950, Brothwell *et al.* in press, Helbaek 1950,1958, Hillman 1986 and Holden 1986). Other waterlogged contexts such as church crypts can result in discoveries of equal potential, like St. Bee's Man (Tapp and Sullivan 1982), or the body of the Marquise of Tai, China (Ascenzi *et al.* 1984:233) but few analyses have yet been undertaken.

Finally, human bodies are occasionally preserved by freezing or by a combination of freezing and drying. Only one example of an analysis of gut contents from a frozen body is known to the author, that being from the body of a thirteenth century Greenlander from Qilakitsok (Hart-Hansen 1985a, 1985b). There are, however, other bodies such as the Cerro el Plomo body from Chile (Mostny 1957), the Eskimo woman from Kialegak Point, St. Lawrence Island (Zimmerman 1983), or the Pazyryk horsemen from Siberia (Rudyenko 1970) which are every bit as well preserved as the north European bog bodies and might yield similar dietary data if suitable analyses are

undertaken.

There are many advantages in looking at food residues taken from the guts of well preserved human bodies. The possibilities of contamination by non-food materials is considerably reduced if samples are taken directly from the gut. Problems related to provenance that plague the study of coprolites from other contexts are also minimised. The low numbers of individuals commonly available for study may not, however, be representative of the diet of a whole population. This may be particularly relevant where religious ritual had surrounded the death or where it is evident that only elite members of society were preserved in this way. Opportunities to circumvent this shortcoming do, however, exist; for example, with the desiccated bodies from Peru and Chile large numbers from a single cemetery are occasionally recovered. These could provide more representative data if the correct sampling procedure was undertaken.

1.2.2.) Why study coprolites and gut residues?

Human faeces and therefore, human gut residues also, are extremely complex assemblages of organic and inorganic material. Cammidge (1914), for example, lists eight different classes of material that can be present in faeces.

a) remnants of food that have escaped digestion and absorption;

b) remnants of food which are totally or partially resistant to digestion;

c) secretions of the mucous membrane and digestive glands;

d) cellular elements and amounts of blood, mucous, leucoctes some of which become particularly noticeable during pathological conditions;

e) breakdown products of foods;

f) excretory products of the intestinal mucous membrane (mineral salts etc.);

g) bacterial flora of the large intestine;

h) adventitious additions to the stools such as intestinal parasites, or their eggs, enteroliths, gall stones etc.

To this list can also be added, accidental contaminants of food such as insects, pollen, hair, and grit, all of which add to the complexity of the assemblage. This diversity of debris has attracted the attention of workers from a number of different disciplines who have recognised their potential for illuminating aspects of past life. It is therefore appropriate here to give some space to other branches of coprolite research, before giving a more detailed outline of the potential offered by a study of food debris for providing information related to diet and subsistence.

1.2.2.1.) Palaeopathological investigations.

The most common type of study carried out is a microscopic analysis aiming at the recovery of evidence of past intestinal endoparasites. Usually, though not always, the evidence is in the form of their highly resistant eggs. In this way, evidence for: *Trichuris trichura* (whipworm) (Helbaek 1958:114, Jones 1986); *Ascaris lumbricoides* (common roundworm) (Fry 1974:61, Jones 1986); *Diphyllobothrium* sp. (fish tapeworm) (Callen 1960:40); *Enterobius vermicularis* (pinworm) (Fry 1970:83, Hall 1977:10), and other *Taeniodea* species (tapeworms) (Fry 1970:86) have all been recovered from coprolites. Other parasites that may not actually be parasitic on humans themselves but appear as false infections that may have been parasitic on some of man's food species have also been recovered. These include *Moniliformis* sp. (thorny-headed worm) (Fry 1970:83, Hall 1977:10), a species that is thought to have been parasitic on rodents eaten by ancient inhabitants of Southwestern North America. Gordon Hill (1989 pers. comm.) has also identified the protozoan *Eimeria* from the gut of Grauballe man. He suggests that this represents a false infection brought about by the eating of animal offal.

Other information regarding past health can also be revealed where, as in the case of the Qilakitsok, Greenland bodies (Hart-Hansen *et al.* 1985:206), ectoparasites such as head lice have been recovered from the gut.

Finally, under certain circumstances, intestinal disorders can result in the production of mineral concretions such as the Charcot-Leyden crystals, noted by Heizer and Napton (1967:11) and Heizer (1969). These were said to be particularly associated with diarrhoea and dysentery as a result of infection by *Entamoeba histolytica*.

1.2.2.2.) Pollen analysis of ancient gut and faecal material.

The application of standard pollen analysis techniques to ancient gut and coprolite debris has been carried out with considerable success from a number of different locations. Such analyses have been able to identify and interpret pollen from two major sources.

a) **Part of the general pollen rain** - this is accidentally ingested as a result of breathing it in or by being taken in with food and drink. It can provide data relating to ancient environment and can be of value in determining the season in which a meal was eaten.

b) **Part of the diet** - pollen can be deliberately ingested by the eating of flowers and pollen rich foods (eg. honey) or the drinking of flower infusions. This class of pollen can be used to complement other forms of data relating to ancient diet.

A review of much of the previous pollen work is included in Scaife's 1986 paper on Lindow man and some of the

major analyses of pollen from gut and faecal material, in particular from desiccated coprolites, include those from: Lovelock cave, Nevada (Napton and Kelso 1969); Glen Canyon, Utah (Martin and Sharrock 1964); Mammoth Cave National Park, Kentucky (Bryant 1974, Schoenwetter 1974); other sites in Southwestern Texas (Bryant, 1974a, 1974b, Bryant and Williams-Dean 1975, Riskind 1970); Tarapaca, Chile (Kautz 1980), and Coahuilla, Mexico (Bryant 1975a). Samples have also been recovered from both waterlogged and frozen bodies such as Lindow man (Scaife 1986) and the Qilakitsok, Greenland bodies (Hart-Hansen *et al.* 1985:202).

1.2.2.3.) Analysis of macroscopic food debris.

The analysis of the macroscopic remains of part digested food remains can produce a substantial quantity of data regarding past diet and subsistence. The following review therefore relates to the potential for study that they offer and form the broad objectives of this thesis.

1.2.2.3.1.) Reconstruction of past diet.

The recovery of data relating to ancient diet from archaeological sites has always been a difficult area for interpretation. Even though substantial data relating to animal bones, plant and insect remains are frequently provided by archaeological excavation, it is often difficult to identify those items that were actually of dietary importance. This problem is exacerbated by the

often limited amount of appropriate detailed ethnographic data available to aid interpretation and can result in a bias in our perception of food resources and their use. The importance of dogs, rodents and most terrestrial invertebrates, for example, in earlier diet are difficult to assess from on-site debris alone. Similarly it is often difficult to separate human foods from resources that would have been used primarily as animal foods or for other economic purposes. The data provided by coprolites and human gut contents is, however, much more secure. Even though some non-food items can be eaten accidentally (eg. small stones, insect pests etc.) the debris can at least be shown to have passed through the alimentary canal. In this respect therefore, they are one of the few sources of **direct** data that can be used to infer past diet. The interpretation of the composition of gut and faecal residues is not, however, without its problems. They are relatively rare artifacts on archaeological sites and have only a minor part to play in more temperate parts of the world where preservation is generally poor. They also suffer from many the usual taphonomic biases during digestion that conventional organic remains suffer from after deposition. Soft starchy foods, for example, tend to be digested leaving few identifiable remains. More fibrous or resistant foods are, however, more likely to survive. In some cases, such as with certain nuts (eg. acorns) or the meat of large animals, it is only as a result of unwanted parts such as nut shell or animal hair being incorporated into the food

accidentally that any evidence of their consumption remains at all. In spite of these problems the potential for illuminating aspects of past diet is considerable.

1.2.2.3.2.) Food processing.

Except by the recovery of food processing equipment such as grinding stones on sites, the analysis of coprolite and gut residues is one of the best ways of identifying food processing practices. As an example of research into this field Callen (1967:276, 1963:188) has shown that roasting of both seeds and maguey (*Agave* sp.) was probably practised at Tehuacan. Other foods were apparently only briefly placed near the fire. The roasting hypothesis was made on the basis of the differential charring of food debris and the continued presence of starch was used to infer partial cooking. Holden (1986:123) has suggested that material from Lindow man had been finely milled on the basis of the size of the cereal bran fragments recovered. Work with the E.S.R. technique (electron spin resonance) is also beginning to show the potential for reconstructing thermal histories of cooked food. Using this technique it was suggested that the "last meal" of Lindow man was perhaps a griddle cake rather than gruel (Robins *el al.* 1986, Sales *et al.* in press). Dickson (1989:144), on the other hand, using the same technique suggested that cereal fragments recovered from faecal material from Bearsden, Scotland were probably eaten as bread. The presence of grit fragments from coprolites has also been used to infer that

milling had taken place.

1.2.2.3.3.) Food Storage.

The storage of foods in the past could have had important implications for the scheduling of different subsistence-linked activities, in both agricultural and pre-agricultural societies. The study of coprolites can add to the available data. The recovery of pests of stored products such as insects and acarid mites not only indicate that food storage was probably practised but can also provide information regarding the conditions in the storage context. Acarid mites have been recovered from a number of faecal samples (Baker 1989, Watson and Yarnell 1966:844, Williams 1980:197, Yarnell 1969:42). Baker (1989) states that certain genera show a preference for high protein foods. It has therefore been suggested that such species were associated with stored products such as dried meats. Other insect pests and their larvae have been recovered (Williams 1980:198) and are probably also a result of storage infestation.

The presence of different categories of food debris that are characteristic of different seasons of the year can also be indicative of storage. Perhaps the best example of this comes from Salts Cave, Kentucky, where Yarnell (1969:47) recorded that there was a positive association between acorn, maygrass and strawberry in a number of samples. Acorn is available only in the autumn while maygrass and wild strawberry are only available after

late spring. In order for these to occur together, one or the other (or all) must have been stored for a period of time. In this case, the difficulty of storing strawberries relative to acorns argues in favour of storing acorns over the winter period until late spring.

1.2.2.3.4.) Transport of foods from site of procurement.

This aspect of subsistence also has important implications for discussions on resource scheduling and can also add to data regarding seasonal movement and trade networks between human groups.

Where, for example, a food from one environment is being deposited in an environment where this resource is not naturally available, transport of some means can be assumed. This might be the result of a food being traded, carried with seasonally nomadic populations or carried in the gut of travellers coming from a different region. In some cases it might prove difficult to distinguish between these three options but where large numbers of samples are available for study, this may be possible. Evidence of marine fish bone and scale in gut samples from the inland site of Tarapaca, Chile (see section 4.3.5. and Williams 1980) is a good example of where this had happened.

Callen (1968:649, 1967:285) also discussed the possibility of food transportation in his analysis of samples from Tehuacan. In this case he favoured the

interpretation that the coprolites had been left by people who had eaten the food in a distant region only to deposit the residue later, in the Tehuacan Valley. The evidence for this was in the form of a number of coprolites with an atypical composition, containing, amongst other things, traces of beans (*Phaseolus* sp.), pineapple and maize. More commonly, coprolites from this region were dominated by: pochote (*Ceiba* sp.); millet (*Setaria* sp.); mesquite (*Prosopis* sp.); maguey (*Agave* sp.), and cactus (*Opuntia* sp.). He therefore interpreted these unusual coprolites as the faeces of travellers or hunters that had been eating a predominantly "city" diet not more than 24 hours earlier and that they had deposited them in the cave as they were passing by.

Hillman (1986:105) suggests that it might also be possible to glean data regarding the ecosystem from which a particular resource came. Where, for example, the plant or animal remains recovered can be associated with a particular ecosystem, soil type etc. its provenance can then be tentatively identified. With hunter-gatherer populations this might give clues relating to ecosystems that were being exploited for food resources. With agricultural populations on the other hand, crop types and their associated weed seed assemblages might give clues to the areas or the conditions under which the crop was cultivated.

Finally, the presence of mineral material in faecal

debris is often associated with food processing techniques such as pounding, grating and milling. A study of the mineral composition of faeces might therefore be expected to yield information regarding the site where the processing of the food resource took place.

1.2.2.3.5.) Season in which the food was eaten.

The presence of some strongly seasonal resources in gut or coprolite samples can be used to identify the seasons in which they were deposited. Unfortunately, even though the harvest of resources such as acorns, pinyon pine nuts or mesquite pods is seasonally dependent they are also readily storable and transportable. Because of this they can not be used, in the absence of other data, to indicate a season of occupation. The type of indicator that is required, therefore, must be in the form of a non-stored resource. Most foods can be stored if the appropriate technology is available and drying is a commonly used and very efficient means of doing this. The likelihood of some foods being treated in this way is, however, less with some species than with others, especially considering the relative palatability of the dried food as opposed to the fresh (see also section 1.2.2.3.3). Thus, foods such as strawberries and other berries, have been used to tentatively identify the season of consumption (Yarnell 1969). The presence of other seasonally available resources such as migrant animals (ducks, fish, large mammals), even though theoretically storable, could also be used to support these other lines

of evidence.

1.2.2.3.6.) Status and ritual.

Of considerable interest to archaeology are data relating to the status of individuals or whether their meals can reveal any type of ritual behaviour. It is reasonable to suppose that the status of an individual could be reflected in his diet. With higher-status individuals imported exotics or finely processed foodstuffs might be more commonly eaten while "commoners" meals might be represented by a lack of variety and contain coarsely prepared and fibrous elements. Ritual meals could be expected to contain specially collected items of possible extraordinary significance, and famine diets might also be recognisable on the basis of their composition.

Hillman (1986:103) has, for example, suggested that the presence of ergot fungus sclerotia (*Claviceps purpurea*) in the gut of Grauballe man might have been either, a "waste" fraction from crop processing or part of a more ritual meal in which their psychotrophic qualities had been taken advantage of. Even in this case it is difficult to distinguish the ritual from the prosaic, but the potential surely exists for identifying such differences in status if they in fact existed. As we become better informed regarding prehistoric dietary patterns, special or atypical meals will be more easily recognised.

1.2.2.3.7.) Medicines and drugs.

Where individuals have died slowly as a result of illness their last few meals could possibly have been atypical being dominated by small amounts of soft foods and medicinal concoctions. To the author"s knowledge few examples of these have ever been recovered. The desiccated body of "little Al" from Salts Cave, Kentucky, (Robbins 1971:204), however, had quantities of mirabilite ($Na_2SO_4:10H_2O$) mixed with his gut contents. The property of this chemical as a cathartic was noted at the time but no real explanation of its presence was offered. Callen and Cameron's discovery (1960:39) of substantial quantities of grit in the coprolites has also been used to suggest that it might have been of medical importance. They comment that this dirt eating might have been practiced as a response to hook worm infection and indicate that there is ethnographic evidence to support this supposition from the tropics (this has been discussed further in relation to the present project in section 4.5). Scaife (1986:131) recorded mistletoe (*Viscum album*) pollen from the gut of Lindow man and suggested, amongst other possibilities, that it could have been used medicinally. Hillman (1986:103) also discusses the possibilities that ergot (*Claviceps purpurea*) recovered from the gut of Grauballe man could have been used as a drug (see also section 1.2.2.3.6.).

The evidence for the use of medicines or drugs in coprolites is therefore, as yet, very poor, although the

potential for recovering such data remains high.

1.2.2.3.8.) Plant husbandry and pathology.

The reconstruction of crop husbandry practices from archaeological plant remains has been well discussed in the literature (see for example Hillman 1981, 1984, Jones 1984). Hillman (1986:103) explains that these reconstructions have been untertaken mainly on charred plant remains, and ancient faecal material will remain generally peripheral in this respect. In spite of this, coprolites and gut contents can provide information not otherwise available from charred remains. Charring, as with other methods of preservation, is a selective process that often removes all traces of the lighter and more delicate plant remains from the archaeological assemblage. In coprolites, however, the selectivity is biased in a different direction and light chaff and more succulent leaves and stems etc. might still be recoverable in an identifiable state. With the Huldremose bog body for example (Brothwell *et al.* 1989), Holden identified quantities of the green parts of corn spurrey (*Spergula arvensis*) and in the Lindow II bog body (Hillman 1986, Holden 1986) quantities of light chaff were recovered in addition to small numbers of agricultural weed seeds. It is therefore clear that although coprolite material may not offer the quantity of material required for a reliable reconstruction of past crop husbandry practices the presence of certain items that would not be represented in charred samples might add an extra

dimension to the study.

With respect to crop diseases and pathology the parasitic fungus, ergot (*Claviceps purpurea*) (Helbaek 1958) and certain rusts (*Ustilago hordei*) (Helbaek 1958, Holden 1986, Scaife 1986) have both been recovered from archaeological gut contents. Further study in this specialised area might be expected to yield more data relating to crop pathology.

1.2.3.) Aims and objectives.

The broad objectives of this project were directed towards the study of ancient diet and subsistence and have been discussed in section 1.2.2.3 as part of the discussion of the potential for the study of gut and coprolite residues. There are, however, a number of procedural difficulties that have hindered both the detailed analysis of the debris and the interpretation of the results. It is a study of these that has formed a major part of the present project.

The specific aims of the project were:

1) To review and reassess the methods of analysis used in previous studies of gut and faecal debris and, as a result of this, to develop a series of procedural steps designed to maximise the recovery of data relating to prehistoric diet and subsistence. This focused particularly on:

a) the identification of human, as opposed to animal coprolites;

b) the sorting of gut and faecal debris;

c) the identification of gut and faecal debris;

d) the quantification of gut and faecal debris.

In order to assess the existing methodologies some experimental work was necessary. Subsequently a series of modified techniques were devised.

2) To investigate, more closely, the process of digestion (here used to include bacterial fermentation in the colon) in order to identify those plant and animal tissues that might be expected to survive passage through the gut in an identifiable form. It was hoped that it would be possible to:

a) identify those tissues which would be expected to survive passage through the gut in an identifiable form and those which are either wholly or partially reduced;

b) understand more closely, the relationship between the identifiable food debris in faeces and the food that was consumed;

c) define more precisely the tissue types that might be represented in ancient faecal/gut debris. This enabled more rapid and accurate identification of the food debris and identified the classes of modern

food tissues that should be collected and prepared for reference purposes.

3) To devise a method of weighting the data from coprolite analyses such that they more closely represent the equivalent weight of food in the diet.

It was hoped that a method of absolute quantification could be developed and the knowledge gained in the early parts of the project used to calculate equivalent weights of undigested foods represented by faecal debris. Amended values of published fibre content of different foods were used as the basis of these calculations.

4) To use the methodologies devised in the experimental part of the project (aims 1 - 3) to analyse in detail, a variety gut and coprolite material preserved by different means and from different locations. This paid particular attention to the problems and methodologies relating to the analysis of food debris recovered from the guts of well preserved human bodies although a considerable number of coprolites have also been studied. It was hoped that these analyses could then be:

a) integrated, where possible, with data from other categories of archaeological remains within the context of the culture and environment of the human groups concerned;

b) used to assess the general applicability of the amended methodologies to different types of food debris.

Chapter two has concentrated upon the methodological aspects outlined above while chapter 3 has focused solely on the differential digestion of a variety of different food types. Using the knowledge gained in these two chapters, three different classes of archaeological faecal and gut remains were studied in detail (chapters 4-6). Each analyses was intended stand up as a piece of work in its own right although generally applicable points are discussed together in chapter 7 which forms the conclusion to the thesis. Detailed information regarding the samples studied and the identification of the archaeological food debris has been presented in appendices 1 (microfiche) and 2 respectively.

Chapter 2 - Methods of Coprolite and Gut Content Analysis.

2.1.) Introduction.

This chapter is concerned with the methodologies used for the analysis of ancient faecal and gut residues. It is evident from previous work that the methods employed for such analyses can considerably influence the accuracy and completeness of the results. They also determine the degree to which the data can be compared and reassessed quantitatively in the light of subsequent work. For these reasons an evaluation of previous methods and a clear outline of the methods used in this project have been presented. These procedures can be divided into three major stages: the identification of human faecal material, laboratory processing of the samples, and quantification of the debris. Experimental work has been carried out, where required, in order to evaluate existing techniques and these have also been presented here for consideration.

2.2.) The identification of human coprolites.

Where faecal material is recovered from contexts other than the gut of a preserved human cadaver it is essential to show beyond reasonable doubt that it is of human

origin. It is not always possible to distinguish human coprolites from certain mammal faeces and in certain circumstances, they can be confused with geological features. A variety of criteria have been used to separate them from other apparently similar artifacts (see for example Bryant 1974:4-5 Callen 1967:263 1969, Fry 1985:131,1970). These include :

a) size, form, weight and colour;
b) composition;
c) presence of specific human gut parasites;
d) context from which they were recovered;
e) presence of specific chemical indicators;
f) production of faecal odours on rehydration with trisodium phosphate;
g) colouration of the trisodium phosphate rehydration solution.

Most authorities recognise that none of these criteria can be used in isolation as a fool proof method of identification. They are therefore normally used as a complete package, such that any one criterion can be used to complement the others. These criteria are discussed in more detail below.

The majority of coprolites are initially identified in the field by their shape, weight, size, and colour. Such identifications are based on the experience of excavators and are frequently correct, but there are other events which can combine to produce at least superficially

similar artifacts.

The dimensions of human stools can be rather variable reaching proportions that today might be considered to be pathological (particularly in the developed countries where low fibre diets are not unusual). Heizer (1967:10) reported the discovery of a number of coprolites from Lovelock cave which were some three inches in diameter. Observations such as these confirm that the variation in shape, size and colour as a result of such factors as health, stature and diet can indeed be considerable.

2.2.1.) Coprolites vs. geological features.

Occasionally, features that superficially resemble coprolites in size and shape are recovered which have a composition dominated by mineral material. Trevor-Deutsch and Bryant (1978), for example, present a discussion of one such sample and their investigations led then to look for other possible explanations such as filled cavities formed by tree roots or rodent burrows. Under certain conditions, it appears that replacement by silts and other fine mineral particles of part of the organic matrix of coprolites can occur (Scaife pers. comm. and see also COPTH04 and COPTH12 in appendix 1). Further confusion might also be caused in cases where geophagy has been practiced (see for example Johns 1986, Vermeer 1971). Samples can, therefore not be rejected as human coprolites purely because they have a mineral content and a closer study of the particle size and the nature of

such mineral inclusions might help to clarify the situation further.

2.2.2.) Human coprolites vs. animal coprolites.

With most suspected coprolite material the greater problem is distinguishing human faeces from those of animals. These animal faeces, or scats, can be broken down into a number of distinct classes:

1) small carnivores/herbivores/omnivores;
2) medium to large herbivores that produce small pellets;
3) large herbivores that produce other than small pellets;
4) medium sized obligate carnivores;
5) large obligate carnivores;
6) medium to large omnivores (including dogs).

With faecal pellets or scats produced by groups 1 and 2 it is relatively simple to distinguish them from human faeces on the basis of their size and shape. The composition of these should confirm this decision where necessary.

A number of the smaller members of groups 4 and 5 will produce scats which are different in both size and shape from human faeces. The scats of some of the larger cats can be distinguished on the basis of a hard, slick coating of dried intestinal mucous (Fry 1985, citing Fry

n.d.). These criteria, together with high quantities of meat, bone, hair and other animal parts and lack of vegetable matter should enable these groups to be relatively easily discerned.

The remaining groups of animals can prove more difficult to separate. The faeces of large herbivores such as certain bovids or equids, can produce large faecal masses which under certain conditions can resemble those of humans. This problem is particularly acute when they have been distorted or fragmented by post depositional disturbance. In most cases it will be possible to distinguish the herbivore faeces on the basis of their composition as they would be expected to be composed of large amounts of finely comminuted vegetable matter. There could, however, still be room for error where, for example, both the herbivores and the humans have been feeding on the same foods. One example of this might be the seasonal consumption of *Prosopis sp.* (*algarrobo* or *mesquite*) in the arid zones of western north and south America by both man and animals.

Medium to large omnivores may also produce faeces which in form and composition could be confused with those of humans. This class of animals includes those which, although predominantly carnivorous will also eat selected vegetal material when it is available. Many of the canids such as dogs, foxes, wolves and also those animals such as the ursids (bears) and suids (pigs) which are more truly omnivorous all belong to this group. These

animals can produce scats which overlap with the size range and shape that are commonly associated with human stools. Being omnivorous, their scats also have a composition that would not be unusual in the faeces of some humans. The situation is further complicated because some of these animals such as dogs or pigs also frequently act as scavengers around human settlements, where they consume both human food and faecal waste. Gade (1975:128), for example, states that human excrement is the single most important source of food for pigs in the Vilcanota Valley, Peru. Scaife (pers.comm.) has also demonstrated this facet of scavenger behaviour archaeologically, with the recovery of of cereal pollen and bran fragments from British dog coprolites.

Fortunately, even though dog coprolites can initially resemble those of humans, they do have a strong tendency to mineralise with time, presumably as a result of the high concentrations of calcium phosphate associated with their high meat/bone diet. It should be possible to eliminate coprolites of some canids on this basis, but the other members of this group and for canids on a predominantly vegetarian diet, other indicators need to be used.

The context in which the coprolites were recovered is of major significance in clarifying their origin. There are only a small number of animals that will deposit substantial quantities of faecal material around human habitation sites (with the exception of some cave habitations),

and fewer still who will do this with any regularity. Further classes of animals can therefore be eliminated from the list of possible coprolite donors.

Identification of specific human intestinal parasites also shows potential for identification of human coprolites, but again, where scavengers are consuming human excrement, human parasite eggs will become incorporated into their faeces. The presence of parasites specific to the animals themselves, however, might clarify the situation further.

Finally, there would seem to be some potential for the separation of the faeces from different species by chemical means. One primitive technique that is commonly used is the colour reaction of coprolites in trisodium phosphate. This is discussed in detail in the following section. More sophisticated techniques such as that used by Knights *et al.* (1983) have used chemical markers (in this case coprosterols) to identify human excrement but a number of technological problems still remain to be solved before a totally reliable method is developed.

2.2.3.) Trisodium phosphate - colour reaction and smell as a means of identifying human coprolites.

The immersion of coprolites and gut contents in trisodium phosphate solution is now a generally applied technique for disagreggation of the samples before sorting. A number of observations during this rehydration process have been used as the basis for confirming their human

origin.

The first of these observations is the production of an odour reminiscent of fresh faecal material. Callen (1967:263), Bryant 1969 (cited by Willimas-Dean 1978) (1974) and Riskind (1970 cited by Willimas-Dean 1978) have all noted that many samples produce strong faecal odours on rehydration. This odour has even been used more recently by Moore (McCarthy 1985) to aid in the identification of food items in coprolites. It does however seem to be an inconsistent feature and was not noted by Williams-Dean (1978) or Wilke and Hall (1975:10). The only samples recorded during this project that showed any odour other than a distinctly musty one were:

a) those with a high seafood content which had a faint oily smell;

b) those samples which were left to rehydrate for an extended period (over two to three weeks). With these samples it was not clear whether the smell was a result of faecal odour released from the coprolites or as a result of fungal activity in the sample.

This phenomenon has been of little use to this project but may add weight to a human provenance where present.

The colouring of the rehydration solution as a result of diffusion of soluble components out of the sample was also noted and was initially thought to be due to bile pigments leaching into the rehydration solution (Callen

1963). Since this early reference, the use of translucence and colour characteristics of the rehydrating solution have been widely used to support identification of the donor species. (eg. Callen 1967:263, Bryant 1974:410, 1974:5, Fry 1985:131-132, Williams-Dean 1978). These authors all recorded that human faeces produce a dark red/brown to black opaque solution. Following work on modern animal faeces there has been a general acceptance that most other animal species, with the exception of the coatamundi (*Nasua nasua*), do not produce a colour matching that produced by control human coprolites and modern faecal samples. All other species produced a colour between pale and red brown whilst retaining their translucent properties. Bryant (1974:410) added to this and indicated that herbivore coprolites will colour reconstitution solutions yellow to light brown.

Fry (1970, 1985) also suggested that the colouration may be affected by the nature of the diet. Williams-Dean (1978), however, using a number of human volunteers, showed that once dried, the dark opaque solution would be produced irrespective of whether there was a high meat or vegetable component in the diet. More recent work by Chame *el al.* (1989), has carried on this experimental work with a survey of modern, naturally dried animal scats from 20 mammalian species. A number of these also produced an opaque, dark brown rehydration solution. They concluded that the factors producing this colour reaction were not clearly understood and that it was not a reliable criterion for identifying the species that produced

the faeces/coprolite.

Having noted that ancient vegetal remains from a site in north Chile also coloured water dark brown colour during flotation it was decided to carry out some experimental work in order to clarify the situation further. To that end, the following experiment was performed.

2.2.3.1.) Spectrophotometric analysis of a variety of organic materials.

2.2.3.1.1.) Method.

Six different classes of organic samples were taken and submitted to rehydration in a 0.5% trisodium phosphate solution. These were:

i) modern dried herbarium specimens;
ii) 15 year old dried herbarium specimens;
iii) ancient non-coprolite plant remains;
iv) ancient animal coprolites;
v) ancient human body tissue;
vi) ancient gut contents and coprolites.

These samples were chosen to show a) how the colour of the rehydration solution varies with the age of the sample and b) how the colour of the rehydration solution varies with different biological tissues.

The weight of each sample was recorded and a volume of

trisodium phosphate solution equivalent to 10mls. per each gram of material was added in order to keep the concentration of the solution as constant as possible. With some samples, notably where the weight was low but surface areas were large, additional solution of known volume was added until the whole of the sample was covered. Each sample was then left for a period of 6 days.

At the end of this period the rehydration solution was put into 1cm. diameter glass tubes. These were held up against the light and the colour and translucency recorded by eye. In addition to this, a Unicam SP8000 Ultraviolet recording spectrophotometer set for analysis in the visible spectrum, was used to record the solution colour. One cm. plastic microcells were employed to hold the solution and for all readings a comparative blank of fresh 0.5% trisodium phosphate was taken as a control. Although these plastic cells were of inferior quality to glass ones they were considered to be sufficiently accurate since they do not appreciably affect absorption above 260nm and the visible spectrum is generally accepted as having a lower range of 290-300nm.

This technique provided a graphical readout of the absorption of a range of light frequencies in the visible spectrum. and therefore gave an accurate record of the solution colour. Some samples exhibited a very concentrated colour and it was necessary to dilute some by as much as 1000 times to keep the traces on the chart paper.

2.2.3.1.2) Results and discussion.

The absorption spectra of a representative number of these samples are presented in figs. 1-3. They all show a pronounced broad absorption towards the blue end of the spectrum with a significant increase in slope beginning at approximately 450 nm. It is the absorption of these wave lengths that give rise to the different red/brown hues so common in most biological material. Only one sample showed any deviation from the general pattern. This was the rehydration solution from a dried leaf of *Schinus molle*, which retained much of its original green colour.

Although there was a considerable difference in the concentration of the solutions, all other samples, without exception, showed the same general shape of curve. To the eye, all of the modern herbarium samples (with one exception, see above) and the 15 year old herbarium samples had turned the rehydration solution a pale yellow/straw colour. The ancient, phosphatised dog coprolites and modern jackal scat also produced a translucent pale yellow colour although the latter sample was somewhat turbid. In contrast, the majority of the ancient samples of human coprolites, plant tissues, and a number of more recently available camelid, goat and sheep droppings gave an opaque, dark, red-brown solution. The human body tissue, however, gave a slightly lighter colour than the other classes of material (see plate 1). It is noteworthy that 3 samples of cereal chaff from a

3000 year old tomb in Thebes, and samples of 3000 year old vegetable material from a midden from Tulan 54, North Chile, had to be diluted by a factor of 1000 times in order to be read by the spectrophotometer. This was in fact, a greater dilution factor than was required by many of the human gut and faecal samples tested.

From these results a number of points become clear.

1) All of the biological material tested, with the exception of one modern dried leaf, showed approximately the same absorption spectra. When these samples were diluted such that they could be used in the spectrophotometer they all showed a pale yellow/straw colour. The difference between the dark red/brown opaque solutions and the pale yellow/brown translucent solutions was therefore, primarily a function of concentration.

2) The ancient non-faecal plant material produced more strongly coloured rehydration solution than modern material of a similar type. The dark coloration is therefore a function of the age of the samples.

Fig. **1** Reproduction of the spectrophotometer readout for the rehydration solutions of a number of modern herbarium samples.

1) Schoenus molle leaf. diluted x 125.
2) Lathyrus laevigatus pod. diluted x 125.
3) Cortadaria sp. leaf fragment. diluted x 500.
4) Cyperus esculentus tuber. diluted x 5.
5) Triticum aestivum stem. (15 year old) diluted x 50.
6) Ptridium aquilinum (15 year old). diluted x 100.

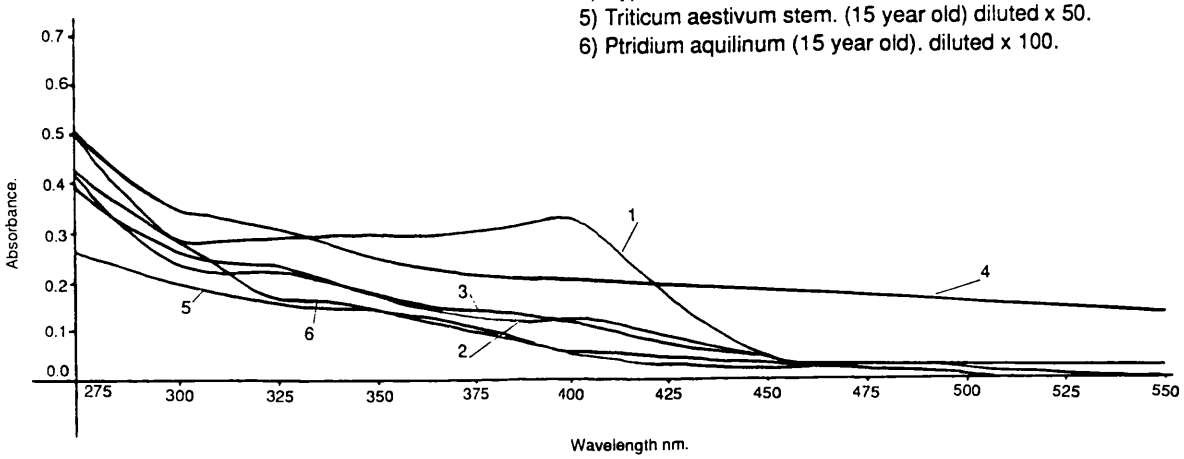


Fig. **2** Reproduction of the spectrophotometer redout for the rehydration solutions of a number of ancient non-coprolite organic samples.

1) Ancient Egyptian bread. diluted x 100.
2) Triticum aestivum chaff (Thebes 1350B.C.). diluted x 800.
3) Hordeum sativum chaff (Thebes 1350 B.C.). diluted x 600.
4) Schoenoplectus americanus stem (Tulan 54 approximately 3000 years old). diluted x 1000.
5) Cereal stem indet. (Thebes 1350 B.C.). diluted x 800.

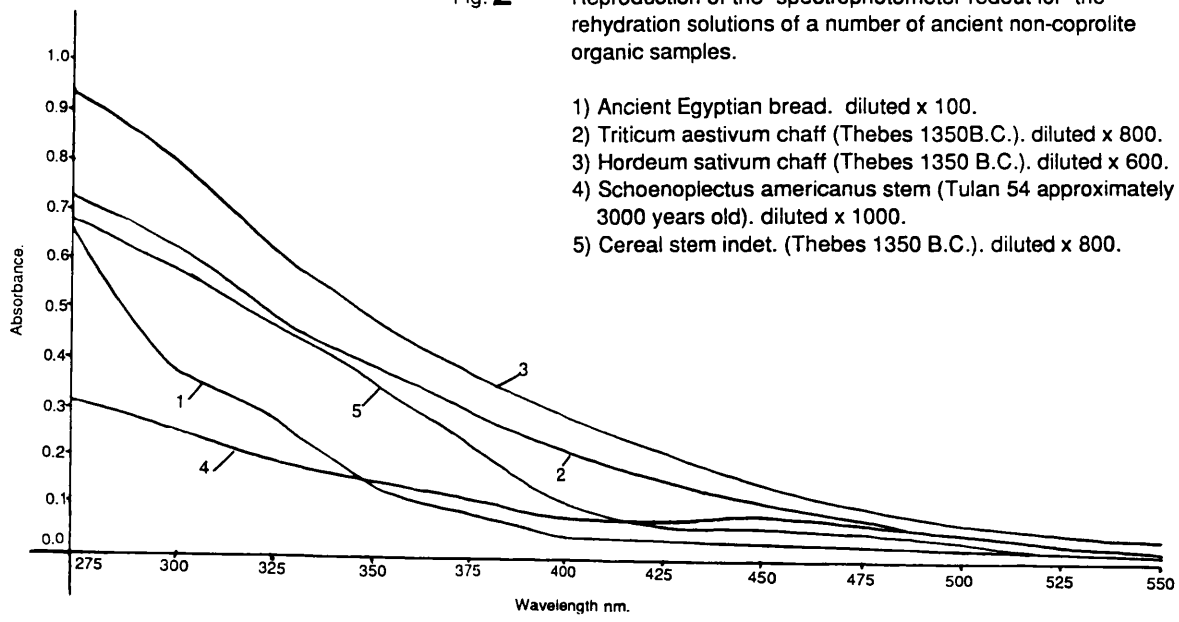


Fig. **3** Reproduction of the spectrophotometer redout for the rehydration solutions of a number of modern and ancient coprolite and gut samples.

1) Human gut contents from Tarapaca, North Chile (TR-40 T-6). diluted x 200.
2) Human gut contents from Tarapaca, North Chile (Pircas 2 T-6). diluted x 200.
3) Human coprolite from Ventana cave, U.S.A. (COPTH03) diluted x 200.
4) Ancient dog coprolite from Loughor castle, UK. (COPTH05) diluted x 20.
5) Modern jackal scat (COPTH06). diluted x 20.

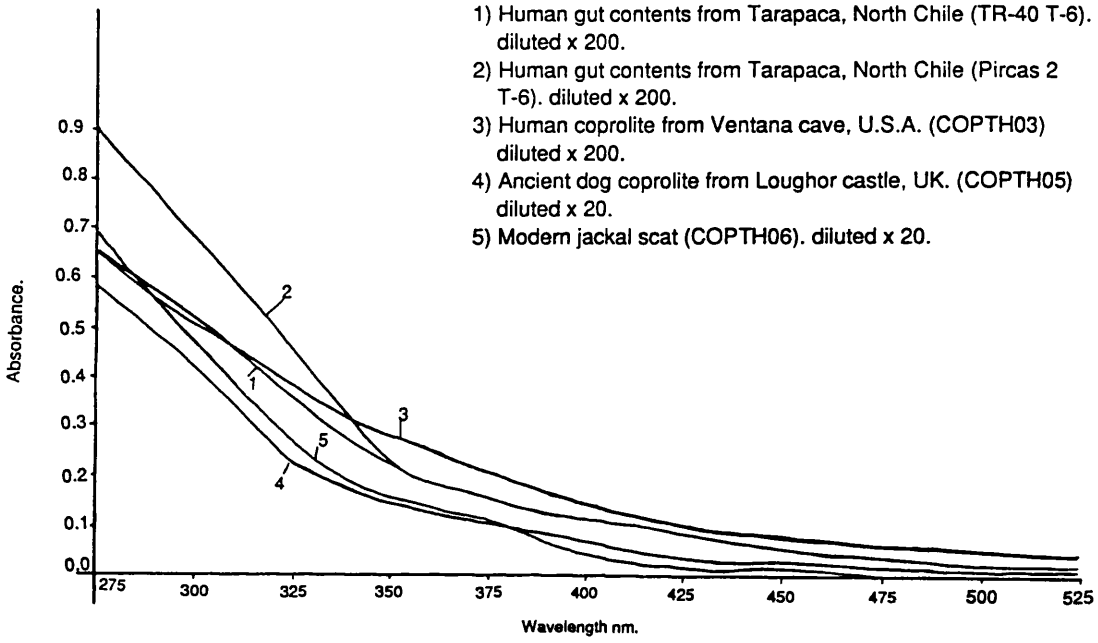
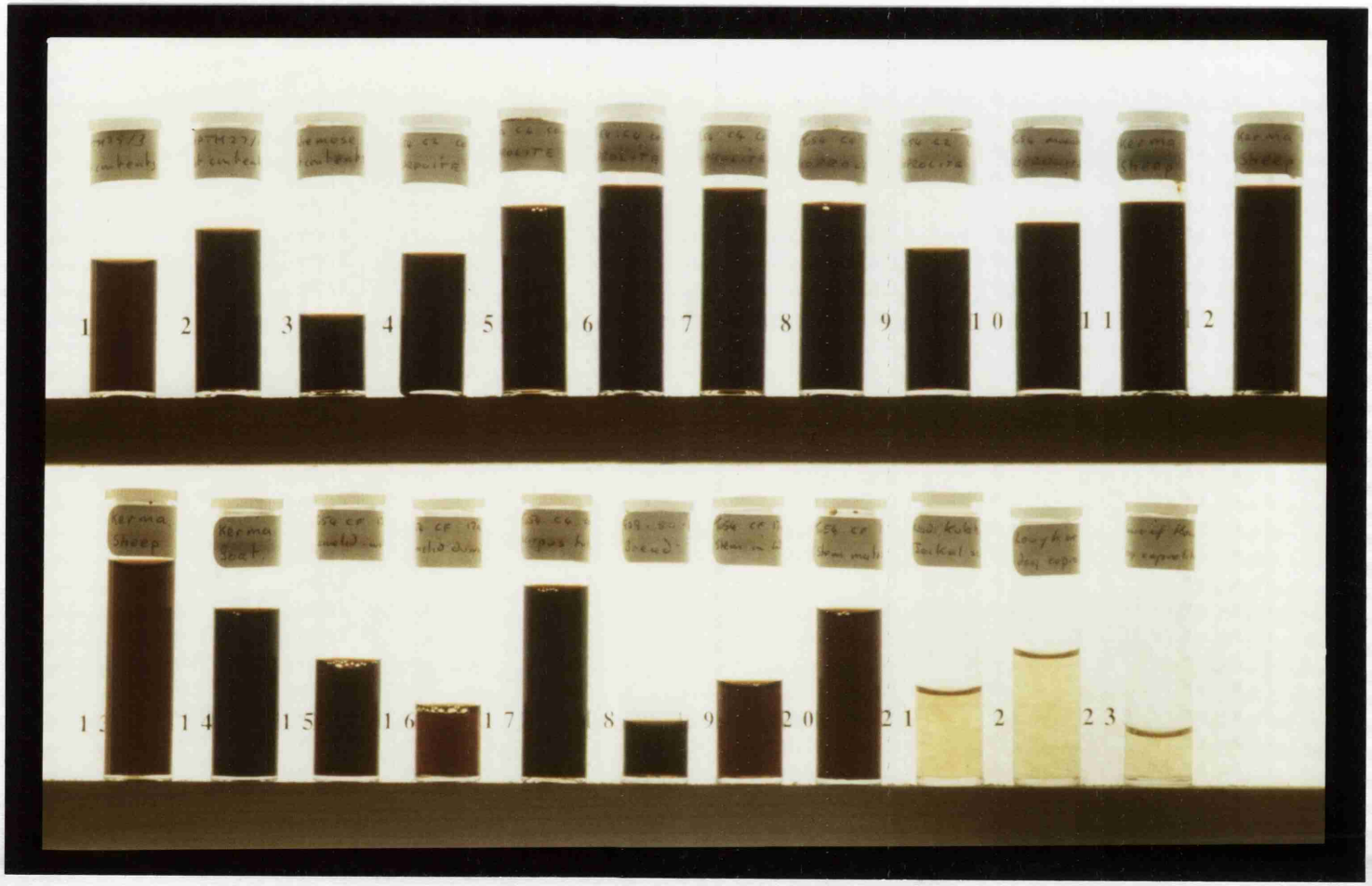


Plate 1.

Photograph Showing the Colour of the Solution after Rehydration of a Number of Ancient and Modern Samples.

1) Pircas 2 T-5. Human Gut Contents.
2) TR40A . Human Gut Contents.
3) Huldremose Bog Body. Human Gut Contents.
4) Tu54 C2 Co-1. Human Coprolite.
5) Tu54 C4 Co-15/1. Human Coprolite.
6) Tu54 C4 Co-14. Human Coprolite.
7) Tu54 C4 Co-15/2. Human Coprolite.
8) Tu54 C4 Co-5. Human Coprolite.
9) Tu54 C2 Co-1. Human Coprolite.
10) Tu54 Sample 2. Human Coprolite.
11) Kerma 77/1. Sheep/Goat Dropping.
12) Kerma 89/4. Sheep/Goat Dropping.
13) Kerma 116. Sheep/Goat Dropping.
14) Kerma 89/2. Sheep/Goat Dropping.
15) Tu54 CF 17a. Camelid Dropping. (in water)
16) Tu54 CF 17a. Camelid Dropping.
17) Tu54 CF Co-5. Scirpus Tuber.
18) 909.80.617.(Deir el Bahri). Egyptian Bread.
19) Tu54 CF 17a. Mixed Plant Stem Fragments. (in water)
20) Tu54 CF 17a. Mixed Plant Stem Fragments.
21) COPTH05. Modern Jackal Scat.
22) COPTH06. Dog Coprolite, Laughor Castle.
23) COPTH08. Dog Coprolite, Howe of Howe.

nb. All samples shown here are of ancient material that has been rehydrated in triSodium phosphate exept where stated otherwise.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

2.2.3.1.3.) Conclusion.

As Chame *el al.* (1989) indicated, this colour reaction is not well understood. It can be produced not only by a range of other modern animal faecal material, but, as presented here, by a broad spectrum of other ancient organic debris. In this latter case the darker colouring appear to be largely a result of the concentration of various organic breakdown products and is controlled by two factors:

a) the amount of organic material present (especially plant material);

b) the age of the sample.

This would explain why earlier experiments on modern animal faecal material (eg. Fry 1970, Bryant 1974:410) gave no dark colour reaction. It would also explain why all of the ancient organic material with the exception of the highly phosphatised dog coprolites with low plant content used in the present experiments, produced a dark coloured rehydration solution. The use of the colour reaction to aid the identification of ancient human faecal material must therefore be considered suspect.

2.2.4.) Concluding remarks related to the identification of human coprolites.

The identification of human coprolite material can not be carried out reliably if based on one characteristic alone. A full account of all possible sources of

information should be made and a strong emphasis put upon the context from which they were recovered, the presence of human parasites and the composition of the food debris. The use of incidental characteristics as a result of rehydration with trisodium phosphate solution can be misleading and can not be used with any reliability.

2.3.) Processing the coprolite samples.

Various techniques have been used to analyse coprolites, and they all require that five basic steps are carried out:

1) cataloguing and recording;
2) sampling;
3) disaggregation of the sample;
4) separation of the components;
5) identification of the components.

These are discussed in more detail below.

2.3.1.) Cataloguing and recording.

The system of recording used throughout this project is basically an adaption of that used by Callen (1967:261). Initially, each coprolite of gut sample was brushed clean to remove any adherent material and was then given a catalogue number prefixed by COPTH in order to distinguish it from flotation or other samples. For most

samples, a black and white photographic record was made and a catalogue sheet as shown below was completed for each. These are presented fully in appendix 1 (see microfiche).

Sample catalogue sheet.

COPTH51 Bloomsbury site, tomb 1, Bloomsbury, London

Received from J.Smith, University College London, United Kingdom.

Context:- Sample taken from the gut of a male mummy aged approximately 25 years at time of death. Dated by C14 to 2400B.C.

Description before rehydration:- Colour - [dark red/brown], Outer crust - [present], Size - [2cm.x 2cm. x 5cm.], Shape - [sub-cylindrical], Folds - [present], Insect intrusions - [none], Adherent material - [charcoal and mineral fragments], Total available for study - [15gms.], Weight taken for rehydration - [5gms.], Comments - [animal hairs visible under low power].

Description after rehydration:- Colour of solution - [dark red/brown], Smell - [musty], Surface scum - [none].

Composition:- Constituents were dominated by cereal fragments which were commonly 2mm.sq. Other items included rodent hairs and a number of fragmentary weed seeds.

Comments:- Parasite analysis show the presence of *Ascaris* ova.

2.3.2.) Sampling.

Where a coprolite or fragment of gut material consisted of one discrete piece this was divided into two pieces longitudinally. One of these was saved for posterity and any future analyses, while the second piece was used for rehydration. Where several pieces from the same coprolite were recovered, half of one of the largest pieces was

taken. In some cases it was not possible to decide whether two discrete pieces taken from the same context were actually from the same coprolite. With such samples they were treated separately and a final decision regarding their provenance was made at a later stage on the basis of their composition.

2.3.3.) Disaggregation.

A number of previous analyses used physical means to break up desiccated faecal material followed by the identification of the dried components (eg. Yarnell 1969, Watson and Yarnell 1966). It is now more usual to use a method of rehydration to gently break up the samples in an attempt to cause minimal damage to the faecal components. Of the various techniques tried (see Napton and Heizer 1970:92), that developed by Callen and Cameron (1960) which required immersion of the samples in a 0.5% aqueous solution of trisodium phosphate appears to be the most effective. This method had earlier been used by Van Cleave and Ross (1947) and Benninghoff (1947) to reconstitute dried botanical specimens and has the effect of restoring much of the consistency of the organic component of the coprolite, thus facilitating their disaggregation.

This technique has been used throughout the project wherever desiccated gut or faecal material has been studied. Where preservation has been by waterlogging such as with the bog bodies of Northern Europe, this type of

disaggregation was not normally necessary unless the body had dried out as happened in the case of the Huldremose bog body. With most waterlogged bodies it was possible to separate the constituents by immersion in distilled water followed by a minimal amount of agitation.

2.3.4.) Separation and sorting.

The way in which these stages are approached are largely determined by the manner in which the food debris are later to be identified and quantified. Two methods have been used previously. The first of these was used initially by Callen (1967:202) and involved decanting the liquid from the rehydration solution. The dense fraction was then suspended in fresh water and representative samples of the different components removed for identification. The decanted liquid and the debris was then mixed with benzene and shaken. Much of the insect cuticle, small seeds, pollen etc. collected at the water benzene interface as the mixture settled. Representative samples of this were then removed for identification. The second method of separation was a dry method and has been more commonly used. (eg. Bryant 1974b:10, Farrell 1988, Fry 1970, 1985, Hall 1977:2, 1979:93, Napton and Heizer 1970:92 and Wilke 1978). This involved the rinsing of the debris followed by sieving, either before, or after drying. The dried material was then sorted. Where the use of high power transmitted light microscopy was required for an identification to be made, the material was rehydrated a second time before being mounted on microscope

slides.

These methods have a number of advantages and disadvantages. Callen's technique, although enabling even the most delicate fragments to be recognised and identified, does not offer any way of providing accurate quantitative data. The dry technique on the other hand, allows for quantification but makes it difficult to recognise the more delicate classes of debris. Remains such as plant epidermal fragments, fine meat fragments, delicate grass testas and pericarp fragments such as those of *Avena* sp. (oats) would be difficult if not impossible to identify or recognise in a distorted dry state. In a wet condition, however, not only can cellular patterns be discerned but colour differences are highlighted, thus aiding separation of the different classes of debris. Sorting may be more time consuming by using this method but more categories of food debris can be recovered and identified. This method has been used throughout this project and it has been possible to identify such items as loosely packed muscle fibres and the flowers of *Prosopis* sp. (with calyx, corolla and anthers all clearly discernible) from samples from Northern Chile. After sorting, these samples were dried ready for weighing during which time considerable distortion and shrivelling occurred. It would seem unlikely that either of these two items could have been identified in this dried and highly distorted condition. Flower eating has been suggested from other locations (Bryant 1974b:13, Wilke 1978:75) based upon the

presence of pollen in coprolites but there is a possibility that such suppositions could have been confirmed if the samples had been sorted wet when the flowers, if present, would have been recognisable.

2.3.4.1.) Outline of sorting and subsampling procedure.

a) The rehydrated material was poured into a geological sieve of mesh size 0.25mm. and washed through with distilled water. Where necessary, the material in the sieve was further disaggregated using a glass rod and a fine jet of water. The liquid and the smaller than 0.25mm. fraction was collected in a large beaker and allowed to settle.

b) After settling, the liquid was decanted from the less than 0.25mm. fraction and stored in 70% alcohol for later examination.

c) An adequate sample for sorting was deemed to be one that would take approximately one working day to sort the largest fraction. The size of sample required was based on experience built up during the early stages of the project and was largely dependent on the type of material being sorted. With some samples in which the debris caused specific sorting problems this time was, however, exceeded considerably. In most cases subsampling was necessary. This was done by suspending the samples in water in a 14cm. diameter petri dish. The sample was then

briefly scanned with a binocular microscope and any large or particularly distinctive items of possible diagnostic significance were removed (corrections were made in the final quantification for items removed). The remaining debris was stirred to give a uniform distribution of material over the base of the petri dish and the water was gradually removed using a fine pipette. Once enough water had been removed for the material to make contact with the bottom of the dish, thus reducing its mobility, the dish was put onto 1cm. square graph paper and the sample was quartered using a blunt seeker. The lines on the graph paper could be seen through the bottom of the dish and ensured that equal divisions were obtained. Where further subsampling was required, this process was repeated, so giving eighth or sixteenth fractions of the original sample.

d) A randomly chosen subsample was then taken and washed through a stack of geological sieves of mesh sizes 1mm. 0.5mm. and 0.25mm.

e) The greater than 1mm. fraction was resuspended in water in a smaller petri dish and sorted into its various categories using fine, flexible metal tweezers. These components were identified where possible and stored separately in 70% alcohol.

f) Each of the smaller (0.25mm. and 0.50mm.) sieve fractions were then sorted in a similar manner except that only those classes of material not represented in the larger fractions were removed for identification. Because of the small size of such debris they were only ever recorded as a trace on the final score sheets.

g) Both the sorted and unsorted remains from all size fractions were dried in a standard laboratory drying oven for a minimum period of two weeks. Each category of remains was then weighed to four decimal places and rounded up to three. (see section 2.5.2 for details of quantification).

2.4.) Processing of flotation samples.

One group of coprolites recovered during the excavation of a prehistoric midden from Tulan, North Chile were analysed. In addition to the analysis of the coprolites, a detailed analysis was undertaken of samples of the charred and desiccated material recovered by flotation from this and one other associated midden. These were processed in the following way:

a) Samples were recovered from regular intervals down the archaeological profile. From the organically rich site of Tulan 54 a sample was taken of each well defined stratum down a 25cm sq. column whereas at the less rich site of Tulan 85, 2 litre samples were taken at approximately 20cm. intervals down the

2 metre profile.

b) Each sample was processed using a simple modification of bucket flotation. The samples were so rich that it was not uncommon to be able to fill standard A4 size plastic bags with the organic remains from just one 25cm square sample.

c) Subsamples of each (approximately 1/4 of an A4 sized bag full) were brought back to the U.K. for analysis.

d) These were further subsampled where necessary using a standard geological riffle box in order to provide samples that would require approximately 8 hours to sort.

e) Each subsample was then sieved through a stack of geological sieves of mesh sizes 2mm., 1mm., 0.5mm. and 0.25mm..

f) The material was sorted under a low power binocular microscope. The variety of material recovered from these samples made it difficult to determine what to separate and what to leave as residue. It was decided, however, that items of possible subsistence value, and other discrete items such as seeds and leaves should be separated from the dominating quantities of wood and stem fragments and faecal material.

g) Identification was made by comparison with modern reference material collected by the author over a period of 2 field seasons.

h) The material was quantified, by weight, to four decimal places (later to be rounded to three) and is presented on the score sheets as weight of each different class of material *per gram of total identifiable debris*. Those other items which were not considered to be of direct importance to the project (and therefore not identified - see step f. above) were also recorded on these score sheets. These were also divided by the same correction factors as the major part of the debris but were reported in the section headed "items present but not quantified per gram of identified material".

2.5.) Quantification of the debris.

2.5.1.) Why quantify?

In presenting the results from coprolite and gut analyses, the data are usually represented as a measure of the identifiable food debris. However, this is not always very helpful and often has little bearing on the food that was eaten. Such methods of quantification are therefore really a measure of the indigestible part of foods eaten rather than a value of their nutritional importance. It would be much more valuable to archaeology if the data could be equated with the undigested food from

which the debris originated. Ideally, the data should make it possible to :

a) make comment on the absolute quantities of undigested foods that are represented by the debris from a given quantity of coprolite/gut material;

b) compare the proportions of different food items in different samples.

The best way of satisfying these two requirements would be to present the results in terms of the dry weight of the original, undigested food per unit weight of the coprolite or gut material. Because considerable mixing occurs in the gut (unless the samples were taken from the stomach) the data would then represent the proportions of different foods from one or two main meals with contaminations from perhaps 3-4 others. Even though this mixing is recognised the term "last meal" is frequently used throughout the text for convenience sake.

In order to fulfil these objectives it would be necessary to convert a measurement of the food debris directly into grams of equivalent dried, undigested food ie. to set up conversion factors for some measure (eg. weight or volume) of the food debris to the equivalent weight of undigested food:

Whether this will be possible to carry out accurately for any single food type will depend upon whether it conforms to two critical criteria:

a) There must be a relatively constant relationship between the part digested food remains and the quantity of the original food;

b) There must be some measurable characteristic of the food debris on which a reconstruction of the original food can be based (eg. weight of epidermis or number of seeds).

With some classes of food debris, such as many animal products and highly processed (low fibre) plant foods, these criteria will not apply. Neither will they be wholly applicable to food remains that only partially survive passage through the gut (eg. some types of leaf epidermis) or to plant organs where the identifiable part does not bear a constant relationship to the original food (eg. some of the larger tubers and fruits that will have varying surface area to volume ratios). Certain elements of the diet, therefore, will not be adequately represented in the results tables and, unless more sophisticated analytical techniques are developed, their importance can only be estimated. Nevertheless, there is still some value in attempting to identify more precisely the importance of those foods that do leave identifiable traces in coprolites or gut residues.

If such reconstructions are to be possible the method of quantification used to record the gut or faecal remains is of vital importance. The various methods available are therefore discussed briefly below.

2.5.2.) Methods of quantifying food debris from faecal and gut residues.

Previous coprolite analysts have used a number of different techniques for the quantification of food debris. These can be split broadly into two categories - subjective assessments and empirical measurements.

2.5.2.1.) Subjective assessments.

The most attractive feature of these methods is the ease with which they can be performed. They allow large numbers of samples to be analysed in a relatively short period of time and there is frequently no requirement to actually sort the material beforehand. Of the methods available, presence and absence is possibly the most simple and has been used to some effect by Callen (1967:284) at Tehuacan. Using this technique he was able to identify trends in food resource usage through time, although the low number of coprolites available from some phases (eg. only two samples from the Ajalpan phase) appear to have been responsible for some of the most prominent features of his diagrams. This technique has also been used by Callen (1969), Rivera (1980), Watson and Yarnell (1966), but in view of the fact that it does not take full advantage of the data, it is more commonly restricted to preliminary reports.

More sophisticated subjective assessments have also been developed in which some note is taken of the abundance of

food items in different samples. Brandt (1950), Callen and Martin (1969), Farrell (1988), Helbaek (1950,58) and Wilke (1978) have all used this method with some success. Yarnell (1969) added a further level of sophistication by giving each class of food debris an abundance value of 1-5. The values given to each category of food could then be totalled for all of the coprolites studied. The totals then gave a picture of the importance of each class of debris on the site as a whole.

Of these subjective methods, perhaps that presented by Napton and Heizer (1970:94), gave the most reliable results. They used what they called the OPTIC (Ocular Proportional Tabulation Control) method by which estimates of volumetric percentages were carried out independently by two different technicians. While reaching some level of accuracy this technique still basically relied on estimations, and, as with the other subjective techniques relied heavily on the experience of the analysts. It is also difficult to reappraise the data at a later stage in the light of new techniques.

Where the material is highly degraded, the sample size small or the debris difficult to sort, a subjective analysis is, however, probably the best method of quantification that can be expected. For this reason, a number of the bog body analyses (Brandt 1950, Helbaek 1959,58 and Holden 1986) have had to rely on a subjective assessment alone.

2.5.2.2.) Empirical measurements and the system used in this project.

A number of methods used by other disciplines have been adopted by coprolite analysts interested in the quantification of diverse ranges of material. Counting the number of items is a commonly used technique in other branches of archaeobotany. This is, however, only appropriate where the debris is not fragmentary and is therefore, only of supplementary value to the present study. Some soil and food scientists (Bullock *et al.* 1985:24, Chayes 1956, Flint and Meech 1978) have dealt with a similar diversity of material to that of gut or coprolite material and have solved it by reducing the problem to a two dimensional one. They do this by making thin section preparations of the samples and then make an area measurement under the microscope by a point count method or by comparison with pre-prepared standards. This method is not directly appropriate for coprolite analysis but Bhadresa (1981,1986) and Stewart (1967) both discuss the merits of the point count system in relation to estimating the composition of herbivore dung. Chamrad and Box (1964) have demonstrated some success with this technique on rumen contents but stress that there must be no large items with unusually large surface area in the samples. It is unlikely, therefore, that this method would prove suitable for human faecal analysis given the diversity of remains that are frequently recovered from such samples.

Korschgen (1971), working in the field of wildlife food

habit studies found that a system of estimated percentage volume gave suitable results. Williams-Dean (1979) and Stock (1983) then used a more accurate version of this for coprolite analysis, although they realised that the problem of air spaces in certain classes of material introduced a degree of inaccuracy. This, they point out, could have been overcome by the more time consuming process of measuring the displacement of water or, as suggested by Korschgen (1971:242) by filling the voids with measured amounts lead shot.

A measurement of weight has been preferred by a number of other workers (Cowan 1967, Fry 1970, Roust 1967, Stewart 1974, Williams 1970, 1980, Winter and Wylie 1974 (after Hall 1972) and Yarnell 1974). These are commonly presented as weight of debris as a percentage of total identified remains. Stewart (1974) and Yarnell (1974), however, presented their data as absolute weights of food debris recovered from known weights of coprolite. This last method has many merits. Firstly, all of the data are presented in a clear, non-subjective way. Re-evaluation is therefore possible at any subsequent stage and percentage values can be calculated if required. In addition, this method shows up both the amount of the sample that is lost during processing (this may be relevant to the type of food eaten), and the quantities of unidentifiable remains that were present. This system has therefore been used, wherever possible, throughout this project. One small amendment has, however, been

made and the data on the score sheets have been corrected such that they represent the weight of food debris recovered from 1 gram of dry coprolite or gut contents. The correction factors that have been used to convert the data to grams are presented at the top of each column on the score sheet. These take into account both the weight of the original sample taken for rehydration and the sub-sampling used. Using this method each value in the score sheets can therefore be directly compared with the values presented for any other coprolite.

This system of weight measurement is not, however, without its problems. With waterlogged specimens such as the bog body samples it was not considered desirable to dry out the samples prior to sorting. Where detailed quantification was viable, it was not possible therefore to relate this back to a dry weight of original gut contents. Similarly, with very small samples, such as the Lindow III sample, it was not possible to recover enough of any one class of food debris to weigh with any accuracy. With such samples it has been necessary to revert to a system of subjective assessment using a four point system such that ++++ = dominant/very common, +++ = common, ++ = rare, + = trace/very rare. Even with larger samples some classes of food debris were still present in such low amounts that they could not be weighed accurately. These have been recorded on the score sheets as trace quantities. In addition to this, where whole items such as seeds, have been recovered intact, the number of

these has been put in brackets at the side.

Finally, one of the best reasons for using weight as a measure of the food debris is that the majority of published nutritional data uses percentage weight as a measure of the different food components (eg. starch, fibre, protein). This is of considerable significance if reconstructions of past meals are to be carried out in any detail and is discussed further below.

2.5.2.3.) The reconstruction of past meals from gut and faecal debris.

As stated in section 2.5.1. it is necessary to provide a series of conversion factors, by which, certain classes of food debris can be related back to approximate quantities of food eaten. This is clearly not going to be possible with all foods and will remain one of the major drawbacks of this approach. Nevertheless, the potential of this quantification method, is considerable, and has proved to be useful for a number of samples presented in chapters 4-6. In these chapters, published values of fibre from the nutritional literature and other sources have been used as the bases for conversion factors for use with plant material (the definition of 'fibre' is discussed further in section 3.3.1.). The basic assumption throughout, has been that what is recovered from the gut and faecal residues corresponds very broadly to dietary fibre as published in the literature. There are clearly a number of problems associated with this

approach, not least that the published fibre values vary considerably. They are highly dependent on such factors as maturity of the plant organ, variety of plant, water content and even the time of year that they were collected. It is also recognised that some elements of the fibre are reduced by the action of colonic bacteria and that for each fragment of recognisable plant debris in the gut or faeces there will be other fragments that are unrecognisable.

In spite of all these problems, for the purposes of this project, it is felt that these published fibre values offer the best opportunity for weighting the data such that they resemble the quantities of food eaten. Each class of food is considered separately and the conversion factors may be amended in the light of other relevant factors. In this way, for example, a crude fibre preparation indicated that the fibre content of the rhizomes of *Schoenoplectus americanus* was approximately 14% by weight (see section 6.4). Only a proportion of this fibre was, however, considered to be identifiable as such. A value of between 7-10% was therefore used as the basis for the conversion factor for this food type. These figures indicated that for every 1 gram of rhizome eaten, 0.07 - 0.1 grams of identifiable *Schoenoplectus* fibre would be potentially recoverable from the faeces. It was therefore possible to calculate that, for example, 0.1 grams of identifiable rhizome fibre in a given coprolite would be the equivalent of between 1 and 1.43 grams of undigested

rhizome. (ie. 100 ÷ 10 x 0.1 = 1 and 100 ÷ 7 x 0.1 = 1.43).

In addition to using percentage fibre as a basis for calculating equivalent weights of undigested material, where a distinct feature can be related directly back to the food eaten, this has been done. In this way, the number of endocarp segments of a *Prosopis* pod or the number of basal fragments of a maize grain have been equated with a weight of undigested food. This therefore allows the relationship between the digested and undigested remains to be calculated.

In circumstances where it has been possible to calculate the equivalent weights of undigested foods by both of the means outlined above, this has been done. In such cases the validity of each method which normally has to be used in isolation can be checked.

The calculations of these conversion factors for each food type are discussed in more detail in the relevant sections.

Chapter 3 - Modern Experimental Work to Identify the Effects of Human Digestion on Different Plant and Animal Tissues.

3.1.) Introduction.

Even under ideal conditions of preservation ancient faecal material can never represent more than an assemblage of much reduced food debris that will differ substantially from the food that it was derived from. As with other forms of taphonomy, digestion does not reduce every type of food uniformly. At one extreme the soft starchy cortex and medulla of a potato tuber will be largely destroyed by digestion while the tough epicarp (skin) of a tomato fruit at the other extreme will remain virtually unaffected by the same processes. This can lead to an under-representation of certain classes of important foods in archaeological faeces and gut residues. Yarnell's (1969:44) analysis from Salts Cave Kentucky, highlights this problem with regard to the visibility of acorn foods in coprolite samples. In these, there was only minimal evidence of acorn consumption although other sources of evidence suggested that they had been one of the staple plant foods. Examples such as this illustrate the requirement for more study relating to the processes of digestion and how it affects different food items - both with a view to identifying where the biases in

preservation lie and - to aid the identification of items once they have been recovered from human coprolites or gut residues.

In the medical and nutritional literature the undigested component of plant foods is commonly referred to by the term "dietary fibre". As Cummings (1976:1) notes, the definition of the word "fibre" "depends on one's point of view" and is used in different ways in different disciplines such as chemistry, botany, and the textile industry. In the field of medicine, however, particularly nutrition, it is reserved for

> "a group of substances of plant origin which are found largely but not entirely in the plant cell wall and which are thought to be neither digested nor absorbed in the upper gastrointestinal tract" (Cummings 1976:1).

These plant substances are more clearly defined as: cellulose; hemicelluloses; pectins; plant gums; mucilages; storage polysaccharides and lignin, together with phytic acid; silica; cuticular substances; proteins and other compounds associated with the fibre. Such is the nature of the subject, however, that these definitions are continually being amended or refined, as it is found that they do not accurately reflect the functional complexity of dietary fibre. In more recent papers, terms such as "non-starch polysaccharides", "substances measuring as lignin" and "resistant starch" are being more frequently

used (eg. Bingham 1987, Cummings and Englyst 1987) to define specific fibre componants. Many of these changes in terminology are as a result of discoveries that compounds previously thought to be digestible in the small intestine (and therefore not strictly speaking "fibre") are being found to be resistant. These are then broken down by bacterial fermentation in the large intestine.

In the above definitions, and in nutritional texts such as Paul and Southgate (1979), for example, the composition of foods is given in terms of its chemistry or loose groupings of poorly understood large organic molecules (eg. non-starch polysaccharides, pectins, hemicelluloses etc.). In the field of human digestion, based on the composition of faeces (see for example, Eastwood *et al.* 1986, Kelleher 1984, Kelsay 1978), the undigested plant remains are represented in similar terms. The medical profession has not needed to define dietary fibre other than by loose botanical descriptions or more specific chemical ones. With the exception of work such as that by Cammidge (1914), Schel et al. (1980) and Bock et al. (1988) few workers have examined the microscopic histology of those tissues that survive passage through portions of the human gut. This is unfortunate because it is only through a microscopic analysis of these understudied anatomical features of dietary fibre and indigestible animal tissues that food debris from ancient faecal material can be identified.

3.2. Objectives.

This part of the thesis aims to examine, in more detail, how food can be altered by preparation techniques and, more particularly by the process of digestion and colonic fermentation. A series of experiments have been conducted that focus on changes occurring in the anatomy of plant and animal tissues during their passage through the human gut. Particular emphasis has also been given to subsequent identification by, microscopic analysis, of surviving food debris. A selection of different foods were prepared using a variety of standard preparation techniques then consumed by human subjects. Faecal material was then collected and the food debris microscopically examined. It was thereby planned to identify the types of tissue potentially recoverable from ancient faecal and gut residues. This enabled:

a) a more accurate picture relating to the taphonomic bias to be developed and improvements at the interpretive level to be made.

b) more specific targetting of relevant modern reference material for comparison with part digested residues.

c) the author to increase his familiarity with the type of comminuted food remains recovered from coprolites and gut contents.

3.3.) From food to faeces.

Before presenting the experimental data it is appropriate to consider in more detail the processes to which food can be subjected as it is converted from food into faecal debris. These can be divided into two clearly defined stages:

a) food processing before the food is consumed;
b) digestion after the food has been consumed (including bacterial fermentation in the large intestine).

These are considered separately, below, along with a discussion on digestion as a variable process.

3.3.1.) The effects of food processing on the structure and composition of foods.

Even before food is consumed, considerable changes to its physical and chemical nature can have occurred depending on how the food has been processed. Processing involves either breaking up the food component or changing the availability of certain tissues to the action of digestion (see Bingham 1987:1228, Eastwood *et al.* 1986:51). Stahl (1984, 1989) illustrated some of the nutritional implications of plant food processing and discusses the importance of the different techniques for archaeology and anthropology. In her 1989 paper she divides processing into four classes.

a) **Grinding, pounding and grating.** These processes (Stahl 1989:172) can be used to:

i) separate undesirable from desirable parts;
ii) change the physical nature of the food;
iii) detoxify certain bitter or toxic foods.

Slicing and even crude cutting should also be added to these three processing techniques since they, too, can be used for the same purpose. The major effects of these processes will be, firstly, to break up certain parts of the plant (ie. the fibrous parts) such that this will be reflected in the size or preservation of of these elements in the faecal debris. Secondly, these processes will affect the availability of certain tissues to the action of digestion (Eastwood *et al.* 1986:51). This will also have a substantial effect on the nature of the undigested component represented in faeces.

b) **Soaking and Leaching.** These processes (Stahl 1989:175) can be used to:

i) soften or hydrate plant tissue;
ii) aid detoxification or later fermentation;
iii) precipitate starch from plant foods.

These processes will have an effect on the composition of food debris in faeces, especially with the hydration of dry-stored foods such as legumes. In such foods previous

hydration can improve both the cooking and digestion. The precipitation of starch may also have its effect upon digestibility of certain foods.

c) **Fermentation.**

This process (Stahl 1989:181) can be used to:

i) facilitate preservation;
ii) enhance flavour;
iii) aid detoxification;
iv) produce alcoholic beverages;
v) increase digestibility.

The effect of fermentation on food is largely chemical rather that physical and therefore most of the important implications of this process are nutritional rather than structural. However, Sinclair and Holligsworth (1969:450), indicate that during the preparation of *sowans*, or porridge that has been left to stand, the influence of fermentative bacteria and subsequent production of certain acids can soften the cellulose of oatmeal.

d) **Heat treatment.** This process (Stahl 1989:181) can be used to:

i) dry foods;
ii) facilitate the removal of fibrous elements;
iii) reduce toxicity;

iv) enhance digestibility of certain elements;

v) improve culinary quality.

This process is also relevant to the processing of meat products and can have a significant effect on the digestibility and palatability of foods. Three types of heat treatment can be used. These are steaming/boiling, parching/roasting/baking, and frying. Each of these can have different effects on the food concerned especially in terms of nutritional loss through denaturation of vitamins, for example, or through loss of soluble nutrients into the cooking solution. Other physical and chemical changes also occur. The most important of these, as outlined by Fox and Cameron (1977:284) and Sinclair and Hollingsworth (1969:442) are listed below.

1) Plant foods:

i) starch grains swell and gelatinise giving a soft texture;

ii) proteins coagulate;

iii) cellulose softens accompanied by rupture of some cell walls;

iv) pectins, particularly in the middle lamellae become more soluble causing separation of cells;

v) proteins in cellular membranes coagulate and become permeable thus allowing water and soluble nutrients to flow in and out of cells;

vi) lignin remains largely unaffected;

vii) chlorophyll is largely destroyed.

2) Animal foods:

i) protein coagulates - low temperatures and slow coagulation gives tender and more digestible meat while higher temperatures make it hard and less digestible;

ii) elastin is unaffected by cooking so meat with high elastin content will not tenderise even with extended cooking;

iii) collagen slowly becomes soluble so that muscle fibres tend to separate after substantial boiling as the collagen dissolves.

When considering changes in the anatomy of foods therefore, it is not only the fact that heat is applied that is important but how this heat is applied. There is also a suggestion (Cummings and Englyst 1987:1249) that whether food was eaten hot or cold might also be of relevance. For instance, they state that if cooked potato is allowed to cool, over 12% of the starch escapes breakdown in the small bowel. This is substantially higher than that of freshly cooked potato.

3.3.2.) The effects of digestion on the structure and composition of foods.

Once in the gut, food is rapidly subjected to a series of body secretions and mechanical actions in order to release nutrients from more complex organic molecules. They can then be absorbed through the gut wall and into

the blood stream. The simplified outline of the digestive process that follows is based upon that presented by Knoebel 1982.

1) **The Mouth**- The food is first chewed in order to reduce the size and alter the consistency so that it becomes suitable for swallowing. This will have an effect on the state of the indigestible part of the food and therefore affect the ease of identification of material in the faeces.

   Secretions of salivary amylase begin the chemical breakdown of the food. This rapidly starts to act on long chain carbohydrates such as starch and glycogen to produce smaller chain polysaccharides, di- and mono-saccharides.

2) **The Stomach** - One of the main functions of the stomach is to store food in order to discharge it into the small intestine at a rate that is optimal for digestion and absorption. In the stomach, secretions of hydrochloric acid, intrinsic factor, mucus and pepsin (the enzyme that initiates protein digestion), are added to the food/secretion mix.

3) **The Small Intestine (duodenum, jejunum, ileum)** - Once in the small intestine, digestion continues with further enzymes being secreted into the lumen from the pancreas. These include trypsin, which, together with chemotrypisn, further breaks down protein and peptide linkages. Pancreatic lipase begins

to break down fats into triglycerides, monoglycerides and free fatty acids, while pancreatic amylase continues the break-down of starch and glycogen into maltose and glucose. A number of minor enzymes specific to other complex organic substrates also begin to break these down to smaller constituent molecules.

Absorption also begins in the small intestine as soluble nutrients are passed from the gut lumen into the blood and lymphatic systems. Such is the efficiency of the duodenum and jejunum that few substances capable of being absorbed are left by the time the food has reached the ileum.

4) **The Large Intestine (colon)** - A substantial percentage of the water in the gut is reabsorbed into the body leaving a relatively dehydrated material. This is stored in the colon before being voided in the form of faeces. The large intestine also contains a variety of micro-organisms which are active in the breakdown of cellulose and other fibrous elements. These bacteria are also important for the production of certain vitamins required to maintain the welfare of the host. In addition to this, it is becoming clear that bacteria of the large intestine are, in fact, also active in the breakdown of certain types of starch, proteins and non-starch polysaccharides. The metabolites of this break down - certain short chain fatty acids - are rapidly absorbed by the

large bowel (Bingham 1987, Cummings and Englyst 1987, Eastwood *et al.* 1986, Kelleher 1984, Salyers 1979).

3.3.3.) Digestion as an inconsistent process.

The preceding section has outlined the way in which food is reduced during its transit through the gut. The resultant faecal mass consists a complex assemblage of organic and inorganic debris (see section 1.2.2.). It is clear that digestion is normally a very efficient process with most of the food breakdown and absorption being completed before the food has even reached the large intestine. It is, however, also evident that it is not a totally uniform nor infallible process. Any one of a variety of conditions can have an affect upon the efficiency of digestion, and, since these might also effect the condition of the microscopic food debris recovered from faecal or gut material some of them are discussed below.

a) **Variation in digestion between individuals** - Much of the available information relating to differences in the digestive process between different races, sexes, and age groups concentrates largely on aspects of nutrition and clinical conditions. It is often confused by lack of data and uncontrolable variables such as differing norms in staple foods etc. There are, however, evidently differences between age groups in cellulose fermentation in the large intestine (Kelleher *et al.* 1984). Drasor

(1974), also indicates that the gut flora and even the structure of the small intestinal mucosa can vary with race, diet and the environment. Motulsky (1987) in a review of human genetic variation and nutrition considers it highly likely that such variability will affect the processes of absorption and secretion. The activity of certain metabolic enzymes is variable within a population so it would not be surprising to find that this also applied to the digestive enzymes. One very clear example of where this does occur is the variability in the enzyme lactase, between different human populations with the result that much of the world's adult population is unable to digest lactose (the main constituent of milk).

b) **Enzyme inhibition by toxic compounds** - There are a number of examples of how toxic components present in one plant food can inhibit the digestion of others. Such is the case with protease inhibition by chemical substances present in many of the leguminosae (Aykroyd 1982:41, Harborne 1988, Liener and Kakade 1969, Weder 1981, Williams and Nakkoul 1983:252) and certain cereals (Boisen and Djurtoft 1981, Chang and Tsen 1981a, 1981b). Although these inhibitors are frequently destroyed by heat (eg. Chang and Tsen 1981b), it is clear that they can have a noticeable effect on the digestion of certain proteins. Similar effects such as inhibition of starch digestion (Liener 1969:429) must also be

considered as sources of variation in the digestive process.

c) **Method of food preparation** - It is clear that the size of densely packed food items, such as dense oil and protein rich nuts, for example, could have a significant effect on the availability of nutrients to digestion. For digestion to take place the enzymes have to physically reach the point where they are to act. With these densely packed tissues this will be less easy to effect than with more finely ground material. In this case, milled or well-chewed material will be more easily digested than larger fragments (see for example *Bertholletia excelsa* section 3.2). This is reinforced by the work of Eastwood *et al*, (1986:51) who suggest that the size of particles and the processing methods used, effect both the ability of the gut enzymes and the colonic bacteria to break down food material. Oser also, (1965:533), records that even though meat residues rarely make up a large part of the total nitrogen in stools, in cases where meat has been bolted, as much as 0.5-16.0g. of macroscopic meat residues have been found in a single stool.

d) **Pathological conditions in the gut** - Many gastric disorders can both, alter the absorption of nutrients and rapidly accelerate the transit time for food passing through the gut. Alvarez (nd.:549) gives perhaps the most graphic illustration of this.

Using dogs as experimental animals, he showed that in cases of diarrhoea, even raw egg taken by itself would run right out of the stomach and down the small bowel without being digested at all. Any manner of digestive disorders in man would, similarly be expected to alter the extent to which food material is digested.

e) **The effect of certain foods on the transit time through the gut** - It has been shown that some food materials can alter the speed of transit of food through the gut. Knoebel (1982:485) notes that meat in large chunks take longer to leave the stomach than when more finely divided. The effect of large quantities of fibre in the diet on transit time has also been established (see the review of over fifty studies on fibre uptake by Kelsay 1978). A number of these experimental results are, however, contradictary, with some data suggesting longer transit times and others shorter times as a result of increased fibre intake. In addition to this, the increased transit times associated with foods such as blackberries, beetroot, and certain British beers are well known. This phenomenon regularly leaves accompanying food in a part digested state.

3.4.) Dietary experiments - Digestion and its effects upon the structure and composition of foods.

3.4.1.) Materials and methods.

3.4.1.1.) Selection of foods for experimental meals.

In order to investigate the anatomical changes in foods as they pass through the gut the following list of foods were selected for digestion experiments. These were chosen to provide a broad picture of differential digestion across a wide range of food types. A number of species of particular relevance to the archaeological material examined in chapters 4-7 have also been added to this list for closer examination.

1) Small hard "seeds":

Grass caryopses -	rice, wheat, oats, maize.
True seeds -	poppy, sesame, tomato, amaranths, pumpkin.
Small dry fruits -	celery.
Pulse seeds -	bean (*Phaseolus sp.*), pea, lentil.

2) Oil rich "nuts":

True Nuts -	hazel.
Seeds -	brazil nut.

3) Fleshy fruits:

Berries - tomato.

Pomes - apple.

Hesperidia - orange.

Legume pods - green bean.

4) Underground vegetative storage organs:

Stem tubers - potato.

Corms - taro.

Bulbs - onion.

Root stock - carrot.

5) Other vegetative organs:

Leaves - cabbage.

6) Fungi:

Fruiting body - mushroom.

7) Animal Foods:

Muscle/connective tissue - beef, pork, fish,

Bone/Scale - fish.

3.4.1.2.) Subjects and sample collection.

It is clear from the preceding section that there are many possible sources of variation in human digestion. Separate, controlled clinical trials taking into account all of this variation would therefore require a prohibitive number of experiments on a broad spectrum of

volunteer subjects. The present experimental work is therefore intended to provide only a general, rather than a complete picture of the process of digestion within the limitations in the facilities and the available pool of willing subjects for the dietary experiments.

The majority of the digestion experiments have therefore been carried out upon one subject (myself) but control experiments have also been carried out on a further two individuals.

During each experiment the subject was required to follow the following procedure.

1) During the 24 hour period before the start of the controlled period low fibre foods such as white bread, cheese or pasta were eaten. Where this was not possible, a record of exactly what was eaten was kept. The subjects were instructed not to eat foods containing the control marker (see below step 3 and 4) or food that might confuse later analysis. In one case it was possible to carry out the controlled meals after a period of 50 hours fast.

2) In the following 24 hour period the subject was required to eat a controlled diet of three meals consisting of a series of food items that could not be confused with one another during microscopic analysis. An example of such a meal might be fish with wheat and tomato. This would yield several

categories of easily distinguishable debris. With each of these meals a control marker was also consumed. Initially, maize was used as a semi-inert marker following Calder (1977), but experience showed that sesame seeds could be used for the same purpose but to better effect.

3) Subjects were then asked to collect faecal samples on the appearance of the control markers, using the standard "pots" provided for the same purposes by medical institutions. The sealed samples were stored in the deep freeze until required.

3.4.1.3.) Sample processing.

When required for analyses the samples were defrosted and a small sub-sample of each was kept aside and mounted in glycerol on standard microscope slides for later analysis of the fine faecal matrix. The samples were slowly sieved through a 0.125mm sieve in a fume cupboard, with the aid of a jet of warm water and a glass rod to break up the samples where necessary. Once most of the fine debris had been washed through the sieve the remaining food debris was placed into an airtight glass bottle containing a 4% aqueous solution of formaldehyde. This acted as a fixative by killing off any bacterial or other microbial activity. After a minimum of a week in this solution the samples were washed again using the 0.125mm sieve in order to remove any traces of formaldehyde and placed in sealed bottles containing a 70% solution of

alcohol in water. In this state, samples could be stored for later examination.

The apparatus was cleaned thoroughly before being immersed in boiling water containing disinfectant and left for 30 minutes before being further washed ready for re-use.

3.4.1.4.) Microscopic analysis.

Following the disaggregation of faeces the debris was sorted into different classes. These were then identified by reference to undigested samples prepared earlier. A detailed microscopic study was then undertaken of each food type. This involved use of transmitted and reflected light microscopy and the use of a scanning electron microscope, where necessary. Where detailed descriptions of the anatomy were available, these were consulted and have been recorded in the text. Staining techniques were employed where necessary, although this was not required with most samples. Each class of food debris was then described. This began with a brief anatomical description of relevant modern undigested material, based upon both the published literature and personal observation. The following description of the digested debris then focused on the differences in structure between the undigested and digested samples and identified those tissues which had survived digestion in a recognisable form and those which had been digested. Descriptions of the debris were made at two different levels.

1) **Macroscopic remains.** Remains recovered from the 0.125mm. sieve size were studied:

a) under low power incident light - to record gross morphological changes;

b) under high power transmitted light and electron microscopy - to record cellular changes within tissues.

2) **Microscopic remains.** Remains present in the fine faecal matrix - less than 0.125mm.

a) Under high power transmitted light microscopy - To look at microscopic debris such as distinctive individual cells, starch grains and other items of possible diagnostic significance.

The results were illustrated with transmitted light and electron micrographs where necessary and are presented here in the order outlined by Heywood (1978).

3.4.1.5.) Results.

3.4.1.5.1) Plant foods.

3.4.1.5.1.1) Fungi.

Agaricus campestris L. Common name: field mushroom. Organ studied: fruiting body.

The fruiting body consists of an umbrella-like cap or pileus mounted on a short stalk. The ground tissue of these organs is composed of a superficially disorganised mass of interwoven, anastomosing hyphae (plectenchyma) (Gaumann 1928). A series of pink or grey gills radiate out from the central part of the underside of the pileus and it is from these that considerable numbers of spores are released into the atmosphere. In common with other fungi the cell walls of the hyphae are composed mainly of chitin.

Procedure: The mushrooms were eaten on several occasions and were prepared either by frying or boiling. They were eaten by both a female in her late 20's and a male in his early 30's over a period of 24 hours. Samples were collected between 24 and 48 hours after the first controlled meal.

Macroscopic remains:

Low power - The sliced or masticated fragments of the

pileus and stalk could be easily identified on the basis of their gross morphology. Their colour and structure appeared to be largely unchanged with even the gill arrangements largely unaltered.

High power - The disorganised, fibrous mass of the ground tissue showed few distinctive features and appeared to have remained largely unchanged.

Microscopic remains: No distinctive microscopic remains were identified although had the mushrooms been more mature the presence of the diagnostic spores would have been expected.

Comments: The structure of these fungi was largely unaltered by digestion. Nutritional texts such as Paul and Southgate (1979) indicate that the major part of the dry weight of mushrooms is "fibre" with the digestible portion being made up mainly of protein. This experiment supports this and suggests that fungal remains should be easily recognisable from digested food debris.

3.4.1.5.1.2.) Papaveraceae.

Papaver somniferum L. Common name: poppy. Organ studied: seed.

Published descriptions of the seed include Gassner (1973:103-104) and Winton and Winton (1932:429-435) (see also Bock et al. 1988:115). The seed has a characteristic

kidney shape and a very distinctive, reticulate surface. The outer layer of the testa, the outer epidermis, is composed of very large cells with wavy edges which correspond to the ridges of the seed surface. Beneath this are between four to five further layers that make up the testa. The most important of these, for the purposes of the present project, are the "fiber layer" which is largely responsible for the surface sculpturing of the seed, and the pigment layer which is responsible for the variety of colours to be seen within this species.

Procedure: The intact, uncooked seeds were consumed over a period of 24 hours. Subjects included a female in her mid 20's and a male in his late 20's. Samples were collected between 24 and 48 hours after the first controlled meal.

Macroscopic remains:

Low Power - The shape and the surface sculpturing of the seeds appeared to have been largely unaffected by digestion. Some of the seeds were, however, cracked or fragmented as a result mastication. Some of these still contained amounts of the oil rich parenchyma of the embryo.

High Power - The testa of both the whole and the fragmentary seeds appeared to have been largely unchanged.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The whole poppy seeds in this sample appeared to have remained largely unchanged by digestion and could be identified on their gross morphology.

3.4.1.5.1.3.) Betulaceae.

Corylus avellana L. Common Name: hazel nut. Organ studied: nut.

Published descriptions of the nut include Gassner (1973:139-141), Winton and Winton (1932:405-409) and Vaughan (1970:45-47). The hardened pericarp (shell) of the nut is composed of an epicarp which encloses several sclereid layers. The innermost layer of the "shell" is made up of a dark brown, compressed parenchyma.

The two outer layers of the testa are composed of polygonally shaped cells with intercellular spaces. These overlie the raphe bundles which are made up of spirally thickened tracheary elements, and surrounding areas of strongly compressed parenchyma filled with brown pigment. The endosperm is composed of one to three layers containing aleurone grains and the cotyledon epidermis is made up of small, thin walled cells. These enclose the cotyledon parenchyma which contains aleurone and starch grains.

Procedure: The nuts (minus the shell) were eaten raw and unprocessed over a period of 24 hours by a male in his early 30's. The faecal samples were taken between 24 and 48 hours after the first controlled meal.

Macroscopic Remains:

Low Power - Fragments of cotyledon parenchyma dominated the samples. A number of these were over 0.5cm. sq. and some retained areas of the adherent brown testa. Portions of the single large vascular bundle that runs up the outside of the seed were also recovered, as were free fragments of testa. These testa fragments were easily discernible by the banded pattern created by consecutive raphe bundles and the intervening areas of parenchyma. Some areas of the darkened and largely structureless parenchyma from the inner surface of the pericarp were also recovered.

High Power - The surface cell patterns of the testa epidermis could still be discerned on many fragments although on others it was only faintly visible and somewhat degraded (plate 2:2,3,4.). Beneath this layer the raphe bundles were largely unaffected by digestion.

The areas of surviving endosperm revealed the relatively thickened walls of the cells and the occasional crystalline inclusions. These overlay the smaller, polygonal cells of the cotyledon epidermis (plate 2:5).

The surviving pieces of cotyledon parenchyma (plate 2:1) had maintained their cellular structure and still contained significant quantities of oil (plate 2:6). Localised parts of this parenchyma showed the continued presence of starch which stained brown with iodine solution.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The testa and fragments of cotyledon parenchyma remained largely unchanged by the action of digestion and would offer good possibilities for identification. In a more finely ground or cooked sample, however, the cotyledon parenchyma would not be expected to survive digestion as well as this sample had.

3.4.1.5.1.4.) Amaranthaceae.

Amaranthus caudatus L. Common name: kiwicha. Organ studied: seed.

To the authors knowledge, no treatise on the anatomical structure of the kiwicha seed has been published. Winton and Winton (1932:326-329) do, however, deal with the seed of the closely related *Amaranthus retroflexus* L. They describe this as having an outer epiderm comprising of isodiametric cells with thickened outer tangential cell walls. Below this is a layer of parenchyma and an inner epiderm composed of cells with spiral/reticulated thickenings. The perisperm (the principal storage tissue in this family) is enclosed within a layer of thin walled and irregularly shaped cells. The aleurone layer is composed of relatively thick-walled and starch-free cells and encloses the much reduced endosperm.

These general features are broadly in accordance with the structure observed in *A. caudatus* L. Some varieties of

this species, notably the pale seeded ones, do, however, have very little pigmentation and virtually no thickening of the walls of the outer epiderm. In these seeds it was still possible to distinguish the layers outlined above, but, because of their pale colour these required staining to show up the cell patterns.

Procedure: The kiwicha was eaten, after "popping" in hot oil, over a period of 24 hours by a male in his early 30's. The sample was taken 48 hours after the first controlled meal.

Macroscopic remains:

Low Power - A number of seeds survived digestion visibly unchanged. Their overall shape and internal structure was unaltered and when broken open, the perisperm reacted positively with iodine solution thus proving the continued presence of starch.

A larger proportion of the seeds had split during "popping" or mastication. These had also retained the structure of the testa in an unchanged form. Some of the more complete specimens contained a white material resembling perisperm tissue. This did not, however, react with iodine solution.

A number of free cotyledon and radicle fragments also appeared to be structurally unchanged.

High Power - The outer layer of the darker seeds remained rigid and strongly pigmented. The cell patterns on this

type of seed were easy to observe under the light microscope, and would seem to have been little affected by digestion (plate 2:7,8). Although obscured in many places by the heavily pigmented upper layer, the pale angular outlines of a second layer (plate 2:9) could be seen overlying a more obvious layer of thick-walled parenchyma and the angular and the distinctively thickened cells of the inner epiderm (plate 3:1). Occasionally these latter three layers were detached from the thickened outer epiderm and appeared as a delicate diaphanous layer.

The various testa layers in the light coloured seeds were more difficult to discern. The outer layer of the testa was largely free of the pigmentation and the heavy thickening that is so characteristic of the darker varieties. The whole of the testa therefore, appeared much as the inner unpigmented layers of the dark seeds (ie. delicate and translucent) and presented a complicated array of superimposed cell patterns. The patterns of these layers were, however, essentially the same as the dark seeded varieties although it was not clear whether the outer epidermis was composed of one or two layers.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The testa of the seed of *A. caudatus* was particularly resistant to the process of digestion. The distinctive cell patterns of the testa of the darker seeds would offer a good possibility for identification even with fragmentary remains. The identification of lighter

coloured seeds would, however, prove more problematic even though, with care, the same layers might be discerned.

3.4.1.5.1.5.) Lecythidaceae.

Bertholletia excelsa Humb. and Bonpl. Common Name: brazil nut. Organ studied: seed.

Published descriptions of the seed include Winton and Winton (1932:577-582) and Vaughan (1970:126-128). The fruit consists of a hollow dry structure with a hard endocarp which is discarded before eating. The seeds normally have a triangular outline in cross section and fit into the fruit in much the same way that segments of an orange are arranged. Each seed has a thick testa consisting of a colourless outer palisade layer in which the cells have a narrow lumen and substantially thickened cell walls. Beneath this, lie several layers of cells with thick, porous cell walls and a deep brown coloration. Near the raphe bundles these cells lose their colouring and are strongly thickened.

The majority of the edible part of the seed is made up of the enlarged radicle with the cotyledons being much reduced. The embryo is surrounded by a brown layer (Winton and Winton 1932:578) which is considered to be part of the inner testa. Underlying this tissue are two to three layers of the perisperm and endosperm which have irregular to polygonally shaped cells containing

occasional aleurone grains. The outermost layer of these also has thickened outer walls and partially thickened radial walls.

The radicle can be divided into three distinct parts, an outer cortex made up of rounded parenchyma with small intercellular spaces, the procambium zone made up of small polygonal cells, and the pith which is composed of relatively large polygonal cells. All of these layers contain aleurone grains and are rich in protein and oil.

Procedure: The "nuts" (minus shell) were eaten unprocessed by a male in his early 30's over a period of 24 hours. The samples were taken between 36 and 48 hours after the first controlled meal.

Macroscopic remains:

Low Power - There were numerous large, rounded fragments of radicle parenchyma (up to 0.5cm. sq.). Much of this appeared to have been altered such that it had a darker brown colour than before. There was still, however, a substantial quantity of what appeared to be largely unchanged creamy-white parenchyma. This often remained adhering to the endosperm, to the inner layers of the testa and to fragments of the brown radicle parenchyma. It would seem likely that the white parenchyma corresponds to that of the cortical area and that the darker parenchyma derived from the pith tissue. Large numbers of smaller fragments were also recovered.

Much of the brown and flattened parenchyma from the outer surface of the radical had also survived apparently unchanged as had occasional adherent pieces of the almost translucent endosperm.

High Power - The two types of radicle parenchyma (White and Brown) were both made up of spherical or rounded parenchyma which had a high oil content that readily formed droplets in the mounting solution (plate 3:4). The brown layer that encloses the radicle could be seen to consist of a compressed thin walled parenchyma in which it was difficult to recognise the cellular outlines (plate 3:2). Below this layer, the endosperm with its thickened cell walls could be discerned. The size and shape of these cells varied considerably with some elongated and others much reduced in size. The majority of these had an angular outline, many had granular cell contents and some contained aleurone crystals (plates 3:3). No reaction was noted with Iodine solution but the starch content of the undigested tissues is, in fact, very low and does not react well with iodine.

Microscopic Remains: No distinctive microscopic components were identified.

Comments: Substantial quantities of storage parenchyma had survived digestion. In this case it would be expected that if the "nuts" had been processed by, for example, cooking and grinding prior to consumption, much less of this parenchyma would have been able to pass through the gut unchanged.

3.4.1.5.1.6.) Cucurbitaceae.

Cucurbita pepo L. Common Name: pumpkin. Organ studied: seed.

Published descriptions of the seed include Barber (1909), Gassner (1973:127-128), Hayward (1938:580-620), Singh (1953), Vaughan (1979:64-65) and Winton and Winton (1935:432-439).

Winton and Winton (1935:434), identify eight layers that make up the testa of the pumpkin seed. The outermost of these, the outer epiderm, is composed of prismatic cells with thickened and branched ribs on the radial walls. The depth of these cells varies greatly over the seed surface, being greatest at a point between the edge of the seed and the flattened central part. It is these cells with the greatest depth that contain the most prominent lignified ridges (Singh 1953) and give the appearance of "hairy" patches on the surface of the seeds.

The tissues below the epidermis consist of several layers of small, pitted, parenchyma cells which overlie a single layer of longitudinally elongated sclerenchyma. These reveal a distinctive sinuous edge pattern when observed in surface view. Below this lies a layer of small porous cells which merge into a broad layer of aerenchyma. This then overlies two further layers of parenchyma and the inner epidermal layer which can be distinguished from the previous layers by the slightly smaller cell size.

Below the testa, the perisperm consists of a layer of longitudinally elongated cells and several layers of thin walled parenchyma. The endosperm consists of a single aleurone layer. The cotyledon epidermis is made up of a layer of small epidermal cells.

Procedure: The roasted pumpkin seeds were consumed by a male in his early 30's. The faecal sample was taken approximately 36 hours after the first controlled meal.

Macroscopic remains:

Low Power - Large numbers of testa fragments were recovered. These had been considerably fragmented by the action of mastication but many could still be identified by their gross morphology. In cross section the testa appeared as a layer of darker material, the sclerenchyma layer, sandwiched between the pale layers of the parenchyma on either side of it. Masses of what appeared to be dark hairs could be seen concentrated in the areas between the edge of the seed and the flattened central area. These were evidently the thickened and branched ribs of the radial walls of the outer layer of the testa (plate 3:5,6).

High Power - The fibrous remnants of the outer layer of the testa remained largely unchanged and the "hairs" were concentrated at a point between the edge of the seed and the flattened central areas. Patches of the roughly hexagonal basal parts of these cells could be seen (plate 3:6,7) over the surface. The hypoderm could be observed

in cross section which, together with the large cells of the sclerenchyma layer and the "cactus-like cells" directly below them, seem to have been largely unaffected by the process of digestion (plate 3:8). Vestiges of the inner parenchyma also survived in places. No evidence of the perisperm, endosperm, cotyledon epidermis or cotyledon parenchyma were recovered. Some degraded material was, however, recovered from the inside of sections of the testa but this did not react with iodine solution.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The testa of this species was largely resistant to the action of digestion with many distinctive features being preserved. These would offer good potential for identification.

3.4.1.5.1.7) Cruciferae.

Brassica oleracea L. var. capitata. Common name: round cabbage. Organ studied: "head" (petioles and leaves).

Published descriptions of the cabbage include Gassner (1973:154-155), and Winton and Winton (1935:233-235). The "head" consists of a terminal bud surrounded by numerous overlapping leaves (Thompson 1976:49) the inner of which are pale due to the limited amount of light penetrating the outer ones. The leaf epidermis is made up of

irregularly shaped cells. These are variable in size, rounded to somewhat angular over the majority of lamina but commonly elongated over the major veins. Stomata are common on both the adaxial and abaxial surfaces and tend to be less frequent over the veins. They are normally accompanied by 3-4 subsidiary cells. Below the epidermis, large, thin-walled and rounded parenchyma with intercellular spaces form the mesophyll. Vascular material with easily discernible bundle sheaths run through this zone.

The stem, petiole, midrib and the main veins are all fleshy. The midrib is enclosed within an epidermis much the same as that covering the rest of the lamina, except that cells of this layer are commonly longitudinally elongated and stomata are present only in low numbers. The vascular material is surrounded by a sheath consisting of thin walled and rectangular to rounded parenchyma cells.

Procedure: The cabbage leaves, petiole and midrib were boiled prior to being eaten by a male in his early 30's over a period of 24 hours. The faecal samples were taken between 24 and 48 hours after the first controlled meal.

Low Power - Large quantities of epidermal fragments, often with quantities of vascular tissue attached, could be observed. Only a small proportion of these showed any marked green colouring.

High Power - Many of the larger fragments consisted of an epidermal tissue showing irregular cell patterns and

frequent stomata (plate 4:1,2). More organised cell patterns with occasional stomata were noted over the midrib and the major veins. Many of these fragments of epidermis were, however, very badly degraded and the cellular outline was only faintly visible. A number of fragments which, under low power, resembled sheets of epidermal cells, revealed no cell patterns under high power. It was assumed that these were areas of detached cuticle (plate 4:3). No mesophyll parenchyma was recovered and those fragments of tissue that retained a pale green colour were found to consist of a granular material and showed no recognisable cell structure (plate 4:4).

Microscopic remains: No distinctive microscopic components were identified.

Comments: It was clear that there was only partial preservation of the epidermis of the leaf and petiole. The cell patterns of these fragments were often considerably degraded but remaining fragments could offer some potential for identification.

3.4.1.5.1.8) Rosaceae.

Malus Mill. sp. Common name: apple. Cox's variety. Organ studied: fruit.

Published descriptions of the fruit include Gassner (1973:161), and Winton and Winton (1935:559-585). The fruit is described as a pome, the bulk of the succulent tissue being formed by a greatly enlarged hypanthium

enclosing, and fused to, the outer layer of the pericarp of the fruit proper. It is surrounded by an epicarp which consists of thick-walled and commonly four-sided cells. Thinner cell walls occur between adjacent daughter cells. This pattern is interrupted in places by patches of cork cells (Winton and Winton 1935:561). Beneath the epidermis the hypoderm consists of several layers of cells with thickened, beaded walls and intercellular spaces. The succulent flesh is formed of large parenchyma cells with intermittent vascular tissue. This is bordered on the inside by the endocarp which is composed of a layer of intercrossing fibres.

Procedure: The flesh of the apple was eaten uncooked over a period of 24 hours by a male in his late 20's. Faecal samples were taken 48 hours after the first controlled meal.

Macroscopic remains:

Low Power - The size of the epicarp fragments varied considerably with the largest being over 1 cm. sq. In many cases these were tightly rolled up with the outer surface of the epicarp facing outwards.

High Power - The epicarp was largely unchanged (plate 4:5) and present as a single layer of cells with occasional groups of four to eight cells which had obviously been derived from the same mother cell. In some places the cells of the epicarp could be seen to radiate out from the darker areas or "russet spots" (plate 4:6).

Below the epicarp patches of hypoderm were still present and could be recognised as a translucent layer of polygonally shaped cells with beaded walls. In places, these were several layers deep. (plate 4:7).

Occasional vascular tissue associated with the epicarp and adherent hypoderm was also recovered.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The surviving epidermal tissue (epicarp) might offer some possibility for making an identification especially where hypodermal tissues also survive.

3.4.1.5.1.9.) Leguminosae.

Lens culinaris Medik. Common name: lentil. (Canadian variety.) Organ studied: seed.

Published descriptions of the seed include Hughes and Swanson (1986:241-246), Winton and Winton (1935:311-314) and Gassner (1973:69-70). The testa consists of an outer layer, the palisade layer, of narrow, elongated cells covered by a thin cuticle and the subepiderm or hourglass cell layer (so called because of the shape of the cells in section). A layer of compressed parenchyma forms the innermost part of the testa.

The mesophyll parenchyma are packed with starch and enclosed within the cotyledon epidermis made up of thin-walled and commonly four-sided cells.

Procedure: The lentils were soaked and then boiled and consumed over a 24 hour period by a male in his late 20's. The faecal sample was taken 48 hours after the first controlled meal.

Macroscopic remains:

Low power - Large quantities of testa were recovered. These fragments varied greatly in size with, in some cases, whole lentils being recovered. Many of the fragments were tightly rolled with the palisade layer to the outside. Some of the larger fragments were found to contain *in situ* vascular and embryo tissue including small amounts of cotyledon parenchyma.

High power - The testa appears to have been largely unaltered by the digestive process. The palisade layer was still intact (plate 4:8,9) and the hourglass cells were frequently adherent to its lower surface (plate 5:1,2, 6:7,8).

In some of the better preserved samples (particularly those that may have been complete before being broken up by the washing process) areas of the pale, thin-walled cells of the cotyledon epidermis and adhering mesophyll parenchyma could be observed (plate 5:4). Some of this parenchyma (plate 5:3,5) stained black with iodine solution suggesting that at least some of the starch had remained unmodified by cooking and digestion.

Microscopic remains: In the fine faecal matrix a number of individual or small groups of mesophyll cells could be seen. These reacted positively when iodine solution was added to the preparation proving the continued presence of starch. Also present were small fragments of cotyledon epidermis and testa.

Comments: The palisade and hour glass layers of the testa would offer some basis for the identifying this species from faecal debris. The continued presence of cotyledon parenchyma and epidermis, together with radicle and plumule fragments were considered to be due to the survival of whole or virtually intact seeds which were only broken up during disaggregation of the faeces. The lack of survival of these tissues in the other, large-seeded legumes indicate that they only resist digestion when protected by a complete testa throughout the passage through the gut. These tissues would not therefore be expected to survive in samples where mastication or processing had fragmented the seeds before ingestion.

Phaseolus vulgaris Metz. Common name: string bean. Organs studied: fruit.

Descriptions have been published by Gassner (1973:158-159) and Winton and Winton 1935:347-353. The pericarp can be divided into six distinct layers. The outer of these, the epicarp, is strongly cutinised. In surface view, the epidermal cells are polygonal in shape and have relatively thick walls. Both the size and the shape of these, however, vary with their proximity to the hairs

and stomata which occur regularly over the surface. The hairs are commonly unicate (hooked) but Winton and Winton (1935:349) also record capitate hairs with unicellular heads. The stomata have between 2-5 subsidiary cells associated with each pair of guard cells. The cuticle makes a distinctive striated pattern that radiates outwards from the hair bases.

Directly below the epicarp is a layer of elongated and interlocking collenchyma cells these overlie the outer mesocarp which consists of rounded parenchyma with intercellular spaces. The inner mesocarp has the same structure as the outer but they are separated from each other by a layer of diagonally orientated fibres that run along the length of the legume. The endocarp consists of a layer of polygonally shaped cells. Both the mesophyll and the fibre layer contain numbers of crystals. In the fibre layer these are small, rectangular and held in rows of regularly shaped rectangular cells that are aligned in the same direction as the fibres.

The immature seeds are attached alternately to each of the valves along the ventral margin. In the immature state, all of the major structural features of the mature seed can be seen (see seed description below). One point of difference, however, is the presence of a broad layer of parenchyma with embedded vascular material which represents the inner parts of the testa and endosperm. In the mature seeds this layer is much compressed and can

only be observed as a thin layer of flattened and poorly defined parenchyma with some associated tracheary elements.

Procedure: The legumes were prepared by boiling. They were consumed by a male in his early 30's over a period of 24 hours. The faecal sample was taken 48 hours after the consumption of the first controlled meal.

Macroscopic remains:

Low power - Fragments of the pedicel could be recognised from their gross morphology. Relatively large sheets of fibres and tightly rolled pieces of translucent cuticular material were also recovered.

High power - The cuticular fragments revealed the distinctive, wrinkled pattern (plate 6:1,2). Hooked hairs, hair bases and stomata occurred at intervals but no cell patterns could be discerned. The sheet of fibres that originally would have separated the inner from the outer mesocarp gave a spotted appearance under low power. At higher magnifications this revealed the elongated, thick-walled and pitted fibres (plate 6:1,2). Occasional strings of crystal containing cells could be seen running parallel to the fibres.

Microscopic remains: Some small groups of crystal containing cells could be seen together with numerous free,

rectangularly shaped crystals. Some degraded palisade cells were also noted.

Comments: No evidence of either the epidermal cells or the sub-epidermal collenchyma were recovered, however the tough distinctive cuticle was diagnostic. Supporting evidence from the remains of the fibre layer and peduncle (which are probably not diagnostic on their own) could also aid identification.

Phaseolus vulgaris Metz. Common name: common or kidney bean. Organ studied: seed.

Published descriptions of the seed include Hughes and Swanson (1985) and Winton and Winton (1935:347-353). The testa is composed of thick walled palisade cells that are typical of many legumes. The subepiderm or hourglass cells can be observed adhering to the lower surface of the palisade layer, with each cell containing a crystal that shows up well under cross polarised light microscopy. Below these two very distinctive layers is a poorly defined layer of flattened parenchyma.

The cotyledon epidermis is composed of thin walled polygonally shaped cells. This layer surrounds the mesophyll parenchyma which consists cells with beaded walls and containing ellipsoidal semi-aggregated starch grains.

Procedure. The seeds were soaked overnight then boiled until soft. They were consumed by a male in his early

30's over a period of 24 hours. Samples were collected 48 hours after the first controlled meal.

Macroscopic remains:

Low power - Large fragments of the palisade layer (some over 1cm. sq.) could be identified together with a number of separated hyla. No remains of the cotyledon parenchyma were recorded but areas of the indistinctive and flattened parenchyma that make up the inner part of the testa were recovered.

High power - The structure of the palisade tissue appeared to be largely unchanged and showed distinctively fluted thickenings (plate 6:5,6). Below this, the hourglass cell layer (plate 6:2,8) with its crystalline inclusions had remained largely intact. Fragments of the pink coloured and disorganised parenchyma of the inner testa could also be identified (plate 7:6,7).

The separated hyla were composed of a double layer of palisade tissue with vestiges of other tissues attached (plate 7:6,7).

Microscopic remains: Numbers of individual and small groups of palisade cells were visible.

Comments: The survival properties of the palisade layer and hourglass cell layers of this species would offer

good potential for making an identification. The crystal cells of the hour glass cells are particularly distinctive. The presence of free hyla in the sample has been noted from other samples of legume based meals (see *Pisum*) and could also prove useful for identification purposes.

Pisum sativum L. Common name : pea. Organ studied: seed.

Description: Published descriptions of the the seed include Butler 1988, Gassner (1973:67-68), Hayward (1938:339- 370), Lersten and Gunn (1982) and Winton and Winton (1935:324-340). The outer palisade tissue consists of thickened, elongated cells. In surface view, however, they appear as a layer of rounded cells with fluted and thickened cell walls. Below this is a layer of hourglass cells which overlies a layer of poorly defined and flattened parenchyma. The cotyledons are composed of a starch rich mesophyll parenchyma enclosed within a thin epidermal layer of elongated and thin walled cells.

Procedure: The dried peas were soaked before boiling then eaten over a 24 hour period by a male in his early 30's. The sample was taken 48 hours after the first controlled meal.

Macroscopic remains:

Low power - The surviving testa was pale in colour and

highly fragmented, exhibiting none of the tendency to curl that was characteristic of other legume genera. Whole or half sections of hyla were also identified.

High power - The palisade layer of the testa remained largely intact and apparently unaffected by digestion (plate 7:2,3,5). The cells were, however, more readily separated from each other than similar tissues in other legume genera (plate 7:3). The hourglass cell layer was commonly present and also appeared to have been largely unaffected by digestion (plate 7:4). Close to the hylum the palisade layer survived particularly well, this being due to the double thickness of the tissue at this point.

Microscopic remains: Numbers of individual or small groups of palisade cells were recovered. These showed clearly the thickened upper part of the cells and the more delicate, wavy structure on their innermost edge.

Comments: Where remains of the palisade and hourglass tissues are recovered it is probable that these could be used for identification purposes. The fragmentation of much of the testa would seem to have been due to it being generally thinner than that of other legumes and the pectic substances that bind adjacent cells in the testa would also seem to be particularly susceptible to the action of cooking and digestion.

3.4.1.5.1.10.) Rutaceae.

Citrus sinensis (L.) Osbeck. Common name: spanish navel orange. Organ studied: fruit.

Published descriptions of the fruit (hesperidium or berry) include Gassner (1973:182-184), Webber and Batchelor (1948:683-692), and Winton and Winton (1935:684). The rind is normally discarded prior to consumption and consists of the epicarp, hypoderm, an oil cavity zone and a spongy parenchyma layer. The spongy parenchyma and the associated vascular tissue form the bulk of the rind but is also present around the fruit segments themselves. The segment walls also consist of three distinct layers: a thin layer of highly branched parenchyma which is the remaining portion of the spongy parenchyma of the mesocarp, and two layers of elongated cells with highly pitted cell walls. The outer of these two layers contain strings or groups of small crystal containing cells and the inner (lower) layer frequently contains sclerenchymatised cells. Their orientation with respect to one another frequently changes as the organisation of cells in each layer alters.

Each segment contains a number of pulp vesicles derived from the multicellular hairs of the endocarp (Pursglove 1984:510). These are distended with juice and are enclosed within several cellular layers. The outer layer of the vesicle is composed of elongated cells with thin and often wavy walls. Beneath this, the sub-epiderm is

composed of transversely elongated cells commonly making a chequer-board or cross-hatch pattern with the layer directly above it when observed in surface view. Inside each vesicle are a number of large, rounded and thin walled cells with occasional small crystal inclusions.

Procedure: The orange segments were consumed raw by a male in his early 30's over a period of 24 hours. The samples were taken 48 hours after the first controlled meal.

Macroscopic remains:

Low power - Fragments of the endocarp (the wall of the segments) with layers of elongated cells and strings of crystal inclusions were common, as were a number of yellow/orange coloured pulp vesicles.

High power - The inner layers of the segment walls (the endocarp) with their elongated cells and highly pitted walls were most predominant (plate 8:4). Fragments of the spongy parenchyma were occasionally adherent to these. The layers of the endocarp were colourless, but the distinctive strings of crystals could be seen at regular intervals. The orange-coloured pulp vesicles were more degraded although the pattern of elongated and interlocking cells with an underlying layer of transversely orientated cells could be discerned in places. Commonly, however, a folded and largely featureless cuticle layer and

associated, amorphous debris was all that remained. No evidence of the juice containing cells were observed but groups of crystals remained adhering to the vesicle walls.

Microscopic remains: No distinctive microscopic components were identified.

Comments: Both of the surviving classes of debris, the endocarp and the pulp vesicles themselves, could possibly be used to identify debris from faecal samples.

3.4.1.5.1.11.) Umbelliferae.

Apium graveolens L. var. *dulce*. (Miller) DC.. Common name: celery. Organ studied: fruit.

Published descriptions of the a schizocarp have been given by Tutin (1980:126). The fruit readily divides into its two constituent mericarps, each of which has five prominent but slender exterior ridges and a number of vittae within the fruit wall. These run the full length of the mericarp. No detailed histological work on the layers that make up the fruit or seeds is known to the author.

Procedure: The fruits were eaten uncooked after a period of 50 hours starvation by a female in her mid 20's, and by a male in his late 20's. The controlled meals were taken over a period of 24 hours and the first faecal

sample was taken between 24 and 48 hours after the first of these.

Macroscopic remains:

Low power - The fruits had maintained their original shape and appeared, at this magnification, to be largely unchanged.

High Power - The outer layer of the epicarp was totally removed by digestion but the rigid framework of vascular material and thick walled sclerenchyma of the interior had enabled the fruit to maintain its overall shape.

Microscopic remains: No distinctive microscopic components were identified.

Comments: Although the outer layers of the fruit were destroyed, the overall shape of the seed was unaltered. They could therefore be identified on the basis of their gross morphology.

Daucus carota L. Common Name: domesticated carrot. Organ studied: tap root.

Anatomical descriptions of the tap root have been published by Esau (1940), Gassner (1973:149-150), Havis (1939) and Winton and Winton (1935:93-100). The edible parts of the plant are formed by both the root and hypocotyl. The outer, or cork tissue (phellem) consists of several layers, which in surface view, are made up of elongated and generally four-sided cells. In common with the cork cells of other species, those of *D.carota* are

stacked radially such that cells in the consecutive concentric layers mirror the shape of the cells on either side of them.

Below the phellem, the remainder of the periderm with its muriform arrangement of cells (as seen in longitudinal section) grades into the broad layer of large, thin walled and rounded parenchyma of the cortex, interspersed with medullary rays. Closer to the vascular cambium the phloem parenchyma becomes smaller and more regular in shape. The cambium itself is continuous and characterised in transverse section by narrow, compressed and more or less rectangular cells that give rise to both the outer phloem parenchyma and the inner xylem tissue. This inner tissue consists of large, disorganised, rounded, parenchyma with interspersed tracheary elements.

The orange colouring is produced by carotine crystals which are most abundant in the phloem parenchyma and are characterised by a variety of different forms.

Procedure: The raw unpeeled and diced carrot (up to about 1 cm. sq.) was consumed by a male in his early 30's over a period of 24 hours. The samples were taken between 36 and 48 hours after the first controlled meal.

Macroscopic remains:

Low Power - Only relatively few small fragments of what appear, under low power, to be pieces of parenchyma could be observed. These still showed a strong orange colour and it was on this basis that they were sorted from the

rest of the food debris. Some of this was associated with vascular material.

High power - The fragments of apparent parenchyma were found to have retained none of their former cellular structure. No cell walls could be discerned. The material had a granular appearance with the frequent inclusions of the bright orange chromatophores which were the only remaining features indicative of carrot (plate 8:7). A considerable amount of vascular material was present in this sample but this could not be conclusively linked with carrot.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The root of *D. carota* has been considerably reduced by the action of the gut. No evidence of cork material nor any other recognisable feature with the exception of the orange chromatophores remained. It is doubtful whether these would be of diagnostic value

3.4.1.5.1.12.) Solanaceae.

Lycopersicon esculentum Mill. Common name: tomato. Organ studied: fruit and seed.

Published descriptions of the berry and seeds include Gassner (1973:156-158), Hayward (1938:550-579) and Winton and Winton (1935:404-416). The epicarp, consists of a single layer of polygonal cells, commonly with five or

six sides, with moderately thickened walls, occasional pits and a bright yellow colour. Below this layer, the hypoderm is composed of similarly shaped but somewhat larger cells with more strongly pitted walls. The fleshy mesocarp is made up of large rounded parenchyma through which run a number of vascular bundles. It is bordered on its inner surface by a thin walled and membranous endocarp.

The seed has a shape that is typical of many of the Solanaceae and has a highly distinctive testa which appears to be covered by long hairs embedded in a gelatinous mass. These represent the remaining, thickened radial walls of the otherwise disintegrated outer seed coat which forms the mucilaginous layer.

Procedure: The whole fruit was eaten uncooked over a period of 24 hours by a male in his late 20's. The faecal sample was taken 24 hours after the first controlled meal.

Macroscopic remains:

Low Power - Numerous large fragments (ie. greater than 1cm. sq.) of tomato "skin" were present in the sample. These were tightly curled in most cases and their bright yellow colour did not make itself apparent until after it had been mounted flat, on a microscope slide.

The seeds were also abundant in the sample and appeared to be have been unaltered by the action of digestion other than by the removal of the mucilaginous outer parts

of the testa.

High Power - As suggested under low power, the epicarp appeared to have been largely unaltered by the digestive process (plate 9:1,2). The cytoplasm was, however, somewhat granular in places and some cells contain an amount of darker coloured material. Patches of remaining hypoderm were also present with their thick and obviously beaded walls adhering to the internal surface of the epicarp (plate 9:2). These cells have a very pale colour and contain no obvious inclusions.

Less frequently, patches of the mesocarp parenchyma could be observed adhering to the epicarp (plate 9:3). These consisted of large, colourless, thin walled cells that were occasionally several deep.

The S.E.M. confirmed that digestion had largely removed the mucilaginous parts of the outer seed coat leaving the distinctively "hairy" surface layer clearly visible (plate 8:8).

Microscopic remains: No distinctive microscopic components were identified.

Comments: During digestion, the tomato fruit was reduced to its epicarp and a collection of seeds which had been only slightly modified. These tissues would offer a good potential for identification. The surviving patches of mesocarp were probably a result of the tight curling of the epicarp which must have provided protection in the form of a physical barrier to the digestive enzymes and

colonic bacteria.

Solanum tuberosum L. Common name: potato. Organ studied: tuber.

Detailed anatomical descriptions of the stem tuber have been published by Artshwager (1924), Reed (1910), Winton and Winton (1935:149-170) and archaeological examples have been described by Martins (1976:95).

There is a wide variation in the texture of the surface between different varieties which can vary from smooth to very roughened. The surface of the tuber is composed of a cork layer of stacked polygonal cells. The surface is broken in places by darker patches that indicate the positions the lenticels.

The cortex and pith of the tuber are separated by a bundle zone (Winton and Winton 1935:152) and contain amounts of vascular tissue and large, thin walled parenchyma containing starch grains.

Procedure: The potatoes were baked in their "jackets" (ie. unpeeled) and consumed over a 24 hour period by a male in his late 20's. Faecal samples were taken 48 hours after the first controlled meal.

Macroscopic remains:

Low Power - The remains were dominated by the cork layer (phelloderm) these were frequently over 1cm. sq. but this was largely dependant on the degree to which the food had been masticated. Darker patches were apparent on the

surface and these occasionally remained attached to lengths of vascular tissue. Substantial quantities of free vascular tissue was also recorded from this sample but this could not be linked, with certainty, to the potato.

High Power - The cork tissue remained largely unchanged (plate 9:4), as had the smaller, rounded cells that bordered the lenticels. No surviving cortex or pith parenchyma was noted.

Microscopic remains: The fine faecal matrix included fragments of the cork layer and vascular fragments. No intact starch cells were seen but a number of thick walled and pitted stone cells were recorded. These were of a type that matched those of potato (plate 9:6,7).

Comments: The main components surviving digestion were the cork and groups of xylem vessel elements. The cork tissue could possibly be used to aid identification (see Martins 1976:95) although it is doubtful whether the organisation of this would be diagnostic in the absence of other lines of evidence. If the potato was peeled before being eaten this would significantly reduce the possibility of identifying them from ancient faecal material. The presence of stone cells might be used to reinforce other identification criteria but without a further detailed study on the anatomy of a broad range of modern reference specimens it would seem unlikely that they would be diagnostic on their own.

3.4.1.5.1.13.) Pedaliaceae.

Sesamum indicum L. Common name : sesame seed. Organ studied: seed.

Published descriptions of the seed include Vaughan (1971:201-203) and Winton and Winton (1932:599-605). The seeds are commonly 3mm. in length and have a flattened pear shape. They vary in colour between pale and dark brown. A faint longitudinal ridge (the raphe) runs along the face of one of the sides.

The outer layer of the testa (plate 10:1) is the most characteristic, and consists of a ridged layer of palisade cells. Most of these contain oxalate crystals, except over the ridged areas. Beneath this lies a collapsed layer of parenchyma which in turn overlies the inner layer of the testa. Winton and Winton (1932:899) describe this as a cuticle layer. The aleurone layer consists of a layer of cells with thickened outer walls and containing aleurone grains and overlies between 2 and 5 cell layers of the endosperm. The cotyledons make up the body of the seed and are composed of a compact, oil rich parenchyma with occasional inclusions of crystaloid or globoid aleurone grains.

Procedure: Seeds were eaten with most of the controlled meals as a marker. In all cases they were consumed uncooked and recovered between 24 and 48 hours after the first controlled meal.

Macroscopic remains:

Low power - The remains of complete or fragmentary, shiny white seeds with a slightly darker tip were recovered from all samples. They could be identified on the basis of their gross morphology.

High power - The outer layer of ridged palisade tissue had been completely removed by digestion thus leaving the seeds with a glossy surface with indistinct undulations corresponding to the outlines the cells below (plate 10:2-3). The cotyledon parenchyma appeared to be largely unchanged in whole seeds, and only partially degraded in fragmentary ones.

Microscopic remains: No distinctive microscopic components were identified.

Comments: These seeds had survived well and could be identified on the basis of their gross morphology. Had they been milled prior to processing, however, less cotyledon parenchyma would have been expected to survive.

3.4.1.5.1.14.) Gramineae.

Avena sativa L. Common name: oats. Organ studied: caryopsis.

Published descriptions of the caryopsis include Gassner (1973:31-33), Winton and Winton 1932:158-175) and Yiu

and Mongeau (1987:143-150). The pericarp, consists of two layers - the outer is composed of a layer of longitudinally elongated cells with strongly pitted walls. At frequent intervals this layer is interrupted by the presence of hairs up to 2000 um in length (Winton and Winton 1932:164). Beneath this, the hypoderm, is made up of poorly defined, thin-walled, branching cells that resemble fungal hyphae. The testa itself is composed of a single layer of cells with thin and unpitted cell walls. These are commonly arranged in rows and often form a characteristic herring-bone pattern in surface view. Finally, the endosperm is surrounded by the aleurone layer consisting of relatively thick-walled and somewhat rounded cells, some of which contain starch grains (Winton and Winton 1932:166).

Procedure: The oats were eaten in the form of porridge and oat cakes over a period of 24 hours by a male in his late 20's. The samples were taken 48 hours after the first controlled meal.

Macroscopic remains:

Low Power - The bran (pericarp and testa) appeared as pale, delicate fragments commonly attached to lengths of hylum. There was a strong tendency for these fragments to curl up, making mounting on microscope slides difficult.

High Power - Many fragments of the outer layer of the pericarp remained intact although these were frequently torn and fragmented due to mastication and the processing

methods used. The cell structure appeared to have been unaffected by digestion with the longitudinally elongated and pitted cells, intermediate hairs, and hair bases all clearly visible (plate 10:4,5). In localised areas, the degraded remains of the tube cells of the hypoderm remained adhered to the testa.

The structure of the testa itself was also seemingly unaltered. It showed up as a colourless, diaphanous layer of thin walled cells arranged in their characteristic herring-bone pattern (plate 10:7). There were no remaining fragments of the aleurone layer or endosperm.

Microscopic remains: Fragments of the longitudinal cell layer and epidermal hairs were recovered.

Comments: The bran fragments survived well and would offer a good possibility of making an identification to the level of genus.

Oryza sativa L. Common name: rice. Organ studied: caryopsis,

Published descriptions of the caryopsis include Gassner (1973:35-37), Grist (1986) and Winton and Winton (1932:130-153). The caryopsis is tightly held within the lemma and palea which cause the formation of a number of shallow longitudinal grooves running the full length of the grain. The hylum is not indented as in many of the gramineae but is very slightly raised. The pericarp and testa form a complicated series of superimposed layers. The pericarp consists of four layers, the outer of which

is composed of distinctive, transversely elongated cells with deeply sinuous walls. Below this layer are a number of thin walled cell layers all of which are transversely elongated except for the tube cell layer which is orientated at right angles to the layers on either side of them.

The testa is composed of two layers of transversely elongated cells which enclose both the aleurone layer and the starchy endosperm. This aleurone layer is easily recognisable, pigmented and consists of more-or-less uniformly rounded cells with thick unpitted walls.

Procedure: Unpolished rice was boiled prior to consumption which took place over a 24 hour period by a female in her mid 20's. The faecal sample was taken 24 hours after the first controlled meal.

Macroscopic remains:

Low Power - Substantial quantities of bran was recovered. This varied considerably in size with some samples of testa and pericarp from whole grains remaining intact. The grooves in the pericarp were clearly visible as was the hylum. No traces of endosperm material was recovered, however, a significant number of complete embryos remained visibly unaltered.

High Power - The strongly sinuous cell walls of the epicarp were present on most fragments of bran (plate 11:1,3,4). This was, however, frequently only faintly visible because of the translucent nature of the cells.

Below this layer the hypoderm was indistinct but it was possible to see the elongated cells of the cross cell layer clearly (plate 11:5). The most distinctive features of the bran were remaining fragments of the pigmented aleurone layer (plate 11:2,6,7).

In larger bran fragments the dark ventral line of the hylum could be seen to contain thickened vascular material running the length of the caryopsis.

Microscopic remains: Fragments of the aleurone and other layers of the pericarp and testa were observed together with occasional vascular fragments.

Comments: Surviving areas of the pericarp, testa and aleurone would be expected to offer good potential for identification. The survival of almost complete embryos was also of note but the survival of these would be expected to be much reduced had they been milled before eating (section 3.6.1.).

Triticum aestivum L. Common name: bread wheat. Organ studied: caryopsis.

Detailed anatomical work include Evers and Reed (1988), Gassner (1973:21-28), Hayward (1938:141-178), Percival (1921) and Winton and Winton (1932:190-255), but the structure has also been discussed in relation to human digestion by Schel *et al.* (1980), to cooking by Davis and Eustace (1984) and in relation to archaeological remains by Colledge (1988), Dickson (1987), Helbaek (1958), Holden (1986, 1990a), Korber-Grohne (1981),

Korber-Grohne and Piening (1980), and Straker (1984).

The pericarp, as described by Winton and Winton (1932) consists of four distinct layers. The outer of these, the epicarp and the hypoderm are composed of essentially similar longitudinally elongated cells with thick, strongly pitted cell walls. The epicarp differs from the hypoderm only in respect of the hairs that can be seen projecting from the apical areas.

Beneath these two layers lies the distinctive transverse cell layer which consists of more-or-less regular rows of transversely elongated cells. They have strongly pitted cell walls and overlie a single layer of tube cells that are often more pronounced at the apical and embryo ends of the grain.

The seed coat or testa is made up of 2 cell layers each consisting of elongated cells with thin, unpitted cell walls. These two layers are often pigmented and are orientated right angles to one another. They therefore produce a characteristic chequerboard pattern when observed together in surface view.

The perisperm has been reduced to a single thin layer that is difficult to discern in surface view because of its thin walls and transparent nature. The endosperm, on the other hand, is composed of large, thin walled cells containing numerous starch grains and is surrounded by an

aleurone layer of thick walled and rounded cells.

Procedure: Fragments of wheat bran were recovered from a number of controlled meals. Several samples included grain that had been eaten as a wholemeal bread (ie. after crude milling and baking) and another sample was taken after the boiling of whole grains. They were eaten by both a male in his late 20's and a female in her late 20's. The samples were eaten over a period of 24 hours. Samples were collected between 24 and 48 hours after the first controlled meal. (nb. one series of controlled meals of the structurally similar grain, rye, were also eaten by a female in her early 20's after a period of 50 hours starvation).

Macroscopic remains:

Low power - In all samples examined, the coloured layers of the testa and the paler layers of the pericarp survived apparently unaltered. The boiled samples provided some whole grains that remained intact. Endosperm material taken from the centre of one of these grains was coloured black by iodine solution showing that starch was still present. In the baked samples no whole grains were recovered and no starch could be identified from partially fragmented grains.

High power - The two outer layers of the pericarp readily became detached from the other bran layers but appeared

to have been structurally unaltered by digestion (plate 13:5,6). The transverse cell (plate 13:7,8,9), tube cell and testa layers (plate 14:1,2) of the pericarp and seed coat were also apparently unaffected. Only rarely could remains of the aleurone layer be seen and only where the grain had passed through the gut whole did any endosperm tissue remain. In this case, starch grains from the interior could be identified.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The results generally conform to those published by Schel *et al.* (1980) and show that ingested samples of both the pericarp and testa remain virtually unchanged. The value of these and the structurally similar, bran of rye (*Secale cereale*) for identification purposes has already been recognised. Other tissues would be expected to survive, and be of use for identification purposes, only in rare circumstances. (nb. The single sample of boiled rye eaten, gave results that conformed to those obtained for wheat).

Zea mays. L. Common name: maize (ten row flour corn Cusco market, Peru). Organ studied: caryopsis.

Anatomical descriptions of the maize caryopsis have been published by Gassner (1973: 33-35) Hayward (1938:111-140) and Winton and Winton (1932: 62-98). The grains separate from the cob leaving remaining fragments of the rachilla

and the papery lemma and palea still adhering to the caryopsis base. Winton and Winton (1932:69) divide the pericarp into four distinct layers. The outer layer of the epicarp is characterised by longitudinally elongated cells with distinctly pitted cell walls. The size and arrangement of these cells does, however, vary towards the apex or the base of the caryopsis. Below this layer are a number of further layers, (up to 12 according to Winton and Winton 1932:69) which are closely adherent to each other and similar in form to the cells of the epicarp. Below these is the transverse cell layer. This is composed of cells that are elongated in a direction perpendicular to the long axis of the cells in the epicarp and hypoderm. They are commonly irregular in shape cells and form "anastomosing arms". The innermost layer of the pericarp consists of a layer of elongated tube cells.

The next layer of consequence is the aleurone layer. This is formed of relatively thick walled and rounded cells that surround the starchy endosperm. This aleurone layer is pigmented in some varieties.

Procedure: The maize was cooked by boiling, then the grains were eaten whole over a period of 24 hours by a male in his early 30's. The faecal sample was taken between 24 and 48 hours after the consumption of the first controlled meal.

Macroscopic remains:

Low Power - Large fragments of pericarp with the adherent

aleurone layer were recovered (plate 12:7). These were occasionally up to 1cm. sq. and retained much of their original brown and yellow colouring. Also seemingly unaffected by digestion were the fibrous caryopses bases and rachillae, together with the adherent lemmas and paleas. Parts of the embryo (detached from the pericarp) were also relatively unchanged by digestion. In a number of cases the embryo, partly surrounded by the dense, protective, scutellum appeared to have remained intact. No reaction with iodine solution was, however, noted. More commonly the scutellar and embryo tissue was fragmented but still maintained its dense structure and pale yellow/cream colouration.

High power - The pericarp was particularly difficult to observe under high power light microscopy because the dense upper layers of the pericarp (plate 12:2) obscured many of the cell layers directly beneath. The heavily pitted, thick walled and elongated cells could, however, be discerned in places (plate 12:1, 13:2). The aleurone layer was more easily identified and consisted of rounded cells with rigid walls (plate 12:4,5,6, 13:2,3). The confused patterns made by the overlapping layers of the tube cells, transverse cell layer and the longitudinally elongated cells of the outer pericarp could also be observed in places where the aleurone and pericarp layers had separated (plate 12:3,7). The microscopic structure of the lemma and palea remained largely unaltered (plate 13:4).

Microscopic remains: No distinctive microscopic components were identified.

Comments: Much of the pericarp and aleurone tissues would offer a good potential for identification. The survival of the embryo and scutellum was an important feature of the debris. Had the grains been milled prior to consumption, however, the survival of this would have been expected to be considerably reduced.

3.4.1.5.1.15.) Araceae.

Colocasia esculenta Schott. Common Name: taro. Organ studied - corm.

Published descriptions of the edible parts include Strauss (1983: 200), Winton and Winton (1935:131-134). The swollen stem base, or corm, makes up the starchy edible part of the plant. Edible cormels often develop the side of the main corm in the axils of the fibrous leaf sheaths.

The cork layer is formed of a number of layers of polygonal cells. The cortex and central cylinder are essentially similar but differ anatomically in the organisation of their parenchyma. Those of the central cylinder are somewhat larger and have thinner walls than the cells of the cortex. Raphides are present in some varieties and both latex tubes and vascular bundles with both helical and reticulated tracheary elements are also common.

Procedure: The corm was peeled (as per normal practice) prior to being boiled. It was then eaten over a period of 24 hours by a male in his late 20's. The sample was taken 48 hours after the first controlled meal.

Macroscopic remains:

Low Power - Large amounts of vascular material was seen. This was present as confused masses in which other food debris had become mixed.

High Power - The vascular material was dominated by tracheary elements with both helical and reticulated thickening. While this type of material is common in many different plant organs its predominance in this sample suggest that it was from taro.

Microscopic remains: No distinctive microscopic components were identified.

Comments: Since it is the usual practice to peal taro prior to consumption none of the corm phellem (cork) was included in the meal. The only material that remained after digestion was therefore the thickened tracheary elements. These are common in most primary plant material and would not be expected to be diagnostic of any one particular species.

3.4.1.5.1.16.) Liliaceae.

Allium cepa L. Common Name: Onion. Organ studied: bulb.

Published descriptions of the bulb include Hayward (1938:179-213), Gassner (1973:153-154) and Winton and Winton (1935:194-198). It consists of a reduced, disc like stem to which are attached the scales (Leaf bases) arranged in a series of concentric rings around the apical bud. The outer scales are dry and are normally discarded prior to eating but the inner ones are thick, fleshy and constitute the majority of the edible parts of the bulb. Both the upper and the lower surfaces of the scales are covered by an epidermis of elongated cells arranged in longitudinal rows. These elongated cells are somewhat larger and more variable in size and shape on the adaxial surface. Occasional sunken stomata become more common towards the tip.

There are several layers of sub-epidermal cells and these are again arranged in longitudinal rows but can vary between polygonal to transversely elongated. Latex tubes occur between the sub-epiderm and the mesophyll which is itself composed of thin walled parenchyma with associated vascular material.

Procedure: The onions were eaten raw over a period of 24 hours by a male in his early 30's. Samples were taken at both 36 and 48 hour intervals after the first controlled meal.

Macroscopic remains:

Low Power - Fragments of the pale diaphanous scale epidermis could clearly be seen. Much of this exhibited a strong tendency to curl up.

High Power - Many of the epidermal fragments showed the characteristic elongated and regularly arranged cells (plate 14:3). Some of these fragments, however, were highly degraded such that the cell patterns were only faintly visible. (plate 14:4,5). There were no surviving remains of parenchyma or hypoderm tissue.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The scale epidermis was commonly found to survive although some fragments were highly degraded. This would however offer a good potential for making an identification. It is interesting to note that one sample contained a considerable quantity of almost intact onion leaf bases and no traces of the original controlled meal. Both the adaxial and abaxial epidermal tissues together with subepidermal parenchyma were all present (plate 14:3). The presence of these tissues in this sample must be somewhat unusual and indicates that given certain conditions, such as a very rapid transit time through the gut, that extraordinary preservation can result.

3.4.1.5.2.) Animal foods.

Animal tissues differ fundamentally from those of plants. The lack of an equivalent of the rigid cellulose cell wall in soft animal tissues frequently makes identifications based upon tissue histology more difficult than for plant tissues. Staining and sectioning are essential to distinguish the different types of cells in soft tissues and even then identifications are possible at only the level of, for example, liver, muscle or tendon. It is therefore doubtful whether it would be possible to distinguish even distantly related taxa on the basis of tissue histology alone. In addition to this, and of particular importance to the present project, is the inherent digestibility of soft animal tissues. Both the accessibility of nutrients to the digestive processes and the lack of a relatively indigestible cell wall (as in plants) make them ideal as foods but difficult if not impossible to identify from faecal debris. In view of this, the present experimental work on soft animal tissues has been restricted to the consumption of standard joints of meat and fish which comprise two principal classes of edible tissue, muscle and connective.

In contrast to these soft tissues certain hard tissues such as hair, scales, bone, invertebrate exoskeleton etc. are highly resistant to digestion and can often be used to identify the species from which they came. These are discussed in more detail below.

Muscle and connective tissue.

Muscle tissue of most vertebrates, including fish, are made up of a series of contractile fibrils arranged in bundles (myofibres), which are held in position by surrounding connective tissue. Under magnification, a repeating striated structure of the fibrils gives rise to light and dark bands along the length of the fibre. The detailed microstructure and organisation of fish muscle fibres do, however, differ from mammals and most other terrestrial vertebrates. A detailed description of the microscopic structure of muscle tissue for birds and mammals is given by Voyle (1979) and for fish by Howgate (1979).

Procedure: The muscle tissues of coley and herring was cooked by frying then eaten over a period of 24 hours by a male in his early 30's. Samples were taken 48 hours after the first controlled meal. The fried muscle tissue and associated connective tissues of both beef and pork were eaten on three different occasions by a male in his early 30's over a 24 hour period. Samples were taken 48 hours after the first controlled meal.

Macroscopic remains:

Low power - No evidence of fish muscle or connective tissue could be recognised from any of the samples. Two samples did, however, contain meat fibres. These were recovered as a tightly packed association of a number of

fibres and were recognised initially, on the basis of their translucent/brown colour.

High power - The beef and pork muscle fibres clearly showed the characteristic banded appearance (plate 14:6,7,8,9) and were identified on this basis.

Microscopic remains: No distinctive microscopic components were identified.

Comments: The survival of muscle fibres from these samples is probably the result of ingesting large pieces of meat the inner portion of which would have been partially protected from enzymic digestion. Only small quantities of elastin rich tissues were eaten in the original samples and only small fragments of indistinct connective tissue were observed in any samples. Such tissues would, however, be expected to survive digestion (and have indeed been recovered from a number of ancient samples), but in this case they probably evaded the collection procedure.

Bone and Scales (*ie. Mineral based tissues*).

The basic structure of both fish and other terrestrial vertebrate bone is centred on a collagen matrix into which calcium and other salts are deposited. Fish bone can easily be separated from other vertebrates on the basis of their glassy texture while other features can be used to distinguish between families, genera and species.

At the microscopic level at least two types of fish bone can be recognised, based upon either the presence or absence of lacunae (Voehringer 1979:427), however, any specific identifications are better based upon the gross morphology of the bones.

Fish scales are also based upon an organic matrix but the superficial layers can be highly mineralised (eg. Voehringer 1979:428). If preservation is good, the morphology of these scales can be used to aid identification.

Procedure: The bone of both coley and herring and the scales of coley were eaten fried, over a period of 24 hours by a male in his early 30's. Samples were collected 48 hours after the first controlled meal. Some beef bone fragments were also eaten after frying of the associated meat by a male in his early 30's. Samples were taken 48 hours after the first controlled meal.

Macroscopic remains:

Low power - Quantities of fish bone were recovered together with a large number of scales. These, together with the small fragments of beef bone appear to have been largely unaffected by the action of digestion.

No microscopic observations were made.

Comments: Experimental work of the digestion on fish bone

has been undertaken in greater detail by Jones (1986, Wheeler and Jones 1989) who indicate that in digestive experiments with a human who ate a total of 80 major elements of herring skeleton, only 15 fragments were recovered after collection of the faeces over a period of seven days. Calder (1977:147) has also shown that certain fish scales are digested by the human gut. These results are inconsistent with some aspects those from the present work and also with the finds from coprolites such as those from el Morro, Arica, Chile, (eg. Mo 1-6 T-18) in which, even the fine gill rays and other delicate bones survived. These differences underline the need for more detailed quantitative data relating to foods of this type

Tissues composed of large, resistant organic molecules (eg. Keratin and Chitin).

In addition to the mineral-rich animal tissues discussed above there is a second class of hard animal tissue in which the structural part is composed of complex and highly resistant organic molecules such as keratin (a protein) and chitin (a polysaccharide). These form the basis of tissues such as hair horn, claws, feather, beaks, mollusc radulae, insect and other invertebrate exoskeletons, all of which are potentially recoverable from faecal debris. The resistance of molecules such as keratin and chitin to the action of enzymic attack is well known (eg. White *et al.* 1973:116) and is confirmed

by the evidence from numerous coprolite samples in which hair, feather and insect parts. have been recovered in a recognisable state. Digestion experiments such as those carried out by Calder (1977) or Osborne (1983:460) which involved the consumption of shark denticles, limpet radulae, winckle operculae and beetles by human subjects have confirmed the resilience of such tissues to human digestion.

3.5.) Conclusions.

The results of these digestion experiments have confirmed that substantial quantities plant and certain animal remains can pass through the human alimentary canal in a form permitting their identification from anatomical/histological criteria. This resistance to digestion is, however, a highly variable feature. In order to survive, a tissue must maintain its basic structure through the processes of food preparation, digestion in the stomach and small intestine and bacterial fermentation in the large intestine. At this point, therefore, it is appropriate to identify some common trends and characteristics that determine which tissues can be expected to survive digestion and which can be expected to leave few microscopically identifiable traces.

3.6.1.) Digestion of plant tissues.

The breakdown of plant tissues during food processing and digestion occurs at three distinct levels:

1) separation of different tissues;
2) breakup of tissues into individual cells or small groups of cells;
3) degradation of individual cells.

While these levels do not necessarily represent the order in which degradation occurs, they do represent an order of ease of identification of plant organs or tissues and therefore provide a convenient simplification with which to begin the discussion.

a) **Separation of different tissues.** - In fresh material the use of gross anatomy to identify plant organs depends largely upon the orientation of different tissues with respect to one another (ie. spatial arrangements of tissues). The combination of digestion and food processing, however, frequently disrupts these diagnostic associations and subsequent identifications have to be made on isolated tissues alone. Where this separation is considerable, as with most stem and root tissue this will severely hinder identifications in the absence of other diagnostic tissues. In other cases, however, where there is a strong adhesion between different resistant tissues such as in the testas of certain seeds,

these can remain together throughout digestion and considerably aid identification.

b) **Break-down of tissues into individual cells.** - The relationship between the different cells can determine whether tissues will survive digestion or be broken down into their constituent cells. It is clear from the experimental results that certain tissues such as epicarp, vascular, or stem cork tissue are highly resistant to the actions of food processing and digestion whereas others, such as storage or other parenchymatous tissues are readily digested. Where tissues have survived intact there often remains a good possibility of identifying the organ or even the species from which it came. Unfortunately, however, a number of the most resistant tissues (eg. vascular or cork tissue) can exhibit a similar structure in many unrelated species and therefore will be of little diagnostic value.

c) **Degradation of individual cells.** - Once a tissue has been broken down, thus losing the frequently distinctive organisation of cells, there is often little to be gained from further analysis. However, some individually resistant cells may add weight to other forms of evidence. Certain types of digestion resistant sclereids, for example, might be particularly abundant in certain families or genera of plant. Some varieties of ergastic substances such as crystals, starch grains, silica bodies, or

certain cellular appendages such as trichomes, where surviving, might also be of importance.

Once digestion has broken down plant material below the level of the tissue there is often no chance of making a specific identification. However, it is essentially at the cellular level that all degradation occurs. The following paragraphs therefore discuss the processes of food preparation and digestion in relation to plant tissues in more detail.

The maintenance of cell shape in plants is largely dependent on two factors - turgor and the rigidity of the cellulose cell wall. The resistance of individual cells to the digestive enzymes and bacterial flora of the human gut is therefore dependent on how each of these can be preserved. Cell turgor relies on the maintenance of an intact phospholipid (plasma) membrane. Any procedure that can disrupt the structure of this will therefore bring about a drop in osmotic pressure, loss of turgor and enable digestive elements and nutrients to flow in and out of the cell more-or-less unhindered. Where a rigid secondary cell wall does not exist, collapse of the cell will follow. Both the application of heat and digestive enzymes can bring about such a change in the phospholipid membrane by coagulation of proteins and enzymic breakdown of its constituents. In this way, they can effect disintegration of the structure of entire tissues composed of thin walled cells such as mesophyll and storage parenchyma. In addition to this, the pectic

substances that form the bond between adjacent cells, are both soluble in water and readily digested by the flora of the gut (eg. Cummings and Englyst 1987:1244). Cells will therefore, tend to separate except where lignification of the middle lamella has occurred or where the destructive elements are physically prevented from reaching the middle lamella. Finally, the walls of the cells are subjected to the action of the gut bacteria which, it is generally becoming accepted, are capable of breaking down certain amounts of cellulose (the percentage of cellulose lost in this way is far from being universally agreed upon eg. Cummings and Englyst 1987 and Kellher *et al.* 1984). The thin cell walls of parenchyma rarely seem to survive this process.

Some classes of cells can, however, survive the combined action of food processing and digestion much better than the thin walled parenchyma of many stem, root, and leaf storage tissues. Cells with thickened cellulose walls such as certain collenchyma for example may be permeable to digestive enzymes but maintain their shape by virtue of the rigidity of their walls. Reductions in the thickness of the cellulose cell walls can, however, also occur through the action of the gut flora. This was observed, for example, with the epidermis of onion (plate 14:4,5). No collenchyma tissue was, in fact, noted in any of the experiments presented in this chapter even though foods such as green beans do contain significant amounts. This might be partially explained in the light of Reeve's

(1970 cited by Jewell 1979:5) observation that the wall thickenings of collenchyma are rich in pectin. This substance, as noted above, is both soluble and amenable to digestion. Collenchyma tissues might therefore be expected a) to breakup into individual cells as the pectin of the middle lamellae dissolves and b) have the cellulose and pectin of the thickened cell wall considerably reduced by the action of the gut bacteria.

Other resistant tissues with lignified, suberised or cutinised walls (eg. vascular, cork and other protective or supportive tissue such as seed testae, fibres, and sclerenchyma) would tend to survive much better than purely cellulose thickened cells. These cell wall inclusions are neither soluble in water nor susceptible to human digestion or bacterial fermentation in the gut. In many species, such as dark seeded *Amaranthus caudatus* or in lentils the hardening of seed coats during ripening is often caused by the secondary thickening of epidermal and sub-epidermal tissues (Esau 1977:86). Cutinisation and the incorporation of dark coloured phenolic compounds and other resistant chemicals also occur. A close adhesion of both adjacent cells and sub-epidermal layers may also be facilitated by lignification of the middle lamella, which, is otherwise composed of soluble, digestible pectic substances. These features will all tend to make such tissues much less susceptible to digestion.

In addition to these resistant tissues, certain others

which would not normally be expected to survive digestion such as starch grains, oil droplets or loose parenchyma can occasionally be recovered from faecal debris. These have all been recovered experimentally but have usually only survived where they have been protected from the action of digestion only to be released during the recovery and sorting procedures (eg. sieving and sorting). There are a number of ways in which this protection can happen:

i) By virtue of the dense, oil and protein rich composition of the tissue. This has been shown to occur with the embryos of brazil nuts, rice, sesame, maize, hazel nuts and peanuts all of which can survive digestion in a recognisable form. In such foods the nature of the tissue has presented a barrier against the passage of hot water (where prepared by boiling), colonic bacteria and water-soluble enzymes to all but the outermost cells. Clearly, the type of processing used (eg. grinding) and mastication will be of importance with this type of tissue by making a greater surface area available to digestion. This will determine, to a large degree, whether identifiable remains of these tissues survive digestion. It should nevertheless be noted that even after roasting and grinding, fragments of recognisable peanut fragments from human faecal material were noted in some experimental samples.

ii) By being enclosed within a structure that is impenetrable to the digestive enzymes. In this way otherwise digestible material such as starch can pass through the gut held within protecting structures. These include complete seed testas and/or parts of the pericarp such as cereal bran or the hard endocarp of *Prosopis*. The present project has shown that starch will pass through the human gut if held within the seeds or fruits of wheat, poppy, lentil and grain amaranths.

The protection of otherwise digestible tissues has also been demonstrated by the tight rolling up of epicarp fragments of fruits such as tomato. In this case the delicate mesophyll parenchyma survived. It is probable, however, that the survival of such tissues only occurred where the fruit had not been cooked before consumption.

In summary then, the following tissues will tend to survive food processing and digestion.

1) Any tissue that it is physically protected from the destructive elements through being enclosed by resistant tissues (eg. whole seeds, dense protein/oil rich storage tissue).

2) Tissues with thickened cellulose walls (although these may be subjected to a degree of degradation).

3) Tissues with cutinised, lignified or suberised cell walls (eg. epicarp, testas, fibres, sclereids).

4) Tissues with lignified middle lamellae.

All other tissues with thin cellulose cell walls such as storage or metabolically active tissues such as leaf mesophyll will, on the other hand, tend to be digested unless they are physically protected.

3.5.2.) Digestion of animal tissue.

It is clear that much animal tissue is readily digested leaving few microscopically identifiable debris in the faeces. The majority of metabolically active cells are rapidly broken down by proteolytic enzymes and the lack of any inert cell wall rapidly results in a break down of the organisation of the tissues. In some cases, however, relatively distinctive soft tissues, notably muscle fibres, do occur in faecal material (both ancient and modern). This, it is felt, occurs as a result of protection of the fibres rather than as a result of their being resistant to digestion. Where muscle tissue does remain it is thought to be the result of meat being swallowed in large pieces such that, the innermost fibres avoid exposure to digestive enzymes and gut flora during passage through the digestive tract. Overcooking of meat, such that it becomes hard and techniques such as the preparation of pemmican might also be expected to increase the potential for survival.

One soft food component that appears to survive passage through the gut is the elastin-rich part of certain connective tissues. It may, under some circumstances, be possible to identify their remains in faecal debris but apart from being able to categorise the debris into very broad categories (eg. tendon, cartilage) such tissues are unlikely to be useful for making more accurate identifications.

In contrast to the poor survival of soft tissues, bone and scale tend to survive with regularity although the experimental work carried out by Jones (1986) would suggest that fish bone, at least, does survive differentially. Other hard tissues made up of large, complex organic molecules such as keratin and chitin regularly survive digestion seemingly unaffected by the action of digestion.

Plate 2.

1) Corylus avellana L. (Hazel nut). Cotyledon parenchyma x 85.

2) Corylus avellana L. (Hazel nut). Testa x 85.

3) Corylus avellana L. (Hazel nut). Testa x 325.

4) Corylus avellana L. (Hazel nut). Testa x 325.

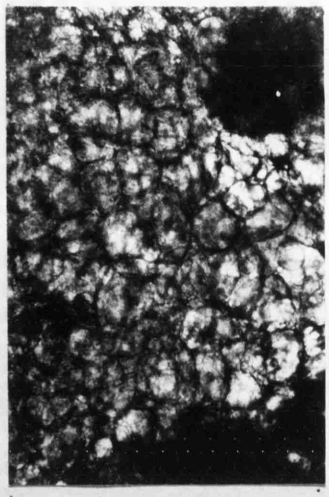
5) Corylus avellana L. (Hazel nut). Cotyledon epidermis x 325.

6) Corylus avellana L. (Hazel nut). Parenchyma with oil droplets x 85.

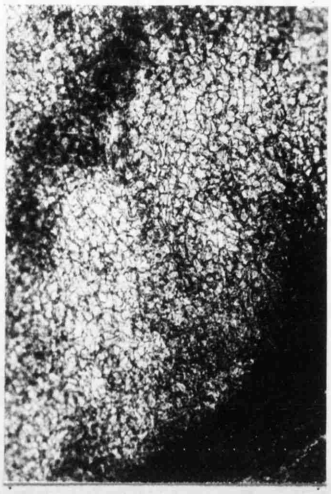
7) Amaranthus caudatus L. (Kiwicha). Outer layer of the testa of a dark seeded variety x 85.

8) Amaranthus caudatus L. (Kiwicha). Outer layer of the testa of a dark seeded variety x 325.

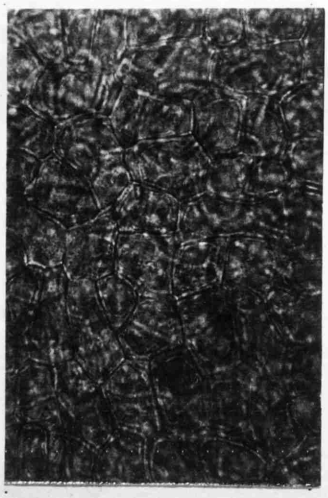
9) Amaranthus caudatus L. (Kiwicha). Inner layers of the testa (compressed parenchyma overlying a layer of 'netted' cells) x 325.



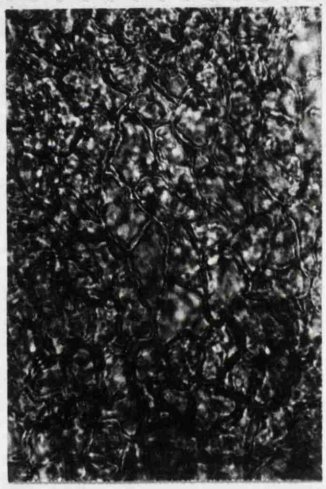
1



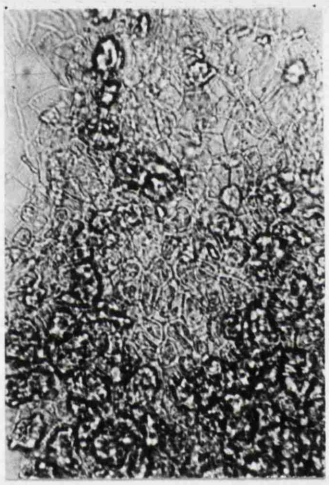
2



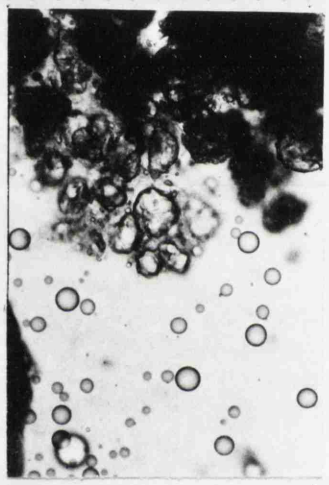
3



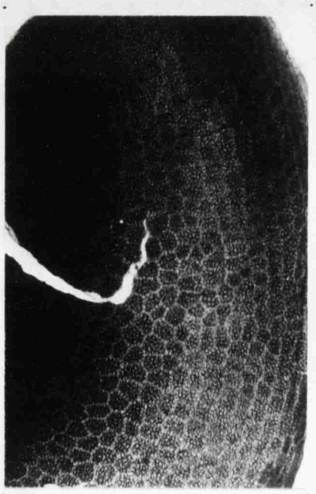
4



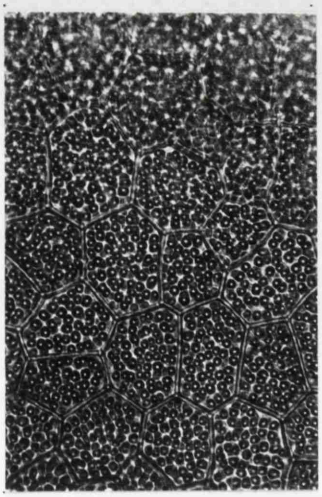
5



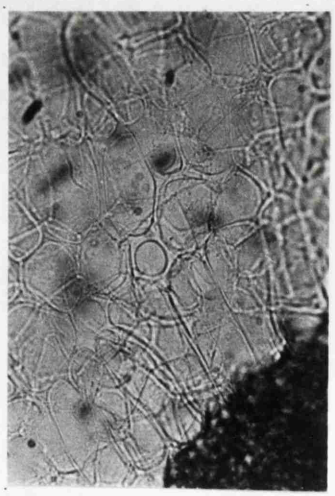
6



7



8



9

Plate 3.

1) Amaranthus caudatus L. (Kiwicha). Inner layer of the testa showing spiral-reticulated thickenings x 325.

2) Bertholletia excelsa Humb. and Bonpl. (Brazil nut). Remnants of brown pigmented layer overlying the endosperm x 85..

3) Bertholletia excelsa Humb. and Bonpl. (Brazil nut). Endosperm layer x 85.

4) Bertholletia excelsa Humb. and Bonpl. (Brazil nut). Radicle parenchyma with oil droplets x 85..

5) Cucurbita pepo L. (Pumpkin). Scanning electron micrograph of a cross section through the seed testa showing the various cell layers.

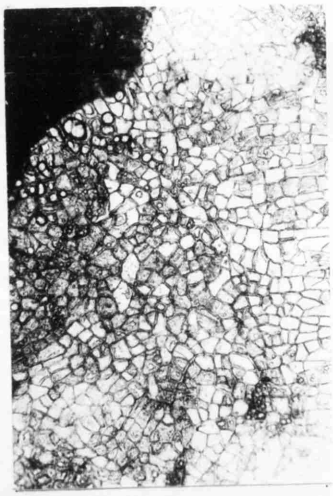
6) Cucurbita pepo L. (Pumpkin). Scanning electron micrograph of the remains of the outer layer of the testa. The thickened radial walls of this layer form the hair-like structures.

7) Cucurbita pepo L. (Pumpkin). Scanning electron micrograph of the surface of the seed showing the interlocking arrangement of the outer epidermis with remaining strands of the thickened radial walls.

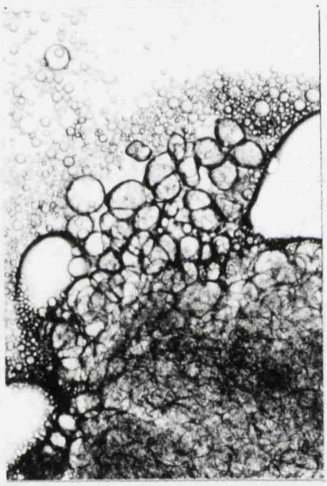
8) Cucurbita pepo L. (Pumpkin). Scanning electron micrograph of a cross-section through the seed testa showing the various cell layers.

1

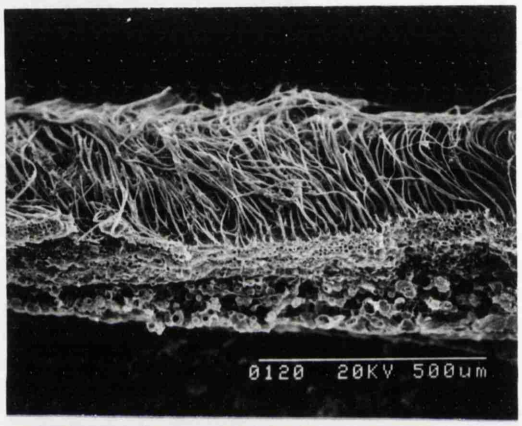
2



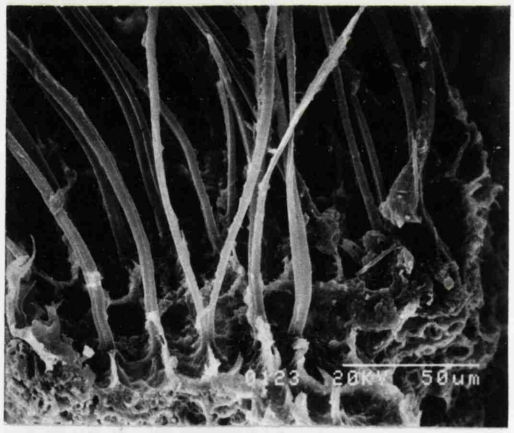
3



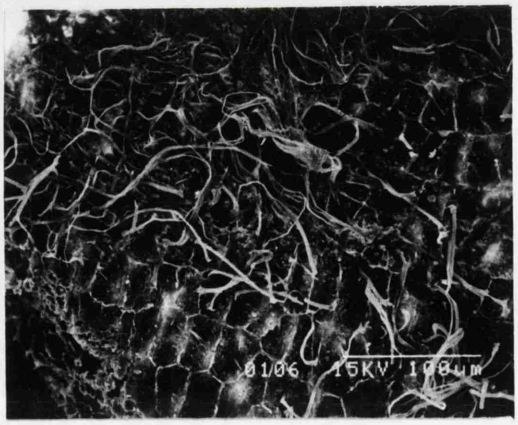
4



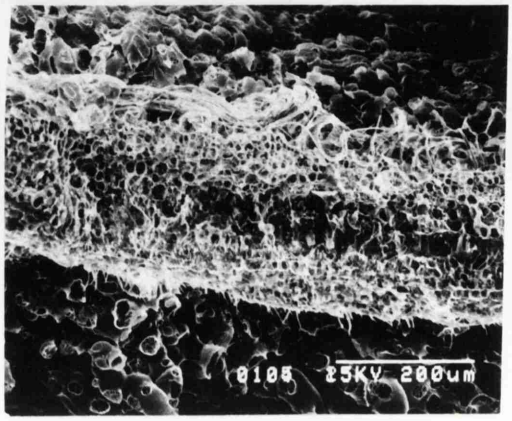
5



6



7



8

Plate 4.

1) Brassica oleracea L. (Cabbage). Leaf epidermis x 85.

2) Brassica oleracea L. (Cabbage). Leaf epidermis x 325.

3) Brassica oleracea L. (Cabbage). Degraded cuticular fragment from leaf x 85.

4) Brassica oleracea L. (Cabbage). Cuticular fragment from the leaf with associated vascular tissue and highly degraded and structureless mesophyll tissue x 85..

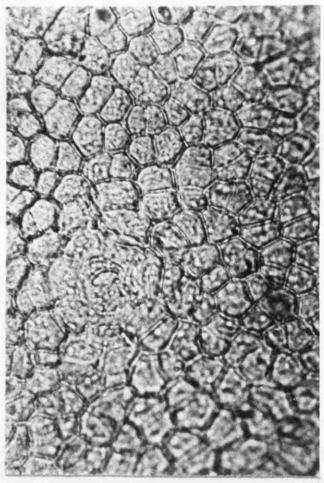
5) Malus L. sp. (apple). Epicarp x 85.

6) Malus L. sp. (apple). Epicarp near a 'russet spot' x 85.

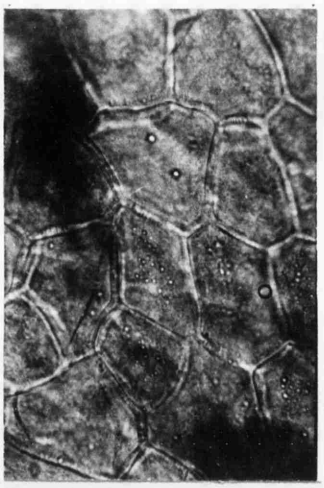
7) Malus L. sp. (apple). Sub-epidermal layer (hypoderm) of the fruit x 85.

8) Lens culinaris L. (Lentil). Palisade layer of the testa x 325.

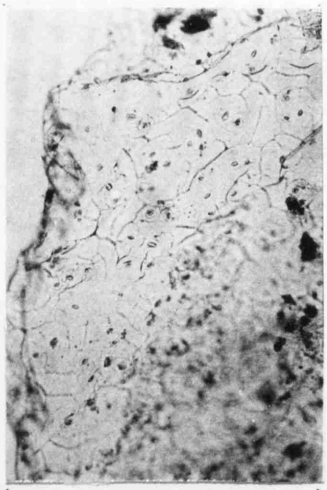
9) Lens culinaris L. (Lentil). Palisade layer of the testa x 40 (focussing further down the cells than no. 8).



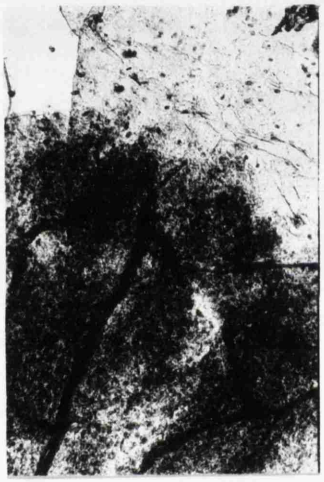
1



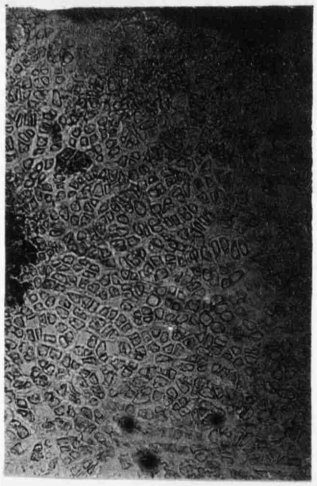
2



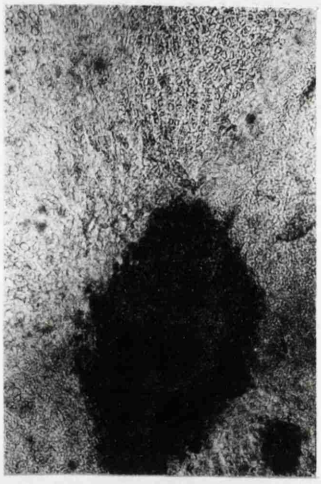
3



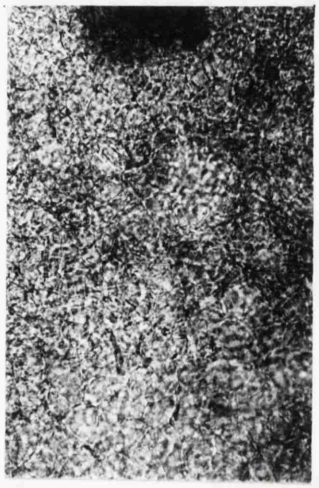
4



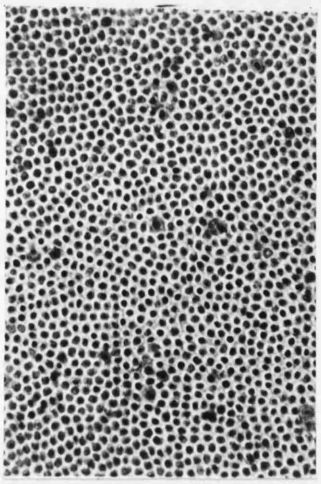
5



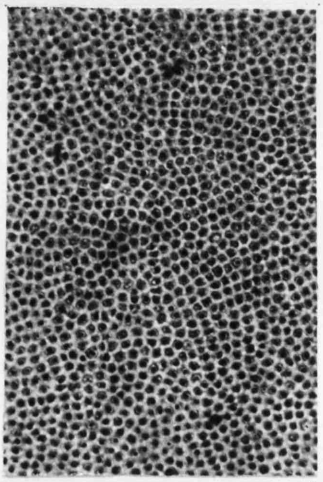
6



7



8



9

Plate 5.

1) Lens culinaris L. (Lentil). Hour-glass cells underlying the palisade layer of the testa x 325.

2) Lens culinaris L. (Lentil). Hour-glass cells of the testa x 325.

3) Lens culinaris L. (Lentil). Cotyledon parenchyma x 85.

4) Lens culinaris L. (Lentil). Cotyledon epidermis x 325.

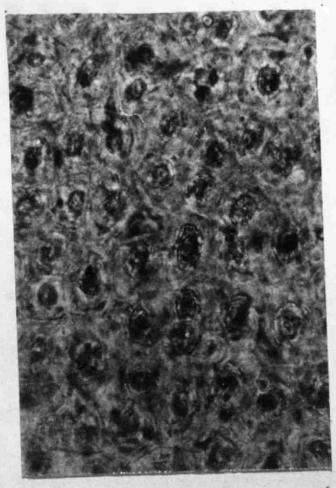
5) Lens culinaris L. (Lentil). Vascular tissue from the seed with adherent parenchyma x 85..

6) Lens culinaris L. (Lentil). Scanning electron micrograph of the testa showing the palisade layer in cross section and the underlying hour-glass cells. (Scale marks = 0.010mm).

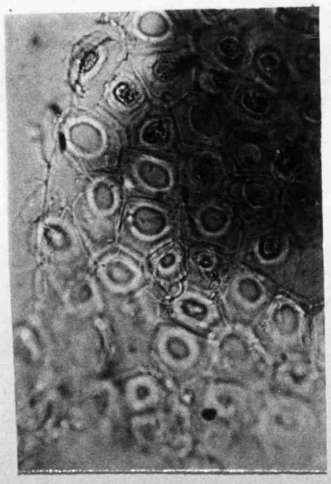
7) Lens culinaris L. (Lentil). Scanning electron micrograph of the testa showing the palisade layer in cross section and the underlying hour-glass cells. (Scale marks = 0.010mm).

8) Lens culinaris L. (Lentil). Scanning electron micrograph of the testa showing the palisade layer in cross section and the underlying hour-glass cells. (Scale marks = 0.010mm).

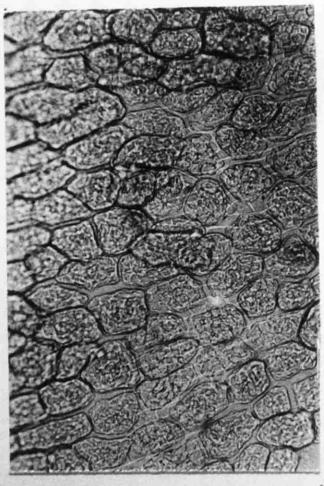
9) Lens culinaris L. (Lentil). Scanning electron micrograph of the surface of the palisade layer of the testa (Scale marks = 0.010mm).



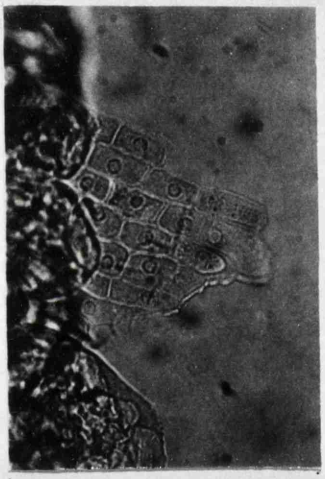
1



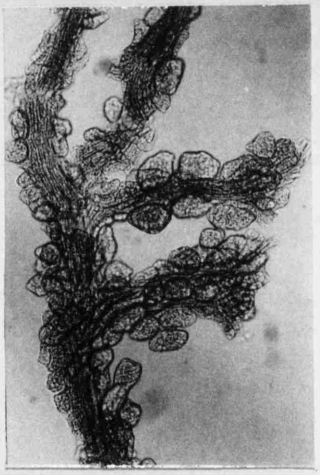
2



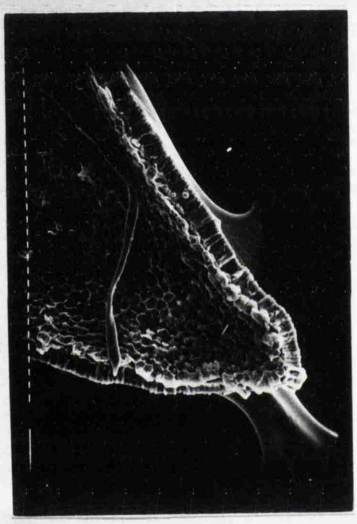
3



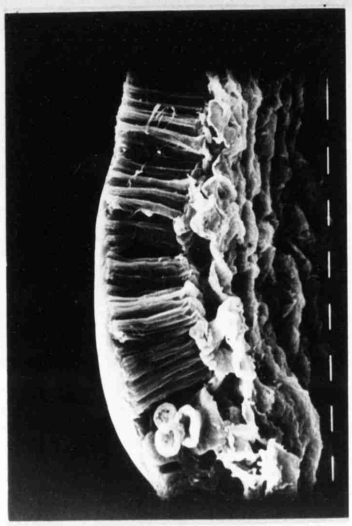
4



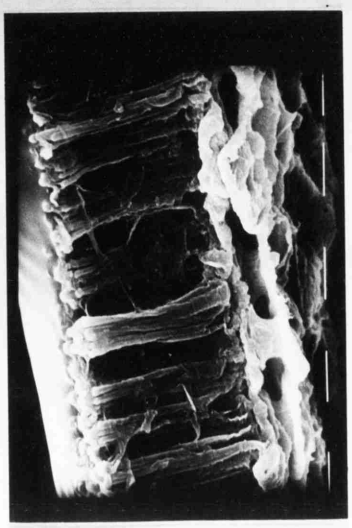
5



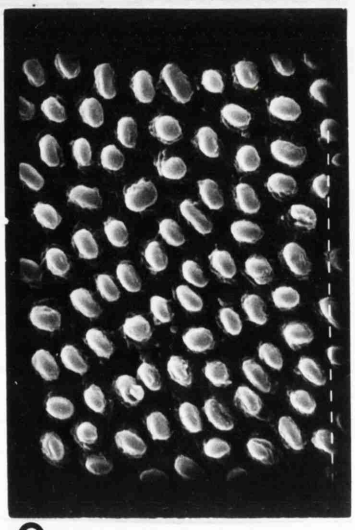
6



7



8



9

Plate 6

1) Phaseolus vulgaris Metz. (Green bean). Legume (fruit) cuticle x 85.

2) Phaseolus vulgaris Metz. (Green bean). Legume (fruit) cuticle x 85.

3) Phaseolus vulgaris Metz. (Green bean). Fibre layer of the legume (fruit) x 85.

4) Phaseolus vulgaris Metz. (Green bean). Fibre layer of the legume (fruit) x 325.

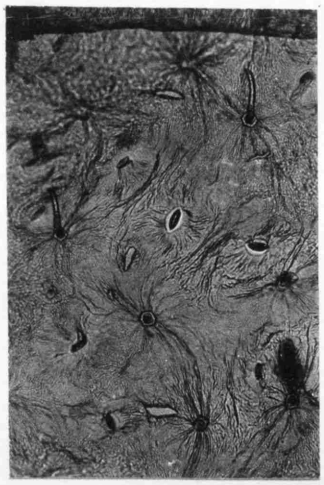
5) Phaseolus vulgaris Metz. (Red kidney bean). Palisade layer of the testa x 325

6) Phaseolus vulgaris Metz. (Red kidney bean). Palisade layer of the testa (at a second focal position) x 325.

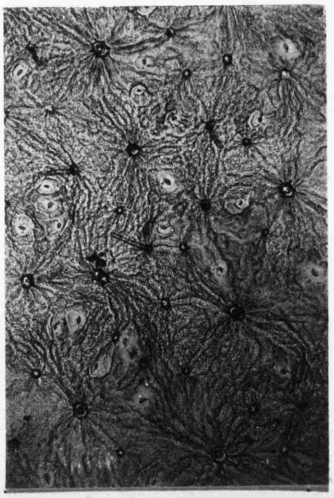
7) Phaseolus vulgaris Metz. (Red kidney bean). Hourglass cell layer of the testa x 85.

8) Phaseolus vulgaris Metz. (Red kidney bean). Hourglass cell layer of the testa showing crystal inclusions x 325.

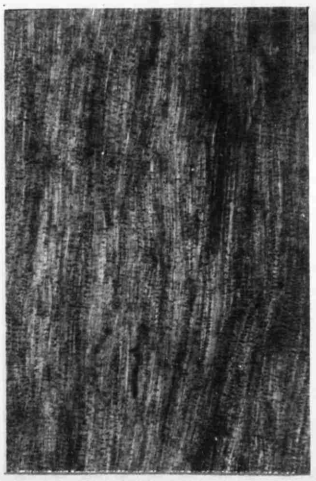
9) Phaseolus vulgaris Metz. (Red kidney bean). Spongy parenchyma and associated vascular material of the inner layer of the testa x 85.



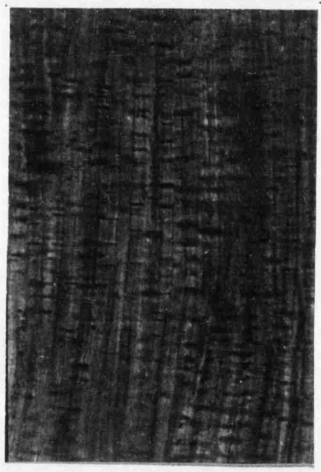
1



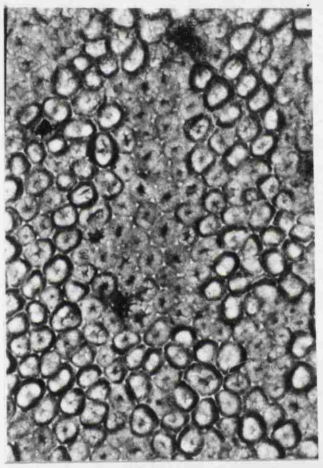
2



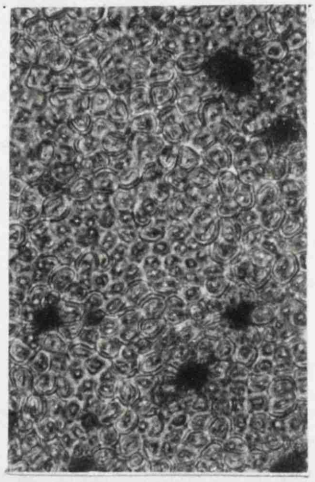
3



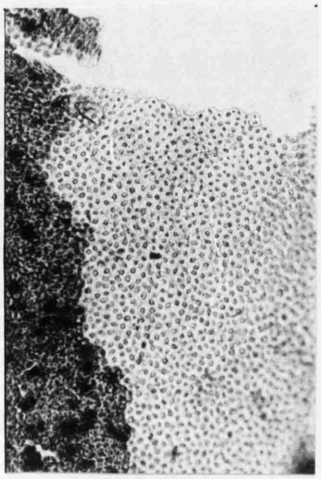
4



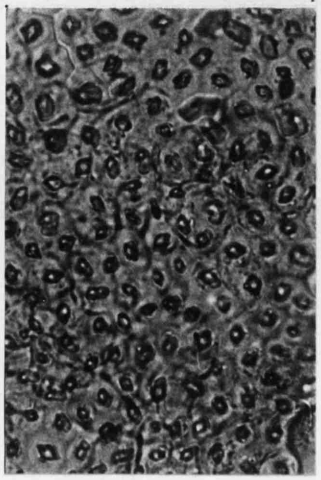
5



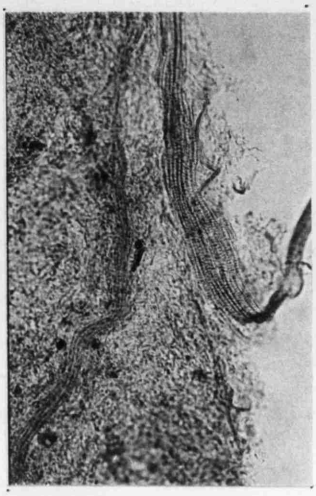
6



7



8



9

Plate 7.

1) Phaseolus vulgaris Metz. (Red kidney bean). Detached fragment of testa palisade tissue with some separation of cells x 50.

2) Pisum sativum L. (Pea). Palisade layer of the testa x 325.

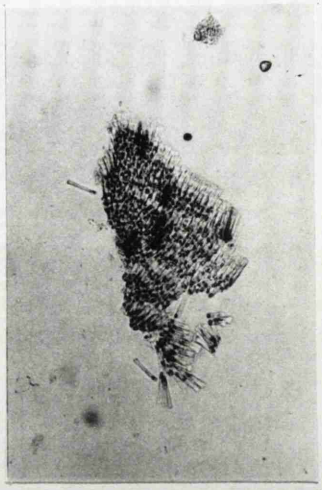
3) Pisum sativum L. (Pea). Palisade layer of the testa with some detached cells x 85..

4) Pisum sativum L. (Pea). Hourglass cells of the testa x 325.

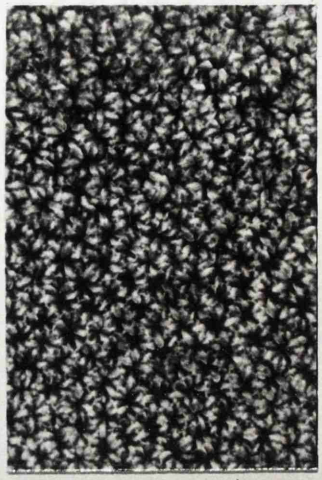
5) Pisum sativum L. (Pea). Scanning electron micrograph showing a cross-section through the palisade layer of the testa.

6) Phaseolus vulgaris Metz. (Red kidney bean). Scanning electron micrograph showing a detached hylum.

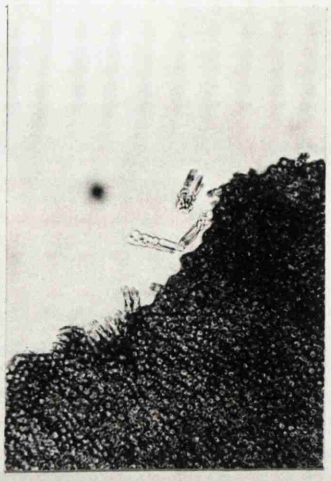
7) Phaseolus vulgaris Metz. (Red kidney bean). Scanning electron micrograph showing a detached hylum.



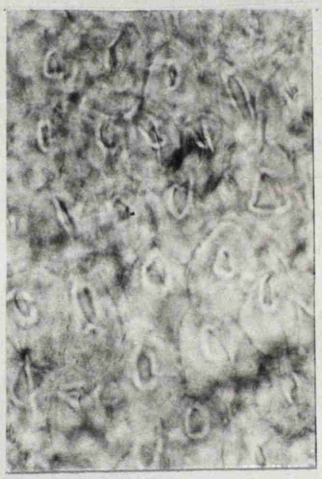
1



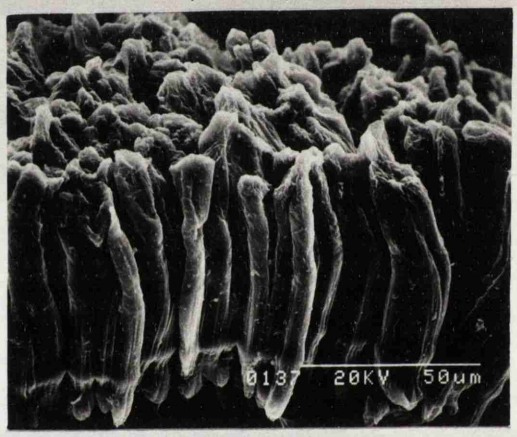
2



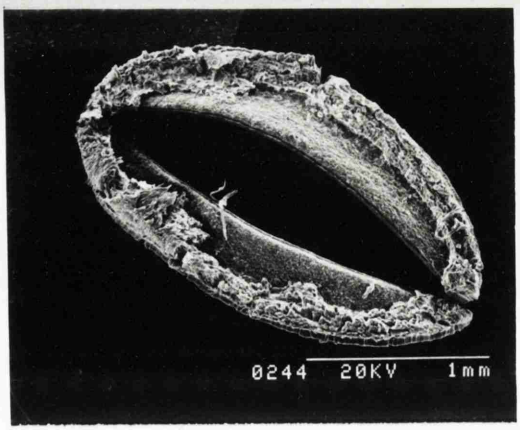
3



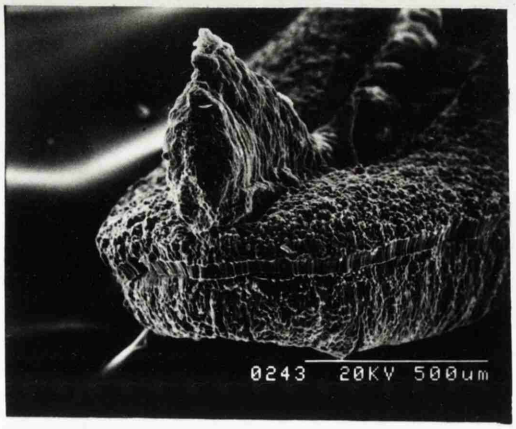
4



5



6



7

Plate 8.

1) Citrus sinensis (L.) Osbeck. (Orange). Tip of a pulp vesicle x 50.

2) Citrus sinensis (L.) Osbeck. (Orange). Degraded vesicle wall x 85.

3) Citrus sinensis (L.) Osbeck. (Orange). Surface of vesicle showing faint cross-hatch pattern of elongated cells of the epiderm overlying the inner, transversely orientated parenchyma x 85.

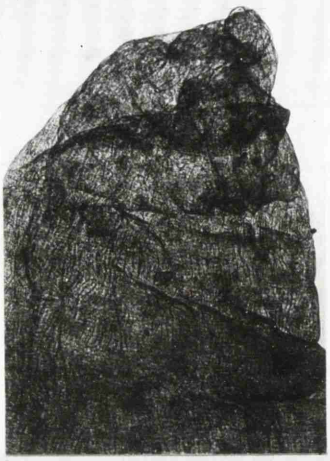
4) Citrus sinensis (L.) Osbeck. (Orange). Poorly defined cells of a segment wall (endocarp) with occasional strings of crystals x 50.

5) Apium graveolens L. (Celery). Scanning electron micrograph of the fruit surface before digestion.

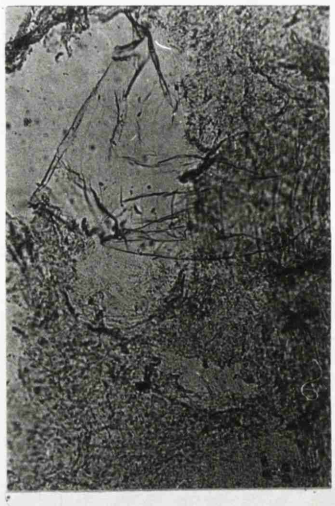
6) Apium graveolens L. (Celery). Scanning electron micrograph of the fruit surface after digestion.

7) Daucus carota L. (Carrot). Degraded material from the root with no cellular structure but with chromatophores still present x 325.

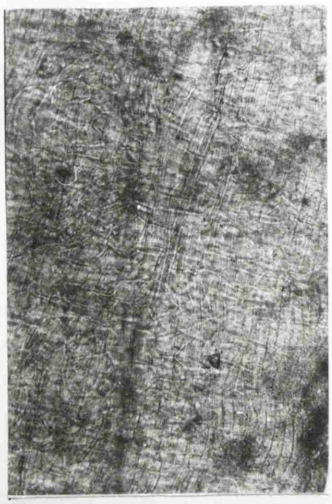
8) Lycopersicum esculentum Mill. (Tomato). Scanning electron micrograph of the outer layer of the testa. The hair like structures are remnants of the thickenings in the radial cell walls of this partially degraded layer.



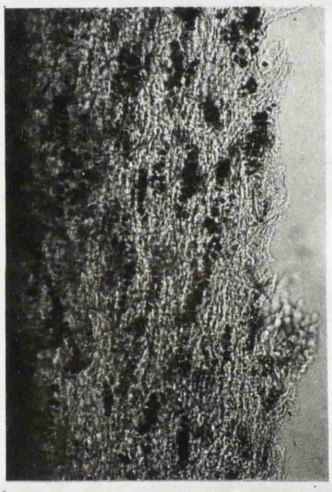
1



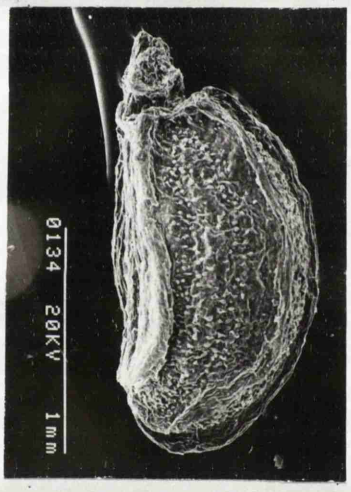
2



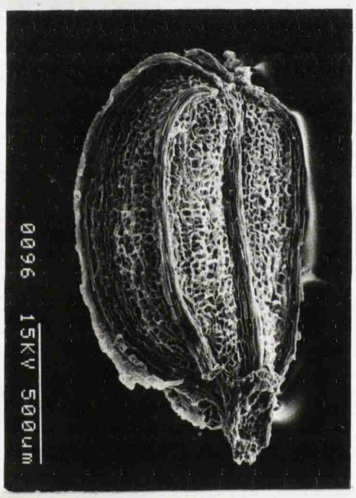
3



4



5



6

7

8

Plate 9.

1) Lycopersicum esculentum Mill. (Tomato). Epicarp x 85..

2) Lycopersicum esculentum Mill. (Tomato). Epicarp x 325.

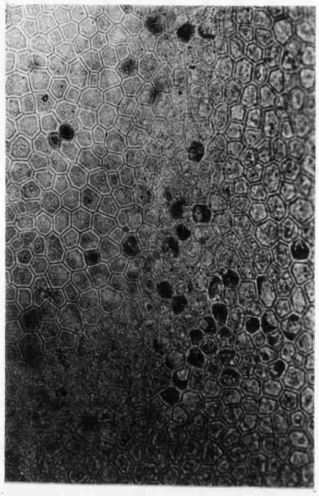
3) Lycopersicum esculentum Mill. (Tomato). Mesocarp parenchyma x 85..

4) Solanum tuberosum L. (Potato). Cork layer of the tuber x 85.

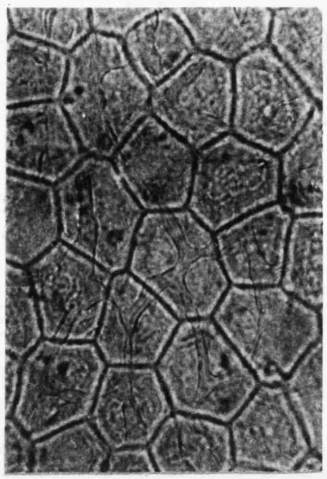
5) Solanum tuberosum L. (Potato). Cork layer of the tuber x 325.

6) Solanum tuberosum L. (Potato). Stone cell from the tuber cortex x 85.

7) Solanum tuberosum L. (Potato). Stone cell from the tuber cortex x 325.

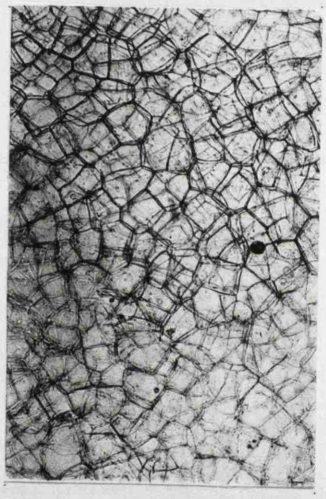


1



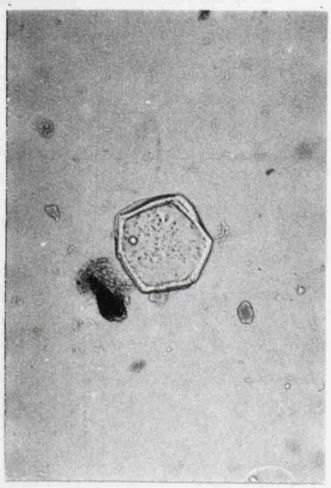
2

3

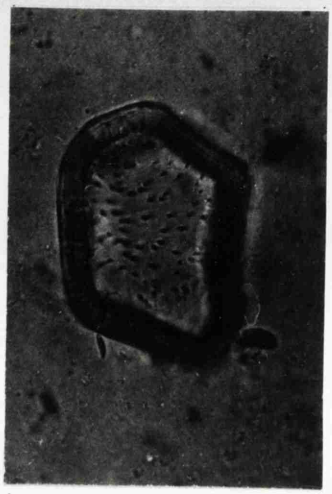


4

5



6



7

Plate 10.

1) Sesamum indicum L. (Sesame). Scanning electron micrograph of the hylum end of the seed before digestion.

2) Sesamum indicum L. (Sesame). Scanning electron micrograph of the hylum end of the seed after digestion.

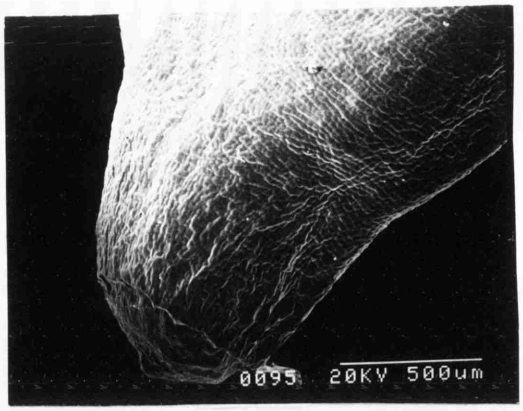
3) Sesamum indicum L. (Sesame). Scanning electron micrograph showing the surface of the endosperm layer.

4) Avena sativa L. (Oat). The longitudinal cell layer of the pericarp x 325.

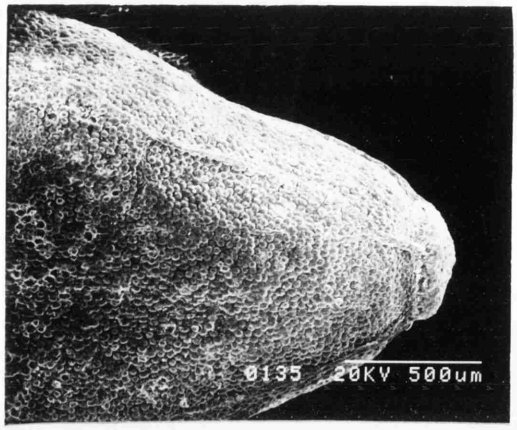
5) Avena sativa L. (Oat). The longitudinal cell layer of the pericarp x 85.

6) Avena sativa L. (Oat). Fungal hyphae growing beneath the pericarp x 325.

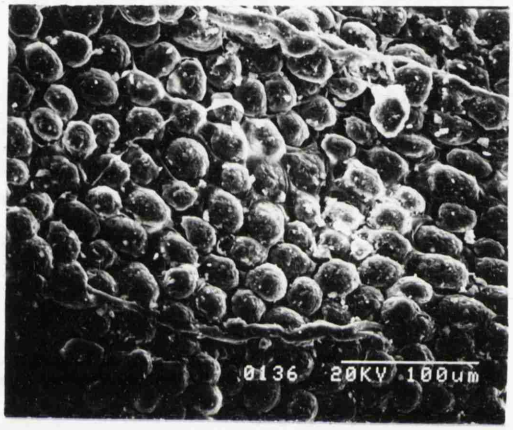
7) Avena sativa L. (Oat). Herring bone pattern of the testa x 85.



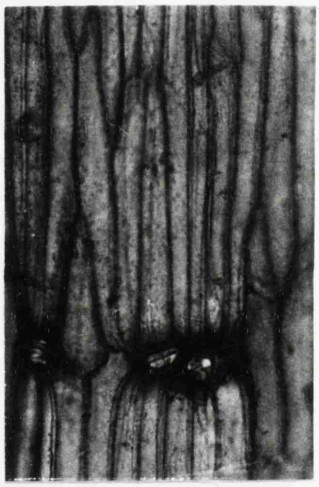
1



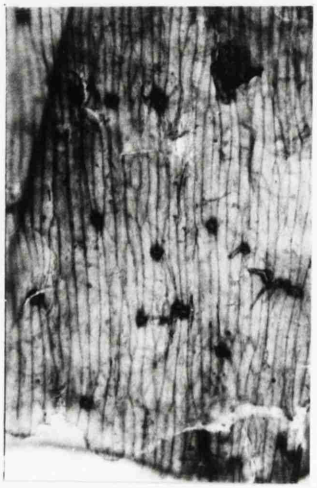
2



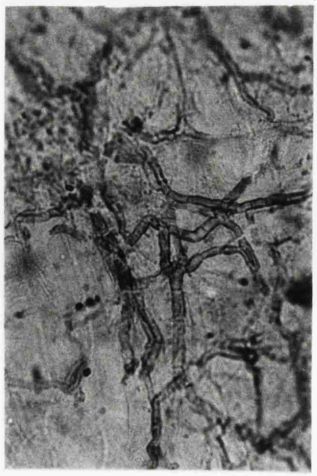
3



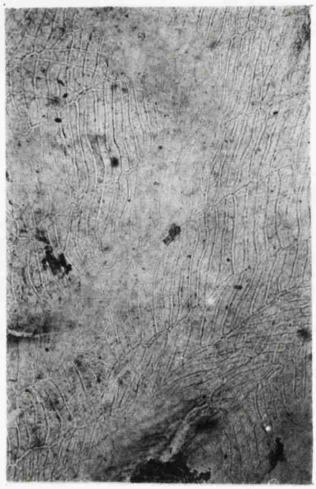
4



5



6



7

Plate 11.

1) Oryza sativa L. (Rice). Scanning electron micrograph of the outer layer of the pericarp.

2) Oryza sativa L. (Rice). Scanning electron micrograph of the sub-epidermal layer of the pericarp.

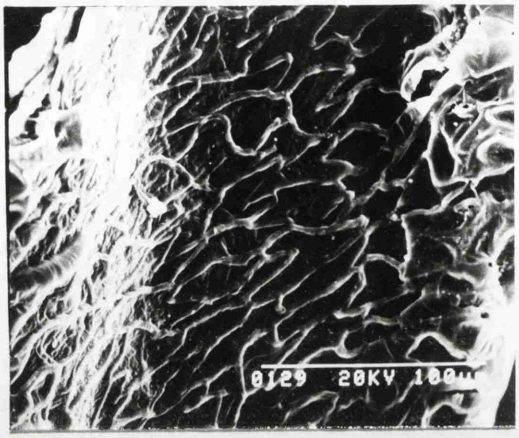
3) Oryza sativa L. (Rice). Scanning electron micrograph of the outer layer of the pericarp over the dorsal part of the grain.

4) Oryza sativa L. (Rice). Outer layer of the pericarp x 250.

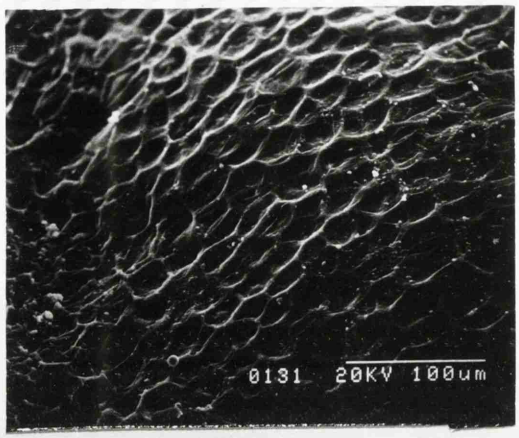
5) Oryza sativa L. (Rice). Transverse cell layer of the pericarp overlying the aleurone layer. x 325.

6) Oryza sativa L. (Rice). The aleurone layer close to the dark ventral line x 50.

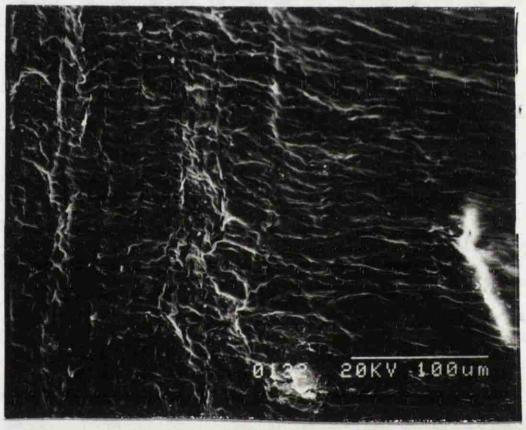
7) Oryza sativa L. (Rice). The aleurone layer x 50.



1

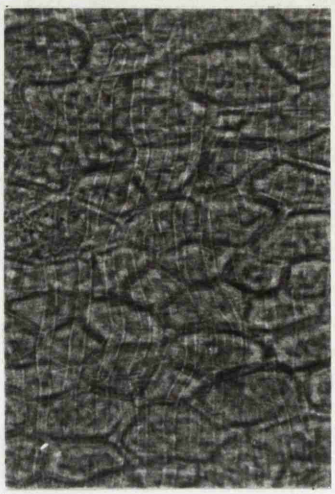


2

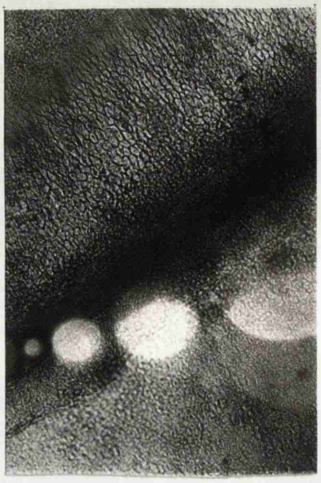


3

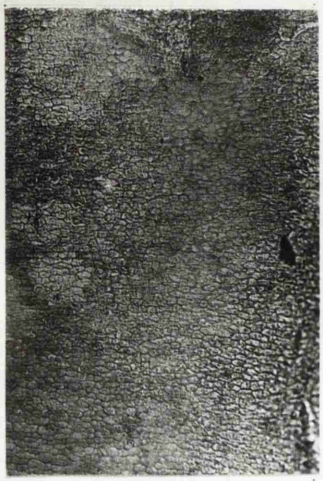
4



5



6



7

Plate 12.

1) Zea mays L. (Maize). Scanning electron micrograph of the outer layer of the pericarp.

2) Zea mays L. (Maize). Scanning electron micrograph of a cross-section through the pericarp.

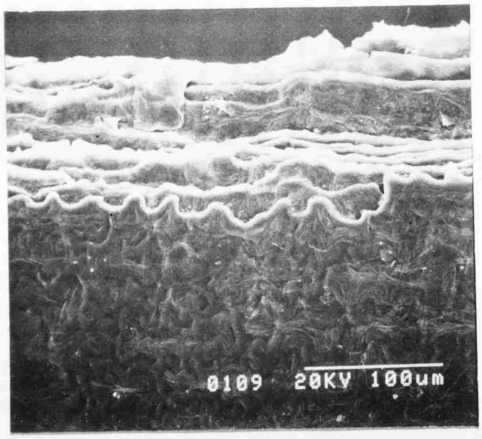
3) Zea mays L. (Maize). Scanning electron micrograph of the interior surface of the pericarp showing the arrangement of the transverse cells, tube cells, and other cellular layers.

4) Zea mays L. (Maize). Scanning electron micrograph of a cross-section through the aleurone layer.

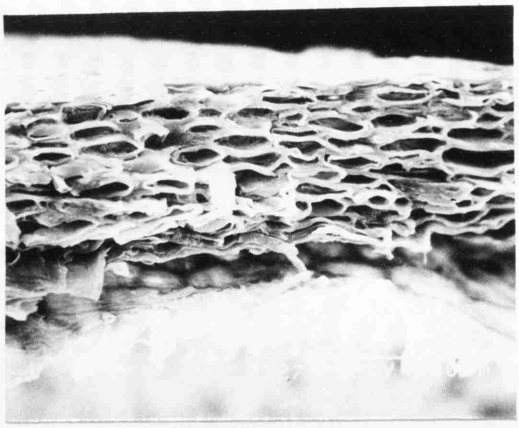
5) Zea mays L. (Maize). Scanning electron micrograph of the aleurone layer as viewed from the interior.

6) Zea mays L. (Maize). Scanning electron micrograph of a cross-section through the aleurone layer.

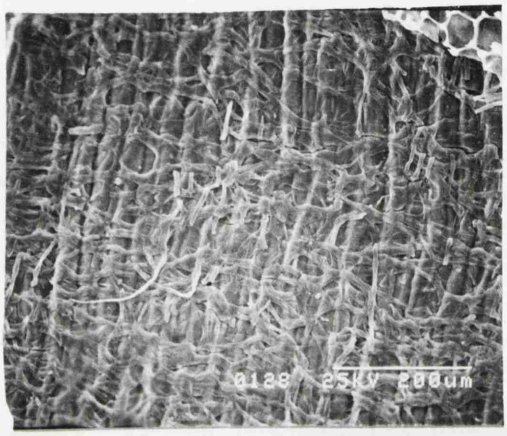
7) Zea mays L. (Maize). Scanning electron micrograph showing the relative orientation of the aleurone layer and the pericarp as viewed from the interior.



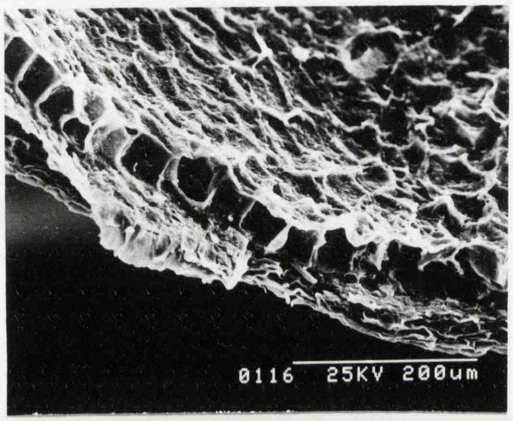
1



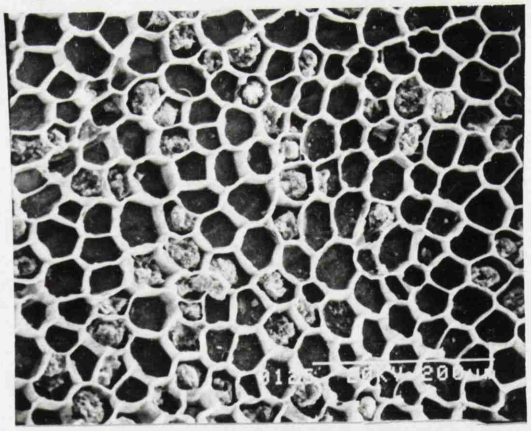
2



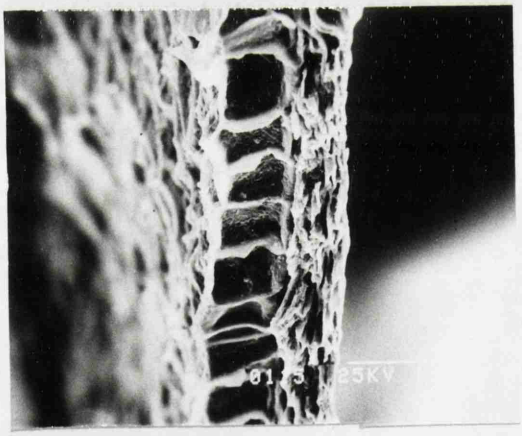
3



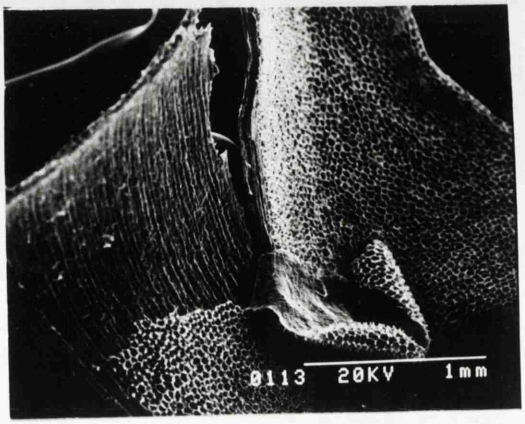
4



5



6



7

Plate 13.

1) Zea mays L. (Maize). Outer layers of the pericarp x 325.

2) Zea mays L. (Maize). Aleurone layer x 85.

3) Zea mays L. (Maize). Aleurone layer x 325.

4) Zea mays L. (Maize). Epidermis from the tip of a flowering glume x 50.

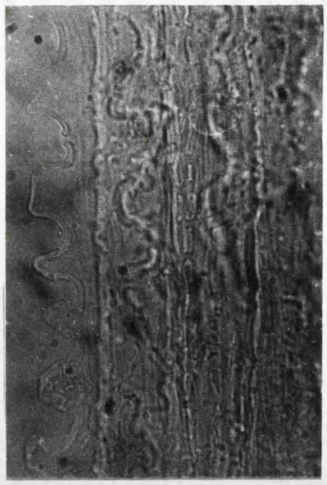
5) Triticum aestivum L. (wheat). Outer layer of the pericarp x 85.

6) Triticum aestivum L. (wheat). Apical hairs on outer surface of the pericarp x 50.

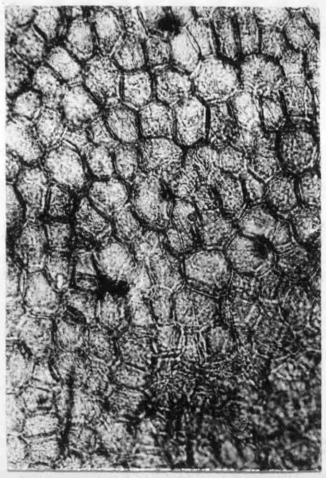
7) Triticum aestivum L. (wheat). Transverse cell layer of the pericarp x 85.

8) Triticum aestivum L. (wheat). Transverse cell layer of the pericarp x 50.

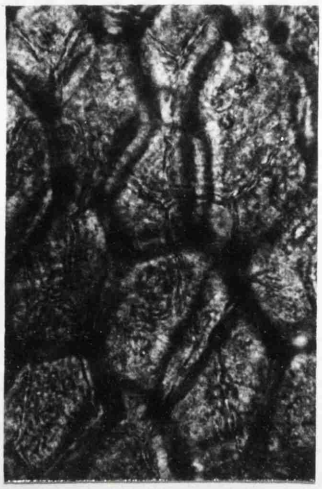
9) Triticum aestivum L. (wheat). Transverse cell layer of the pericarp x 325.



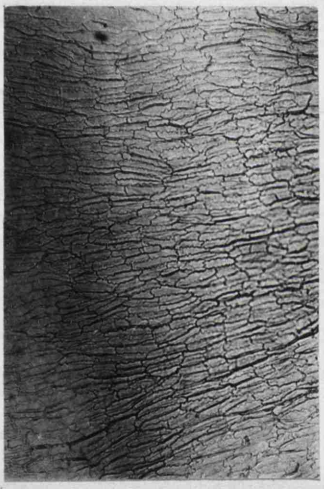
1



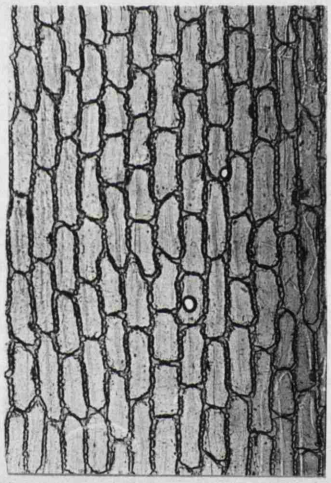
2



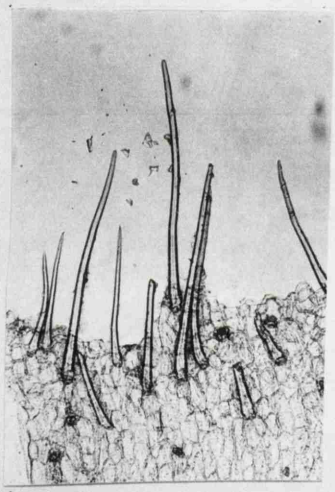
3



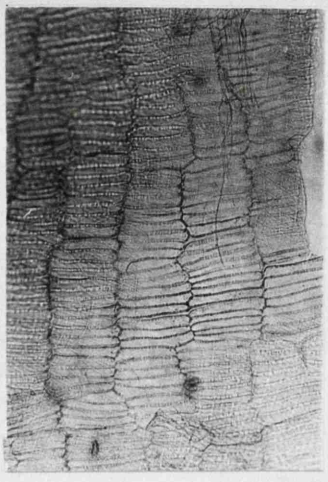
4



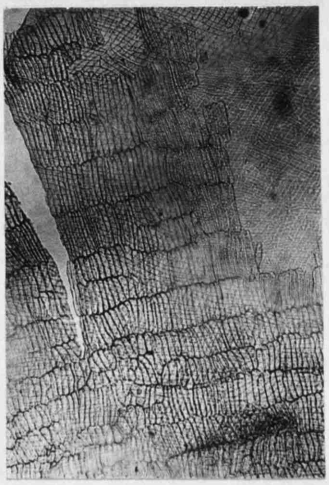
5



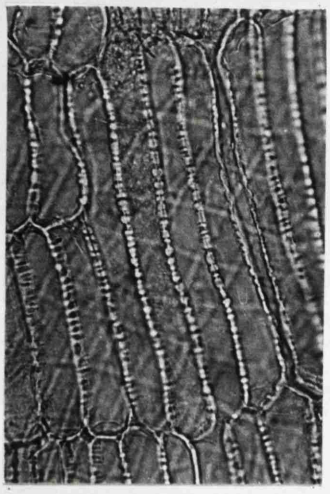
6



7



8



9

Plate 14.

1) Triticum aestivum L. (wheat). Tube cells and transverse cell layer of the pericarp x 50.

2) Triticum aestivum L. (wheat). Chequerboard pattern made by the two consecutive layers of the testa x 50.

3) Allium cepa L. (Onion). Scale epidermis of the bulb, well preserved showing sub-epidermal tissues x 50.

4) Allium cepa L. (Onion). Degraded scale epidermis of the bulb x 50.

5) Allium cepa L. (Onion). Highly degraded scale epidermis of the bulb x 50.

6) cf. Pork. Muscle fibres. x 50.

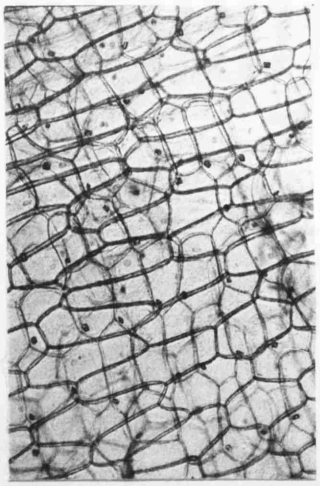
7) Beef. Muscle fibres. x 85.

8) Beef. Muscle fibres. x 325.

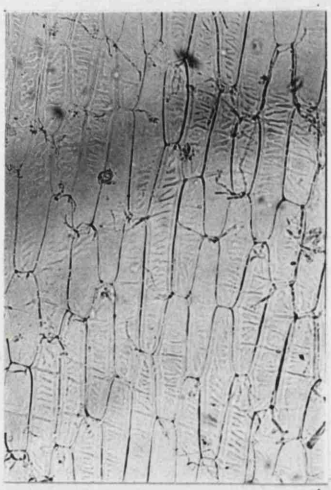
9) Beef. Muscle fibre. x 800.

1

2



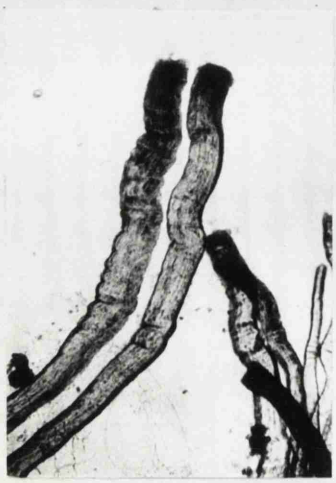
3



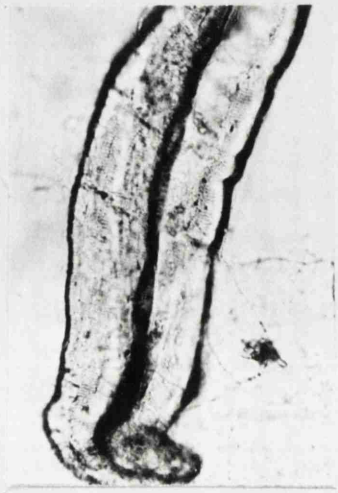
4

5

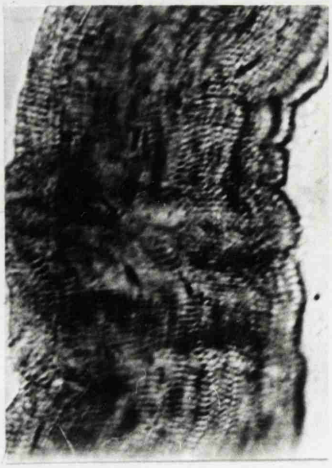
6



7



8



9

Chapter 4 - The Gut Contents of Ancient, Desiccated Human Bodies.

4.1.) Introduction.

Conditions suitable for the continued preservation of human bodies occur naturally in only very few places in the world. Of these, by far the greatest number are recovered from North Africa in an area centring upon Egypt and from a narrow stretch of coastal desert along the occidental coast of South America in Peru and Chile. In these areas both naturally-dried (ie. preserved without the use of elaborate mummification procedure) and deliberately preserved mummies (ie. preserved by an elaborate mummification procedure) are to be found. Except for a few possible cases where bodies have been partially smoked, deliberate mummification has normally involved the removal of various tissues such as the brain and viscera in order to eliminate centres of putrefaction (See for example Allison *et al.* 1984 and Sandison 1986). Such eviscerated bodies are of little use for the study of ancient human faecal material.

Even within the category of naturally-preserved remains a broad spectrum of different states of preservation exist. In some cases complete bodies are recovered, while at the other end of the spectrum virtually skeletonised remains

have been recovered inside of which are to be found the unmistakable remains of pieces of the alimentary canal and its contents (eg. Tu58 T-6). Evidently, this variation has much to do with local conditions in which soil types, depth and type of burial, water regimes and post-depositional disturbance all play their part.

This chapter deals with the analysis of a number of these well preserved bodies from South America. All have been preserved by desiccation and all are characterised by quantities of surviving soft body tissue. The details of each sample are presented in appendix 1 and the analyses presented below are grouped firstly by geographic zone or collection and then by culture.

4.2.) Bodies held at the British Museum - a first attempt at the recovery of gut material.

A study of a number of desiccated bodies of South American origin held at the British museum was made as a first attempt at recovering gut material and remains of food debris. This has been reported in more detail by Holden (1989) but essentially involved the use of extended forceps to take samples of abdominal material through damage holes in the surface tissues. These samples were then subjected to a microscopic analysis in the hope that evidence of food debris might be recovered. They were found to consist mainly of degraded textile and body tissue, with frequent evidence of insect activity. There were no obvious signs of evisceration so it is probable that the

putrefaction of the internal organs had contributed to the poor preservation of the interior of the bodies.

4.3.) Samples from the valley of Tarapaca - North Chile.

4.3.1.) Cultural and geographical context.

Five samples were recovered from bodies that were excavated from three different sites in the valley of Tarapaca. This valley has been well studied archaeologically (Nunez 1984b, Nunez 1986, True 1980, True and Crew 1980, True and Gildersleeve 1980, True *et al.* 1970) and is one of a number that run in a westerly direction from the Andes only to terminate before reaching the sea in the Pampa of Tamarugal, part of the Arid lands of Northern Chile at a latitude of about 20 degrees South. The present day vegetation is indeed sparse with close to 0% ground cover on the valley sides but with more concentrated vegetation on the valley bottom. Plants of possible economic value include *Atriplex atacamensis*, *Geoffroea decorticans*, *Schoenoplectus americanus*, *Typha* sp., *Amaranthus* sp., *Calandrinia* sp. and *Prosopis* sp.. Around the present town of San Lorenzo a certain amount of irrigation farming is still practiced, but closer to the archaeological sites of Pircas and Caserones the river is now dry and few attempts at agriculture have been made in recent years. Evidence of deserted fields are abundant in this part of the valley.

It is evident that this area has changed considerably in

the post-conquest period (Nunez 1986) as European farming methods and the nearby mining industries have drastically reduced the area of the once sizable *Prosopis* groves near the mouth of the valley. Even so, archaeological evidence suggests that in the past (as is still observed today) the productivity of the valley was highly dependant upon the prevailing water regimes. The maintenance of seasonal human camps in dry periods and sedentary ones during more favourable periods would seem to be a cycle that has repeated itself more than once in the past.

4.3.2) The Sites.

4.3.2.1) Pircas.

The ancient habitation at the site of Pircas (Nunez 1984a, 1984b) is situated on the northern border of the quebrada of Tarapaca and is characterised by an accumulation of over 50 discrete functional assemblages. This site has been defined, in terms of its material culture by Nunez (1984a:8) who includes the presence of fish bone and marine mollusca as being characteristic features. The cemetery of Pircas-2 is close to these occupation sites and is associated with them. C14 dates taken from human muscle tissue from this cemetery have a value of 2420 $\pm$ 80 B.P., while more recently available radiocarbon accelerator dates give values of 2490 B.P. $\pm$ 60 and 2460 B.P. $\pm$ 60 for gut contents and skin respectively (Hedges *et al.* 1989:231).

4.3.2.2.) Tarapaca 40a.

The cemetery of TR-40a is situated in the northern side of the quebrada and is probably linked with the initial population of the nearby village of Caserones (Nunez 1982:89, True 1980). Nunez (1976:95) states that this phase was characterised by an archaic economy of nomadic hunting and gathering supplemented by early attempts at horticulture. There would appear to have been a relatively dense population of people who wore turbans, practiced head deformation and used baskets and crude textiles. Very few ceramics have been recovered from this period with only 3 pieces recorded in 100 interments. Nunez also gives evidence that collection of *Chenopodium* sp. and *Prosopis* sp. (algarrobo) was also carried out and that squash, gourds and possibly also maize were cultivated. Two dates of 1660 $\pm$ 90 B.P. and 1590 $\pm$ 170 B.P. for an *algarrobo* pod and human hair respectively are available for this cemetery (Nunez (1976:93). The lower part of the quebrada of Tarapaca is considered to have acted as a focus of sedentary occupation when the conditions were favourable.

4.3.2.3.) Caserones sur.

The cemetery of Caserones sur was also culturally linked to the nearby village of Caserones. No C14 dates are available from these sites but artefactual evidence would put them into a period between 0 and 600 A.D. The culture represented by TR-40a is located in the earlier part

of this period.

4.3.3.) The samples.

As part of a detailed palaeopathological study, samples of gut contents were taken and made available for analysis. The majority of these samples consisted of cylindrical masses of debris that were often surrounded by remains of the gut wall. They were therefore easily recognisable as gut residues. One sample, however, was in a highly fragmented condition. This was recovered from a body (TR-40A T-6) which was suspected of having been the victim of the parasite *Trypanosoma cruzi*, known locally as Chagas' disease (Rothhammer *et al.* 1984). This was diagnosed in populations from Tarapaca by the presence of "megacardia" (an enlarged heart) and "megacolon". The latter of these two symptoms, manifests itself as largely distended intestines. The gut contents recovered from the intestines and pelvic cavity of TR-40A T-6, for example, amounted to some 570gms.

4.3.4.) Quantification of the debris and calculation of equivalent quantities of undigested food.

The food debris was, in most cases, quantified by dry weight (table 1) and where possible, the equivalent weights of undigested foods were calculated for the major classes of debris (as outlined in section 2.5.2.3.). The following logic was used to calculate the percentage weight of fibre in the different foods and the results of

these calculations are shown in table 2.

A value of 7-10% for the percentage weight of fibre from the rhizome of *Schoenoplectus* sp. have been used (as discussed in section 6.5.2.). With respect to the dark-seeded species of *Chenopodium*, Risi and Galway (1984:188) cite cellulose values of between 1.50% and 12.20% (by weight) for modern *Chenopodium quinoa*. The dark seeded species recovered from Pircas T-6 will probably will have a fibre value towards the high end of this range closer to that of *C.album* for which Spinner and Bishop (1950:176) give a value of 14.6%. A figure of 12.20% would therefore seem to be a reasonable estimate of percentage fibre for the seeds recovered from Tarapaca.

For *Prosopis* sp. two separate methods have been used for the calculation of equivalent weights of undigested foods. The first of these uses a fibre value of 23.2% as the basis of a conversion factor, (the value given by Beck and Beck (1955:200) for the closely related species of *P.juliflora*). In calculating the equivalent weight of undigested food for this species all of the classes of *Prosopis* were summed (ie. endocarp, epidermis and testa) to calculate the weight of the food debris.

The second method used the number of endocarp segments recovered from a given weight of *Prosopis* pods, in order to calculate the equivalent weight of pod consumed. Two modern samples of *Prosopis* pods collected from San Pedro de Atacama gave a mean value of 0.24 grams of dried pod

My reference number.		COPTH01/3	COPTH01/4	COPTH25/1	COPTH02/b	COPTH21/1a	COPTH21/2a
Location.		Tarapaca.	Tarapaca.	Tarapaca.	Tarapaca.	Tarapaca.	Tarapaca.
Site.		Pircas -2	Pircas -2	Pircas -2	TR-40.	Cas-Sur	Cas-Sur
Context.		T-6.	T-6.	T-5.	T-6.	T-1B	T-1C
Context type.		Gut contents.	Gut contents.	Gut contents.	Gut contents.	Gut contents.	Gut contents.
Source.		M.A.	M.A.	M.A.	M.A.	M.A.	M.A.
Conversion factor to gram.		x 8 +1.9	x 8 + 1.9	+ 4.3	+ 3.4	x 4 + 3.2	x 4 + 3.8.
Plants							
Atriplex atacamensis.	Seed/Bracteole.				Trace (3)		
	Bracteole.				0.001		
	Leaf bract.				0.003		
	Leaf frags.				0.006		
Atriplex sp.	Seed.				Trace (1)		
Chenopodium sp. (dark seed).	Whole seeds.						
	Seed frags.	0.166	0.161			Trace	Trace
Chenopodium sp. (Pale seed).	Whole seeds.			0.002 (2)			
	Seed frags.						
Prosopis sp.	Seed frags.			Trace	0.003	Trace	
	Endocarp segs.			0.138 (3)	0.539 (9)	0.028 (1)	0.017 (1)
	Pod fibre.	0.040	0.059	0.094	0.039	0.042	0.056
	Pod Epidermis.	Trace	0.003	0.011	0.005	0.007	
	Florets.						0.007 (5)
	Leaflets.		Trace (1)	0.003 (6)	Trace (1)		
Schoenoplectus type	Rhizome fibre.	0.009	0.012			0.035	0.045
Cortaderia sp.	Leaf frags.				0.003		
Zea mays.	Caryopsis base.		0.002 (1)	Trace (2)			
	Pericarp frags.			Trace			
Graminae indet.	Florets.				Trace (1)	Trace (3)	Trace (2)
Root/Stem/Storage organ indet.						0.065	0.079
Epidermal fragments indet.		Trace	0.007				
Leaf fragments indet.						Trace	
Fibre fragments indet.							0.009
Cork layer.				Trace		0.003	Trace
Seed indet.							Trace
Charred fragments.	Vesicular.			Trace			
	Wood.			0.002			
	Indet.			Trace	Trace		
Animals							
Acarid mites.						Trace (100's)	
Beetle larvae (Dermestidae)					Trace (1)		
Fish.	Bone	0.110	0.068				0.005
	Scale.	0.007	Trace.			Trace	Trace
Other animals.	Bone.				0.004		
	Hair.				Trace		
	cf. Muscle fibre.				Trace		
Organic debris indet.							
Fine fraction. < 1mm.		0.116	0.150	0.246	0.058	0.162	0.221
Large Fraction. > 1mm.		0.115	0.147	0.002	Trace	0.151	0.112
Mineral fragments.		Trace	0.017	0.192	0.006	0.064	
Total Weights		0.561	0.622	0.690	0.667	0.557	0.551

Table 1. Score sheet for the food debris from the gut of a number of bodies recovered from the Tarapaca Valley, Northern Chile. Values given as grams dry weight per gram of gut contents.

tissue for each segment of hard endocarp. This weight of undigested food represented by the faecal debris could therefore be calculated by simply multiplying this value by the number of endocarp segments recovered.

A sample of ancient maize from Tarapaca gave a mean weight of 0.007gms. for each maize grain. The calculation of equivalent undigested grain for maize was therefore carried out on the basis of the number of caryopses base fragments recovered from the ancient gut samples. The caryopses bases were estimated to be approximately the same size as those recovered from the gut. These were thought to be a better measure of weight than modern varieties which are generally much larger. (nb. There are a numbers of unresolved problems relating to the use of this technique with maize, these have been discussed further in section 7.5.c.).

4.3.5) Discussion of the Results from Tarapaca.

The five samples recovered from Tarapaca can now be discussed in more detail.

Pircas 2 T-5 - This sample was dominated by a number of different classes of the pod tissue *Prosopis*. The presence of these and a number of *Prosopis* leaflets would tend to support the supposition that this food had been only crudely prepared. Calculations of the equivalent amounts of undigested food indicate that *Prosopis* had been consumed in a quantity (dry weight) of over 10 times

Sample.	Food type.	Weight of identified debris (dry weight).	% fibre present in the different foods.	Conversion factor. 100 ÷ %fibre	Equivalent weight of undigested food per gram of gut contents.
Pircas 2 T-5.	Prosopis endocarp.	3 segments.	1 seg = 0.24gms.	N/A.	0.72grams.
	Prosopis total fibre.	0.243grams.	23.2	4.3	1.05grams.
	Z.mays.	2 grains	1grain = 0.007	N/A.	0.014grams.
Pircas 2 T-6/3.	Chenopodium sp.	0.166grams.	12.2	8.2	1.36grams.
	Prosopis endocarp.	0.04grams.	23.2	4.3	0.17grams.
	Schoenoplectus sp.	0.009grams.	7 - 10	10-14.3	0.09-0.13grams.
Pircas 2 T-6/4.	Chenopodium sp.	0.161grams.	12.2	8.2	1.32grams.
	Prosopis endocarp.	0.059grams.	23.2	4.3	0.25grams.
	Schoenoplectus sp.	0.012grams.	7 - 10	10-14.3	0.12-0.17grams.
	Z.mays.	1 grain.	1grain = 0.007	N/A.	0.007grams.
TR-40 T-6.	Prosopis endocarp.	9 segments.	1 seg= 0.24 gms.	N/A.	2.16grams.
	Prosopis total fibre.	0.583grams.	23.2	4.3	2.50grams.
Cas-sur T-1b.	Prosopis endocarp.	1 seg ment.	1seg = 0.24gms.	N/A.	0.24grams.
	Prosopis total fibre.	0.077grams.	23.2	4.3	0.33grams.
	Schoenoplectus sp.	0.035grams.	7 - 10	10-14.3	0.35-0.50grams.
Cas-sur T-1c.	Prosopis endocarp.	1 segment.	1seg = 0.24gms.	N/A.	0.24grams.
	Prosopis total fibre.	0.073grams.	23.2	4.3	0.31grams.
	Schoenoplectus sp.	0.045grams.	7 - 10	10-14.3	0.45-0.64grams.

Table 2. Table showing the conversion of the major classes of plant food debris into equivalent values of undigested food per gram of gut contents. Samples from The Tarapaca Valley, Northern Chile.

that of maize. The low frequency of the small pale-seeded *Chenopodium* seeds showed that these had not been a major constituent of the main meal and there was no evidence to suggest that they had been milled before being eaten.

Pircas 2 T-6 - The values of the equivalent undigested food per gram of dry gut content showed that it is the *Chenopodium* seeds that had dominated the "last meal".

These had been finely ground before eating. The presence of bone and tendon/cartilage material testified to the consumption of meat while fish scales and bone indicated that fish had also been eaten. Small amounts of maize grain, *Schoenoplectus* fibre and *Prosopis* pod were also present. The low quantities of these possibly indicate that the food had been processed in order to remove much of the fibrous component.

TR40A T-6 - This sample was not recovered as a faecal mass but as a large amount of loose material in the abdomen. It was dominated by the endocarp fragments and other tissues of the *Prosopis* pod. Calculations of equivalent undigested food indicate that these represented between 2.16 and 2.50 grams of *Prosopis* pod per gram of dried gut material.

In addition to this, small quantities of *Atriplex* fruits were recovered but it was not clear whether these were deliberately eaten. It is possible that they were post-depositional contaminants, as the fragments of yarn and *Cortaderia* leaf must also have been. *Atriplex atacamensis*, commonly known as *cachiyuyo*, has not been well reported from either archaeological or published ethnobotanical work in this area. With the minimal evidence provided here it is not feasible to comment with any certainty regarding their position in past human subsistence. It would, however, not be surprising to find that the seeds had also been used as wild food resource.

Certainly, a number of *Atriplex* species have been used as such by inhabitants of the arid areas of North America who collected them by beating them into baskets and then preparing them by parching and grinding (eg. Bean and Saubel 1972:45). If these were used as a wild food resource their high frequency in the modern Atacama environment as well as their high productivity and ease of collection would quickly be expected to repay the time spent in collection.

The presence of animal bone and muscle fibres confirms that meat had been part of the "last meal". The size of the bone fragments would indicate a that they belonged to a relatively large animal but no diagnostic fragments were recovered. Small fragments of a plant tissue that resembled the cork layer of an underground storage organ, such as that of potato, was also identified.

Cas-Sur T-1B - This sample also contained considerable quantities of different *Prosopis* pod tissues. The other dominant component of this sample was *Schoenoplectus* fibre. This was highly fragmented and would suggest that the rhizomes had either been well chewed or subjected to some form of processing prior to being eaten. The data from table 2 suggest that *Schoenoplectus* and *Prosopis* had been consumed in roughly equal quantities. Fragments of unidentified stem/root tissue might indicate the consumption of a second underground storage organ. Relatively small amounts of *Chenopodium* seeds and fish scale were

also recovered as were a large number of acarid mites.

Cas-sur T-1C - This sample was very similar to the sample Cas-Sur T-1b but it contained the additional components of *Prosopis* sp. florets and quantities of an unidentified leaf.

The exceptional preservation of organic remains on sites in this and neighbouring valleys have already provided a wealth of data relating to prehistoric plant and animal exploitation (see the specialist reports by Kautz 1980, Williams 1980, and Tartaglia 1980). The composition of the gut samples supports evidence from these other sources. The highly productive *Prosopis* legume was constantly represented in quantity and varying amounts of other collected or cultivated plant remains were also present. The position of *Schoenoplectus* type rhizomes in the diet of inhabitants of Tarapaca, has already been briefly referred to by Nunez (1982:100) but has been shown to be of more importance than was previously believed. One conspicuous feature of the results was the lack of maize in the later sites. This was, in fact, in agreement with Nunez's (1989 pers. comm.) observations that only one example of maize was recovered from the whole of the TR-40A cemetery (from a partially disturbed tomb). The available data, however, may not be representative and do not provide an adequate explanation for this.

These samples have also given an insight into preparation techniques that were used in the valley. Some meals were apparently bolted with little processing while others had been conscientiously processed. (NB. the processing of *Prosopis* and *Schoenoplectus* have been discussed further in sections 4.5 and 6.5.2.). Curiously, the sample which would appear to have been most thoroughly processed (Pircas 2 T-6), was from a series of occupation deposits that have, to date, yielded very few grinding implements. In this case, it is evident that further data are required if this anomaly is to be clarified.

These samples are chronologically scattered around an important transition from an economy based upon the efficient exploitation of wild plant and animal (fish, camelid and rodent) resources with experimental horticulture, to one in which agricultural products, domesticated animals and a more sedentary life style were becoming evident (Nunez 1986). The development of the large walled town of Caserones (True 1980) is the most obvious evidence for moves towards sedentism but changes can also be seen in both the organic remains recovered from the sites and in the changing settlement patterns. The results from the analysis presented here support these other forms of data and clearly show that even as agriculture was becoming able to support more people in the valley the wild resources *Prosopis* legumes and *Schoenoplectus* rhizomes were not just cast aside in favour of agricultural products. They continued to be used throughout the period and must have provided, both - a certain safety

net against crop failure and famine, and also appear to have been used to supplement the more normal diet. Indeed, at Caserones, there was also some suggestion that these "wild" resources were in fact managed by methods such as irrigation of the *Prosopis* woods (Nunez 1986:27). It is also probable that management of the *Schoenoplectus* stands was also carried out (this has been discussed further in section 6.5.2.).

In addition to these major foods a number of the minor components deserve further comment here. The presence of acarid mites in sample Cas-sur T-1b is of some interest. The species of *Lardoglyphus robustisetus* belongs to a genus that has a preference for high protein foods (Baker in press.). It has therefore been suggested (eg. Williams 1980:197) that these mites may have been feeding on stored meat products and that they were accidentally consumed when this was eaten. Sample Cas-sur T-1c also some interesting minor components. These were the remains of *Prosopis* flowers and an unidentified leaf. The status of these in the "last meal" is unclear and it is equally possible that they represent the remains of food, flavouring or a medicinal concoction. These, together with some of the more general points relating to various food species have been discussed further in section 4.5.

4.4.) Samples from the Extreme North of Chile.

All of the samples of intestinal contents presented in this section were provided as a result of a series of detailed palaeopathological studies. An attempt was made to recover as many samples from each cultural group as possible but only rarely could this be achieved. In some cases therefore, only one or two samples from any particular site were available for study.

4.4.1) Geographical context.

The Azapa valley is one of a number of valleys in the extreme north of Chile that run westwards out of the Andes towards the Pacific Ocean. While the flow in the Azapa river is not continuous throughout the year, except when rainfall in the mountains is plentiful, the neighbouring valleys of the Lluta and Camarones do have a perennial flow (Llagostera 1989:61). Rainfall on the coast is practically unheard of, but the water supply from the river Azapa together with the relatively hot and humid atmosphere provide a fertile environment for a diverse flora and fauna. Travelling up these valleys a number of distinct and widely varying ecological zones can be defined (Rivera 1987, Santoro and Nunez 1987, Veloso and Kalin 1982, Villagran *et al.* 1982) in which plant cover can vary between 0.1% in the desert of the Precordillera and 70% in the high puna (Villagran *et al.* 1982:13) The nature of these zones are discussed briefly below .

4.4.1.1.) The Coastal zone 0-1500m.

The Azapa valley reaches the sea at a point where the Coastal cordillera comes to an abrupt halt in the form of the Morro de Arica and gives way to the broad sweeping coastal plane to the North. This low and sandy coastline to the north with strong ocean currents would have offered few food resources for people in the past but to the south the more varied coastline with numerous rocky inlets would have provided many opportunities for shellfish collecting and hand-line fishing (Willey 1971:202). Inland, along the valley floor, the river supports a varied biota and irrigation agriculture has been practiced here since prehistoric times. Important plant food resources in the form of the tree legumes *Geoffroea decorticans* (*chanar*) and *Prosopis* sp. (*algarrobo*) are plentiful today and around the water courses members of the Cyperaceae and other water loving plants can be observed. In contrast to the valley floor, the steep valley sides above the water table are virtually devoid of any form of plant life. It is in these areas that the ancient cemeteries are commonly found.

4.4.1.2.) Precordilleran valleys. 1.500-2800m..

This is the least productive of the four zones with a plant cover of approximately 10% (Santoro and Nunez 1987:59) in a dry, inhospitable environment. However, certain shrubs, and cacti (eg. Villagran *et al.* 1982:17) manage to eke out a sparse existence. The topography is

abrupt, as the dry slopes ascend towards the high pastures, and is of little economic value today although some species can be used as forage by grazing animals. A prehistoric human presence focusing on the exploitation of camelids and rodents has been demonstrated (Santoro and Nunez 1987:59).

4.4.1.3.) Cordilleran Valleys. 3000-4000m..

This zone is dominated by small, evergreen shrubs (*tolas*) which provide a rich forage for camelids, such as the guanaco, and for a number of different rodents and birds. Even though there is little land suitable for cultivation in this area the use of traditional forms of agriculture such as the *caracole* irrigation systems (sinuous, secondary flow canal systems) enable the present inhabitants to grow crops such as potatoes, maize, vegetables, beans, peppers, herbs and forage crops (Rivera 1987:227).

4.4.1.4.) High Puna. 4000-5000m..

This zone is dominated by highland grass species, and small shrub species also being abundant. Cushion plants, such as, *Azorella compacta* are also common in suitable localities. This diverse vegetation today supports large numbers of both domesticated camelids and the wild vicuna as well as numerous rodent species such as the viscacha in the rocky outcrops. Large numbers of birds live in and around the lakes and marshy areas. As Santoro and Nunez (1987:60) point out, this high percentage plant cover may

provide ample forage for animals but few species are known to provide food for humans. The climate is also too extreme to allow any form of reliable agriculture. Because of this, the main emphasis of human activity in this area is today, as it must have been in the past, directed toward the exploitation of animal resources.

As I hope to have shown in the preceding paragraphs the diversity of plant and animal resources available in these four zones is considerable. With abundant sea resources on the coast, suitable areas for agriculture in both the lower and Cordilleran valleys, and abundant wild animal resources in the puna, it is little wonder that much of the prehistory of the area revolves around ideas of a so-called "vertical economy" (eg. Murra 1980). The additional presence of resources from the tropical rain forests (*selva*) on the other side of the Andes from an early date (Rivera 1984:146, Rivera and Rothhammer 1986:295) adds weight to arguments for early forms of nomadism or trade. It is within this context that the following samples are discussed.

4.4.2.) El Morro 1-6 samples.

Since 1983 the site of El Morro de Arica has yielded a considerable number of well preserved bodies. Many of these were preserved by artificial mummification and have been linked to earlier discoveries by Max Uhle (1919 cited by Allison *et al.* 1984). Uhle originally described this culture as "Los Aborigenes de Arica" but they are

now more generally referred to as the Chinchorro mummies. Using data from this and similar sites to the south, however, Rivera (1984:146) and Rivera and Rothhammer (1986:295) divide the Chinchorro tradition into 3 distinct phases. Of these, the latest, (phase 3), is reported not to finish until approximately 2500 B.P.. The samples studied in this analysis, were recovered from El Morro in 1987 and were originally thought to be part of the earlier site (El Morro-1) dated between approximately 7810 and 4000 B.P. They were, however, later redefined as a separate group (El Morro 1-6) when C14 dating uniformly demonstrated dates of around 4000 B.P. They are therefore considered to be a sub-group of the Chinchorros representing the terminal part of that tradition (A.Aufderheide 1988 pers. comm.). All of the bodies were in an extended to very slightly flexed position with the majority having been wholly or partially wrapped in *totora* (cf. *Schoenoplectus* sp.) fibre matting or in one case by a bird feather blanket. In this respect and because of the dates given above, they would seem to fit into type 1.1 or 1.2 of the Chinchorro mummification sequence as outlined by Allison *et al.* (1984). The published data clearly show that the Chinchorro tradition has, from its earliest phase been reliant on an economy based upon the exploitation of sea food resources. The later phases, however, show a greater independence from the sea such that in Rivera's (Rivera and Rothhammer 1986:296) phase 3, cotton and wool are becoming more common. Evidence for *yuca* (cassava) and *quinoa* is becoming

My reference number. Location. Site. Context number. Context type. Source. Conversion factor to gram.		COPTH24E Arica, Chile. El Morro. Mo1-6 T-18 Gut contents. M.A. ÷ 1.7	COPTH24F Arica , Chile El Morro. Mo1-6 T-22 Gut contents. M.A. ÷ 2	COPTH24A Arica, Chile. El Morro. Mo1-6 T-32 Gut contents. M.A. ÷ 1.6	COPTH24G Arica, Chile El Morro. Mo1-6 T-33 Gut contents. M.A. ÷ 7.3	COPTH24I/1 Arica, Chile. El Morro. Mo1-6 T-46 Gut contents. M.A. ÷ 2.6	COPTH24I/2 Arica, Chile. El Morro. Mo 1-6 T-46 Gut contents. M.A. ÷ 2.2	COPTH24C Arica, Chile. El Morro. Mo1-6 T-53 Gut contents. M.A. ÷ 0.9	COPTH24B Arica, Chile El Morro. Mo1-6 T-56 Gut contents. M.A. x 4 ÷ 1.7	COPTH24D Arica, Chile El Morro. Mo1-6 T-U3 Gut contents. M.A. ÷ 0.5	COPTH24H Arica, Chile El Morro. Mo1-6 T-U7 Gutcontents. M.A. x 4 ÷ 3.6
Plants											
Chenopodium cf. quinoa (pale).	Seeds whole. Seed frags.										0.006 (13) 0.113
cf. Solanaceae	seed.			Trace (2)				Trace (1)			
Schoenoplectus type.	Rhyzome fibre.	0.040	0.011	Trace					0.104	0.018	0.002
Seeds indet.											Trace (2)
Epidermal fragments indet.											Trace.
Fibre fragments indet.		0.009									
Cork Layer indet.				0.005							
cf. Stem/Root tissue indet.				0.014							
Charred fragments.	Vesicular.			0.004	Trace			Trace			
	Seed indet.									Trace (1)	
	Indet.										Trace
Animals											
Cf. Marine invertebrate.				0.004							
Ceolenterate indet.				Trace							
Chlorostoma cf. atra (Mollusca)	Radulae large.	0.004 (1)									
Chlorostoma sp. (Mollusca)	small.	Trace (1)									
Fish	Bone.	0.118	0.071	0.090	Trace	0.008		0.008	0.208	0.005	Trace
	Scale.		0.044	0.002				Trace	Trace	Trace	
Animal	cf. connective.	Trace									
Unidentified organic debris.											
Fine fraction. < 1mm.		0.270	0.518	0.334	0.488	Trace	0.004	0.160	0.572	0.310	0.561
Large Fraction. >1mm.		0.046		0.159				0.016	0.024	0.006	0.086
Mineral fragments.		Trace	Trace	0.007	0.245	0.520	0.776	0.051	0.008	Trace	0.031
Total Weights		0.487	0.644	0.619	0.733	0.528	0.780	0.235	0.916	0.339	0.799

Table 3. Score sheet of the food debris from the site of El Morro, Northern Chile. Values given as grams dry weight per gram of gut contents.

more common and towards the end of the phase, experimentation in ceramics is evident.

A number of different samples from this group were made available and these were subjected to the procedure outlined in section 2.3.4.1.

4.4.2.1.) Quantification of the debris and the calculation of equivalent weights of undigested food.

The food debris was, wherever possible quantified by weight and have been presented in table 3. From this data it can be seen that the identifiable vegetable component of the debris was dominated by two species - *Schoenoplectus* type and *Chenopodium* sp. although not all of the samples contain either of these species. Table 4 shows equivalent weights of undigested food per gram of gut material which have been calculated as outlined in section 2.5.2.3. For these calculations the following percentage fibre values of the foods were used:

That for *Schoenoplectus* was calculated as shown in section 2.5.2.3. Those for *Chenopodium quinoa* were taken from the figures presented by Risi & Galway 1984:188). They give a value between 1.5% and 12.2% fibre, by weight, for *C.quinoa* with an mean value of 4.4%. The seeds recovered from this sample were pale seeded but with a relatively robust testa. The mean value of 4.4% has therefore been used here as the basis for conversion factors used in the calculations.

Sample.	Food type.	Weight of identified debris (dry weight).	% fibre present in th different foods.	Conversion factor. 100 ÷ %fibre	Equivalent weight of undigested food per gram of gut contents.
Mo 1-6 T-18.	Schoenoplectus sp. Mollusc radulae.	0.04gms. 2 radulae.	7 - 10 N/A.	10-14.3	0.4-0.57gms. 2 shellfish
Mo1-6 T-22.	Schoenoplectus sp.	0.11gms.	7 - 10	10-14.3	1.11-1.57gms.
Mo1-6 T-56.	Schoenoplectus sp.	0.104gms.	7 - 10	10-14.3	1.04-1.49gms.
Mo1-6 T-u3.	Schoenoplectus sp.	0.018gms.	7 - 10	10-14.3	0.18-0.26gms.
Mo1-6 T-u7.	Schoenoplectus sp. Chenopodium sp.	0.002gms. 0.119gms.	7 - 10 4.4	10-14.3 22.7	0.02-0.03gms. 2.70gms.

Table 4. Table showing the conversion of the major classes of food debris into equivalent values of undigested food per gram of gut contents. Samples from the site of El Morro, Northern Chile

4.4.2.2.) Discussion of the results from El Morro 1-6.

The samples from these bodies have yielded widely varying results. Unfortunately, only two of the samples contained more than one species that were suitable for the calculation of equivalent undigested food. Sample Mo 1-6 T-18 showed that one gram of coprolite contained the remains from approximately 0.40-0.57 grams of *Schoenoplectus* type rhizome, at least 2 *Chlorostoma* shellfish and an unknown quantity of marine fish. One gram of sample Mo1-6 T-U7 on the other hand, contained debris that represent only a trace of *Schoenoplectus* type rhizomes, 2.70gms of *Chenopodium* seeds and an amount of fish.

Of the remaining samples it is evident that some of them

probably do not represent the remains of ancient meals. The samples recovered from the body Mo 1-6 T-46, T-4 and T-33 for example, were found to be composed largely of coarse mineral debris. These are discussed further in section 4.5. All of the other samples contain quantities of organic debris although some samples (eg. Mo1-6 T-U3) show generally poor preservation of identifiable plant remains.

The remains of fish in the form of bones or scales were present in varying amounts from most samples. Of these, gill rays and spines were the most common bones although one sample (Mo1-6 T-18) contained substantial quantities of bones from the pharyngeal region of at least two species of fish (A.Wheeler 1988 pers. comm.). In addition to the strong evidence for the eating of fish this same sample revealed examples of the radulae of two different species of marine gastropod (*Chlorostoma* spp.). To the author's knowledge this is the first time that evidence of shell fish eating has been recovered from human coprolites and the first time that archaeological mollusc radulae have been used to make an identification of marine food resources.

Five samples contained the remains of the rhizomes of what are most likely *Schoenoplectus americanus*. The author has not identified this species himself growing in the Azapa valley but its abundance in other river valleys in the Atacama region would indicate that it was most

probably also present there. This is, according to Koyama (1963:1114), well within its ecological range. Further details relating to the use of this species have been presented in section 6.5.2.

The sample Mo1-6 T-U7 contained seeds of a pale-seeded variety of *Chenopodium*. The pale, thin testa of these seeds are an indication that they probably belong to domesticated *quinoa* and are therefore the only example of a cultivated resource in these samples. Other plant foods that were present included one sample of the remains of a distinctive cork layer (See section a2.2.21). This might indicate that potato or similar class of food had been consumed while other unidentified stem/shoot fragments were thought to belong to a further class of underground storage organ.

Only one example of possible animal connective tissue was recovered but it was not clear what type of animal this had come from. There was no other evidence to suggest the exploitation of terrestrial animals.

Given that these "mummies" are dated to about 4000 B.P. (A.Aufderheide 1988 pers. comm.) this will put them into the beginning of Rivera's third phase of the Chinchorro tradition (Rivera 1984:147, Rivera and Rothhammer 1986:296). The results of this study suggest a considerable emphasis on maritime resources that could either be caught by line or collected on the rocky shoreline and

shallow waters, characterised the diet of this population. They also tend to support Rivera's suggestion that this phase begins to see a greater independence from sea resources as the cultivation of new crops, such as *yuca* and *quinoa* begin to appear (although the former has not been identified in this project).

4.4.3.) Azapa - 6.

The ancient cemetery of Azapa - 6 has been tentatively dated to approximately 500 A.D. (Erices 1975:65) and is considered to belong to the Cabuza tradition in the Azapa valley (although some tombs of the later Loreto Viejo phase have also been recorded.). This cultural phase is notable for its distinctive stylistic links to the Tiwanaku culture centred around lake Titicaca in the high Andes. This is normally considered to have continued from 300 A.D. until 700 A.D.. Although there is no universal agreement relating to the exact nature of this highland influence and the gradual disappearance of the previous Alto-Ramirez culture, certain aspects of the economy are thought to be better understood. It is clear that this phase saw the introduction of new instruments of cultivation and agriculture in which techniques of artificial irrigation began to be employed. This, together with a considerable trade with the altiplano enabled the population access to resources such as maize, sweet potato, beans, *quinoa* , squash, gourds, coca and dried meat (Berenguer and Dauelsberg 1989:150, Erices 1975) by

either direct cultivation or trade with populations in other ecological zones. Relations with people living on the coast are less well understood. There is little evidence of Cabuza type ceramics on the coast but dried fish remains have been recovered from a number of tombs inland. Nevertheless, Berenguer and Dauelsberg (1989:150) support the hypothesis that, in this period, contributions from the altiplano were responsible for a greater proportion of the protein consumed in the valley than were marine resources.

A single sample was available from this cemetery. This was from Tomb T-6 which contained a female aged between 25 and thirty years (see appendix 1) who was found to have a quantity of well-preserved gut material in the abdomen.

4.4.3.1.) Quantification of the debris and calculation of the equivalent weights of undigested food.

The food debris has been quantified by weight and the results are shown in table 5.

The calculation of the equivalent undigested weight of maize caryopsis was carried out using the conversion factors presented in section 4.3.4. The details are shown in table 6.

My reference number.		COPTH22		COPTH28		COPTH20/6	COPTH20/1	COPTH20/3	COPTH20/5	COPTH20/4	COPTH20/2
Location.		Arica, N Chile.		Arica, N Chile.		Arica, N Chile.	Arica, N Chile.	Arica, N Chile.	Arica, N Chile.	Arica, N Chile.	Arica, N Chile.
Site.		Azapa 6.		Azapa 71.		Azapa 141.	Azapa 141.	Azapa 141.	Azapa 141.	Azapa 141.	Azapa 141.
Context number.		T-6		T-230		T-12	T-26	T-26 3A	T-26	T-28	T-46
Context type.		Gut contents.		Gut contents.		Gut contents.	Gut contents.	Gut contents.	Gut contents.	Gut contents.	Gut contents.
Source		M.A.		M.A.		M.A.	M.A.	M.A.	M.A.	M.A.	M.A.
Conversion factor to gram.		+ 3.5		+ 2.0 x 2					+ 3.2	+ 0.7	
Plants											
Chenopodium sp. (Dark)	Seeds whole.			Trace							
	Seed frags.	Trace									
Amaranthus cf. caudatus.	Seed.					Not	possible	to quantify		0.001 (10)	Not possible to quantify
	Utricle.									Trace (1)	
Capsicum sp.	Seed.	0.006 (4)		Trace							
Schoenoplectus type	Rhyzome fibre.			Trace							
Zea mays	Caryopsis base.	0.006 (18)		0.006 (7)							
	Pericarp frags.	Trace		Trace						0.001	
	Endosperm.									Trace	
Seeds indet.				Trace (1)							
Epidermal fragments indet.		Trace		Trace							
Stem/root tissue indet.		0.006		0.013							
Cork Layer .				0.003							
White organic crystals.				0.018							
Charred fragments.	Indet.	Trace									
Animals											
Insect Fragment indet.		Trace		Trace						Trace	
Fish.	Bone.	0.005		0.006							
Mammals.	Muscle fibre.	Trace									
Unidentified organic debris.											
Fine fraction. < 1mm.		0.251		0.273					0.172	0.244	
Large Fraction. >1mm.		0.015		Trace							
Mineral fragments.		0.009		0.125					0.734	0.002	
Total Weights		0.298		0.444					0.906	0.248	

Table 5. Score sheet for the food debris from the gut of a number of bodies recovered from the Azapa Valley, Northern Chile. Values given as grams dry weight per gram of gut contents.

Sample.	Food type.	Number of caryopses recovered	Mean weight of one caryopsis.	Conversion factors.	Equivalent weight of undigested food per gram of gut gut contents.
Az-6 T-6	Zea mays	18 caryopses	1 grain = 0.007	n/a	0.13gms.
Az -71 T-230	Zea mays	7 caryopses	1 grain = 0.007	n/a	0.05gms

Table 6.
Table showing the conversion of of the major classes of food debris into equivalent values of undigested food per gram of gut contents. Samples from the Azapa valley, Chile.

4.4.3.2.) Discussion of the results from Azapa 6.

On rehydration maize was found to be the dominant component although the equivalent weight of undigested material was still very low. A second major component is represented by *Capsicum* pepper seeds (4 per gram of gut material) but, interestingly, no remains of the fruit epidermis were recovered. The seeds were whole and had evidently not been milled. There were no traces of *Schoenoplectus* sp. fibre but it was of note that the few fragmentary remains of the testa of *Chenopodium* were of the dark variety. It was therefore not possible to say whether they had been cultivated or wild. A further plant food was represented by an unidentified association of

cork material and fibres possibly being the remains of a species of underground storage organ.

Of the animal remains, it is clear that fish must have played a substantial part in the last few meals but some samples of what are thought to be terrestrial animal muscle fibres were also present.

4.4.4.) Azapa - 71.

The cemetery of Az-71 is a large cemetery situated on an alluvial terrace close to the present cemetery of the village of San Miguel de Azapa. It is reported to be an area of high local salinity which provides for generally good preservation of bodies and other classes of organic artifacts. A number of tombs have been identified at Az-71 and these correspond to two separate cultural phases. The first of these from approximately 1300 B.C. to 300 A.D. includes elements of the Azapa and Alto Ramirez traditions while the later phase from approximately 300 B.C. to 1300 A.D. includes elements of the Cabuza, Maytas Chiribaya and Loreto Viejo traditions (Santoro 1980).

The single sample (Az71 T-230) was recovered from the abdomen of a flexed, intact human male aged about 12-13 years old. Preservation of the gut contents was generally good. This tomb has been classified by association with cultural artifacts associated with the body as belonging to the Cabuza tradition (described in section 4.4.3.).

4.4.4.1.) Quantification of the debris and calculation of the equivalent weight of undigested food.

The results of the analysis of the debris have been presented in table 5. The calculation of the equivalent undigested weight of maize caryopsis was carried out using the conversion factors presented in section 4.3.4.

4.4.4.2.) Discussion of the results from Azapa 71.

The sample was dominated by basal fragments and pericarp of maize caryopses. Smaller amounts of a pale seeded variety of *Chenopodium* sp., were also present. This therefore provided further evidence to support other classes of data regarding the agricultural systems being used in the valley (eg. Berenguer and Dauelsberg 1989:150). There is also, however, evidence for the continued use of wild plant resources such as *Schoenoplectus* type rhizome. The presence of fish bone shows that contacts with the coast still played a part in the economy of the population.

Quantities of an as yet unidentified dietary item was also represented by considerable amounts of fibre associated with fragments of cork tissue. These are considered to be the the remains of an underground storage organ although few of the fragments would appear to be of possible diagnostic value. A small fragment of what is probably a piece of *Capsicum* sp. (pepper) seed may indicate contact with the jungle areas to the east of the

Andes although this could also have been grown in the Azapa valley itself. The small size of this fragment prevents discussion of whether this was from a wild or domesticated pepper.

Of note in this sample is the observation that the smaller fraction, that is, less that 1mm. was estimated to be made up of 20% *Chenopodium* sp. seed testa, 30% unidentified cork layer and only 5% maize pericarp. This would indicate that possibly the *Chenopodium* seed and the unidentified underground storage organ had made up a larger part of the last few meals than was indicated by quantification of the larger fraction (ie. > 1mm.) alone. These had been considerably broken up and consequently their quantification by reference to the larger fraction only may have resulted in their being under-represented.

4.4.5.) Azapa - 141.

Samples were recovered from four bodies from the cemetery of Azapa 141. One of these bodies has been dated to 1000 A.D. (Aufderheide ms.) and although this is a late date for the Cabuza phase, which is usually considered to have finished around 700 A.D. (Berenguer and Dauelsberg 1989:147, Santoro and Ulloa 1985:8) the Azapa 141 cemetery autopsy reports suggest that they belong to this phase. Some general features of this tradition have been given in relation to the sample recovered from Azapa-6 (section 4.4.3).

4.4.5.1.) Quantification of the debris.

The samples were quantified, where possible, by dry weight (table 5) but the poor condition of the samples did not allow for the calculation of the equivalent weights of undigested food.

4.4.5.2.) Discussion of the results.

At least one of the samples was found to be made up almost entirely of coarse mineral material. This has been discussed further in section 4.5. Of the remaining samples the contents were disappointing. Two samples (Az-141 T-46 and Az-141 T-26) contained no identifiable food debris and solidified into a jelly like substance on rehydration. These have been interpreted as highly degraded body tissue or food debris.

Two samples did, however, produce identifiable food debris. The first of these (Az-141 T-28) was taken from the abdomen of a child of about 1 year and was found to be composed of a mixture of maize and *Amaranthus* sp. seed which was apparently unchanged by the process of digestion. Large quantities of starch were still present and the sample did not resemble most other coprolite material. A.Aufderheide (1989 pers. comm.), however, notes that the soft tissues of the back and trunk were absent. It was therefore considered likely that this sample represented contamination by food offerings that had been placed upon the body when it was buried and then

subsequently fallen into the body cavity as it decomposed (see appendix 1). Sample (Az-141 T-12) was made up of vegetable remains that were so degraded that they could be neither sorted nor quantified. On rehydration it was clear that the sample consisted of a number of pieces of highly fragmented but clearly discernible palisade tissue from a the testa of species of legume. There would appear to be two possible explanations for this:

a) That it was a poorly preserved sample in which the debris was highly degraded and largely unidentifiable;

b) That it was the remains of a highly processed food in which the legumes had been prepared in such a way that they would be suitable for a sick infant.

4.4.6.) Camarones Desembocadura (Camarones - 9).

The valley of Camarones is some 100 Km. to the south of the Azapa valley but in most respects conforms to similar ecological and cultural influences although the river itself, unlike the Azapa, has a perennial flow. There is little available information regarding the site of Camarones - 9 in the literature. The autopsy reports, however, put it into the Inca period (Standen 1985), that is, some time after approximately 1300 A.D. The samples were recovered from two individuals. The first (Cam-9 T-13), from tomb T-13 is recorded as being a male in his 60's although there is a possibility that he/she was, in fact, a hermaphrodite (Standen 1985). The second sample

from this cemetery (Cam-9 T-12) was from the body of a female aged between 35 and 40 years.

4.4.6.1.) Quantification of the debris.

The dry weight of the different classes of debris are shown in table 7. For the calculation of equivalent values of undigested foods, the fibre values for *Prosopis* sp. and from maize were used, as shown in section 4.3.4. The calculations are presented in table 8.

4.4.6.2.) Discussion of the results.

Interestingly, even though by this period irrigation agriculture was supporting considerable populations on the coast and in the lower valleys, wild resources were the dominant component in sample (Cam-9 T-13). Various different tissues from the pod of *Prosopis* sp. were present including the hard indigestible endocarp segments. Also present were florets of *Prosopis* which have been discussed further in section 4.5.

A further wild resource that was present in this sample was *Schoenoplectus* type rhizome which was represented by small fragments of the fibrous part of the tubers or rhizomes. Marine resources were present in the form of both fish bone and scales. The remains of a colonial marine invertebrate was most likely a contaminant of the sea food component of one of the last few meals and does not represent an item of any dietary importance.

My reference number.		COPTH23a.
Location.		N.Chile.
Site.		Camarones 9.
Context number.		T-13.
Context type.		Gut contents.
Source.		M.A.
Conversion factor to gram.		÷ 3.8 x 4
Plants		
Prosopis sp.	Seed testa.	Trace
	Endocarp segs.	0.004 (2)
	Pod Fibre.	0.033
	Florets.	0.003
Capsicum sp.	Seed.	0.001 (1)
Schoenoplectus americanus.	Rhyzome Fibre.	Trace
Zea mays.	Caryopsis base.	0.005 (27)
	Pericarp.	0.007
	Aleurone.	Trace
Seeds indet.		Trace (1)
Epidermal fragments indet.		Trace
Leaf fragments indet.		0.002
Animals.		
cf. Colonial marine invertebrate.	Calcareous skeleton.	Trace
Fish.	Bone.	0.003
	Scale.	Trace
Animal.	Bone.	
	Hair.	Trace
	Conective tissue.	Trace
Unidentified organic debris.		
Fine fraction. < 1mm.		0.527
Large Fraction. > 1mm.		Trace
Mineral fragments.		0.032
Total Weights		**0.616**

Table 7. Score sheet for the food debris from the gut of a body recovered from Camarones, Northern Chile. Values given as grams dry weight per gram of gut contents.

Evidence for the consumption of terrestrial animal species was also shown by the presence of what appears to be connective tissue and samples of mammal hair.

Sample.	Food type.	Measure of identified debris	% fibre present in the different foods.	Conversion factors. 100 +% fibre	Equivalent weight of undigested food per gram of gut contents.
Cam 9 T-6	Zea mays Prosopis endocarp. Prosopis total fibre	18 caryopses 2 segments. 0.037 gms.	n/a 1 seg= 0.24 gms 23.20	0.007 n/a 4.300	0.13 0.48 0.30

Table 8 . Table showing the calculation of eguivalent quantities of undigested maize from one gram of gut contents from the site of Camarones , North Chile.

The only possible cultivars recovered from this sample were a small quantity of *Capsicum* pepper seeds.

On rehydration of sample Cam-9 T-12 it could be seen to be made up of a quantity of very degraded plant foods. It was largely composed of plant vascular tissue, although one example of some highly degraded parenchyma was also recovered. This disintegrated as soon as any attempt at separation was made. Much of the darker-coloured and amorphous material in this sample would appear to be the remains of the decomposed gut wall. The survival of vascular elements indicate that, had other fibrous foods been ingested, they would probably have also been recognisable as such.

4.4.7.) Playa Miller - 6.

One degraded sample was received from the site of Playa Miller-6 for which very little data is available. The sample (PM-6 T-19) was recovered from the abdomen of a male aged between 30 and 35 years but was very poorly preserved. The only identifiable components were the bones of fish which were recovered from a matrix of generally amorphous organic debris (see table 9).

4.4.8.) Discussion of the results from the extreme North of Chile.

From the earliest period at El Morro 1-6, the exploitation of marine resources in the form of both fishing and shell-fish collecting (including by diving) seems to have been one of the main subsistence activities. Carbohydrate-rich resources in the form of plant foods such as *Schoenoplectus* type rhizomes complemented the marine foods and it is possible that the remains of pale-seeded varieties of *Chenopodium* sp. represent early attempts at agriculture. In later phases, such as the Cabuza phase, the results presented here tend to support other classes of evidence. They point toward the expansion of increasingly sophisticated methods of agriculture in which irrigation probably played an important part, linked with a lively trade in resources between coast and altiplano. This phase shows the use of maize, *Chenopodium* and *Capsicum* peppers with increasing regularity. However, even though agriculture was blossoming during

My reference number.		COPTH26.
Location.		Arica, N.Chile.
Site.		Playa Miller 6.
Context number.		T-19.
Context type.		Gut contents.
Source.		M.A.
Conversion factor to gram.		+ 0.5
Animal remains.		
Fish	Bone.	0.002
	Scale.	
Unidentified organic debris.		
Fine fraction. < 1mm.		0.224
Large Fraction. > 1 mm.		0.013
Total Weights		**0.239**

Table 9. Score sheet for the food debris from the gut of a body from Playa Miller, Northern Chile. Values given as grams dry weight per gram of gut contents.

the Cabuza period the use of wild resources continued to play a part in the diet and many aspects of earlier economies. Fishing and collection of *Schoenoplectus* rhizomes continued. The evidence from the gut remains does not tend to support the supposition that later periods saw a greater percentage of protein-rich resources being brought to sites in the Azapa valley in place of sea food resources (eg. Berenguer and Dauelsberg 1989:150). Fish resources in the form of bone and scale were recovered from most samples including the Inca sample from the nearby valley of Camarones (Cam - 9). The lack of evidence for the eating of protein-rich resources such as dried meat from the altiplano, may, however, be a result of the difficulty in recognising

this in digested food remains. Such is not the case with the fibre of *algarrobo* (*Prosopis* sp.) pods, which would, if present in the diet, have survived in a recognisable form. The absence of this major resource from all but one of the later samples is of some interest but the data do not allow for an adequate explanation of this at present.

4.5.) Discussion of the desiccated bodies from South America.

On points of detail the samples represent a diverse spectrum of states of preservation and composition. Nevertheless, there are a number of points of discussion that relate to more than one sample. These have been addressed below.

A number of samples contained quantities of sand or grit. Where this was present in small amounts it most probably represented mineral contamination of food from the crude pounding or grinding equipment used for processing. The substantial sand and grit component of some of the other samples, however, could not be explained in this way. There is evidence of humans eating sand in the literature, either, as Callen and Cameron (1960:39) suggest, to relieve hookworm infestation, or, as cited by Vermeer (1971), as part of general geophagic practices. It is unlikely, however, that the quantity of sand recovered here could have been from these sources. Aufderheide (1980 pers. comm.) notes that it is common for sand to

enter the rectum via the anus *post mortem*. This is a possibility but, it would seem more likely that the substantial quantities of material recovered from the abdomen of some of the bodies (eg. Mo 1-6 T-46/1, Mo 1-6 T-4, Mo 1-6 T-33) was the result of some kind of post-depositional disturbance. Possibly this involved the mixing of sand with visceral components during the early stages of putrefaction thus forming coprolite-like lumps in the body cavity as they dried out.

A number of the samples yielded data relating to food processing. Several of the samples from which maize was recovered contained the thickened basal parts of the caryopsis. With the large grained varieties frequently found in the andes today it is common to discard the basal part of the caryopses before eating. The varieties recovered here were, however, very small in comparison to these and it is probable that the whole grains could have been consumed without significantly reducing the palatability of the food. These fragments do not give any further indication regarding whether they had been processed by boiling and roasting.

In some of samples maize and *quinoa* were of only secondary importance to certain wild resources. One of these was the pods of *Prosopis* sp. (*algarrobo*). The presence of remains of the pods have been reported from numerous archaeological sites in Northern Chile (eg. Nunez 1981:98, Nunez 1983:182 (citing Bird 1979), Towle

(1961:55), Williams 1980) and it is evident that it was an important resource in the past. It is still regularly used today by the inhabitants of Northern Chile who make flour and fermented drinks from the sweet pulp. Children also frequently chew on the unprocessed pod. It has been reported ethnographically by D'Antoni and Solbrig (1977:192), Gunckel (1967:18), Latcham (1936:35), Ortiz (1969:14), and Yacovleff and Herrera (1934:291), but few details regarding processing have been recorded. Observations made by the author in San Pedro de Atacama, however, indicate that the pods are commonly sun dried before being pounded in a large mortar. Williams (1980) also reports that they are parched before pounding. This process separates the hard endocarp segments from the sweet, powdery mesocarp which could, if required, be removed by sieving.

Traditional used of *algarrobo* pod in many ways mirrors the use of the closely related species of *P.juliflora* (*mesquite*) in mexico and the Southwestern U.S.A. (eg. Felger 1977, Bean and Saubel 1972:107). With respect of this, it is interesting to note that the specialised gyratory crushers used by the Pinacate of Mexico for *mesquite* processing bear more than a passing resemblence to those recovered from a number of sites in North Chile.

Evidence for the processing of *Algarrobo* from coprolites is based mainly on the pod tissues that are present in the samples. For example, from Pircas 2 T-6 none of the

distinctive oseous segments or epicarp were present in the sample. Only small fragments of the distinctive fibre were identifiable. In this case this probably indicates that a relatively fine product was eaten. This is in sharp contrast with the samples from Tr40 T-6 in which all classes of pod tissue were identified thus indicating that little or no processing of the legume has taken place.

In addition to the pods a number of samples contained the flowers of *Prosopis*. Bean and Saubel (1972:108) record this practice with the closely related species of *Prosopis juliflora* from the Colorado desert of North America where they would be either roasted before eating or drunk as an effusion. While there is no evidence to suggest that the blossoms had been roasted in this case it would appear that the practices recorded from the North American deserts were also being carried out in Northern Chile.

The seeds of a species of *Chenopodium* were also recovered from a number of samples. On some occasions these were of a dark variety while others had a pale translucent testa. Generally speaking the thin pale testa is considered to belong to a more highly evolved domesticate than darker seeded varieties that more commonly resemble wild species. (see section a2.2.5.). There are, however, even today dark seeded varieties of *C.quinoa* (Risi and Galwey 1984:150) that are cultivated. In view of this it is not

possible to state whether the dark seeded samples from these gut contents were wild or cultivated. The paler varieties were, however, in all probability cultivated. Today *quinoa* is traditionally prepared by roasting, popping, boiling or grinding into flour.

Both highly fragmented examples (eg. Pircas 2 T-6) and more complete examples (eg.Mo1-6 T-u7) have been recorded during this project. These make it possible to identify those samples in which the seeds had been milled and those in which they had been prepared by some other means.

4.6.) Some implications of the results.

These samples have produced a broad range of animal and plant remains. The results were, however, clearly biased in favour of those foods that left hard or fibrous identifiable remains. Where these remains bore a consistent relationship to the original undigested foods it was possible to calculate, with varying degrees of accuracy, the quantities of original food consumed. Foods such as the seeds of *Chenopodium* sp. or the endocarp segments of *Prosopis* sp. proved particularly amenable to this type of manipulation. The uniformity of their size and shape made it relatively simple to calculate the approximate dry weights of the ingested foods represented by a given quantity of gut contents. Similarly, it should also eventually be possible, given relevant data on the growth characteristics, to suggest the actual weight of edible

flesh represented by the different sized radulae of species such as those of *Chlorostoma* (top shells) recovered from El Morro.

Other classes of foods left less clearly defined evidence of the original quantities eaten. For example, evidence for the consumption of small mammals, fish and, as yet, unidentified underground storage organs were frequently recovered. However, in addition to problems of identification, such foods showed no direct relationship between the identifiable food debris from the gut contents and the quantities of food originally ingested. These classes of foods therefore provide a much less clear picture of the relative proportions consumed.

An even greater problem is posed by food types which leave little or no identifiable remains in the gut contents even though other (non-faecal) sources of evidence suggest that they were of importance in the local diet. It is most clearly demonstrated by the lack of evidence relating to the consumption of large mammals, especially camelids from gut and faecal remains. This is at variance with evidence from bones, woollen textiles and rock art which all suggested that these probably played an important part in the economy during certain periods. This problem would seem to be inherent to reconstructions based purely on microscopic analysis of faecal debris and emphasises the importance of supporting such evidence from coprolites and gut contents with that from other

Age and Early Roman period in North Western Europe.

The idea that important data regarding past diet could be obtained from these bodies is not a new one. As far back as the 1950's such analyses were carried out on a series of Danish bodies from Borremose (Brandt 1950), Tollund (Helbaek 1950, 1958) and Grauballe (Helbaek 1958). These have produced considerable information regarding Iron Age foods in Denmark although questions related to how representative of past diet these may be, have still not been totally resolved.

As part of this project it has been possible to obtain a number of samples of gut residues from several different Northern European bog bodies. Some of these have not been studied before in detail but others have been subject to differing degrees of analysis. These are all discussed below.

5.2.) The Huldremose bog body.

The Huldremose bog body was recovered from a peat bog at Ramten, Djursland, Denmark in 1879. It has never been subject to conservation methods and over the years has gradually dried out. One C14 date of A.D. 30 $\pm$ 100 is available but this was based upon samples of textile which were supposed to have been associated with the body. There is, however, some doubt regarding the provenance of these textiles and new material has been submitted to the Oxford accelerator for dating. Detailed

studies of the body have been made by Liversage (1982), and later by Brothwell, Liversage and Gottleib (in press) who reported a number of interesting observations. Despite the at death lacerations to her legs, and amputation of one of her arms, followed by damage to her hands at the time of discovery, the condition of the body was remarkable. The abdomen and chest were not collapsed down onto the vertebral column as in many of the other bog bodies, and there remained a good chance that areas of gut had remained intact. In view of this, arrangements were made for the body to undergo a C.T. (Computed Tomography) scan. With the aid of this equipment it was possible to identify accurately the position of the remaining gut material in the body which showed up as a dense area in the lower abdomen. In consultation with the conservation department at the Nationalmuseet, Copenhagen, it was decided that it would be possible to sample the dense area with minimal damage to the body and approximately two grams of material were later extracted for analysis. A number of the techniques developed during this study have not been used before and are presented in more detail by Brothwell, Holden, Liversage, Gottleib, Bennike and Bosen (in press).

5.2.1.) The analysis of the gut contents.

Two samples of the gut contents weighing 0.35 and 0.95 grams were taken for analysis. The desiccated gut samples were then subjected to the rehydration procedure outlined in section 2.3.4.1. Contrary to the normal sorting

procedure, the greater than 0.5mm sample was sorted in addition to the 1mm. fraction, for cereal bran and seed testa material. In this way it was hoped that sufficient quantities of debris to weigh would be recovered. The sample was dominated by three categories of material:-

a) **Cereal debris** - This consisted of amounts of cereal bran some of which exhibited characteristics that were considered to be indicative of rye (*Secale cereale*). Most of fragments of bran did not retain these distinctive cell patterns and have therefore been put into a wheat/rye category. It would seem highly likely, however, that much of this material was, in fact, also rye.

b) **Weed seed component** - This was overwhelmingly dominated by the testa fragments of *Spergula arvensis* (corn spurrey).

c) **Other plant tissues** - This comprised a mixture of dicotyledon stem and capsule fragments that matched well with comparative examples of modern *S.arvensis*.

Trace amounts of other items such as weed seeds, siliqua and wood fragments together with small fragments of animal connective and mineral material were also recovered.

5.2.2.) Quantification of the debris from the Huldremose body.

The quantities and state of preservation of most of the debris was such that a four point subjective estimate was considered to be the best method of representing the samples. This is presented in table 10. The size, and abundance of both the cereal bran fragments (primarily testa fragments) and the weed fraction from these two samples were, however, such that they proved to be sufficient for a more detailed quantification based upon dry weight. To this end the cereal bran (which for the purposes of quantification was assumed to be rye bran) and the weed seed fraction were dried, weighed and equivalent undigested food calculated as shown in section 2.5.2.3. Values given for the percentage by weight of fibre in rye grain, taken from four different studies (Winton and Winton 1932:260), give an average value of 1.99%. For the purposes of this project, however, this value is probably too high. It is a notable feature of cereal bran that the outer layers of the pericarp (the longitudinal and transverse cell layers) degrade significantly on passing through the human gut. Few examples of the longitudinal cell layer remain attached to the testa in the Huldremose sample and the transverse cell layer was often considerably reduced. In view of this, the percentage fibre value used for this project has been reduced by approximately a third, to 1.3%. This is, however, probably a conservative estimate of the loss in weight of the fibre component of the grain and this figure may need to be reduced further

if more accurate data become available.

Data related to the fibre component of *S.arvensis* is not readily available and an estimate of the percentage by weight of the fibre component has had to be made on the basis of other similarly sized seeds. *Chenopodium album* was given a value of 14.63% fibre by Spinner and Bishop (1950) and Winton and Winton (citing various authors 1932) give values for *Raphanus raphanistrum* - 10.13%, *Amaranthus retroflexus* - 10.92% and various *Brassica* sp. - between 6.42% and 14.74%. The seeds of *C.album* have, however, thick seed coats relative to those of *S.arvensis* and a value closer to most of the other, similarly sized seeds with thinner testas of 11% would therefore seem to be more suitable.

These amended percentage fibre values for rye grain and corn spurrey seed have been used as the basis for conversion factors to give a more reliable estimate of their relative importance in the last meal of the Huldremose woman. The calculation of equivalent weights of undigested food based upon these conversion factors have been presented in table 11.

5.2.3.) Discussion of the results of the Huldremose gut analysis.

It was rye and corn spurrey seed that had made up the largest portion of the meal. The calculation of equivalent weights of undigested foods indicate that a

My reference number. Site. Location. Context type. Context number. Source		COPTH29/1. Huldremose. Denmark. Gut. 1a. D.L.	COPTH29/2 Huldremose. Denmark. Gut. 1b. D.L.
Plants			
Camelina sativa.	Testa frag. Siliqua.	+ +	
Spergula arvensis.	Testa frags. Seed without testa Calyx teeth. Capsule base. Stem/axil.	++++ +++(26) +++ ++ ++++	++++ +++(68) +++ ++ ++++
Polygonum cf. lapathifolium	Nutlet whole. Nutlet frags.	+(2) +	 ++
Fagus sp.	Wood frag.	+	
Dicolyledon leaf fragments.		+	+
Secale cereale.	Testa frags.	++	++
Setaria viridis.	Floret.	+(1)	
Triticum/Secale.	Bran frags.	++++	++++
Graminae indet.	Light chaff.	++	++
Indeterminate.	Testa frags.	+	
Charcoal fragments.		++	++
cf. Animal connective tissue.		+	+
Animal Hair.			+
Mineral indet.		+	+

Table 10 Score sheet for the food debris from the gut contents of Huldremose, bog body.

Sample	Weight of gut contents sorted.	Food type.	Weight of identified debris in grams dry weight.	% fibre present in the different foods.	Conversion factors.	Equivalent weight of undigested food in the total sorted gut contents.	Equivalent weight of undigested food per gram of gut contents.
1a.	0.35gms.	S. cereale. S. arvensis.	0.004gms. 0.011gms.	1.30 11.00	76.90 9.10	0.31gms. 0.1gms.	0.89ms. 0.29gms.
1b.	0.95gms.	S. cereale. S. arvensis.	0.013gms. 0.033gms.	1.30 11.00	76.90 9.10	1.0gms. 0.30gms.	1.05gms. 0.32gms.

Table 11. Table showing the conversion of the major classes of food debris into equivalent values of undigested food per gram of gut contents. Samples from the gut of the Huldremose Woman, Denmark.

mixture of approximately 3 parts rye to 1 part corn spurrey had made up the bulk of the "last meal".

Other parts of corn spurrey were also present in the sample including fragments of the capsule and stem. This might imply that parts of the plants had been eaten green although the presence of so many of the black seeds indicate that the plants must have been harvested close to maturity. It would seem more likely that it was the seeds that were the main focus of attention and that the presence of other parts of the plant represent residual unwanted fragments in a poorly cleaned product.

There is, an amount of ethnohistorical data available, relating the use of *S. arvensis* in Denmark. Steensberg (citing Hansen 1921:114) gives, in translation, an example from Brejning in West Jutland. In this area the people were poor and the children only had dry bread to eat

at school,

> "the bread was even partly made from *Spergula arvensis*, because rye was so sparse"

This combination exactly mirrors that represented by the food debris in the Huldremose samples. The relatively large fragments of cereal bran and seed testa, however, suggest that this same combination was probably eaten as gruel or as coarse bread although other preparation techniques such as roasting or crushing of the grain are possible alternatives that might also produce similarly sized fragments.

Few of the weed seeds had remained whole but a considerable number of testa fragments were larger than 1mm., suggesting that they too, had been only coarsely milled.

The ethnohistorical example given above, not only shows how *S.arvensis* seed was used but also links it with rye. *S.arvensis* is an aggressive competitor on light and lime deficient soils (Watson and Moore 1962:118) while rye can tolerate low fertility, acidic and dry soils (Jones 1981:108). These two species will therefore be expected to produce well on similar soils. There is a possibility therefore, that these two may even have been growing together, or in close association such as first year and second year crops in a system of shifting agriculture (see section 5.6.2.). The first of these possibilities is an attractive one but the lack of cereal chaff and the

presence of significant quantities of stem and capsule fragments from *S.arvensis* in the samples indicate that they were probably collected and processed separately.

A few fragments of the testa and siliqua of *Camelina cf. sativa* (gold of pleasure) have also been identified from these samples. This plant has been recovered in quantity from a number of Iron Age sites (eg. Helbaek 1954:255, Korber-Grohne 1988:393, van Zeist 1981:183) and the evidence indicates that it was probably cultivated in the past for its oil rich seeds. It is also a weed of corn, lucerne and flax fields (Clapham *et al.* 1962) and the small quantities recovered from the Huldremose samples indicated that these seeds were probably a contaminant in a meal rather than a deliberate inclusion.

5.3.) The Lindow II bog body.

The first evidence of the Lindow man was discovered in August 1984 during peat cutting operations on Lindow Moss, Cheshire (Stead and Turner 1985, Turner 1986). The initial title of "Lindow man" was given at the time, but in view of the discovery further human remains the term Lindow II has been generally adopted and is used throughout this thesis.

C14 dating revealed that the the Lindow II bog body was of some antiquity but this has suffered from a number of technical problems. At present, a date in the first century A.D. seems to be the most likely although it is

recognised that this date could be as much as 100 years in error (Gowlett *et al.* 1986). An examination of the body revealed that it was that of a young male (Bourke 1986:51) and that apart from the generally good state of preservation a substantial quantity of the lower part of the body had been lost during peat cutting activities. The upper part of the body, including the head and thorax, together with part of the lower right leg, had however, survived intact. A certain amount of decalcification of the bones had occurred resulting in considerable distortion. The anterior abdominal wall had become flattened against the vertebral column, nevertheless, it was possible to identify some internal features. Of these, part of the stomach and upper section of the small intestine were identified and their contents were taken for analysis.

5.3.1.) Analysis of the gut contents.

A preliminary analysis of a sample from the fundus and body of the stomach has already been made by Hillman (1986) and Holden (1986). These analyses indicated that the major part of the meal had been made up of a cereal component. The bran of wheat or rye and the chaff of barley were reported as being the most dominant features of the food debris. Further samples have since been analysed from this, and other parts of the gut in order to add to the data available.

Of the samples provided for analysis four proved to be

suitable for detailed study. These were:-

LP/EE Gastric content 4.3gms.

LP/EF Antrum content 2.2gms.

LP/EL Small intestine 5.8gms.

LP/EN Upper small intestine 6.8gms.

nb. Weights = wet weight.

The composition of all four samples proved to be in close agreement and were therefore considered to have been part of the same meal. They were all dominated by two classes of material - a cereal bran fraction and a cereal chaff fraction. These were supplemented with minor quantities of weed seed fragments, charred organic debris, moss leaves, fine animal hair and mineral fragments. Most of the cereal bran was characteristic of rye or wheat and can not, at this point, be used to distinguish between the two. A number of fragments of cereal chaff , however, confirmed that both spelt and emmer wheat were present. These included the glume bases of emmer recovered from the preliminary samples studied (Holden 1986) and degraded glume bases and rachis fragments of wheat from most other samples. It would seem likely therefore, that the majority of the wheat/rye bran fraction was, in fact, derived from wheat. In addition to this, traces of testa identified as oat (*Avena*) and barley (*Hordeum*) were also present in small quantities. Fragments of barley lemma, palea and rachilla were also recovered in substantial

amounts and indicate that barley had made up a substantial proportion the "last meal".

5.3.2.) Quantification of the debris.

All of the major classes of debris recovered from these samples were highly fragmented. Because of this, and the small sample sizes available, it was not considered practical to separate the different components such as the cereal bran and weed seed fragments for further quantification by weight. The results have therefore been presented as a four point subjective scale in table 12 as outlined in section 2.5.2.2.

5.3.3.) Discussion of the Lindow II results.

Information relating to how the food was prepared has been given in the discussions by Holden (1986), Hillman (1986:109), Robins *et al.* (1986), Sales *et al.* (in press). The size of the fragments of both the cereal bran and the associated weed seeds were consistent with it having been finely milled. The fragmentation of the barley chaff was compatible with it having been crushed although further experimental work concentrating on the relationships between patterns of fragmentation and processing techniques would be expected to throw more light on the situation. At present it is not possible to state whether the barley and wheat fragments were part of the same meal or whether they were prepared separately but eaten together. The data provided by E.S.R. (Electron

My reference number. Context type. Context number. Site. Location. Source		COPTH33 Gut. LP/EE Lindow Moss. Cheshire, U.K. I.Stead.	COPTH33 Stomach. LP/EF Lindow Moss. Cheshire, U.K. I.Stead.	COPTH33 Gut. LP/EL Lindow Moss. Cheshire, U.K. I.Stead.	COPTH33 Gut. LP/EN Lindow Moss. Cheshire, U.K. I.Stead.
Plants					
Sphagnum Moss.	Leaf.	++	++	+	+++
Brassica sp.	Testa frag,	+			
Chenopodium album.	Seed frags.		+	+	+
Polygonum cf. lapathifolium	Nutlet frags.	++	+	++	+
cf. Polygonum convolvulus	Nutlet frags.			+	+
Polygonum indet.	Nutlet frags.	+		+	
Rumex sp.	Nutlet frags.		+	+	+
Galeopsis type.	Testa frags.	+			
Alnus sp.	Charcoal frag.			+	+
Lampsana communis	Achene frags.	+			
Testa Indet.	Testa frags.	+			+
Triticum cf. spelta.	Glume base. Rachis frag.	+		 +	
Triticum. Glume wheat indet.	Glume.			+	+
cf Triticum sp.	Glume/rachis.	+	+	+	+
Triticum/Secale.	Bran frags.	++++	++++	++++	++++
Hordeum sp.	Rachis frags.			+(2)	+(1)
Hordeum type.	Bran frags.		+	+	
Hordeum/Rye.	Rachis.	+(3)		+(1)	
Bromus type.	Bran frags.	++	++	++	++
Avena sp.	Bran frags.		+	+	
Charred indet.		++	++	++	++
Animal Hair.		+	+		+
cf. Animal connective tissue.		+			
Mineral indet.		+	+	+	+

Table 12. Score sheet for the food debris from the gut contents of the Lindow II bog body.

Spin Resonance) by Robins *et al.* (1986) and Sales *et al.* (in press) indicated that the wheat chaff component had been heated to a temperature of between 200 and 250 degrees C. This therefore suggested that the wheat, at least, had not been eaten as a gruel which would have given a value of closer to 100 degrees C. A combination of the poor rising qualities of the cereals used (barley, emmer and spelt) and the presence of burned fragments of food have been used to speculate that they were eaten as an unleavened bread or "griddle cake". These burned fragments, however, could have been produced by a number of different means so their value to this argument may have been overstated.

5.4.) The Lindow III bog body.

The remains of a second well preserved bog body were first revealed by peat cutting activities at Lindow Moss in February 1987. As with earlier finds the first signs were noted some distance from the actual burial site by men working in the peat cutting depot. Following this discovery a detailed excavation was carried out in the hope that further parts of the body from both the disturbed area of the site and from within the remaining undisturbed stratigraphy, would be recovered. This operation resulted in the retrieval of over 70 pieces of the body. No head has yet been recovered, although there was speculation that an earlier recovered head from the Moss may have been part of this body. Provisional dates give a mean value of 1790 $\pm$ 40 years B.P (Housley 1990 pers.

comm.). Several of the pieces recovered were evidently parts of the trunk and were submitted to a detailed examination. Bone preservation was generally poor but a number of vertebrae had survived. These enabled Bourke (pers. comm.) to isolate parts of the abdomen and thorax which had been virtually turned inside out by the action of the peat cutting machinery. Nevertheless his analysis enabled him to identify the body as being that of a post adolescent male and fragments of body tissue that were thought to be part of the gastrointestinal tract were removed for later examination.

5.4.1.) The analysis of the gut contents.

The following samples were studied in detail. Weights = wet weight.

LW/EW	cf. faeces 5.5gms.
LW/EX	cf. faeces 4.3gms.
LW/EY	intestinal contents 3.6gms
LW/FG	colonic content 5.9gms.
LW/FH	colonic content 2.4gms.
LW/FJ	colonic content with adherent faeces 12.8 gms.
LW/FO	rectal passage 1.1gms.
LW/FP	stomach wall 4.4gms.
LW/FR	stomach contents 3.0gms.
LW/FS	duodenal wall 13.77.
LW/FT	duodenal contents 0.7 gms.
LW/FU	transverse colon and adherent

faeces 26.8gms.

LW/FV transverse mesocolon 12.0gms.

LW/FW gastrointestinal debris 8.6gms.

The initial results were disappointing with many of the samples yielding no remains of food debris. Samples, such as LW/EW, LW/FR and LW/EX, which were thought to originate from the gut proved to be made up of an amorphous brown organic material into which *Sphagnum* moss leaf had become embedded. These were assumed to have been either the remains of a non-fibrous meal, or, more probably, highly degraded and compacted body tissue or gut residue. Two samples did, however, yield evidence of identifiable plant debris. These were a sample of the intestinal contents (LW/EY) and a sample of the colonic contents (LW/FJ). Both samples consisted of substantial quantities of moss leaves and stems and other indeterminate vegetable material intermixed with fragments of highly degraded cereal testa and the remains of other food plants.

It was the testa and brown inner layer of the pericarp of *Corylus avellana* (hazel) that were the most abundant food resource in the samples. In addition to this there were quantities of cereal bran that were typical of either wheat or rye (*Triticum/Secale*) and very rare examples of testa fragments that matched best with those of barley (*Hordeum* sp.). One or two fragments of weed seeds were also present in very low quantities.

5.4.2.) Quantification of the debris.

Unfortunately, the nature of this contamination, the small sample size and the highly fragmented nature of the debris made any form of detailed quantification impractical. As with the Lindow II body, a four point subjective assessment of the composition was therefore made, as outlined in section 2.5.2.2. This has been presented in table 13.

5.4.3.) Discussion of the Lindow III results.

The intestinal and colonic contents showed a close agreement in their composition but the small quantities available, and contaminated nature of these samples did not lend themselves to detailed interpretation. As with the Lindow II sample, the diversity of food remains represented in the debris was not high. It would appear that hazel nuts made up the largest part of the "last meal" with much smaller amounts of the bran of wheat or rye also being present. None of the more diagnostic chaff fragments were recovered thus making a more detailed identification impossible.

The size of the cereal bran fraction of the debris was indicative of it having been finely milled. In contrast to this, the size of the hazel testa fragments were consistent with having been eaten raw or only coarsely processed by pounding or some other crude preparation technique.

My reference number. Site. Location. Context type. Context number. Source		COPTH34/1 Lindow III. Britain. Intestine. LW/EY. I.S.	COPTH34/1 Lindow III. Britain. Colon. LW/FJ. I.S.
Plants			
Sphagnum moss.	Leaf/stem.	+ + + +	+ + + +
Raphanus sp.		+	
Chenopodium album.	Seed frags.	+	+ +
Polygonum cf. lapathifolium	Nutlet frags.	+ +	
Corylus avellana	Testa. Endocarp.	+ + + + + + +	+ + + + + + +
Juncus sp.	Seed.		+
cf. Bromus sp.	Bran frags.	+	+
Hordeum sp.	Bran frags.	+	+
Triticum/Secale.	Bran frags.	+ +	+ +
Charcoal fragments.		+ +	+ +
Mineral indet.		+	+

Table 13 Score sheet for the food debris from the gut contents of the Lindow III bog body.

5.5.) The Zweeloo bog body.

This body was recovered from a small bog close to the village of Zweeloo in the province of Drenthe in the Netherlands. The body is not complete and the head, hands and feet are missing. It is the body of an adult but the sex is unknown (Van der Sanden pers. comm.) and has been dated by C14 to 183 ± 40 B.C. Van Zeist (Van der Sanden 1990) has made a detailed study of the macroscopic remains from the gut during which he identified substantial quantities of the chaff of millet (*Panicum miliaceum*) and seeds of blackberry (*Rubus fruticosus*). Also present were fragments of the seeds of linseed (*Linum usitatissimum*) and a species of *Brassica*. Van Zeist also recorded the presence of cereal bran but no further analysis of this was made at the time. Two samples from the stomach of the body were subsequently made available for the present project (by kind permission of Dr. Van der Sanden, Museum of Assen).

5.5.1.) The analysis of the Zweeloo samples.

The samples had been subsampled before being received and one had dried out. This was rehydrated in trisodium phosphate and the wet sample was re-suspended in water before sorting. The bran fragments were composed of the cereals wheat/rye (*Triticum/Secale*), barley (*Hordeum* sp.) oats (*Avena* sp.) and probably brome grass (cf. *Bromus* sp.). These are only present in small amounts and are highly degraded. Also present but as yet unidentified were

fragments of what appear to be leaf epidermis.

5.5.2.) Quantification of the debris.

The fragmentation of the cereal bran and weed seed element were too small to be quantified by weight so a subjective estimation of the composition using a four point scale was used. This has been presented in table 14. The millet chaff fraction and the blackberry seeds were present in the larger of the two samples in sufficient quantity to attempt a reconstruction of the equivalent weight of undigested food.

According to Winton and Winton (1932:124) the fibre content of foxtail millet (*Panicum miliaceum*) varies between 6.38% and 10.89%, in addition to this, Kuzayli *et al.* 1966 give a value of 7.6%. The figure of 8% would therefore seem to be a reasonable value to use as the basis for a conversion factor. The calculation of the equivalent undigested quantities of blackberry was considered to be best calculated using the number of seeds recovered. On the basis of a number of fruits examined in 1989 an average of 43 seeds per fruit was calculated. These calculations are shown in table 15.

5.5.3.) Discussion of the results.

A detailed report on these samples by Van Zeist is presently in press so the discussion has been be restricted largely to the cereal bran identified as part of

My reference number. Site. Location. Context type. Context number. Source		COPTH30/1. Zweeloo. Holand. Gut. a. W.vS.	COPTH30/2 Zweeloo. Holand. Gut. b. W.vS.
Plants			
Sphagnum Moss.	Leaf.	+	+
Brassica sp.	Testa frag.	+	+
Spergula arvensis.	Testa frags.	+	
Linum usitatissimum.	Seed frags.	+	+
Rubus fruticosus. agg.	Seed frags.	+++ (38)	++ (3)
Polygonum cf. lapathifolium	Nutlet whole. Nutlet frags.	+ (1) +	
Galeopsis sp.	Testa frags.	+	
Avena sp.	Bran frags.	+ +	
cf. Bromus sp.	Bran frags.	+	
Hordeum sp.	Bran frags.	+ +	+
Panicum miliacium.	Floret. Chaff. Testa frags.	+ (1) + + + + +	++++
Triticum/Secale.	Bran frags.	+	
Graminae indet.	Light chaff.	+	
Indeterminate.	Testa frags.	+	
Charcoal fragments.		+	+
Animal Hair.		+	
Insect fragments.			+
Mineral indet.			

Table 14 Score sheet for the food debris from the gut contents of Zweeloo, bog body.

this project. This new data relating to the Zweeloo samples was in accordance with data from the pollen analysis of the gut contents of Troostheide (1990) who had previously identified a number of cereal pollen types for which no evidence had been reported from the macroscopic plant remains. He indicated that in addition to substantial quantities of *Panicum miliaceum* pollen, the classes *Triticum* type, *Avena* type, *Secale* and *Bromus* type were also present. All of these have been identified in low quantities in the present analyses. The size of the wheat and barley bran fraction would suggest that it had been finely milled but it was present in such low quantities that it was possible to do little more than note its presence.

Sample	Weight of gut contents sorted.	Food type.	Measure of identified debris.	% fibre present in the different foods.	Conversion factors. 100 +% fibre	Equivalent weight of undigested food in the total sorted gut contents.
a	0.22 (dry)	Panicum miliacium Rubus fruticosus	0.126 gms. 38 seeds	8.00 n/a	12.50 44 per fruit	1.58 1 fruit
b	0.52 (wet)	Panicum miliacium Rubus fruticosus	0.01 gms. 3 seeds.	8.00 n/a	12.50 44 per fruit	0.12 0.1 fruit

Table 15. Table showing the conversion of the major classes of food debris into values of undigested food. Samples from the gut of the Zweeloo bog body, Holland.

It is noteworthy that the presence of blackberry is possibly an indicator of the season in which the last meal was eaten. Although blackberries can be stored in a variety of ways, for example, by drying or jam making there is a possibility that they were eaten fresh. If this was the case it would indicate a season of death between August and October. Interestingly, no remains of the epicarp (outer skin) were recovered from these samples.

5.6.) Discussion of the bog body analyses.

The following discussion is based upon the data provided by this project. Certain, accompanying analyses that could have a significant bearing upon the discussion have, however, not yet been completed. Of these, further C14 dates for the Huldremose woman and parasite and pollen analyses for the Huldremose and Lindow III bog bodies are eagerly awaited.

One of the most noticeable features of the samples is that the diversity of the debris is not as great as the samples recovered from the previously studied bodies from Grauballe, Tollund and Borremose (Brandt 1950, Helbaek 1950,1958). The more recently examined Lindow, Huldremose and Zweeloo samples are made up of one or possibly two major plant resources which would seem to have been relatively pure in composition. Other remains that were recovered were present in only small quantities.

5.6.1.) The cereal component.

The cereal component of these gut samples were not at variance with many of previously published inventories of cultivated plants from the Iron Age/Roman period. Unfortunately, it is often not possible to identify to species level, the crops eaten, from the remains of the bran alone. For example, where preservation is poor it is often not possible to distinguish rye from different species of wheat, nor is it possible to separate cultivated and wild species of oats or barley. Because of this, it was often only possible to put the bran into broad categories unless supporting evidence from more diagnostic cereal chaff was available.

Rye would appear to have been the major component of the Huldremose woman's "last meal" although the presence of wheat can not be ruled out. The antiquity of rye in Northern Europe has been a point for discussion for a number of years but there is now evidence for its introduction before the Roman period (Chambers 1989, Chambers and Jones 1984, Van Zeist 1981). Chambers does, however, believe that rye was not of great importance in Denmark and the low countries until the early first millenium A.D. If this is the case, the Huldremose sample could represent an early find in this area.

The evidence for wheat (both emmer and spelt in the Lindow II sample was definitely identified, only from the Lindow II body. In all other samples, bran fragments of

wheat could not be distinguished from those of rye. The presence of wheat was of little surprise as it has been a major resource from the neolithic period. Of more significance is the presence of emmer in the Lindow II samples because at this time in Britain this species is thought to have been being replaced by spelt wheat (eg. Jones 1981:106). In this case, there was evidence that emmer and spelt were being eaten together.

With the exception of the Lindow II sample, barley was poorly represented in the samples in comparison its occurrence in charred archaeological assemblages from approximately the same period (eg. Monk and Fasham 1980, van Zeist 1981). This was thought to be partially due to the fact that the testa and pericarp have a tendency to survive badly in comparison with cereal bran from other genera. Dickson (1989:138) has shown experimentally, that the cell structure is highly degraded as a result of pearling followed by boiling. In spite of this, fragments of barley bran are recovered regularly, but at a consistently low level. This would seem to imply that certain areas of the testa survive more readily than others. There is a clear gap in our understanding of the taphonomic processes involved during the preparation and digestion of barley and there is an urgent requirement of further experimental work in this area.

The testa of oats was also commonly present in low quantities though in some samples such as the Lindow II

sample they were highly degraded. In such cases, the difficulty in recognising the bran may mean that they have been under-represented in the species lists. It would seem likely that oats were, in fact, being grown in parts of Britain during the Iron Age (Jones 1981:108) although the evidence tends to suggest that they do not become an important cereal until the Saxon period (Green 1981). The low quantities of oat bran in these samples, however, do not suggest that they were a major part of any of the "last meals" and it is more likely that they represent the remains of tolerated crop contaminants rather than deliberate additions to the prehistoric meals analysed here.

5.6.2.) The weed seed element.

It is clear from the reports of Brandt (1950) and Helbaek (1950, 1958) relating to previously discovered bog corpses, and from other reports (eg. Helbaek 1954), that a number of predominantly segetal weed seeds played an important part in the domestic economy of Iron Age Denmark. The combination of a cereal component and an abundant weed seed element in the Huldremose samples therefore conforms to an already recognised pattern. Helbaek (1950, 1958) reported that the Grauballe man had eaten a meal in which *Spergula arvensis*, *Polygonum lapathifolium/persicaria*, *Polygonum convolvulus* and *Chenopodium album* together with a number of grass caryopses had made up the weed seed element. The Tollund

man (Helbaek 1950), on the other hand, had eaten barley with a substantial amount of *Spergula arvensis*, *Polygonum lapathifolium/persicaria*, *Polygonum convolvulus*, *Chenopodium album*, *Camelina linicola*, *Linum usitatissimum* and *Viola arvensis*. Finally, the Borremose corpse (Brandt 1950) had been eating *Spergula arvensis*, *Polygonum lapathifolium/persicaria*, and *Chenopodium album* with the addition of *Rumex acetosella*. No cereal element was noted in this case.

In comparison with these earlier reports, those presented in this thesis are unusual in respect of the lack of weed seeds represented. Only the Huldremose sample contained a substantial weed seed element. This was, however, dominated by the seeds of only one species - *Spergula arvensis*.

There is little room for doubt that these seeds were not accidentally incorporated into the ancient meals of the Grauballe, Tollund, Borremose and Huldremose people. They must have been, at very least, a tolerated component but were, more probably included deliberately. In support of this, Steensberg (citing Hansen 1921:114, 1941:122 in translation) gives two examples where weed seeds (*S.arvensis*, *R.acetosa* and *P.convolvulus*) were mixed with cereal grains in order to make bread. More recently, British prisoners reported being fed on pearl barley and cakes of weed seed during the last war (Blythe 1969:46). Thus, in respect of the Huldremose sample, it is

reasonable to suggest that rye and corn spurrey had been deliberately mixed in order to make a gruel or coarse bread. The literature indicates that there are three ways in which these weed seeds could possibly have been procured for consumption:

a) **Collection from field and other environments** - Helbaek (1958:114) suggested that these would have been collected from areas of fallow or waste land.

> "In the poorer districts of Jutland, the land had to lie fallow for long periods, and, arable land being thus restricted, the peasants could not afford to disregard the food value of the wild plants which sprang up on otherwise unproductive land".

b) **Recovered from the waste fraction of crop processing** - Hillman (1986:102) suggests that both the weed seed component and the cereal chaff fragments are typical elements in the composition of the "waste" fraction from crop processing. This, he comments, could have been saved from the previous year and used as a means of stretching out meagre supplies during years of scarcity in much the same way as Maurizio 1927 (cited by Hillman 1986) recorded ethnographically.

c) **Deliberate cultivation:** As Professor Axel Steensberg has kindly pointed out, (pers. comm. citing Hansen 1939:75) crops of *Spergula arvensis* were grown separately in Denmark even as late as the 1850's. He also translates Hansen (1959:110) with regard to the a system of shifting agriculture in the area of Kolkaer South of Herning, that

> "when they had burned the heather and taken one or two crops of rye, they used to sow *Spergula arvensis* the next year".

They also grew *Rumex acetosa* in this way. Unfortunately, however, it is not clear with a number of these references whether the crops were planted with the intention of it being for human or animal consumption. It is probable, however, that distinctions between what was considered to be fit for animal and human food, or what was a fallow field and what was a secondary crop, were not clear cut and must have become further blurred in times of food shortage.

Most probably, all three of these methods of procurement were important during the Iron Age. The presence of certain chaff elements such as those recovered from the Grauballe sample (ie. even whole spikelets of wheat) would, however, tend to support Hillman's (1986) suggestions in this case. Other samples such as that from the Huldremose body, on the other hand, contained virtually no cereal chaff and the weed seeds were more probably harvested separately from either,

cultivated fields or, from the wild.

One point of note is that of all of the bog bodies so far studied in detail, only those from Denmark have yielded the substantial quantities of the weed seeds discussed above. Whether this is as a result of the unreliable yields of cereal agriculture on the generally light soils in this area or as a result of other social, ritual or political pressures remains to be seen.

In the samples from Lindow II, Lindow III and the Zweeloo body, weed seeds played only a very minor part in the "last meals". Remains of *Bromus* sp., *Brassica* sp. *Raphanus* sp. *Polygonum* sp. *Rumex* sp. and *Galeopsis* were all present in trace quantities. They are all common weeds of agriculture and are probably best interpreted as minor contaminants of the cereal element in the diet.

5.6.3.) Other components of the "last meals".

Only two of the samples contained substantial resources that had originated from plants that were neither cultivated nor associated with cultivation. The Zweeloo samples contained the seeds of blackberry (*Rubus fruticosus* agg.), but, interestingly no remains of the fruit itself were recovered. The Lindow III samples on the other hand yielded amounts of the testa of hazel (*Corylus avellana*). That these resources were

being exploited should be of no great surprise. Both must have been plentiful in the Northern Europe at this time. The presence of hazel close to the site of interment was confirmed at Lindow by pollen analysis from peat in the vicinty of where the Lindow III body was discovered (Branch pers. comm.). These resources were most probably used to supplement agricultural produce in the past in much the same way as they do today.

There was evidence of meat consumption in very few samples. This has been in the form of small fragments of largely structureless, rubbery material with a distinctive glossy appearance under light microscopy. One or two individual hairs were recovered from some samples. These were all small, with very delicate scale patterns but it is unlikely that it will be possible to make a species identification of these. As with the Lindow II hairs, (Holden 1986 citing Priston pers. comm.) they were very fine and other than being mammalian body hair there is little more that can be deduced at this stage. Whether such animal hairs were the remains of a meal or a contaminant of food was impossible to say.

Finally, there are three classes of frequently recovered material that were assumed not to have been deliberately consumed as part of the diet. The first of these were contaminants from the bog itself. This

included moss and other vegetable fragments that have contaminated the samples after their deposition in the bog (eg. Lindow III). In other cases, as with the Lindow II body, moss leaves were recovered from within the faecal matrix with little chance that post depositional contamination had occurred. These *Sphagnum* leaves were therefore probably ingested with drinking or cooking water taken from the bog environment.

The other contaminants were possibly the result of contamination during the preparation of the food. This fine mineral component of many samples are thought to have been the result of the processing of cereals and other foods on primitive grinding equipment from which tiny stone fragments frequently became detached. Small fragments of burned food or charcoal were also commonly recovered. This type of material had probably been allowed to contaminate food as a result of the untidy cooking methods. The burning of small parts of the food and contamination of the food by fragments of fuel (both charred and uncharred) would have been an inevitable consequence of using open fires for cooking. There is no evidence for deliberate burning in any of the samples and in no samples is this contamination more than slight.

5.6.4.) Seasonality and ritual.

As outlined in chapter one, questions relating to seasonality and ritual are among those potentially answerable from analyses of the gut contents.

With respect to the season in which the meals were eaten, the data do not add significantly to the picture. Most of the resources identified, are readily stored, and because of this could have been eaten at any time during the year. The only possible exception to this could be the blackberries eaten by Zweeloo man which, if eaten fresh would indicate that he had died in the late summer or autumn.

From the macroscopic remains studied in this project there was nothing that could be considered to have been obviously ritual in nature. Even though there is a wealth of data that indicate that the bog body phenomenon is an expression of Iron Age ritual, there is, to date, nothing to link the composition of these "last meals" with other ceremonial acts that evidently surrounded the deaths of the unfortunate victims.

5.6.5.) Some implications of the results.

Although it was originally hoped that it would be possible to quantify accurately the food debris from all of these samples, only those from the Huldremose and Zweeloo bodies proved amenable. With the samples from

Lindow, the small sample size and finely comminuted food fragments made it impossible to do more than produce a four-point subjective assessment and illustrated that the methods of food processing used before eating also affect our ability to identify and quantify the debris and thus introduce yet another bias into the analysis.

As with the samples analysed in chapter 4, it is apparent that certain dietary components, especially meats and other animal products (eg.eggs or milk), were probably under-represented in the results. Fragments of what appear to be degraded leaf cuticle in the Zweeloo samples also give a tantalizing hint of other foods such as root and leaf vegetables that were conspicuously absent from the list of food species identified. It is therefore clear that these analyses were able to provide an accurate picture of only the relatively small number of foods that leave resistant, identifiable remains in the gut. Nevertheless, as illustrated by the analysis of the samples from the Huldremose bog body, it is possible to generate important data relating to the relative proportions of an admittedly limited proportion of dietary constituents if suitable techniques are applied.

Chapter 6 - Coprolites, Gut Contents and Flotation Samples from Tulan, Northern Chile.

6.1.) Introduction.

The area around San Pedro de Atacama in the second region of northern Chile is rich in archaeological remains. In many respects it is a marginal area for human habitation but sites from all periods frequently lie exposed at the surface and the hyper-arid environment commonly results in exceptional preservation of organic remains. The potential therefore exists for detailed study of past settlement, economy, and subsistence based upon classes of debris that do not normally survive in archaeological contexts. The quebrada of Tulan is situated on the eastern shore line of the Salar (salt lake) de Atacama, some 114 Km. to the south of the town of San Pedro de Atacama by road. Here, at the site of Tulan 54 (see figs. 4 and 5) the good preservation of organic remains has resulted in the accumulation of a midden, rich in plant and animal remains and over one and a half metres in depth. This midden was excavated and flotation of distinct strata for recovery of organic debris including a number of human coprolites was undertaken.

In addition to this, two, well preserved bodies from a nearby cemetery produced samples of gut material for

analysis and a second midden, some kilometres from the first, produced more flotation samples. With this series of three sites the potential therefore exists to compare and contrast data relating to diet and subsistence activities from three complimentary sources - coprolites, gut contents and flotation samples. Data from the dry sieving operations were also available.

6.2.) Geographical context.

In contrast to the puna of the North of Chile (see ch. 4) the high altitude human occupation. This area is made up of a very different series of interrelating ecosystems that have necessitated the development of an alternative set of human adaptive strategies. It rains very occasionally in the Atacama desert, below approximately 3100m. although above 4000m. Lynch (1986:148 citing Stoertz and Ericksen 1974) estimates that irregular rainfall probably averages 100-200mm. each year. Villagran *et. al.* (1981:6 citing Di Castri and Hajek 1976), support this, and give figures from Calama (2260m altitude) of 0.0mm rainfall each year and 70.6mm. from Ollague (3700m. altitude) with mean annual temperatures of 13.3C and 6.8C respectively. The timing of this rainfall is very unpredictable, although the majority falls in the summer months between December and February. This climatic regime and rapidly changing topography has a dramatic effect upon the local flora and consequently upon the animal and human life that it supports. From work near Toconce, some 200km. to the North, Villagran *et. al.* (1981) identify four major

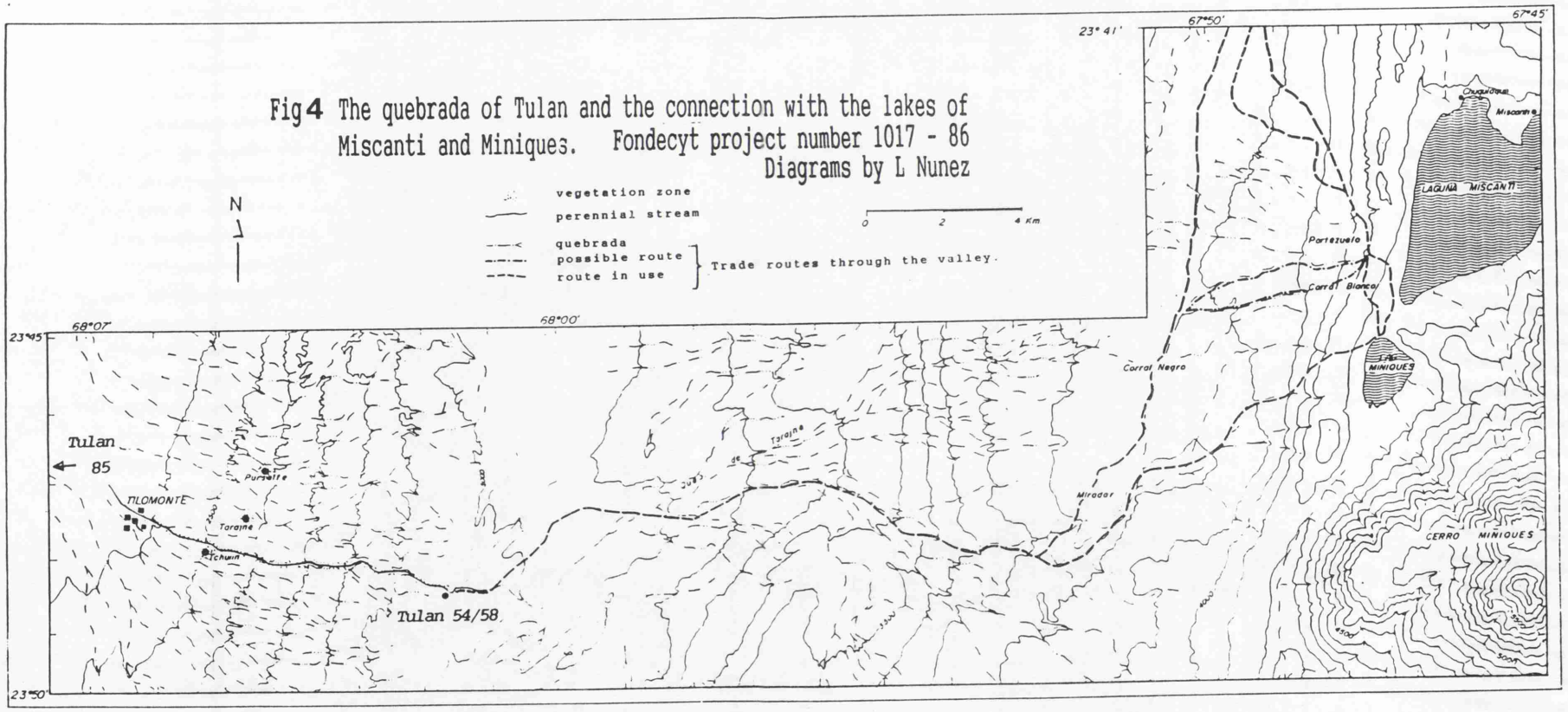
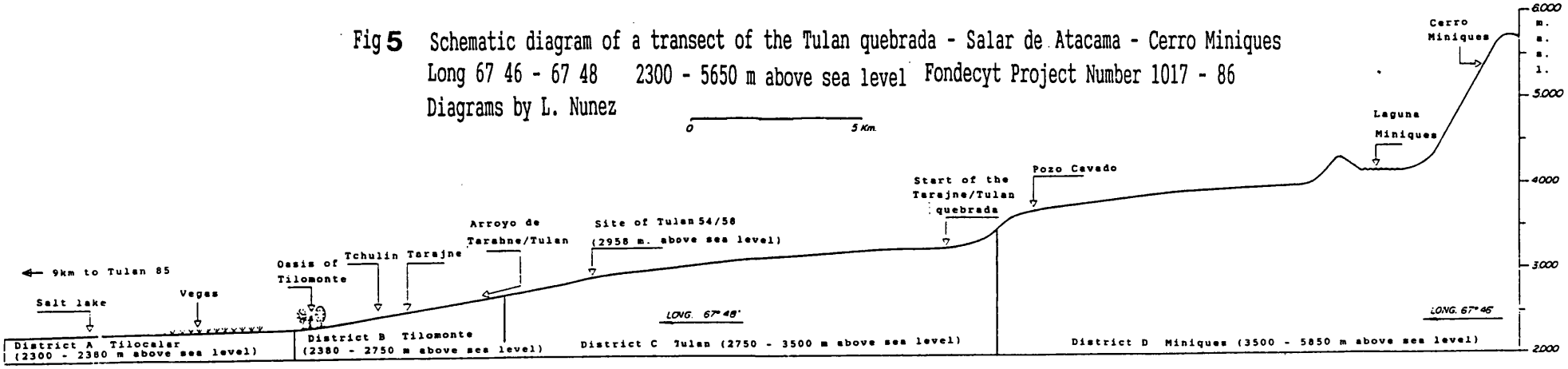


Fig 4 The quebrada of Tulan and the connection with the lakes of Miscanti and Miniques. Fondecyt project number 1017 - 86
Diagrams by L Nunez

Fig 5 Schematic diagram of a transect of the Tulan quebrada - Salar de Atacama - Cerro Miniques
Long 67 46 - 67 48 2300 - 5650 m above sea level Fondecyt Project Number 1017 - 86
Diagrams by L. Nunez



physiognomic zones and six plant associations on a transect from 2700m. at the edge of the absolute desert, up to 4380m. which defines the uppermost limit for vascular plants in this area. Along this transect plant cover varies from 2.5% to 35.7%. In the Tulan area this zonation (see fig. 5) is similar to that at Toconce but, the presence of perennial streams and the Salar de Atacama itself, provide additional favourable environments for plant communities down to an altitude of about 2400m. There is a general lack of detailed botanical data from this area and little previous archaeobotanical work has been carried out. In view of this, a brief vegetation survey based largely upon the author's own work over a period of two seasons field work in 1987 and 1989 is presented here. This concentrates on the different ecological zones in an area between 2400m. and 4400m. It adheres loosely to the general zonal classification used by Villagran *et al.* (1981) but has identified a number of further subdivisions since these are of relevance to the local situation in and around the *quebrada* of Tulan. The species identifications presented below generally follow the system used at the Royal Botanic Gardens, Kew and because of this some of the latin binomials may differ from those given by authorities using the Chilean system.

6.2.1.) Oasis and Salares (salt lakes).

This zone consists of the dry lake bed and immediate shore line of the Salar de Atacama. Within 15Km. of the mouth of Tulan quebrada (valley) two distinct classes of

vegetation can be identified although these are far from being uniform in terms of the species present.

a) *Vega* (Salt plain vegetation): These consist mainly of the flat tracts of land of the old lake bed which supports a a relatively abundant vegetation. The vegetation is particularly rich surrounding water holes such as at Tilocalar and Tilopozo and can be seen to change in composition as a function of distance from the water source. Tilocalar, the site of Tulan 85 (see below), is situated at the edge of one of these vegas, approximately 1km. from the present source of water. To the North and East it is bordered by salt flats while to the South and West there is a rapid ascent to a rolling but barren plane upon which occasional plants of *Opuntia atacamensis*, *Krameria cistoidae*, *Acantholippia riojana* and a number of other small woody shrubs are to be found. Around the water holes, in the vega proper, *Schoenoplecus americanus* is dominant and very heavily grazed. Further from the water source the grass - *Distichlis spicata* - becomes common and supports large colonies of rodents known locally as *cholulu* or *tuco tuco* (*Ctenomys fulvus*). Dense stands of *brea* (*Tessaria absinthioides*) are common and large bushes of *cachiyuyo* (*Atriplex atacamensis*) occur at intervals. The nearby water hole of Tilopozo today supports much larger stands of *Schoenoplecus americanus* together with *Juncus* sp. and *Phragmites australis* and is probably and indication

of what a less heavily grazed but otherwise similar environment look like.

b) Oasis (Alluvial fan): The "oasis" of Tilomonte is situated at the point where the river Tulan broadens out from its narrow valley as it enters the Salar de Atacama at about 2400m. Here, it eventually terminates as it soaks into the dry lake bed. It is therefore located on and around the small alluvial fan of the river Tulan. The river is perennial, brackish and is used to support irrigation agriculture with maize, alfalfa and wheat being the major crops. The area under cultivation today can be seen to be a fraction of the area cultivated in the past and most of the habitations are only used for part of the year, around periods of intensive agricultural activity. The present flora is dominated by large stands of *chilca* (*Baccharis petiolata*), *chanar* (*Geoffroea decorticans*), *algarrobo* (*Prosopis* sp., *brea* (*Tessaria absinthioides*) and *cachiyuyo* (*Atriplex atacamensis*) although numerous herbs live in and around the agricultural fields and canals. Some stands of *Juncus* sp. and heavily grazed areas of *Schoenoplecus americanus* (*unquillo*) are also evident.

Further up stream from Tilomonte where the river has gouged deep gullies into the rhyolitic plateau many of these species die out but *Brea, cachiyuyo and Distichlis spicata* persist. *Cola del zorro*

(*Cortaderia* sp.) and *unquillo* (*Schoenoplecus americanus*) become very common. This type of vegetation continues more or less unchanged up to an altitude of approximately 3000m.

6.2.2.) Rhyolitic plateau and intermediate quebradas.

At the altitude of about 3000m. close to the site of Tulan 54 the stream that forms the beginning of the Tulan river emerges from the ground. Below the source of the water, *unquillo* (*Schoenoplecus americanus*) is common and heavily grazed. Only in faster flowing parts of the stream or in inaccessible places, however, do larger plants grow, and it is only on such plants that rhizomes of any size are present. Numerous species of gramineae grow on the quebrada bottom close to the stream, these too have been substantially grazed. Above the water source a flora more characteristic of many of the dry water courses at this altitude is to be seen. This is dominated by a number of resinous shrubs although there is evidence that small herbs such as *Sysimbrium* sp. and some caryophyllaceae are more common after rainfall. These would appear to be rapidly cleared up by grazing sheep, goats and camelids. Higher up the valley sides *Opuntia atacamensis* and *Calandrinia cf. borchersi* grow in abundance while amongst these, and on the rhyolitic plateau itself on either side of the valley *Acantholippia riojana*, *Atriplex cf. axilaris* and a number of other species of verbenaceae, compositae and solanaceae grow. The percentage ground cover on the valley sides is very

low. Colonies of the rodents *Ctenomys fulvus* live in burrows in favourable places on the plateau.

Wild camelids and rhea (*Pterocnemia pennata*) are also to be seen in and around these valleys at this altitude and ducks (*Anas* sp.) and small birds inhabit many parts of the *quebrada*.

Above about 3300m. the so called 'Tolar' vegetation begins with an increasing number of resinous, xerophytic shrubs coming to dominate the vegetation. In the higher part of this zone, at an altitude of approximately 3800m. the puna grasses such as *Festuca crysophylla* (*Paja brave*) start to replace these.

6.2.3.) High Puna.

At an altitude of about 3900m. the narrow valleys give way to the broad open planes dominated by a single species, *Festuca crysophylla* (*paja brava*), a tussock grass that provides forage during the warmer months (December - March, Santoro and Nunez 1987:61) for herds of wild vicuna and domestic camelids. At higher altitudes still, this grassland gives way to an almost total desert, broken only where perennial rivers or high lakes provide year round water. In these areas both bird, plant life and vicuna herds abound, at least during the warmer periods of the year. The most abundant plants are species of tussock grass, reeds, rushes and other water plants. On the drier ground on either side of these areas there

is close to 0% ground cover but occasional rocky outcrops provide sufficient shelter for the cushion plants *Azorella compacta* and various other resinous shrubs.

Data relating to climatic changes in this area are very scarce. However, for the period directly before that with which this project is concerned, Druss (1978) presents data from the nearby Loa Valley indicating that small oscillations in climate were frequent occurrences in the past. There is much less reliable data relating to broader changes in climate over the last 3000 years.

In summary, the lower regions of the Tulan valley and the salar itself offer areas of rich vegetation which provide food resources for man and animals alike. Both the vegas and the oases provide rich fodder for animals in the form of various grasses and rushes (*Schoenoplectus* sp.). The latter of these can also be used as food for humans (see below). The oases have additional resources in the form of the tree legumes, *chanar* and *algarrobo*, both of which provide substantial and regularly available amounts of fruit that can be eaten by both humans and animals. Further up from the oases, a thin green strip of vegetation dominated by *S.americanus* provide an important area for animal forrage during the dry seasons. Higher up the profile still, the tolar vegetation becomes richer and provides potential fodder for heard animals while abundant cacti also provide limited food for human consumption. This starts to be replaced by the high Andean step vegetation (puna) at about 3800m. in which *paja brava* is

dominant. Few plant resources in this zone are suitable for human consumption but large herds of herbivorous mammals can be supported during all but the winter months of may-september (Santoro and Nunez 1987:77). Around water sources in this region, up to an altitude of 4200m. a more varied biota is evident from which animals (birds and mammals) and probably man, would extract limited food resources.

6.3.) Archaeological context.

As Santoro and Nunez (1987:61) point out, in this part of Chile, the salt puna region, settlement systems must have been concentrated around the and salares with the high altitude zones being left for warm season occupations. As a result of this, a hypothetical model for late Archaic (5500-4000 B.P.) nomadic hunting and gathering involving seasonal movement between the puna and the salares, with principal settlements in the quebradas of the rhyolitic plateau has been proposed (Nunez 1981). The dates for the sites discussed in this chapter are generally later than those discussed by Nunez but this system of transhumant exploitation of the herd camelids is one that has, in all probability, continued, uninterrupted to the present day.

The samples discussed in this thesis come from 3 distinct sites and these are discussed in more detail below.

6.3.1.) Tulan 54.

This site consists of a low, broad mound situated on the rhyolitic plateau at the very edge of the Tulan *quebrada* at an altitude of approximately 2950m. It occupies an area of least 2700sq.m. and the remains of what are apparently enclosure walls and possible dwelling structures can be seen on the surface. Considerable numbers of surface finds of stone tools and beads have been recorded. One of the most characteristic of these is a type of microperforator but other small projectile points are also common. These, together with rare examples of thick, polished pottery, sea shell fragments and stone grinding tools (*morteros*) have also been recovered during a preliminary excavation (Nunez pers. comm.). This consisted of a small excavation carried in the south eastern part of the site (Nunez 1988, see fig. 6) which revealed a midden with over 1.5m. of stratigraphy abutting a substantial stone wall. This midden was characterised by a large number of strata, many of which were very narrow and were consistent with a build up of organic and other domestic rubbish (figs. 7,8). A large number of hearths could be identified within the midden and ashy strata were frequently associated with these. Preservation of organic material by desiccation within the midden was exceptional, with both vegetable matter (plant fibre, seeds, etc.) and animal material (bone, wool, feather, skins) all being recovered in quantity. This preservation was largely as a result of the presence of a dense ashy layer close to the present land surface that had sealed

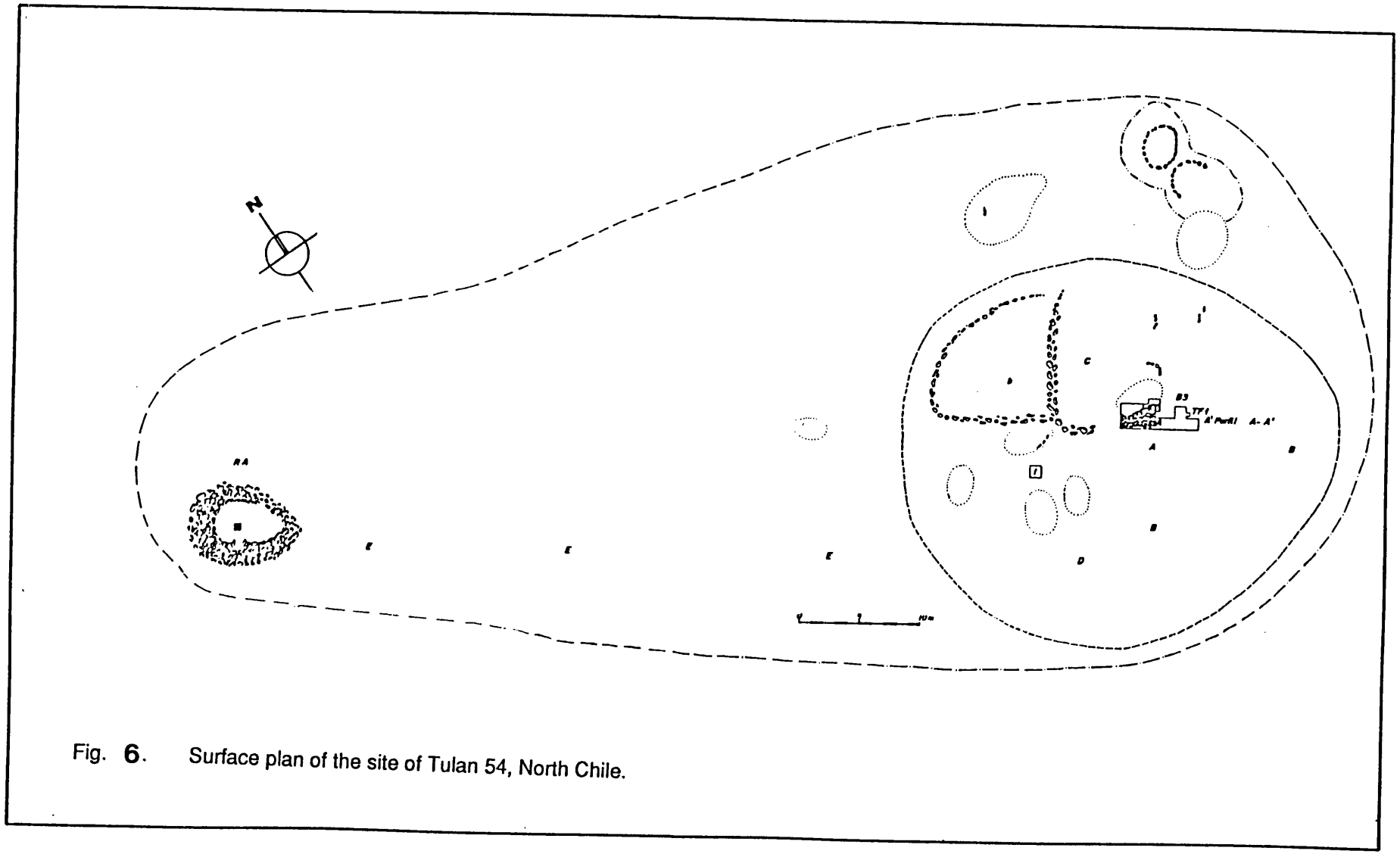


Fig. **6**. Surface plan of the site of Tulan 54, North Chile.

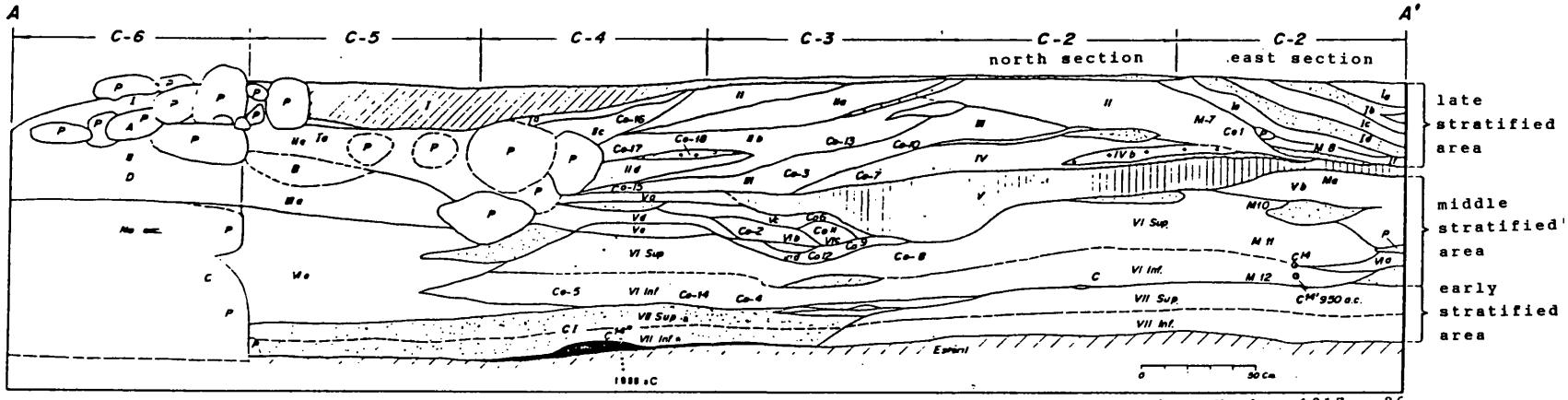
Fig. 7. Section through the midden of Tulan 54, North Chile.

Tulan Site 54

Stratographic Profile A - A

Quantrants 6 5 4 3 2

north section



co = coprolites

p = large stones

Fondecyt Project Number 1017 - 86

Diagrams by L Nunez

off all the lower layers. In view of this, it is probable that the build up of debris had taken place over a relatively short period of time. This hypothesis is also backed by two conventional C14 dates for the site of, 3030 ± 70 and 2900 ± 70 (Nunez 1988 pers. comm.) and a number of Radiocarbon Accelerator dates (Hedges *et al.* 1989:232).

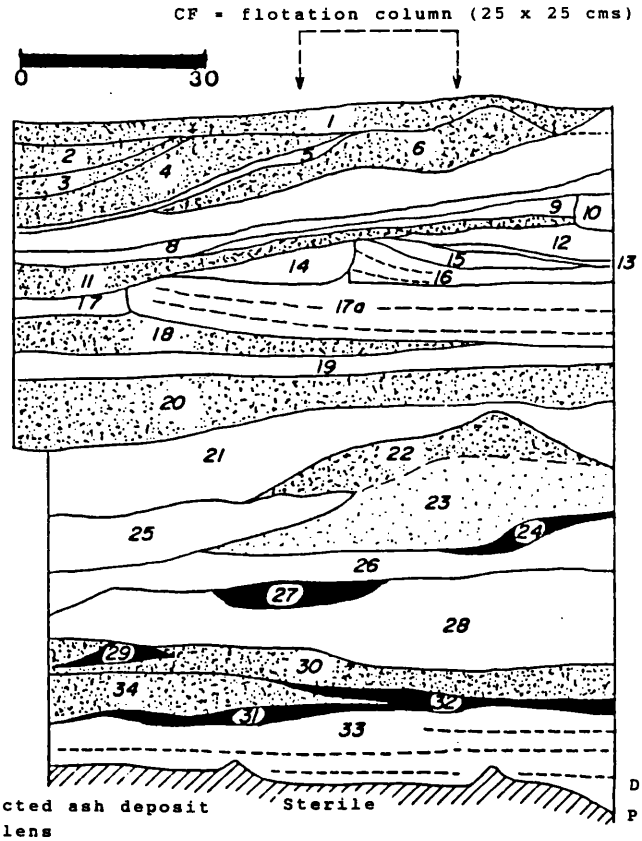
Tu54/B3/a - 2940 ± 60;
Tu54/B3/b - 2840 ± 70;
Tu54/B3/d - 3080 ± 70;
Tu54/B3/f - 3000 ± 65.

These demonstrate that the build up of the midden had occurred over a period of time possibly as short as 180 years.

Nunez (1988) considers the occupation to be part of the early agro-pastoral phase in the area and abundant remains of mature llama bone and camelid dung suggest an active presence in the stable forage zones of the *quebrada*.

Throughout the excavation of this site numerous human coprolites were recovered and put aside for later examination (fig. 7). They were identified as such on both their shape, which was largely cylindrical/sub-cylindrical with obvious folds. Some were however, somewhat flattened. In addition to this they were all

Fig. 8. Stratigraphic profile (C-CBC east section) through the midden of Tulan 54, North Chile showing the position of the flotation column (c.f.).



1 compacted ash deposit
2 ashy lens
3 dense and compressed lens of vegetal matter
4 ashy deposit with charcoal
5 dense and compressed lens of vegetal matter with stones
6 ashy lens with charcoal
7 thin deposit of vegetal matter
8 grey ashy deposit with scarce vegetal matter
9 lens of compacted clay
10 very compact vegetal layer
11 vegetal layer
12 compact layer of vegetal material
13 thin layer of red clay
14 pocket of a brown sandy deposit with scarce vegetal matter
15 ashy layer with vegetal matter
16 thin lens of dense vegetal matter with ash
17 deposit of alternating layers of vegetal matter and ash
18 ashy layer
19 deposit of dense and compressed vegetal matter
20 ashy layer
21 gravel deposit
22 ashy lens
23 ash deposit
24 dark burnt lens
25 gravel deposit
26 dense vegetal deposit
27 hearth
28 dense vegetal lens with ash
29 black ashy lens
30 ashy deposit compacted in places
31 hearth
32 ash lens and hearth
33 compact deposit of vegetal matter with ash (various levels)
34 ash deposit (various levels)

deposited in the midden at the edge of what is considered to be a habitation site. Their composition also supports their identification as human coprolites. They are dominated by two classes of material, *Opuntia* (*cume* cactus) seed and *Schoenoplectus* (rush/*unquillo*) rhizome fibre with occasional meat, bone and hair. The similarity of the composition of these coprolites to samples of human gut contents taken from the cemetery of Tulan 58 confirm that these are of human origin. Some of the smaller samples were however, fragmentary and very distorted (eg. COPTH16G/1).

In addition to these coprolites, a column 25cm. by 25cm. was taken and subjected to a system of simple bucket flotation. The results of the analyses of these two series of samples are shown in tables 16 and 17.

6.3.2.) Tulan 58.

This cemetery is situated close the the above mentioned site of Tulan 54 on the edge of the Tulan *quebrada* at an altitude of approximately 2700m. A number of tombs from this cemetery show cultural links, in terms of associated grave goods, with the habitation site of Tulan 54 (Nunez pers. comm.). Available C14 dates from tomb Tu58 T-6 (S-1) do, however, give a later date of approximately 2240 $\pm$ 50 B.P.

The two bodies (Tu58 T-6 and Tu58 T-4) recovered from this site were practically reduced to skeletons but a

My reference number. Location. Site. Context number. Context type. Source. Conversion fasctor to gram.		COPTH16A Tulan, Chile TU-54 Muestra 1 Midden L.N. + 2.5	COPTH16B Tulan, Chile TU-54 Muestra 2 Midden L.N. x 16 +16.4	COPTH16C Tulan, Chile TU-54 C-1 Co2 Midden L.N. x 2 + 8.8	COPTH16D/1 Tulan, Chile TU-54 C-2 Co1 Midden L.N. x 0.37	COPTH16D/2 Tulan, Chile TU-54 C-2 Co1 Midden L.N. + 2.0	COPTH16D/3 Tulan, Chile TU-54 C-2 C01 Midden L.N. + 1.4	COPTH16E Tulan, Chile TU-54 C-4 C05 Midden L.N. +7.0	COPTH16F Tulan, Chile TU-54 C-4 Co14 Midden L.N. + 2.6	COPTH16G/1 Tulan, Chile. TU-54 C-4 Co15 Midden L.N. + 1.0	COPTH16G/2 Tulan, Chile. TU-54 C-4 Co15 Midden L.N. + 2.5
Plants											
Sisymbrium sp.	Seed. Seed frag.	Trace						Trace (1)		0.010	0.004 (15) 0.001
Opuntia cf. atacamensis.	Whole seed. Seed frag. Epidermis. Areoles. Spines.	0.015 (8)	0.045 (47) 0.179 Trace Trace (1)	0.022 (79) 0.054	0.025 (13) 0.330	0.012 (17) 0.143	0.045 (17) 0.128	0.018 (24) 0.135 Trace Trace	0.003 0.014 Trace	 Trace	0.004 (3) 0.017
Chenopodium sp. (pale seed).	Whole seed. Seed frags.										
Calandrinia sp.	Seed.										
Schoenoplectus americanus	Rhizome fibre. Fibre + starch.	0.027	0.050	Trace	0.014	0.010	0.023		0.002	0.025	0.094
Cortaderia sp.	Leaf frags.										
Gramineae.	Florets.										
Seeds indet.											
Epidermal fragments indet.											
Stem fragments indet.											
Leaf fragments indet.											
cf . degraded Parenchyma indet.											
cf. endocarp indet.											
cf. prercarp (Geoffroea type)											
Fibre fragments indet.					0.024						
Cork Layer cf. Solanum sp.											
Charred fragments.	Vesicular. Wood.	Trace						Trace	Trace		
Animals											
Insect parts.		Trace	Trace								
Amphibian bone (juvanile).											
Other animal remains.	Bone. Large animal. Bone. Intermediate. Bone. Small animal.	0.052	 0.256	0.003			0.009	0.015	0.001	0.030	
	Hair. Rodent type. Hair. Camelid type. Hair. Other.	0.061	 0.050				0.023	Trace.		0.274	Trace
	Connective tissue. Muscle fibre.							Trace	Trace	Trace	
Unidentified organic debris.											
Fine fraction. < 1mm. Large Fraction. > 1mm.		0.304	0.061 0.019	0.102 0.001	0.134	0.028 0.001	0.186 0.006	0.291 0.008	0.311 0.005	0.133 0.021	0.081 0.221
Mineral fragments.		Trace	Trace	0.001	Trace	0.031	0.002		Trace	Trace	
Total Weights		0.459	0.660	0.183	0.527	0.389	0.422	0.467	0.336	0.493	0.422

Table 16. Score sheet of the food debris from coprolites from the site of Tulan 54, Northern Chile. Values given as grams dry weight per gram of coprolite. Part I.

My reference number. Location. Site. Context number. Context type. Source. Conversion fasctor to gram.		COPTH16H Tulan, Chile. TU-54 C-3 Co2 Midden L.N. x 2 + 3.5	COPTH16I/1 Tulan, Chile. TU-54 C-3 Co10 Midden L.N. x 4 + 6.8	COPTH16I/2 Tulan, Chile. TU-54 C-3 Co10 Midden L.N. x 0.71	COPTH16I/3 Tulan, Chile. TU-54 C-3 Co10 Midden L.N. x 4 + 3.1	COPTH16J/1 Tulan, Chile. TU-54 C-3 Co7 Midden L.N. x 0.7	COPTH16J/2 Tulan, Chile. TU-54 C-3 Co7 Midden L.N. + 2.1	COPTH16J/3 Tulan, Chile. TU-54 C-3 Co7 Midden L.N. + 4.4	COPTH16K/1 Tulan, Chile. TU-54 C-3 Co8 Midden L.N. + 3.0	COPTH16K/2 Tulan, Chile. TU-54 C-3 Co8 Midden L.N. + 4.2	COPTH16K/3 Tulan, Chile. TU-54 C-3 Co8 Midden L.N. + 2.9
Plants											
Sisymbrium sp.	Seed.		0.024 (43)		Trace						
	Seed frag.										
Opuntia cf. atacamensis.	Whole seed.	0.238 (140)	0.022 (14)	0.043 (32)	0.027 (25)	0.031 (23)	0.008 (8)	0.019 (8)		0.009 (5)	.002 (2)
	Seed frag.	0.038	0.400	0.111	0.391	0.296	0.131	0.415		0.467	0.033
	Epidermis.										
	Areoles.										
	Spines.										
Chenopodium sp. (pale seed).	Whole seed.								Trace (7)	Trace (4)	Trace (1)
	Seed frags.								Trace		
Calandrinia sp.	Seed.										
Schoenoplectus americanus	Rhizome fibre.	0.025		0.012	0.027	0.009	0.022	0.005	0.012		0.031
	Fibre + starch.				Trace			Trace			
Cortaderia sp.	Leaf frags.					Trace					
Gramineae.	Florets.										
Seeds indet.											
Epidermal fragments indet.											
Stem fragments indet.											
Leaf fragments indet.									Trace		
cf . degraded Parenchyma indet.									0.005		
cf. endocarp indet.									0.001		
cf. pericarp (Geoffroea type)		0.043									
Fibre fragments indet.				0.047	0.006	0.005	0.010	Trace			
Cork Layer cf. Solanum sp.											
Charred fragments.	Vesicular.										
	Wood.								Trace	Trace	Trace
Animals											
Insect parts											
Amphibian bone (juvanile)											
Mammals.	Bone. Large animal.										
	Bone. Intermediate.			0.003							
	Bone. Small animal.								0.060		
	Hair. Rodent type.		0.024				0.098				
	Hair. Camelid type.		Trace			Trace		Trace	Trace		Trace
	Hair. Other.			Trace.							
	Connective tissue.										Trace
	Muscle fibre.										Trace
Unidentified organic debris.											
Fine fraction. < 1mm.		0.048	0.352	0.225	0.143	0.167	0.188	0.111	0.255	0.027	0.074
Large Fraction. > 1mm.		0.029		0.018			0.004		0.264	Trace	0.086
Mineral fragments.			0.017	0.020		0.002	Trace	0.002	0.649	0.550	0.017
Total Weights		0.413	0.839	0.479	0.594	0.510	0.461	0.552	0.614	0.550	0.380

Table 16. Score sheet of the food debris from coprolites from the site of Tulan 54, Northern Chile. Values given as grams dry weight per gram of coprolite. Part II.

My reference number. Location. Site. Context number. Context type. Source. Conversion fasctor to gram.		COPTH16K/4 Tulan, Chile. TU-54 C-3 Co8 Midden L.N. + 1.1	COPTH16L/1 Tulan, Chile. TU-54 CB-3 XVII Midden L.N. x 4 + 7.8	COPTH16L/2 Tulan, Chile. TU-54 CB-3 XVII Midden L.N. + 4.2	COPTH16M Midden CB-3 XXI TU-54 Tulan L.N. x 4 + 4.5	COPTH16N/1 Tulan, Chile. TU-54 CB-3 XXXVIII Midden L.N. x 4 + 10.8	COPTH16N/2 Tulan, Chile. TU-54 CB-3 XXXVIII Midden L.N. + 57	COPTH16N/3 Tulan, Chile. TU-54 CB-3 XXXVIII Midden L.N. + 4.0	COPTH16O Tulan, Chile. TU-54 CB-3 XL Midden L.N. + 3.1
Plants									
Sisymbrium sp.	Seed.								
	Seed frag.								
Opuntia cf. atacamensis.	Whole seed.		0.027 (14)	0.026 (18)	0.014 (11)	0.013 (14)	0.010 (11)	0.021 (21)	0.010 (8)
	Seed frag.		0.433	0.194	0.124	0.068	0.116	0.128	0.241
	Epidermis.						Trace		
	Areoles.					Trace	Trace (1)	Trace (1)	Trace
	Spines.								
Chenopodium sp. (pale seed).	Whole seed.	Trace (7)							
	Seed frags.								
Calandrinia sp.	Seed.					Trace (1)			
Schoenoplectus americanus	Rhizome fibre.	0.025	0.001	0.018	0.043	0.024	0.004	0.001	0.003
	Fibre + starch.								
Cortaderia sp.	Leaf frags.								
Gramineae.	Florets.	Trace (1)							
Seeds indet.									
Epidermal fragments indet.									
Stem fragments indet.									
Leaf fragments indet.									
cf . degraded Parenchyma indet.									
cf. endocarp indet.									
cf. pericarp (Geoffroea type)									
Fibre fragments indet.									
Cork Layer cf. Solanum sp.									
Charred fragments.	Vesicular.								
	Wood.			Trace		Trace	Trace		
Animals									
Insect parts									
Amphibian bone (juvanile)									0.004
Mammals.	Bone. Large animal.								
	Bone. Intermediate.	0.122			0.004	0.342			
	Bone. Small animal.								
	Hair. Rodent type.						Trace		
	Hair. Camelid type.	0.012	Trace	Trace		Trace	Trace	Trace	
	Hair. Other.								
	Connective tissue.					0.001			
	Muscle fibre.					0.002	Trace	Trace	Trace
Unidentified organic debris.									
Fine fraction. < 1mm.		0.240	0.095	0.217	0.191	0.347	0.338	0.285	0.138
Large Fraction. > 1mm.		0.029	0.004	0.099	0.041	0.040	0.073	0.071	0.033
Mineral fragments.		Trace		0.008			Trace	Trace	
Total Weights		0.428	0.560	0.562	0.417	0.837	0.541	0.506	0.429

Table 16. Score sheet of the food debris from coprolites from the site of Tulan 54, Nortern Chile. Values given as grams dry weight per gram of coprolite. Part III.

considerable quantity of organic material was recovered from the pelvic basin of each. This material showed both the folded and contorted form of the large intestine and a composition that made it clear that they were the remains of gut contents. Their preservation while all surrounding traces of flesh had long since disappeared was unusual, and is worthy of some comment. It is probable that the samples had been subjected to wetting in antiquity on at least one occasion and that a certain amount of very fine silt from the surrounding soil had become incorporated into the gut material (which being largely vegetable material had more readily absorbed water and silt than the surrounding body tissues). This had percolated between the vegetable debris, thus consolidating it, giving it its dusty appearance, and aiding in its preservation while the surrounding corpse deteriorated. Confirmation of this was obtained when a sample of one of these was embedded in resin and a thin section preparation made. This revealed patches of fine silt in the matrix of the gut residue. This partial replacement would also explain why trisodium phosphate had only limited success in rehydrating this sample while calgon met with more success (nb. the use of calgon is a standard laboratory technique for breaking up compacted soil samples). The results of the analysis are shown in table 18.

My reference number. Location. Site. Context number. Context type. Source Conversion factor to gram.		INDTH10/1 Tulan, Chile. Tu 54. CF 1A Midden L.N. + 0.22	INDTH10/2 Tulan, Chile. Tu 54. CF 1B Midden. L.N. + 0.70	INDTH10/3 Tulan, Chile. Tu 54. CF 6 Midden. L.N. + 0.42	INDTH10/4 Tulan, Chile. Tu 54. CF8+10 Midden. L.N. + 0.33	INDTH10/5 Tulan, Chile. Tu 54. CF 14 Midden. L.N. + 1.46	INDTH10/6 Tulan, Chile. Tu 54. CF 15 Midden. L.N. + 2.84	INDTH10/7 Tulan, Chile. Tu 54. CF 17a Midden. L.N. + 1.73	INDTH10/8 Tulan, Chile. Tu 54. CF 17 Midden. L.N. + 1.81	INDTH10/9 Tulan, Chile. Tu54. CF 20 Midden. L.N. + 1.73
Plants										
Sisymbrium sp.	Whole seed.			Trace (10)	0.004 (24)	Trace (4)	Trace (1)	0.001 (6)	0.001 (8)	Trace (6)
Sisymbrium sp. (charred).	Whole seed.							Trace (1)		
Opuntia cf. atacamensis.	Whole seed.	0.035 (27)		0.199 (95)	0.125 (73)	0.123 (77)	0.092 (34)	0.033 (10)	0.033 (10)	0.327 (150)
	Seed frags.	0.043		0.068	0.119	0.018	0.070	0.012	0.037	0.242
	Epidermis.			0.015						
	Areoles.							0.007 (1)		Trace (1)
O. cf. atacamensis. (charred).	Whole seed.		0.015 (12)	0.011 (7)	0.006 (9)	0.003 (4)	0.002 (3)			Trace (2)
	Seed Frags.		0.008			0.002				
	Areoles.		0.004							
Atriplex sp.	Seed.									
	Bracteoles.	Trace (5)							0.001 (1)	
	Leaf frags.			0.013 (5)	0.007	0.002 (5)	Trace (1)	0.011	0.006	0.002
Chenopodium sp. (pale seeds)	Whole seed.					Trace (1)				
	Seed frags.									
Chenopodium/Atriplex type.	Seed.	Trace (2)			Trace (3)		Trace (1)			
	Seed (charred).	Trace (2)								
Calandrinia sp.	Seed.	Trace (9)	Trace	0.020 (199)	0.058 (833)	Trace (1)	Trace (2)	Trace (2)	Trace (3)	0.006 (81)
Calandrinia sp. (charred).	Seed.									
Malvaceae sp.	Seed.	Trace (2)				0.008 (12)		Trace (2)	Trace (1)	Trace (1)
cf. Capsicum sp.	Seed.				0.009 (3)					
Cacabus prostratus.	seed.									0.003 (4)
Solanaceae indet.	Seed.	Trace (2)								
Acantholippia sp.	Seed.						Trace (1)			Trace (1)
	Leaves.			0.006 (19)	0.003 (21)	0.004 (25)	0.002 (15)	0.003 (10)	0.001 (7)	Trace (6)
Acantholippia sp. (charred).	Leaves.									
Verbenaceae sp.	Seed.									
Tessaria absinthoides.	Leaf frag.									
Schoenoplectus americanus	Tuber/rhizome frags.	0.018		0.006	0.348	0.585	0.798	0.747	0.863	0.380
Schoenoplectus americanus	Seed.	Trace (9)		0.013 (21)	0.014 (33)	0.002 (6)	Trace (1)	0.001 (5)	0.002 (2)	0.010 (21)
S. americanus (charred)	Tuber/rhizome frags.	0.708	0.766	0.203		0.152	0.001		Trace	
S. americanus (charred)	Seed.		0.004 (4)					Trace (1)		
Stipa sp.	Spikelet.								Trace (1)	
Graminae indet.	Florets.									
	Caryopsis.									Trace (1)
Monocotyledon fibre indet.										
Seeds indet.	whole.			Trace (2)		Trace (2)				Trace (1)
	frags.						Trace (2)		Trace (1)	
Seeds indet. (charred).	whole.			0.008 (12)		Trace (1)				
	frags.		0.017							
Floret indet.									Trace (1)	Trace (1)
Vesicular fragments (Charred).		0.181	0.173	0.143	0.070	0.001	0.004		0.006	
Animals										
Insect parts.				0.009	0.002		Trace	Trace	Trace	0.020
Snail Shell.		0.003 (5)	0.009 (3)							
Bird.	Feather.	Trace				0.007				Trace
	Beak.									0.033
Rodent.	tooth.				0.029 (3)					
Mammal	Hair.			Trace		0.015	Trace	0.105	Trace	0.003
	Conective tissue.			Trace	0.007				0.034	
Animal bone.		Trace		0.287	0.196	0.088	0.030	0.123	0.015	0.001
Items present but not quantified per gram of identified material .										
vegetable material indet.		3.645	6.548	12.766	29.858	8.125	4.713	3.985	4.458	5.463
Charcoal.		2.509	3.056	1.720	1.344	0.593	0.182	0.166	0.151	0.431
Camelid droppings.		0.031								
Other animal droppings.					0.015	0.046	0.019		0.058	0.171
Calandrinia mass cf. Bird Dropping.							0.003			
Rodent skin.										
Wool/yarn						0.065				

Table 17. Score sheet of the flotation samples from the site of Tulan 54, Northern Chile. Values given as grams dry weight per gram of of identified debris. Part I.

My reference number.		INDTH10/10	INDTH10/11	INDTH10/12	INDTH10/13	INDTH10/14	INDTH10/15
Location.		Tulan, Chile.	Tulan, Chile.	Tulan, Chile.	Tulan, Chile.	Tulan, Chile.	Tulan, Chile.
Site.		Tu54.	Tu54.	Tu54.	Tu54.	Tu54.	Tu54.
Context number.		CF 23	CF 26	CF 28	CF 30	CF 32	CF 33b
Context type.		Midden.	Midden.	Midden.	Midden.	Midden.	Midden.
Source		L.N.	L.N.	L.N.	L.N.	L.N.	L.N.
Conversion factor to gram.		+ 0.69	+ 1.69	+ 2.50	+ 0.29	+ 0.58	+ 0.98
Plants							
Sisymbrium sp.	Whole seed.	0.009 (107)	0.002 (8)	0.002 (38)			
Sisymbrium sp. (charred).	Whole seed.	0.002 (27)		Trace (3)		0.008 (50)	
Opuntia cf. atacamensis.	Whole seed.	0.204 (120)	0.196 (70)	0.326 (156)	0.329 (148)	0.098 (78)	0.179 (86)
	Seed frags.	0.190	0.073	0.154	0.098	0.237	0.072
	Epidermis.			0.003	0.005	Trace	0.054
	Areoles.	0.003 (3)	0.006 (1)	0.006 (10)	0.006 (5)	0.013 (17)	0.113 (36)
O. cf. atacamensis. (charred).	Whole seed.	0.029 (14)	0.010 (12)	0.002 (3)	0.029 (20)	0.086 (100)	
	Seed Frags.		0.002	Trace	Trace	0.011	
	Areoles.					Trace (1)	
Atriplex sp.	Seed.						
	Bracteoles.			Trace (1)			0.003 (4)
	Leaf frags.	Trace (3)	0.001 (2)	Trace (1)			
Chenopodium sp. (pale seeds).	Whole seed.						
	Seed frags.						
Chenopodium/Atriplex type.	Seed.	0.001 (10)				Trace (3)	
	Seed (charred).						
Calandrinia sp.	Seed.	Trace (3)	Trace (1)	0.001 (28)	0.001 (34)	0.005 (43)	0.003 (67)
Calandrinia sp. (charred).	Seed.	Trace (1)			Trace (3)		
Malvaceae sp.	Seed.		Trace (1)		Trace (1)		
cf. Capsicum sp.	Seed.						
Cacabus prostratus.	Seed.						
Solanaceae indet.	Seed.					Trace (2)	
Acantholippia sp.	Seed.						
	Leaves.	Trace (6)	Trace (2)	Trace (3)	Trace (14)	Trace (1)	Trace (10)
Acantholippia sp. (charred).	Leaves.				Trace (1)		
Verbenacea sp.	Seed.					Trace (2)	
Tessaria absinthoides.	Leaf frag.	0.005					
Schoenoplectus americanus	Tuber/rhizome frags.	0.356	0.403	0.464	0.471	0.298	0.466
Schoenoplectus americanus	Seed.	0.003 (6)	0.002 (4)	0.006 (10)	0.017 (34)	0.007 (9)	0.006 (17)
S. americanus (charred)	Tuber/rhizome frags.	0.006	0.149	0.005		0.019	
S. americanus (charred)	Seed.		0.002 (4)		Trace (3)		
Stipa sp.	Spikelet.			Trace (1)			
Graminae indet.	Florets.			Trace (2)	Trace (3)	Trace (9)	
	Caryopsis.						
Monocotyledon fibre indet.							
Seeds indet.	whole.	Trace (2)		Trace (1)		0.007 (14)	
	frags.						
Seeds indet. (charred).	whole.	Trace (3)	Trace (1)	Trace (1)			Trace (2)
	frags.						
Floret Indet.							
Vesicular fragments (Charred).		0.037	0.014	0.013	0.033	0.121	
Animals							
Insect parts.		0.001	Trace	0.001	0.005	0.015	0.015
Snail Shell.							
Bird.	Feather.	Trace		0.002			0.011
	Beak.		0.007 (1)				
Rodent.	tooth.			Trace (1)			
	Hair.	0.005	0.072	0.048	Trace	0.011	0.073
	Conective tissue.						
Animal bone indet.		0.115	0.054	0.014	0.012	0.066	0.005
Items present but not quantified per gram of identified material .							
vegetable material indet.		5.346	3.670	1.382	11.300	9.561	2.348
Charcoal.		1.397	0.794	0.240	1.292	2.411	0.213
Camelid droppings.							
Other animal droppings.		0.506	1.518	0.118	4.667		
Calandrinia mass cf. Bird Dropping.					0.006		0.174
Rodent skin.				0.910			
Wool/yarn			0.061	0.043			

Table 17. Score sheet of the flotation samples from the site of Tulan 54, Northern Chile. Values given as grams dry weight per gram of of identified debris. Part II.

6.3.3.) Tulan 85.

The site of Tulan 85 is situated some 20Km. from Tulan 54 on the edge of the *vega* at Tilocalar (see section). It consists of a low broad mound of approximately 2m. depth. The excavations carried out during the 1989 field season revealed that this was largely composed of successive lenses of ashy material which were rich in both charred camelid bone and dung together with quantities of charred plant remains. Quantities of desiccated remains were also evident where these had been protected by a consolidated ashy layer. The basic inventory of finds has not yet been analysed in detail but shows similarities to that described for Tulan 54 (Nunez pers. comm.). The two C14 dates of 3140 $\pm$ 70 and 2660 $\pm$ place it close to, or slightly before, the site of Tulan 54.

It was not possible to sample and process each stratum so samples for flotation were taken at 20cm. intervals down the profile of quadrant 9 (neither section diagrams nor plans are yet available for this site). The results of the analysis is presented in table 19.

6.4.) Quantification of the debris and calculation of equivalent quantities of undigested food from the coprolites and gut contents.

No published values for the fibre content of the tubers/rhizomes of *Schoenoplectus americanus* are known to the author. In view of this a crude fibre preparation

My reference number. Location. Site. Context number. Context type. Source Conversion factor to gram.		COPTH31 Tulan, Chile. TU-58 T-4 Gut contents. L.N. + 1.9	COPTH32/1 Tulan, Chile. Tu-58 T-6 (1) Gut contents. L.N. + 7.4	COPTH32/2 Tulan, Chile. Tu-58 T-6 (2) Gut contents. L.N. + 3.2
Plants				
Opuntia cf. atacamensis.	Whole Seeds. Seed frag. Epidermis.	0.019 (30) 0.120	 Trace	0.006 (12) 0.188 0.001
cf. Krameria sp.				Trace
Schoenoplectus americanus.	Rhizome fibre. Fibre and starch.	0.033	0.001	0.026
Cortaderia sp.	Leaf frags.			
Gramineae.	Florets.			
Seeds indet.				Trace (1)
Animals				
Insect parts				Trace
Feather				Trace
Animals	Bone. Hair.	0.023	0.004	0.113 Trace
Unidentified organic debris.				
Fine fraction. < 1mm. Large fraction. > 1mm.		0.477 0.067	0.187 Trace	0.271 0.022
Mineral fragments.		0.003	0.013	0.629
Total Weights		0.675	0.205	0.629
Root contamination			Trace	Trace

Table18. Score sheet of the food debris from the guts of two bodies from the cemerary Tulan 58, Northern Chile. Values given as grams dry weight per gram of gut contents..

Location. Site. Context number. Context type. Source Conversion factor to gram.		Tulan, Chile. Tu85. I Midden L.N. + 0.90	Tulan, Chile. Tu85. II Midden L.N. + 1.02	Tulan, Chile. Tu85. III Midden L.N. + 1.01	Tulan, Chile. Tu85. IV Midden L.N. + 0.99	Tulan, Chile. Tu85. V Midden L.N. + 3.57	Tulan, Chile. Tu85. VI Midden L.N. + 074	Tulan, Chile. Tu85. VII Midden L.N. + 3.76	Tulan, Chile. Tu85. selected. Midden L.N. + 0.30
Plants									
Sisymbrium sp.	Whole seed.	Trace (15)	0.110 (83)						
Opuntia cf. atacamensis.	Whole seed.	0.016 (7)	0.004 (1)					0.004 (6)	0.033 (21)
	Seed frags.	0.005		Trace					
	Epidermis.								
	Areoles.								
O. cf. atacamensis (charred).	Whole seed.		Trace (1)		Trace (1)	Trace (1)		Trace (1)	
	Seed Frags.								
	Areoles.								
Atriplex sp.	Leaf frags.	Trace (9)	0.015 (24)	Trace (1)					Trace (17)
Calandrinia sp.	Seed.	Trace (19)	Trace (23)						
Calandrinia sp. (charred).	Seed.								
Malvaceae indet.	seed.		Trace (1)						
Tessaria absinthoides.	Leaf frag.								
Schoenoplectus americanus.	Tuber/rhizome frags.	0.734	0.8	0.222				0.065	0.694
Schoenoplectus americanus.	Seed.	0.031 (38)	0.012 (23)					0.010 (21)	0.057 (109)
S. americanus (charred)	Tuber frags.	0.056	0.013	0.117	0.587	0.658	0.376	0.663	0.115
S. americanus (charred)	Seed.	Trace (1)			0.003 (9)	0.003 (9)		0.001 (4)	
cf. Schoenoplectus sp.	vesicular fragments.	0.029		0.362	0.372	0.328	0.572	0.249	0.094
Graminae	Florets.		0.003 (10)						
	Caryopsis.		Trace (3)						
Vesicular fragments (Charred).		0.008		0.017	0.011	0.012	0.027	0.008	0.006
Animals									
Insect parts.									
Snail Shell.		0.002 (4)						0.001 (1)	Trace (3)
Bird.	Feather.	Trace		Trace				Trace	
Rodent.	tooth.	0.007 (3)							
Animal.	Bone.	0.115	0.019	0.277	0.028		0.025		
	Hair.	Trace	0.026						Trace
	Muscle fibre.	Trace	Trace	Trace					
Items present but not Quantified per gram of identified material.									
Vegetable material indet.		14.401	8.143		4.254		6.459	1.954	19.105
Charcoal.			0.299	0.805	0.967	4.213	3.096	1.01	1.072
Other animal droppings.			0.018 (2)			0.011	0.058		
Calandrinia mass cf. Bird Dropping.			Trace						

Table 19. Score sheet of the flotation samples from the site of Tulan 85, Northern Chile. Values given in grams (dry weight) of identified debris.

(see Holden 1990a) of a dried, unprocessed sample of some the larger rhizomes and tubers of *S.americanus* from the mid stream area of the river Tulan was carried out. This relatively unsophisticated technique gave a fibre value of approximately 14%. A number of other related species have, however, been subjected to more rigorous analytical techniques and are cited by Hillman, Madeyska and Hather (1989). They give a value of 12% (fresh weight) for *Cyperus rotundus*, (even when pealed); 5.7% for *C.bulbosus* and between 5% and 14% *C.esculentus*. In view of this, the value of 14% fibre for the tuber and rhizomes of *S.americanus* would appear reasonable. If, however, the smaller, more woody tubers from the stunted plants that grow at the river edge had been taken, this value would be expected to be considerably higher.

With this type of food there is a further problem related to the reconstruction of undigested food from part digested debris. Firstly, differing degrees of processing may have been carried out such that differing quantities of identifiable fibre might be removed. At Tulan the evidence suggests that this processing was only minimal, with possibly only the tops being cut off the tubers (these tops were commonly recovered from the flotation deposits) and a small amount of peeling. The second point to take into account is that it is only a fraction of the total fibre that can be identified and subsequently quantified. This is clearly not going to correspond to the fibre values given in the literature which will include

My reference number. Site. Context number.		COPTH16A TU-54 Muestra 1	COPTH16B TU-54 Muestra 2	COPTH16C TU-54 C-1 Co2	COPTH16D/1 TU-54 C-2 Co1	COPTH16D/2 TU-54 C-2 Co1	COPTH16D/3 TU-54 C-2 C01	COPTH16E TU-54 C-4 C05	COPTH16F TU-54 C-4 Co14	COPTH16G/1 TU-54 C-4 Co15
Sisymbrium sp.	Seed.									0.067
Opuntia cf. atacamensis.	Seed.	0.063	0.941	0.319	1.491	0.651	0.727	0.643	0.072	
Schoenoplectus americanus	Rhizome fibre.	0.270-0.386	0.500-0.715		0.140-0.200	0.100-0.143	0.230-0.329		0.020-0.029	0.250-0.357
My reference number. Site. Context number.		COPTH16G/2 TU-54 C-4 Co15	COPTH16H TU-54 C-3 Co2	COPTH16I/1 TU-54 C-3 Co10	COPTH16I/2 TU-54 C-3 Co10	COPTH16I/3 TU-54 C-3 Co10	COPTH16J/1 TU-54 C-3 Co7	COPTH16J/2 TU-54 C-3 Co7	COPTH16J/3 TU-54 C-3 Co7	COPTH16K/1 TU-54 C-3 Co8
Sisymbrium sp.	Seed.	0.340		0.161						
Opuntia cf. atacamensis.	Seed.	0.088	1.160	1.772	0.647	1.753	1.373	0.584	1.823	
Schoenoplectus americanus	Rhizome fibre.	0.940-1.344	0.250-0.358		0.120-0.300	0.270-0.386	0.090-0.129	0.220-0.315	0.050-0.071	0.120-0.172
My reference number. Site. Context number.		COPTH16K/2 TU-54 C-3 Co8	COPTH16K/3 TU-54 C-3 Co8	COPTH16K/4 TU-54 C-3 Co8	COPTH16L/1 TU-54 CB-3 XVII	COPTH16L/2 TU-54 CB-3 XVII	COPTH16M TU-54 CB-3 XXI	COPTH16N/1 TU-54 CB-3 XXXVIII	COPTH16N/2 TU-54 CB-3 XXXVIII	COPTH16N/3 TU-54 CB-3 XXXVIII
Sisymbrium sp.	Seed.									
Opuntia cf. atacamensis.	Seed.	1.999	0.147		1.932	0.924	0.579	0.341	0.529	0.626
Schoenoplectus americanus	Rhizome fibre.		0.310-0.443	0.250-0.357	0.010-0.014	0.180-0.257	0.430-0.615	0.240-0.343	0.040-0.057	0.010-0.014

My reference number. Site. Context number.		COPTH16O TU-54 CB-3 XL	Totals.
Sisymbrium sp.	Seed.		0.255
Opuntia cf. atacamensis.	Seed.	1.054	22.238
Schoenoplectus americanus	Rhizome fibre.	0.030-0.430	5.070-7.764

Table **20.** Table showing the conversion of the major classes of food debris into equivalent values of undigested food per gram of gut contents. Samples from the site of Tulan 54, Northern Chile.

Sample.	Food type.	Weight of identified debris (dry weight).	% fibre present in th different foods.	Conversion factor. 100 + %fibre	Equivalent weight of undigested food per gram of gut contents.
Tu58 T-4.	Opuntia seed.	0.139gms.	24	4.2	0.584gms.
	Schoenoplectus sp.	0.033gms.	7 - 10	10-14.3	0.33-0.47gms.
Tu58 T-6/1.	Schoenoplectus sp.	0.001gms.	7 - 10	10-14.3	0.01-0.02gms.
	Opuntia seed.	0.194gms.	24	4.2	0.814gms.
Tu58 T-6/2.	Schoenoplectus sp.	0.026gms.	7 - 10	10-14.3	0.26-0.37gms.

Table 21. Table showing the conversion of the major classes of food debris into equivalent values of undigested food per gram of gut contents from Tulan 58, Northern Chile.

considerable quantities of non-identifiable debris. In view of these points, it would seem reasonable to use a value for identifiable fibre considerably below the one given above. A value of between 7-10% of the total dry weight has therefore been used.

There are no published values available for *Opuntia atacamensis* fruit but a simple, crude fibre preparation of the dried pulp (mesocarp and endocarp) and seeds, after pounding in a pestle and mortar, gave a value of 24% fibre. This may at first appear to be a very high value but it should be remembered that not only is each seed surrounded by a thick endocarp layer but that there is also considerable amount of fibre within the pulp itself which is otherwise, largely made up of water.

Finally, for the small quantities of *Sisymbrium* type seeds present no data on fibre content are available. However, Winton and Winton (1932) give a value for the larger seeded *Camelina sativa* of 11.6% and for a number of *Brassica* species values from 14.74% for *B.campestris* to 6.45 for *Brassica napus*. *Sisymbrium* being a small seed would be expected to be towards the top of this range and a value of 15% would appear to be reasonable until the time when more accurate data becomes available.

Using these values approximate equivalent weights of undigested food was calculated and are presented in tables 20 and 21.

6.5.) Discussion.

The most prominent feature of the samples were that two resources dominated all others. These were the cactus seed (*Opuntia* sp.) and the starchy rhizomes of a species of rush (*Schoenoplectus americanus*). The cactus seed dominate both the flotation, coprolite and gut samples from Tulan 54 and 58 but are relatively rare at the site of Tulan 85. Today *Opuntia* cacti are common at the elevation of Tulan 54 but very scarce at the lower altitudes close to Tulan 85. This suggested that the environment during the site occupation was not considerably different to now. The other major resource, *Schoenoplectus*, however, grows in abundance at both locations today and is common in all of the samples studied.

The equivalent weights of undigested foods presented in table 20 show that it in nearly all samples, cactus seed made up the largest part of the meals. When figures for all coprolites are totalled then these calculations suggest that 3-4 times as much *Opuntia* as *Schoenoplectus* rhizome was eaten with much smaller amounts of *Sisymbrium* seed. At present, it is difficult to determine whether this data can be taken at face value or not. The figures for *Opuntia* and *Sisymbrium* would seem to be relatively trustworthy as there is little evidence that much of the fibre was removed by processing techniques. With the *Schoenoplectus* rhizomes, however, it is possible that the percentage of fibre that was discarded by removing the tops and partially peeling may have under-estimated. If

this is the case then the value of *Schoenoplectus* in table 20 could be much lower than was actually present in the meal. Further detailed data relating to traditional methods of processing of such rhizomes are therefore required. If this is forthcoming, then the undigested food values may need to be reassessed.

6.5.1.) The use of Opuntia (*Cume* cactus) at Tulan.

The fruits of the *Cume* cactus are edible if somewhat acidic. The area around San Pedro de Atacama, Chile at an altitude of 2400m up to approximately 3800m, is rich in two species of cushion forming cacti. The first of these is *Opuntia cf. atacamensis* which is especially common today in the area of Tulan at approximately 2900m above sea level. Here, close to the site of Tulan 54, clumps of these produce large numbers of fruits that can be gathered during the long fruiting season (the author has collected fruits in the months of both April and September). Further up the elevation (above 3100m) the second species, *Opuntia* sp., with its yellow coloured spines (as opposed to the red ones of *O.atacamensis*) begins to take over. The remains from Tulan 54 match well with that from the former of these two species but it is possible that the more high altitude species was also used as a complementary resource at other times.

A number of ethnobotanical reports from the Atacama region make mention of edible fruits of both *Opuntia* and other species of cacti (eg. Aldunate *et.al.* 1981:213,

1983:128, Castro *et. al.* 1982:186, Gunckel 1967:16, Munoz *et al.* 1981:20, Ortiz 1969:8 and Yacovleff and Herrera 1934:318) none give any details of how or why they were used. This is in contrast to the wealth of more detailed ethnobotanical data that has been collected in the arid zones of North and Mesoamerica. These reports frequently give details relating to the preparation and consumption of cactus fruit and seeds. In addition to being eaten fresh, when the fruits are ripe, as they still are today in parts of Chile, they can be stored and used for the starch content of their seeds. Barrows (1900:68), Castetter and Bell (1937:15) and Gifford (1932:210), for example, all refer to the drying out of the fruits followed by threshing, beating (to remove the fibre) and/or pounding prior to the making of a meal which could be either eaten dry, made into a gruel, alcoholic drink or bread. In addition to this, Castetter and Bell state that the pulp was sometimes also scraped out and made into cakes by being dried in the field ready for later storage. Such was the value of these seeds to people such as the Seri, the Pima and the Papago the North American South West that Castetter and Bell (1937:16) cite no less than three references relating to the consumption of *Opuntia* seeds that were collected from human faeces. These were then recycled (ie. eaten for a second time) after washing and processing the same as fresh specimens. This procedure presumably followed the eating of fresh fruits the first time round.

As can be seen from table 16, the fragmentary remains of *Opuntia* seeds, make up, in nearly all cases a considerably greater part of the food debris than do the the whole ones. This suggests that they were probably ground or pounded prior to consumption since it is unlikely that mastication alone would have produced this effect. Indeed, in experiments carried out by the author the loose fibre or dried pulp made it difficult to thoroughly break up all of the seeds in a pestle and mortar. Another feature noted in the coprolite material was the presence or absence of loose, fibrous endocarp material. Although, as suggested in section a2.2.2. this may have been related to factors such as the state of maturity or the preparation techniques used. For example, could the lack of fine mesocarp fibre in a sample relate to a meal in which the seeds were dried, beaten and then winnowed before being eaten? The presence of so much testa and endocarp fibre ,however, suggested that this was unlikely. In contrast, could samples in which considerable amounts of this fibre were recovered be the result eating the fruits after only minimal processing or after a process such as the one described by Castetter and Bell in which the pulp, in its entirely was dried in the sun prior to storage and later consumption? It is clear that a degree of experimental work with the different *Opuntia* species could clarify this point considerably.

Although most of the samples have evidently been processed, some samples such as COPTH16H have a considerably

higher quantity of whole seeds than others. This might be interpreted as eating the pulp and seeds fresh from the fruit.

With regard to the collection of the fruits it is interesting to note that relatively few examples of the epicarp itself, was recovered from the flotation samples or midden. This would suggest that the actual removal of the seeds and associated pulp was carried out, away from the site where all of the remaining pericarp would have been discarded.

6.5.2.) The use of Schoenoplectus tubers at Tulan.

There is a substantial ethnobotanical literature on the use of species of *Scirpus* in Northern Chile (eg. Browman 1983:32, Yacovleff and Herrera 1934:294). There are also numerous reports of these being recovered from archaeological sites (eg. Nunez and Hall 1982, Nunez 1981:98, Towle 1961:55 and Williams 1980). The majority of these reports, however, refer to the more succulent species of *Scirpus californicus* var. *tatora* (after the naming convention of Koyama 1963:1127), known locally as *totora*. Browman (1983:32) reports that the tubers and the basal parts of the stem of totora are still consumed as a special dish at fiestas in modern Bolivia and it has evidently been used as a food resource throughout much its range. There is much less data available that relates to the use of the less succulent *Schoenoplectus* (*syn. Scirpus*) *americanus*. other than as a fodder for sheep

(Aldunate *et. al* 1981:216). It, does appear, however, that this was a highly prized resource in the past, in the arid areas of Northern Chile.

6.5.2.1.) Processing.

The coprolite evidence clearly demonstrate the use of this species as a food resource and, at the same time, the remains from the flotation samples from Tulan 54 and Tulan 85 add further data regarding processing. In a number of samples from Tulan 54, remains of the plant stem and the tops of the tubers (swollen nodes on the rhizome) were recovered. These had been cleanly cut off the tubers which would then have been taken for eating. Large quantities of stem material was also recovered from the midden samples. Although there is a possibility that this was brought onto the site for other economic purposes it is probable that the plants were carried, in their entirety to the site for processing. The stems would be cut off, the tubers and probably other parts of the rhizome kept for processing by pounding or grinding and the remaining parts of the plant discarded or later re-used for fuel, baskets, roofing, animal fodder etc. Partial peeling of the tubers may also have been carried out at this stage since strips of epidermal fibre were recovered from some of the desiccated midden samples of Tulan 54. One puzzling observation here, is the presence of large quantities of charred tuber material in the midden at Tulan 85. Here, both whole and fragmentary tubers were recovered from several different levels. It is

strange that they should go to the trouble of digging then up then drying the tubers only to burn them. Whatever the cause, it must have occurred on more than one occasion since the deposits occur at several points down the profile.

The available data relating to the preparation and consumption of *Schoenoplectus/Scirpus* tubers is sparse but there are a few other examples of the use of these genera from North America. Bean and Saubel (1972:139), for example, record that the Cahuilla Indians grind the tubers of a species of *Scirpus* into a sweet tasting flour. Various other ethnographic data also exist for the processing of similar tuber bearing genera, notably, *Cyperus* from Africa, India and Australia. These include roasting and rubbing to remove the fibrous skin and also drying, followed by grinding into flour (Hillman *et. al* 1989:188). It would seem highly probable that the Chilean equivalent of these tubers would have needed a similar type of treatment to make them palatable. The often substantial quantities of fibre incorporated in the faeces, however, suggests that this processing may not, in all cases, have been very thorough.

6.5.2.2.) Management of the wild resource.

Remains of the fibre from these tubers were recovered from most of the coprolite/gut samples and complete charred and uncharred tubers from many of the flotation samples. Clearly, it was a major resource in the past,

however, on digging up modern samples from the stream or waterhole sides in Chile today the tubers are generally small, fibrous and black in colour (the epidermis). Only in favourable places such as in the central parts of the streams or very edge of the waterholes, where grazing has been restricted and crowding of the plants is not evident, do larger more succulent and pale coloured rhizomes prevail. This suggests that they were being managed, (whether consciously or unconsciously) by thinning out stands of plants and restricting grazing. In this way, larger and more edible rhizomes would have resulted. Just by digging up areas of these tubers for consumption, year after year, a more favourable environment for the growth of a better quality of resource would be created. Thus the present paltry stands of over-grazed plants probably represent just a fraction of the potential that they could have done in the past. This situation is remarkably similar to the situation noted from the late palaeolithic site of Wadi Kubbaniya, Upper Egypt where the exploitation of *Cyperus* tubers was of major importance. In a discussion of the management of these tubers Hillman (Hillman *et al.* 1989) states that the annual harvesting of *Cyperus* tubers can largely prevent the buildup of old, woody tubers and promote the rapid production of young ones. Thus he has recorded exactly the same management of tubers that was suggested for Tulan and other parts of Northern Chile (see ch. 4).

6.5.3.) Other plant and animal resources from Tulan.

A number of the samples from Tulan 54 (both coprolites and Flotation samples) contained considerable numbers of cf. *Sisymbrium* seeds. In the coprolite samples these had evidently been ground into small fragments while they remained whole, in the flotation samples. They clearly represented a supplementary gathered resource which would have been available only at certain times of the year. Ethnographic data from Southern California indicate that members of this genera were collected, ground and cooked in water (Barrows 1900) and it is possible that the ancient dwellers of Tulan carried out a similar procedure.

In terms of agricultural produce very little evidence was forthcoming. A few coprolites produced examples of pale seeded *Chenopodium* sp. but there numbers were so low that they can have added little to the local diet (if the samples examined as part of this project can be considered to be representative). Nevertheless, it is interesting that all of the *Chenopodium* seeds were concentrated into just four samples. Even if two of these were considered to be fragments of the same coprolite (NB. samples COPTH16K/2 and COPTH16K/3 had almost identical composition) these samples were significantly different from the majority. One also contained amounts of degraded but compacted organic debris, leaf fragments and unidentified plant tissue that resembled a tough epicarp. These food items represented resources that were unlikely to have

been obtained from the immediate area around Tulan 54. They must therefore represent one of a number of possibilities,

a) coprolites of travellers passing through Tulan, possibly in one of the camelid trains that are thought to have used the valley as a route to the high puna;

b) coprolites of local inhabitants who had been trading consumable goods with people living in different resource zones;

c) coprolites of local inhabitants who had been bringing food resources with them (either in their guts or as food) as they moved from one ecological zone to another as part of their pattern of seasonal movement.

It would be difficult to distinguish between these possibilities at present.

One flotation sample also produced a single seed of cf. *Capsicum* pepper which may have arrived on site in much the same way as the samples described above. This seed is, however, very small for a cultivated variety but on the basis of such a small sample, speculation would seem premature.

One of the gut samples from Tulan 58 also had a composition that is worthy of comment here. In the non-hydrated state, fragments of a thick sclerenchymatised plant tissue was evident but on rehydration this tended to break

up such that it could no longer be recognised. From the fragmentary remains available this bore a strong similarity to the endocarp of *Krameria cistoidae*. If this is correct it causes a problem for interpretation. This species grows close to the present site in protected areas and dry water courses, but is characterised by an epicarp that is covered in tough barbed hairs. Nevertheless, Ortiz (1969) records that 'los choroyes' break open the woody endocarp (which is about the size of a chick-pea) and eat the kernel. If indeed, this is *Krameria* in the gut contents from Tu58 then it is strange that they have been eating the fragments of woody endocarp as well as the kernel and that none of these distinctive and very troublesome barbs were not accidentally ingested.

Calandrinia sp. have been used as a food resource for their high oil content in parts of the North American Southwest (Barret and Gifford 1933:152). But there is no data for their use either from the archaeological or ethnographic records from Chile.

Of the other botanical remains identified, most would seem to be of minor importance in terms of diet. A number do, however, reveal a certain amount regarding the environment in Tulan during the occupation of the sites. The presence of genera such as *Acantholippia* (*rica rica*), *Tessaria* (*brea*) and *Calandrinia* all point to an environment that was not significantly different to todays.

A considerable quantity of bone material was recovered from a number of coprolites and many of the flotation samples. Both camelid bone and smaller rodent bones were recovered from flotation samples. The rodents *Lagidium/Chinchilla* (viscacha/chinchilla), *Ctnomys fulvus* (*cholulo*) and *Phylottis* sp. (leaf eared mouse) have all been previously reported from Tulan 54 (Hesse 1984:60) and support the idea that these, together with a number of bird species, were important food resources in this area. The bone fragments from the coprolites were frequently very small and it is unlikely whether they could be used to make detailed identifications. These were frequently associated with quantities of animal hair and have both been grouped only into very broad categories on the score sheets.

With respect of processing of these animal resources one sample is of particular interest. In this sample the bone appeared to have been finely ground. Williams 1981 also noted this phenomenon from the Tarapaca valley and it matches well with ethnographic evidence from North America for the grinding up and eating of even quite large bones such as those of Deer (Bean 1972, Dickson 1907:425).

6.6.) Considering the sites together.

The three sites considered in this chapter have certain types of artifacts in common. There are similarities in the lithic and ceramic styles but there is also a gap of

over 500 years between the available dates for the cemetery at Tulan 58 and the two habitation sites. There is, however, a strong possibility that the cemetery had been used over a number of years and it is clear that more C14 dates are required. Nevertheless, it has been suggested (Nunez pers. comm.) that they may have been linked in some way but the nature of this association is not, at present well, understood. A detailed study of the lithic and other cultural artifacts is in progress.

The evidence from the biological remains does, even in the absence of this archaeological data, reveal a number of important features. Firstly, the dependence upon domesticated plant species by the inhabitants of these sites was, at least for the duration of their stay, absolutely minimal. Only a few examples of seeds of a *Chenopodium* species and only one possible *Capsicum* pepper seed were recovered. The major food resources, *Opuntia* cactus seed, *Schoenoplectus* rhizomes/tubers, *Sisymbrium* seed, rodents, birds and camelids are all present in the area directly around the sites today. The lack of *Opuntia* seed from Tulan 85 is therefore thought to indicate they were as scarce in this area in the past, as they are today.

The data suggest that inhabitants were only exploiting their immediate environment with little transport of foods from other areas. This last point is particularly important. As indicated in section 6.2.1. above, a number of highly productive food species notably *Prosopis* sp.

(Algarrobo) and *Geoffroea decorticans* (chanar) grow in abundance at the nearby oasis of Tilomonte (only 2-3 hours away on foot from any of the above mentioned sites). The alluvial fan that forms the oasis is also the area where, if agriculture was being practiced, it would have been most likely to have occurred. None of the most productive resources (eg. *chanar* and *algarrobo*) that are abundant at Tilomonte, with the possible exception of one possible sample of *chanar* and a few *Chenopodium* seeds, have, however, been recovered from any of the sites analysed. It is unlikely that the sweet and highly productive tree legumes from Tilomonte would have been overlooked by the population and would not have been exploited at the appropriate times of the year. The fact they were not brought to the sites of Tulan 54 and Tulan 58 would therefore imply that the inhabitants must have moved to this area for periods of time in order to collect and consume the legumes and that Tulan 54 was not a year round occupation site.

The presence of camelid bones and droppings at Tulan 54 and Tulan 85 also indicated that camelid herding was taking place. If this is the case, then summer pasture in the high puna would have been a very likely option and would have necessitated that a percentage of the population accompanied the herds during this time. These data give strong support to the hypotheses of seasonal nomadism (eg. Nunez 1981) previously put forward for this part of Chile. They suggest a system in which the exploitation

of complimentary human food resources (cactus seeds, *unquillo* rhizomes and the tree legumes of *algarrobo* and *chanar*) were reconciled with the pasture requirements of the camelid herds. Niemeyer and Schiappacasse (1976) have already reported the discovery of early habitation sites in the high puna above Tulan but, as yet, little data has been recovered from a number of the other resource zones.

Today, the area of Tulan and Tilocalar (ie. the area around Tu54/58 and Tu85 respectively) are visited only periodically, by local herders, when pasture in the puna is not available because of the harsh winter weather. These same herders also tend fields of fodder crops (alfalfa) and subsistence crops of maize in the nearby oases. These people would still seem to be following this ancient cycle in which the oases, high puna and intermittent valleys all play an integral part.

Unfortunately, the data available does not make it possible to accurately identify the season of occupation of these sites. Cactus fruits are available during the period when the puna is said to be uninhabitable (may-sept - Santoro and Nunez 1987). No data are available regarding the periods in which the *unquillo* rhizome/tubers are at their most palatable. A closer study of this aspect might, however, give a more complete picture of the seasonal exploitation of plant and animal resources.

6.7.) Discussion of the quality of the data from the coprolites, gut contents and flotation samples.

The preceding discussion has concentrated upon the interpretation of the results of the botanical analyses of coprolites, gut contents, charred and desiccated flotation samples. It is therefore appropriate here, to discuss further the quality of data recovered from the different sources of data.

It is apparent that the different classes of debris were highly complementary. Firstly, the presence of two samples of gut material from the cemetery of Tulan 58 made it possible to confirm that the coprolites from Tulan 54 were indeed of human origin. The composition of the two different classes of material were so similar that this was proved beyond reasonable doubt. This being confirmed both the gut contents and coprolites provided similar qualities of data with the caveat that some contamination of the coprolites by adherent plant material, hair and mineral could have occurred. These were then be used to identify, the food items that were eaten. The identification of the debris was not always a simple opperation and the material from the flotation samples provided an invaluable start. Generally, the remains, be they charred or desiccated, from flotation samples were larger and better preserved than from the coprolites. They therefore gave a much better chance for identifications of unfamiliar, part-digested debris from the coprolites to be made.

Both faecal and flotation samples provided data relating to the processing of food. From the coprolites and gut samples it was evident that the cactus seed was frequently ground or pounded before consumption whereas flotation samples showed that only the inner pulp of the fruit was brought to the site. Similarly, the coprolites showed that considerable quantities of *unquillo* epidermal tissue was consumed even after processing. The flotation material on the other hand showed that the stems and the tops of the tubers were cut from the edible part of the plant, on site, and that a certain amount of peeling may have taken place before they were eaten.

In terms of gaining a more complete picture relating to diet, the samples were highly complementary. For example, the coprolites contained only occasional remains of meat, fragmentary remains of animal bone and feather and quantities of hair. The flotation and dry sieved samples from the site, on the other hand, revealed whole rodent skins, bird bones and beaks, rodent bones and teeth and camelid remains in the form of faecal pellets, wool and identifiable bone. This added substantially to the quality of the data. Especially with foods like camelid meat few identifiable remains would remain in faecal or gut residues other than the occasional accidentally consumed hairs or unidentifiable bone slivers. This bias can be rectified only by an analysis of other classes of organic remains.

Aspects of site activities can also be gained from an

analysis of the different types of debris. In the absence of the large quantities of flotation data it would be difficult to demonstrate that the samples were not deposited by passing travellers on a well used trade route. (See Callen 1968:694, 1967:285 as an example of where this may have happened). The quantity of the flotation debris confirmed that collection and processing of most food material was carried out close to the site. Exotic coprolites were, under these circumstances, easily recognised.

Finally, with respect to general data relating to the site, the macroscopic remains from the flotation samples gave a clue to the environment within which the inhabitants operated. By recording the species brought to the site for fire wood, by accident etc. a further dimension was brought to the analysis that would not be available from coprolites or gut remains alone.

6.7.) Some implications of the results.

These results have again reinforced the conclusions drawn in chapters 4 and 5. Certain food elements recovered from the coprolites and gut contents have proved to be easier to identify and quantify than others and evidence for the consumption of certain food resources is again lacking. In this particular case, evidence for the consumption of *Opuntia* sp. seed is overwhelming and it was relatively easy to relate this back to the undigested equivalents with some accuracy on account of the robust endocarp and

seed testa. Fibre from the rhizomes of *Schoenoplectus* was similarly resistant to digestion but evidence that some processing involving the removal of part of the fibrous outer layers make the calculation of the original amount of food consumed more problematic. There was frequently evidence for the consumption of small mammals, birds and amphibians but, as already noted in section 4.6, it was difficult relate these back to the original amounts of food consumed with any accuracy. Concrete evidence for the consumption of camelids from the coprolite and gut samples was once again lacking. Camelid bone, fibre (hair and wool) and droppings were common in many of the flotation samples suggesting that the lack of significant camelid remains from the faecal residues was probably misleading. Luckily, however, in the case of Tulan, the flotation samples may enable this balance to be redressed as more data relating to the consumption of camelids and rodents are forthcoming. It will then hopefully be possible to correlate this with data on the size and duration of occupation of the human population at the various sites.

Chapter 7 - Discussion and Conclusions.

7.1.) Introduction.

The aims and objectives of this thesis, as outlined in chapter 1, are concerned with the recovery of information on prehistoric human diet and subsistence from ancient gut and faecal remains. It can be divided broadly into two parts. The first part (chapters 2-3) focused on methodological and taphonomic aspects of the analysis of ancient human gut and faecal residues. The second part (chapters 4-7) then attempted to apply these revised methodologies to a wide range of ancient human gut and coprolite samples. Because of the nature of the project, much of the discussion and conclusions relating to the results from each of the different areas of study have, of necessity, been presented separately in the relevant sections. Nevertheless, it is possible to draw a number of broad conclusions, and these are discussed in more detail in this final chapter.

7.2 .) Processing of gut and coprolite samples.

A number of amendments were made to the techniques commonly used in coprolite analysis (see chapter 2). These have clarified some outstanding deficiencies and resulted in a number of benefits for the present project, as

follows:

a) The use of the coloration of the rehydration solution (trisodium phosphate) as an indicator of the human or non-human origin of coprolites was investigated. The same dark red/brown coloration was shown to occur with a wide variety of other ancient organic materials and was not unique to ancient human coprolites. It was therefore concluded that coloration of the the rehydration solution was of only minimal value in identifying the donor species and it was clearly necessary to use as many different characteristics as possible. The size, shape and composition of the coprolites, the context in which they were found, and the presence of human parasites were of particular importance.

b) Throughout the project, gut and faecal remains were sorted while still suspended in water, thus making it easier to recognise different classes of debris and identify the more delicate tissues. In this way, the spectrum of dietary elements recovered was thought to be greater than if more standard dry sorting techniques had been used. This added information is considered to have justified the extra time required for the sorting of each sample.

c) Detailed histological observations using both high-powered light microscopy and scanning electron microscopy were used to identify much of the food debris. Cellular characteristics were frequently

used as the basis for identifications and these were presented as written descriptions and also as a series of photo-micrographs (appendix 2). Where different tissues from a single species were recovered, these were recorded separately. In some cases this allowed identification of certain aspects of food processing prior to consumption. Other features, such as the colour of the plant tissues was also recorded, as it was considered that they could provide evidence for the maturity or the degree of domestication of certain plant foods (eg. 6.5.2.). Detailed recording of which tissues were recovered and their anatomy will form a corpus of reference data for future studies and allow reassessements in the light of newly developed identification and interpretive techniques.

d) Where possible, detailed quantification of the different classes of food debris was done by dry weight per gram of gut or coprolite material (see section 4.5.6). This allowed the data to be presented in a clear, non-subjective way, and resulted in a number of advantages over other methods, as follows:

i) The data can be reassessed and manipulated in other ways at a later stage, if required.

ii) The quantification technique does not rely on the skill and experience of the analyst and is therefore scientifically repeatable.

iii) The results can be used in conjunction with

nutritional data to estimate the equivalent amounts of undigested food represented by the identified debris (see section 7.4).

To maximise information recovered from the samples it became apparent that the analytical techniques had to be tailored to specific samples with the methods employed reflecting the composition, preservation and degree of contamination of the sample. Some samples, for example, showed only limited scope for analysis and interpretation by virtue of their poor preservation or highly processed food constituents. In these cases, therefore, it was only possible to undertake only a subjective evaluation of the composition. However, even though this failed to provide detailed quantitative data, it was still of considerable value.

7.3.) Taphonomy.

7.3.1.) Food processing and digestion.

Chapter three was concerned with the detailed analysis of how the anatomy of different food tissues change as they pass through the human alimentary canal. Those tissues which were most likely to survive digestion and bacterial fermentation in the intestinal tract were identified for a number of different plant and animal species. These data can be extrapolated to other similar foods and thus be used to identify those tissues that would be most

likely to survive digestion in an identifiable form. This has a number of important implications for the study of ancient human gut and faecal residues, as follows:

a) A knowledge of those tissues which commonly survive passage through the gut effectively increases the value of negative evidence. Consequently, if indigestible elements are absent from samples, especially in the presence of other similarly or more digestible elements, they can be assumed not to have been eaten.

b) A knowledge of foods which are commonly digested such that they leave little or no identifiable debris helps to identify deficiencies in the data, and other more appropriate methods of recovery can be sought. More specifically it allows identification of those food types whose absence in faecal remains cannot be used to demonstrate absence in the local diet.

c) A knowledge of those items which are most likely to survive enables appropriate reference preparations to be selected. There would be little value in preparing reference specimens of tissues that are regularly reduced to an unidentifiable form, and time would be better spent in preparing more commonly surviving tissues.

d) A knowledge of the processes of digestion have enabled some of the fibre values used in the calculation of undigested foods (see section 7.4) to be amended so that they more closely reflect those from the faecal debris.

There are certain other important implications of this work, notably that the availability of nutrients for digestion is affected by the form in which the food is eaten. A number of samples described in chapter 3 showed that otherwise readily digestible foods such as starch- and oil-rich parenchyma, could survive if they were protected from enzymic and bacterial attack in the gut. This occurred as a result of complete seeds passing through the gut (eg. lentils) or when compact oil- and protein-rich tissues were eaten with only minimal processing (eg. maize embryos, hazel embryos). In this last case the impenetrability of the tissues to water-soluble enzymes restricted their ability to break down otherwise digestible foods. It was concluded that the availability of nutrients in such foods was largely dependent on the degree to which they were processed prior to consumption. Nutrient yields from such foods may therefore be considerably lower than the usual published values produced by total extraction of nutrients by in vitro chemical means, and illustrates the danger of using such values uncritically for nutritional analyses or in the reconstruction of past food needs. The fact that these normally digestible food components can survive apparently unaltered also indicates that the use of techniques such as starch grain

or chemical analysis of surviving compacted organic debris from ancient gut and faecal residues could, in some cases, usefully add to the available data.

7.3.2.) Post depositional decay.

The experimental work presented in chapter 3 reported on the taphonomic aspects of food processing and digestion but did not consider the effect of post depositional decay on food debris. The variation in survival and decay is considerable, and dependent on a complex series of interacting factors such as acidity, salinity, temperature and aridity that must have remained more-or-less constant since the body was buried or the coprolite deposited. Chapters 4-6 dealt with a number of different classes of gut and faecal debris and certain points relating to the taphonomy of these have become apparent, as follows:

a) **Desiccated human gut contents.** Where substantial quantities of body tissue survive, the gut contents would also be expected to survive if they were, in fact, present when the body was interred. In such samples the preservation of food debris can approach that recorded from modern digestion experiments. Where localised deterioration of body tissues has occurred by putrefaction or subsequent microbial or insect attack, however, much poorer preservation was recorded even though large quantities of surface tissue (eg. skin and hair) may remain.

b) **Desiccated human coprolites.** If these survive as discrete entities, then preservation can generally be assumed to be good. They had often been rapidly desiccated and preservation commonly approached that observed in modern faecal samples. One good example of this came from Tulan 54 (COPTH16K/1) in which a plant tissue resembling the dense oil- and protein-rich parenchyma of certain nuts was recovered. Unfortunately this could not be identified from the microscopic evidence alone and may be a prime candidate for eventual chemical analysis.

c) **Waterlogged human gut contents.** Preservation of the dense parenchyma noted above contrasts with the absence of equivalent tissues in samples preserved by waterlogging. The waterlogged Lindow III sample, for example, yielded substantial remains of hazel testa but no remains of the cotyledons. The experiments conducted in chapter 3 indicated that traces of hazel cotyledon would be expected to survive in the gut and suggested that they had disappeared in the Lindow III sample as a result of post depositional decomposition. Other plant tissues, such as, the outer pericarp of cereal grains were not commonly recovered from archaeological samples although they survived relatively well in modern digestion experiments. It would seem that, in the waterlogged environment, a definite, albeit slow, breakdown of cellulose and other organic molecules - both chemically and by microorganisms - occurs.

Preservation in waterlogged environments consequently appears to be less complete than with preservation by rapid desiccation. In some desiccated samples even starch was recovered but it is doubtful whether this would have occurred in waterlogged samples. These results suggest that, while it will be necessary to resolve a number of problems of decomposition chemistry before identifying part-digested foods in waterlogged faecal debris from chemical markers, chemical identification of food residues in desiccated faeces should be more straightforward.

7.4.) Calculating the amounts of each food ingested.

One of the main reasons for the sorting methods used and for using an absolute method of quantification was to be able to quantify the amount of different foods that had originally been eaten. Most previous coprolite analyses have presented the data in terms of the surviving food debris alone, with few attempts at reconstructing the equivalent amounts of undigested foods that these represented. Such analyses are of only limited value, and are heavily biased towards the more fibrous elements in the diet which tend to survive digestion. An attempt has been made to partially redress this balance by using published values for the percentage of fibre present in foods as the basis for calculating original weights of the ingested foods.

In calculating these weights it was not intended to

suggest that they represented the amounts of ingested food with any accuracy. They gave, at best, only approximate values of this and their principal function was to compensate for the differential digestion of the diverse food types.

There were relatively few cases which provided an opportunity to confirm the accuracy of this technique. With some samples, however, it was possible to calculate the equivalent weights of undigested food by two separate means (eg. *Prosopis* in TR40 T-6, section 4.3.4.). In such cases the results showed good agreement and provided a degree of confidence in the technique. So far, therefore, the proposed method of calculating the original proportions of different foodstuffs in ingested foods has been vindicated. Such an approach to quantification is clearly central to any attempt at dietary reconstruction for analyses of palaeofaeces.

A further point relating to the quantification of the debris has also become apparent. In some samples it was evident that the proportions of different food items in the smaller than 1mm. sieve sizes (as determined by a subjective assessment) was different from those recorded from the larger sieve sizes. While this means that the proportions of different foods that were calculated from the larger sieve sizes may not always accurately reflect those in the smaller ones it potentially offers a means of identifying the use of differing processing techniques

on different foods. Such was the case with a sample from Azapa 71 (section 4.4.4.2) where the *Chenopodium* part of the meal would seem to have been more finely milled than had the rest of the meal.

7.5.) Some remaining methodological problems.

The preceding sections have outlined a number of positive advantages relating to the quantification methods used in this thesis. There are, however, still a number of areas where the present microscopic approach is deficient.

a) **Under-representation of highly processed or low fibre foods.** Where foods were finely processed such that the fibrous component was removed, or where low-fibre foods were eaten, few identifiable remains are recovered from gut or faecal remains. The different components of the debris from such samples cannot be weighed and are therefore under-represented on the score sheets.

b) **Partial processing and removal of fibre** - Certain processing techniques may remove a proportion of the identifiable food debris (eg. partial removal of plant fibre). In such cases, the values calculated for the equivalent weights of undigested food will not accurately reflect the quantity of food eaten. *Schoenoplectus* sp. rhizome fibre, or *Prosopis* sp. pod, for example, might be processed such that part of the identifiable fibre was removed. In such cases two sources of evidence might help to clarify the

situation.

i) In the case of *Schoenoplectus* sp. from Tulan, for example, evidence from the flotation samples showed that the fibrous top of the tubers was removed before eating and that a small amount of peeling may also have taken place. The fibre values used as the basis of the calculation of equivalent food debris could therefore be amended in the light of these data.

ii) With a sample of *Prosopis* pod fibre, (TR40 T-6) it was possible to calculate the equivalent weight of undigested food by two different means - by the weight of the total fibre and by the number of endocarp segments present. In this case the results from both methods proved to be very similar, thus suggesting that no single element of fibre had been selectively removed.

Unfortunately no supplementary data was available to indicate how maize was thought to have been processed in these societies. It was therefore impossible to assess whether the number of rachillae in the samples was representative of the total quantity of ingested maize, or whether a percentage of these fibrous parts had been removed prior to being eaten. If the latter was the case, then maize may be severely under-represented in certain samples.

These examples highlight the importance of:

i) examining where possible other sources of associated archaeological remains such as flotation and dry sieving samples.
ii) using as many different techniques as possible to calculate the equivalent amounts of undigested food.

c) **The limited range of food debris usable for calculating their undigested equivalents.** In some samples only one or possibly two food elements proved useful in the calculation of equivalent amounts of undigested food. In these cases, the calculation of the amount of food ingested did not significantly add to the quantitative data relating to the components within a single sample. Nevertheless it could be of more importance in comparing the approximate quantities of foods between different samples. It may therefore prove possible to trace the changing usage of these foods between different sites or through time, as more samples are studied in the same way.

These three limitations would seem to be inherent in all purely macroscopic analyses of gut and faecal remains. In reconstructing past diet therefore, it is clearly important to combine the results from as many different types of analyses as possible.

7.6.) Samples from the guts of well-preserved ancient humans.

As outlined in section 1.2.1.3., the analysis of human gut contents has a number of advantages over other classes of human faecal remains. A number of specific points relating to such analyses have, however, been highlighted and are outlined below.

a) The supposition that was made during the initial stages of this project was that the gut contents of human bodies would be less susceptible to contamination than coprolites or cess material. While this was found to be generally true, a significant number of samples from the guts of well preserved human bodies yielded debris that superficially resembled faecal material but which proved to be contaminants. These included: insect frass, degraded textile remains, degraded body tissues, sandy concretions, grave goods and other debris that had entered the bodies in the years since their interment.

b) A number of the bodies sampled produced few traces of gut contents. It would seem likely that such samples had been recovered from people who had died as the result of certain forms of illness. This conclusion was based on the fact that people do not eat normally when suffering from severe illness (especially if this is a gastrointestinal disorder), and small quantities of food debris might thus be expected in their gut at death.

Nevertheless, it was notable that a number of the bog bodies from Northern Europe contained relatively large quantities of gut contents. Most of these bodies showed evidence of having met a violent death and the quantity of food debris in their intestines may indicate that this had occurred somewhat unexpectedly. Such was also the case with a body from El Morro (Mo1-6 T-18) which showed several signs of having met a violent end. This body produced by far the richest samples of gut material from that group.

This study of human intestinal contents also showed the importance of recording the parts of the gut from which the samples were taken, thus allowing different meals to be identified within the alimentary canal of a single individual. Methods of accurate sampling of well preserved bodies using minimum damage procedures were therefore developed during the latter part of this project (Brothwell *et al.* in press). Using the non-destructive scanning techniques of radiography and computed tomography it proved possible to locate and remove intestinal material by means of a small 'trap door' in the abdomen. The procedure worked well and is showing considerable potential with more recently investigated desiccated bodies.

7.7.) Integrating the data from guts and coprolites with other forms of dietary evidence.

The information provided by the analytical approach adopted throughout the project indicated that it should, wherever possible, be amalgamated with data from other non-faecal remains. These include remains recovered by flotation (for plant remains), dry sieving (for bone) and other non-organic artifacts (lithics, ceramics etc.).

From the sites in the Tulan region of Northern Chile it was possible to achieve this integration. The data from the coprolites and intestinal contents were in close agreement with each other. This similarity of composition confirmed that the coprolites were of human origin. The site also provided quantities of camelid, bird and rodent bone which compensated for the low visibility of such animal foods in the coprolite material (see section 6.5.3.). The flotation samples yielded data relating to the processing of the plant foods as did the lithic artifacts in the form of grinding equipment. In the absence of detailed pollen spectra for the area, the plant remains on the site also provided a certain amount of data relating to the environment in which the populations operated. These different forms of data have been shown to be complementary, and only by taking all of the different aspects into account can a balanced picture of ancient diet can be obtained.

7.8.) Some implications of the results.

During the study of a wide range of ancient and modern faecal material it has become clear that only certain classes of food leave significant quantities of identifiable remains once they have passed through the human gut. This selective process has been studied in some detail in chapter 3 and a number of criteria determining which of these plant and animal tissues will survive digestion in an identifyable form, have been discussed. One of the most important implications of this part of the research was the demonstration that the digestibility of certain food types (eg. dense oil rich parenchyma) was highly dependant on the degree to which they were processed prior to ingestion. The number of calories available to the human body will therefore be likewise dependant on how such foods were processed. This feature is of considerable importance when attempts are being made to understand a) the calorific requirements of human populations based upon *in vitro* measurements of the nutritional values of their foods and b) the relationship between the costs and returns of subsistence related activities. It is therefore apparent that the methods of food preparation should also be considered during such calculations.

The surviving food debris from the ancient samples was clearly biased in favour of those foods that contained hard or fibrous elements. In some foods, the relationship between these surviving elements and the original foods could be used to calculate the equivalent amounts of

undigested foods represented by a given quantity of faecal debris. In such cases, it was possible to reconstruct a reasonably accurate picture of the quantities of different foods represented by the debris recovered from one gram of coprolite or gut contents. With some samples this has proved very informative. The different proportions of rye and corn spurrey seeds from the gut of the Huldremose body, for example, could be calculated with some accuracy and has added a further dimension to the understanding of the composition of her "last meal".

Unfortunately, however, the number of different classes of foods which were amenable to this type of reconstruction was limited. Foods such as, seeds or fruits with a tough testa or pericarp proved to be well suited to these techniques as were other plant or animal tissues where there was a consistent relationship between the undigested to the digested parts (eg. mollusc radulae to mollusc flesh). Many other foods also regularly left identifiable traces in ancient faecal material but were not amenable to the type of reconstruction outlined above. This category included such remains as the bones of small mammals or fish and fragments of the cork layer or certain underground storage organs (eg.potato or manioc).

As discussed in chapters 4-6, a third category of foods left neither identifiable remains in the faecal debris nor any means of estimating the amounts consumed. The meat of larger animals, milk products, eggs, highly

processed plant foods, for example, will all remain invisible to this microscopical approach unless radically different methods can be developed.

In short, some foods are both identifiable and amenable to some form of reconstruction, others are identifyable but provide, at best, unreliable data on the amounts consumed, and some foods cannot even be identified using a purely microscopic approach. This creates serious problems for accurate reconstruction past meals involving different classes of foods. Nevertheless, even though it is only possible to calculate accurately the proportions of certain classes of foods ingested it is still important to understand the relationships between such foods in the diet even if this does not represent the complete picture. The techniques used throughout this thesis provide an relatively accurate means of undertaking reconstructions at this level. It can only be hoped that as other analytical techniques and detailed quantitative techniques related to other classes of archaeological remains are developed these will be be able to provide a similar quality of complementary data for those foods that cannot be adequately dealt with by faecal or gut content analyses alone.

7.9.) *Final comments and future potential.*

This project has focused specifically on aspects of diet (ie. what people eat) and subsistence (how people support themselves). It has not attempted to address questions relating to nutrition, which remains, even in relatively well-studied modern populations, an imprecise science. Many of the data relating to human nutritional requirements are based upon urban western populations and are probably much higher than basic human needs. With ancient populations, periods of stress in which certain essential nutrients were below basic requirements were probably counteracted by periods of plenty. In such situations a study of diet over a short period of time (as revealed by coprolites or gut contents) provides only a poor picture of nutrient intake over longer periods. Nevertheless it is only by detailed analyses such as the ones presented here (in conjunction with data from the chemistry of human tissues - see below) that accurate data can begin to accumulate.

The need for an integrated approach has been underlined and has necessitated the application of techniques and specialist help from a number of different disciplines (see appendix 2). Beyond these specialities, however, chemical analysis is an approach that might also add significantly to the data, especially if applied to the identification of food items that are not readily recognised from their microscopic remains alone. Residual chemicals such as waxes, protein and fatty acids from

faecal remains are beginning to be analysed (eg. Wales *et al.* 1989) and it is to be hoped that they might eventually be able to add significantly to the data on ancient diet.

Analysis of coprolites from Tulan, Chile was supported by data from analysis of macroscopic plant and animal remains from several different sites. With the analysis of most of the human intestinal samples presented here, however, few supporting data were available. Nevertheless the bodies themselves could provide a valuable source of information on past diet if the correct techniques were employed. In this respect the chemical analysis of bone and hair for example, (eg. Benfer *et al.* 1976, Bumstead 1984, Hrdy 1976, Lambert *el al.* 1979 and Spzunar *et al.* 1978), has already proved its worth. Such analyses have, however, yet to be undertaken on the same bodies that have provided gut contents for analysis.

These chemical techniques can give a more general picture of diet over long periods in time. Seasonal changes in diet might even be revealed by chemical analyses along lengths of hair by the use of microanalytical techniques such as Proton Induced X-ray Emission (PIXE). These approaches might therefore provide a broad dietary framework for the detailed data from gut and faecal analyses. Plans for such analyses are already in hand and if used

in conjunction with the other approaches outlined in this thesis would represent an important step in research on post human diet and subsistence.

Artschwager,E. 1924.
Studies on the Potato Tuber. *Journal of Agricultural Research*, 27(2), 809-833.

Ascenzi,A. Cockburn,A and Kleiss,E. 1984.
Miscellaneous Mummies. In (A.Cockburn and E.Cockburn eds.) *Mummies, Disease, and Ancient Cultures* (Abridged). Cambridge: Cambridge University Press. pp. 225-238.

Aufderheide,A. n.d.
Protocolo de Autopsia de Mumias y/o Osteologia de Esqueletas Arqueologicas (Autopsy reports), Unpublished Reports from the Instituto de Antropologia, Universidad de Tarapaca, Arica-Chile.

Ayckroyd.W.R. and Doughy,J. 1982.
Legumes in Human Nutrition. F.A.O. Food and Nutrition Paper no. 20 Rome.

Baker,A. (in press).
Two New Species of *Lardoglyphus* Ovdemans (Acari: Lardoglyphidae). Found in the Gut Content of Human Mummies.

Barber,K.G. 1909.
Comparative Histology of Fruits and Seeds of Certain Species of Cucurbitaceae. *Botanical Gazette*, 47, 263-310.

Barranco,R.A. 1978.
Preservation of Proteins in Mummified Tissues. *American Journal of Physical Anthropology*, 48, 487-492.

Barret,S.A. and Gifford,E.W. 1933.
Miwok Material Culture. *Bulletin of the Milwaukee Public Museum*, 2(4).

Barrows,D.P. 1900.
The Ethno-botany of the Coahuilla Indians of Southern California. Chicago: University of Chicago Press.

Basly,J. 1982.
Moluscos Marinos del Norte de Chile, Iquique: McLean and Andrade.

Bean,L.J. 1972.
Mukats People: The Cahuilla Indians of Southern California. Berkley: University of California Press.

Bean,L.J. and Saubel,K.S. 1972.
Temalpakh, Cahuilla Knowledge and Usage of Plants Morongo Indian Reservation: Malki Museum Press.

Beck,J.R. and Beck,D.O. 1955.
A Method for Nutritional Evaluation of Wildlife Foods. *Journal of Wildlife Management*, 19(2), 198-205.

Benfer,R.A. Typpo,J.T. Graf,V.B. and Pickett,E.E. 1978.
Mineral Analysis of Ancient Peruvian Hair. *American Journal of Physical Anthropology*, 48, 277-282.

Benninghoff,W.S. 1947.
Use of Trisodium Phosphate with Herbarium Material and Microfossils in Peat. *Science*, 106, 325-326.

Berenguer,J. and Dauelsberg,P. 1889.
El Norte Grande en la Orbita de Tiwanaku (400 a 1200 D.C.). In (J.Hidalgo, V.Schiappacasse, H.Niemeyer, C.Aldunate and I.Solimano eds.) *Culturas de Chile: Prehistoria desde sus Origenes Hasta los Albores de la Conquista*. Santiago: Editorial Andres Bello. pp. 129-180.

Berggren,G. 1981.
Atlas of Seeds and Small Fruits of Northwest-European Plant Species. Part 3: Salicaceae - Cruciferae. Stockholm: Swedish Natural Science Research Council.

Bhadresa,R. 1981.
Identification of leaf Epidermal Fragments in Rabbit faeces (With Reference to Highland Vegetation). *Rogate Papers*, 4. Kings College London. pp. 1-23.

Bhadresa,R. 1986.
Faecal Analysis and Enclosure Studies. In (P.D.Moore and S.B.Chapman eds.) *Methods in Plant Ecology*. Oxford and London: Blackwell Scientific Publications. pp. 61-71.

Bird,J.B. 1963.
The Cultural Sequence of the North Chile Coast. In (J.H.Steward ed.) *Handbook of South American Indians. Volume Two: The Andean Civilisations.* New York: Cooper Square Publishers. pp. 587-594.

Bird,R. 1979.
Report on Plant Remains from the Tilaviche site, Tarapaca Province, Chile. Manuscript - Dept of Anthropology, National Museum of Natural History, Smithsonian Institution.

Blythe,R. 1969.
Akenfield. (1985 reprint). London: Penguin Books.

Bock,J.H. Lane,M.A. and Norris,D.O. 1988.
Identifying Plant Food Cells in Gastric Contents for Use in Forensic Investigations: A laboratory Manual. U.S. Department of Justice, National Institute of Justice.

Bourke,J.B. 1986.
The Medical Examination of Lindow Man. In (I.M.Stead, J.B.Bourke and D.R.Brothwell eds.) *Lindow Man: The Body in the Bog.* London: British Museum Publications. pp. 46-52.

Bourke,J.G. 1891.
Scatologic Rites of All Nations. Washington, D.C.: W.H.Lowdermilk and Co.

Brandt,J. 1950.
Planterester fra et Moselig fra Aeldre Jernalder : Borremose (Plant Remains in the Body of an Early Iron Age Man from Borre Fen). *Arboger for Nordisk Oldkyndighed og Historie,* 1950, 348-350.

Brothwell,D.R. 1986.
The Bog Man and the Archaeology of People. London: British Museums Publications.

Brothwell,D.R. Holden,T.G. Liversage,D. Gottlieb,B. Bennike,P. and Bosen,J. in press.
Establishing a Minimum Damage Procedure for the Gut Sampling of Intact Human Bodies. The Case of the Huldremose Woman. Submitted to Antiquity

Brothwell,D.R. Liversage,D and Gottleib,B. (in press).
Radiographic and Forensic Aspects of the Huldremose Body. *Journal of Danish Archaeology*, forthcoming volume.

Browman,D.L. 1983.
Aspectos de Nutricion Prehistorica en la Cuenca del Lago Titicaca. *Dialogo Andino*, 2, 29-42. Departamento de Historia y Geografia, Universidad de Tarapaca, Arica, Chile.

Bryant,V.M. 1969.
Late Full-Glacial and Postglacial Pollen Analysis of Texas Sediments. PhD. Dissertation, University of Texas, Austin.

Bryant,V.M. 1974.
Pollen Analysis of Prehistoric Human Feces from Mammoth Cave. In (P.J.Watson ed.) *Archaeology of the Mammoth Cave Area*. New York: Academic Press. pp.203-209.

Bryant,V.M. 1974a.
Diet in Southwest Texas, the Coprolite Evidence. *American Antiquity*, 39, 407-420.

Bryant,V.M. 1974b.
The Role of Coprolite Analysis in Archaeology. *Bulletin of the Texas Archaeological Society*, 45, 1-28.

Bryant,V.M. and Williams-Dean,G. 1975.
The Coprolites of Man. *Scientific American*, 232(1), 100-109.

Buckland,P.C. 1976. (ed.)
The Environmental Evidence from the Church Street Roman Sewer System. The Archaeology of York - The Past Environment of York 14/1. Published for the York Archaeological Trust by the Council for British Archaeology.

Buckland,W. 1829.
On the Discovery of Coprolites, or Fossil Faeces, in the Lias at Lyme Regis, and in Other Formations. *Transactions of the Geological Society - series II*, 3(1), 223-236.

Bullock,P. Federoff,N. Jongerius,A. Stoops,G. and Tursina,T.V. 1985.
Handbook for Soil Thin Section Description. Wolverhampton: Waine Research Publications.

Bumstead,M.P. 1984.
Human Variation: C13 in Adult Bone Collagen and the Relation to Diet in an Isochronous C4 (Maize) Archaeological Population. Phd Thesis submitted to Los Alamos, National Laboratory, New Mexico.

Burkart,A. 1952.
Las Leguminosas Argentinas (Silvestres y Cultivadas). (2nd. edition). Buenas Aires: Acme Agency.

Burkart,A. 1976.
A Monograph on the Genus Prosopis. (Leguminosae subfam. Mimosoideae). *Journal of the Arnold Arboretum*, 57(3), 219-249, and 57(4), 450-455.

Butler,E.A. 1988.
The SEM and Seed Identification, with Particular Reference to the Vicieae. In (Olsen,S.L. ed.) *Scanning Electron Microscopy in Archaeology*. Oxford: British Archaeological Reports, International Series 452, 215-224.

Calder,A.M. 1977.
Survival Properties of Organic Residues through the Human Digestive Tract. *Journal of Archaeological Science*, 4, 141-151.

Callen,E.O. 1963.
Diet as Revealed by Coprolites. In (D.R.Brothwell and E.Higgs eds.). *Science in Archaeology*. London: Thames and Hudson. pp. 186-194.

Callen,E.O. 1967a.
The First New World Cereal. *American Antiquity* 32, 535-538.

Callen,E.O. 1967b.
Analysis of the Tehuacan Coprolites. In (Byers,D.S. ed.) *The Prehistory of the Tehuacan Valley. Vol. 1: Environment and Subsistence*. Austin: University of Texas Press. pp. 261-289.

Callen,E.O. 1968.
Plants, Diet, and Early Agriculture of some Cave Dwelling Pre-Colombian Mexican Indians. *Actas and Memorias del XXXVII Congresso International de Americanistas*, 2, 641-656.

Callen,E.O. 1969.
Diet as Revealed by Coprolites. In (D.R.Brothwell and E.Higgs. eds.) *Science in Archaeology. (Second Edition)*. New York: Praeger Publishers. pp 235-243.

Callen,E.O. and Cameron,T.W.M. 1960.
A Prehistoric Diet Revealed in Coprolites. *The New Scientist* 8(190), 35-37, 39-40.

Callen,E.O. and Martin,P.S. 1969.
Plant Remains in Some Coprolites from Utah. *American Antiquity*, 34, 329-331.

Cammidge,P.J. 1914.
The Faeces of Children and Adults. New York: William Wood and Company.

Castetter,E.F. and Bell,W.H. 1937.
Ethnobiological Studies in the American Southwest IV: The Aboriginal Utilization of the Tall Cacti in the American South West. *The University of New Mexico Bulletin*. Whole Number 307. Biological Series, 5(1): Albuquerque, New Mexico.

Castri,F,Di. Hajek,E. 1976.
Bioclimatologia de Chile. Universidad Catolico de Chile, Santiago.

Castro,M. Villagran,C. and Arroyo.M. 1982.
Estudio Ethnobotanico en la Precordillera y Altiplano de los Andes del Norte de Chile (18-19 Degrees S) in *El Hombre y los Ecosystemas - vol. II: Biologia Humana y Aspectos de la Antropologia Social en el Transecto Arica - Lago Chungara*. M.A.B. 6, 133-199.

Chambers,F.M. 1989.
The Evidence for Early Rye Cultivation in North West Europe. In A.Milles D.Williams and N.Gardner. *The Beginnings of Agriculture*.. Oxford: British Archaeological Reports. International Series. No. 496. pp. 165-175.

Chambers,F.M. and Jones,M.K. 1984.
Antiquity of Rye in Britain. *Antiquity*, 58, 219-224.

Chame,M., Ferreira,L.F., Arajo,A. and Confalonieri,U. 1989.
Testing the Colour Parameter of Coprolite Rehydration Solution. *Paleopathology Newsletter*, 68, 9-11.

Chamrad,A.D. and Box.T.W. 1964.
A Point Frame for Sampling Rumen Contents. *Journal of Wildlife Management*, 28(3), 473-477.

Chang,C.R. and Tsen,C.C. 1981.
Characterization and Heat Stability of Trypsin Inhibitors from Rye, Triticale and Wheat Samples. *Cereal Chemistry*, 58(3), 211-213.

Chang,C.R. and Tsen,C.C. 1981.
Isolation of Trypsin Inhibitors from Rye, Triticale and Wheat Samples. *Cereal Chemistry*, 58(3), 207-210.

Chayes,F. 1956.
Petrographic Modal Analysis. New York: J. Wiley.

Clapham,A.R. Tutin,T.G. and Warburg,E.F. 1962
Flora of the British Isles second edition. Cambridge: Cambridge University Press.

Colledge,S. 1988.
Scanning Electron Studies of the Cell Patterns of the Pericarp Layers of Some Wild Wheats and Ryes. Methods and Problems. In (Olsen.S.L. ed.) *Scanning Electron Microscopy in Archaeology*. Oxford: British Archaeological Reports, International Series. 452, 225-236.

Cowan,R.A. 1967.
Lake-Margin Ecologic Exploitation in the Great Basin as Demonstrated by an Analysis of Coprolites from Lovelock Cave, Nevada. In *Reports of the University of California Archaeological Survey* no. 70. Papers on Great Basin Archaeology, Berkeley. pp. 21-36.

Cummings,J.H. 1976.
What is Fiber. In (G.A.Spiller and R.J.Amen eds.) *Fiber in Human Nutrition*. New York and London: Plenum Press. pp. 1-30.

Cummings,J.H.and Englyst,H.N. 1987.
Fermentation in the Human Large Intestine and the Available Substrates. *American Journal of Clinical Nutrition*, 45, 1243, 1255.

D'Antoni,H.L. and O.J.Solbrig. 1977.
Algarrobos in South American Cultures Past and Present. In (B.B.Simpson ed.) *Mesquite: Its Biology in two Desert Ecosystems*. US/IBP Synthesis Series 4. Stroudsbury Pennsylvania: Dowden Hutchinson and Ross Inc. pp. 189-199.

Davis,A.B. and W.D.Eustace 1984.
Scanning Electron Microscope Views of Material from Various Stages in the Milling of Hard Red Winter, Soft Red Winter and Durum Wheat. *Cereal Chemistry*, 61(2), 182-186.

Dawson,W.R. 1928.
Two Mummies from Colombia. *Man*, May 1928, 72-74.

Dennell,R.W. 1970.
Seeds from a Medieval Sewer at Woolster Street, Plymouth. *Economic Botany*, 24, 151-154.

Dickson,C. 1987.
The Identification of Cereals from Ancient Bran Fragments. *Circaea*, 4(2), 95-102.

Dickson,C. 1989.
The Roman Army Diet in Britain and Germany. *Archaobotanik Dissertationes Botanicae*, 133, 135-154.

Dickson,C. and Dickson,J. 1988.
The Diet of the Roman Army in Deforested Central Scotland. *Plants Today*, July-August, 121-126.

Dickson,J.H. Dickson,C.A. and Breeze,D.J. 1979 .
Flour or Bread in a Roman Military Ditch at Bearsden, Scotland. *Antiquity*, 53, 47-51.

Dickson,R.B. 1907.
The Shasta. *Bulletin of the American Museum of Natural History*, 17, 1902- 1907.

Drasar,B.S. 1974.
Some Factors Associated with Geographical Variations in the Intestinal Microflora. In (F.A.Skinner and Carr,J.G. eds.) *The Normal Microbial Flora of Man.* London and New York: Academic press. pp. 187-197.

Druss,M. 1978.
Environment, Subsistence, Economy and Settlement Patterns of the Chiuchiu Complex (CA. 2700 to 1600 B.C.) of the Atacama Desert. PhD. Thesis submitted to the University of Columbia.

Eastwood,M. and Mitchell,W.D. 1976.
Physical Properties of Fiber. In (G.A.Spiller and R.J.Amen eds.) *Fiber in Human Nutrition.* New York and London: Plenum Press. pp. 109-131.

Eastwood,M.A. Brydon,W.G. and Anderson,D.M.W 1986.
The Effect of the Polysaccharide Composition and Structure of Dietary Fibres on Cecal Fermentation and Fecal Excretion. *American Journal of Clinical Nutrition,* 44, 51-55.

Erices,S. 1975.
Evidencias de Vegetales en Tres Cementarios Prehispanicos, Arica, Chile. *Chungara,* 5, 65-71.

Esau,K. 1940.
Developmental Anatomy of the Fleshy Organs of *Daucus carota. Hilgardia,* 13, 175-226.

Esau,K. 1965.
Plant Anatomy. Second Edition. New York: John Wiley and Sons.

Esau,K. 1977.
Anatomy of Seed Plants (second edition). New York: J.Wiley and Sons.

Evers,A.D. and Reed,M. 1988.
Some Novel Observations by Scanning Electron Microscopy on the Seed Coat and Nucellus of the Mature Wheat Grain. *Cereal Chemistry,* 65(2), 81-85.

Farrell,N. in press
Analysis of Human Coprolites from RIV-1179 and RIV-2827 near La Quinta, California.

Felger,R.S. 1977.
Mesquite in Indian Cultures of Southwestern North America. In (B.B.Simpson ed.) *Mesquite: Its Biology in Two Desert Ecosystems*. US/IBP Synthesis Series 4. Stroudsbury Pennsylvania: Dowden Hutchinson and Ross Inc. pp. 150-188.

Flint,F.O. and Meech,M.V. 1978.
Quantitative Determination of Textured Soya Protein by Steriological Technique. *Analyst*, 103, 252-258.

Focacci,G. 1980.
Sintesis de la Arqueologia del Extremo Norte de Chile. *Chungara*, 6, 3-23.

Focacci G. 1981.
Descripcion de un Cementario Incaico en el Valle de Azapa. *Chungara*, 7, 212-217.

Fox,B.A. and Cameron,A.G. 1977.
Food Science: A Chemical Approach (third edition). London: Hodder and Stoughton.

Fretter,V. and Graham,A. 1962.
British Prosobranch Molluscs London: Ray Society.

Freud,S. 1917-19.
Standard Edition of the Complete Psychological Works of Sigmund Freud - Volume 17. 1955 edition. London: Hogarth Press.

Fry,G.F. 1970.
Prehistoric Human Ecology in Utah: Based on the Analysis of Coprolites. Dissertation for the Doctor of Philosophy Degree, University of Utah.

Fry,G.F. 1985.
Analysis of Fecal Material. In (R.Gilbert and J.I.Mielke eds.) *The Analysis of Prehistoric Diets*. New York: Academic press. pp. 127-148..

Gade,D.W. 1975.
Plants, Man and the Land in the Vilcanota Valley of Peru - Biogeographica VI. The Hague: Dr W.Junk B.V.

Gajardo,R. and Alliende,P. 1986.
Perspectivas para Interpretar la Relacion Hombre-Planta en el Ambito Arqueologico. *Chungara*, 16-17, 395-402.

Gassner,G. 1973.
Mikroskopische Untersuchung Pflanzlicher Lebensmittel. 4th edition. Stuttgart: Gustav Fischer Verlag.

Gaumann,E.A. 1928.
Comparative Morphology of Fungi. New York: McGraw-Hill Book Co.

Gifford,E.W. 1932.
The Southeastern Yavapai. *University of California Publications in American Archaeology and Ethnology*, 29, 177-252.

Glob,P.V. 1969.
The Bog People. London: Faber and Faber.

Gowlett,J.A.J. Gilespie,R. Hall,E.T. and Hedges,R.E.M. 1986.
Accelerator Radiocarbon Dating of Ancient Human Remains from Lindow Moss. (In I.M.Stead, J.B.Bourke and D.R.Brothwell eds.). *Lindow Man: The Body in the Bog*. London: British Museum Publications. pp. 22-25.

Green,F.J. 1979.
Phosphatic Mineralisation of Seeds from Archaeological Sites. *Journal of Archaeological Science*, 6, 279-284.

Green,F.J. 1981.
Iron-Age, Roman and Saxon Crops. The Archaeological Evidence from Wessex. (In M.Jones and G.Dimbleby eds). *The Environment of Man: The Iron Age to the Anglo-Saxon Period*. Oxford: British Archaeological Reports. British Series. No. 87. pp. 129-155.

Greig,J.R.A. 1976.
The Plant Remains. In (P.C.Buckland ed.) *The Environmental Evidence from the Church Street Roman Sewer System*. The Archaeology of York - The Past Environment of York 14/1. Published for the York Archaeological Trust by the Council for British Archaeology. pp. 23-28.

Greig,J.R.A. 1981.
The Investigation of a Medieval Barrel-Latrine from Worcester. *Journal of Archaeological Science*, 8, 265-282.

Greig,J.R.A. 1984.
Garderobes, Sewers, Cesspits and Latrines. *Current Archaeology*. 85, 49-52.

Grist,D.H. 1986.
Rice. London and New York: Longman.

Gunckel,L. 1967.
Fitonomia Atacamena: Especialmente Cunza. *Revista Universitaria*: *Catolica de Chile*. *Anales de la Academia Chilena de Ciencias Naturales*, 30, 3-81.

Gunckel,L. 1983.
Algunas Plantas de la Aquada de Puquios. *Boletin de Prehistoria* Universidad de Chile, Santiago, 9, 186-193.

Gunn,C.R. 1984.
Fruits and Seeds of Genera in the Subfamily Mimosoideae (Fabiaceae). Technical Bulletin No.1681. Agricultural Research Service. United States Department of Agriculture.

Hall,A.R. Jones,A.K.G. and Kenwood,H.K. 1983.
Cereal Bran and Human Feacal Remains from Archaeological Deposits - Some Preliminary Observations. In (B.Proudfoot ed.) *Site, Environment and Economy*. Oxford: British Archaeological Reports, International Series, 173, 85-103.

Hall,H.J. 1972.
Diet and Disease at Clyde's Cavern, Utah, as Determined via Paleoscatology. MA. thesis, Department of Anthropology, University of Utah, Salt Lake City.

Hall,H.J. 1977.
A Paleoscatological Study of Diet and Disease at Dirty Shame Rockshelter, Southeast Oregon. *Tebiwa*, 8, 1-13.

Hall,H.J. 1979.
Antelope House: A Paleoscatological Perspective. Unpublished Phd. Thesis from the University of Chicago.

Hanson,H.P. 1921.
Fra Gamle Dage - vol I. Herning: Forfatherens forlag.

Hanson,H.P. 1939.
De Gamle Fortalte - vol I. Arhus.

Hanson,H.P. 1941.
Hyrdeliv pa Heden. Copenhagen.

Hanson,H.P. 1959.
Hedebonder i tre Slaegtled. Copenhagen.

Harborne,J.B. 1988.
Inroduction to Ecological Biochemistry. London and New York: Academic Press.

Harshburger,J.W. 1896.
The Purposes of Ethnobotany. *Botanical Gazette,* 21, 146-154.

Hart-Hansen,J.P. Meldgaard,J. and Nordquist,J. 1985.
Qilakitsoq: De Gronlandske Mummier fra 1400 - tallet. Kobenhaun : Gyldendals Bogklub.

Hart-Hansen,J.P. Meldgaard,J. and Nordqvist,J. 1985.
The Mummies of Qilakitsoq *National Geographical, 167(2), 191-207.*

Hather,J.H. 1988.
The Morphological and Anatomical Interpretation and Identification of Charred Vegetative Parenchymatous Plant Remains. Unpublished Ph.D. Thesis Submitted to the Institute of Archaeology, University College London.

Havis,L, 1939.
Anatomy of the Hypocotyl and Roots of *Daucus carota. Journal of Agricultural Research,* 58, 557-564.

Hayward,H.E. 1938.
The Structure of Economic Plants. New York: Macmillan and Co.

Hedges,R.E.M. Housley,R.A. Law,I.A. and Bronk,C.R. 1989. Radiocarbon dates from the Oxford AMS System: Archaeometry Datelist 9. *Archaeometry*, 31(2), 207-234.

Heizer,R.F. and Napton,L.K. 1970. Archaeology and the Prehistoric Lacustrine Subsistence Regime as seen from Lovelock Cave, Nevada. *Contributions of the California Archaeological Research Facility*, 10. Berkley.

Heizer.R.F. 1967. Analysis of Human Coprolites from a Dry Nevada Cave. In *Reports of the University of California Archaeological Survey, no. 70. Papers in Great Basin Archaeology, Berkeley. pp. 1-20.*

Heizer.R.F. 1969. The Anthropology of Prehistoric Great Basin Human Coprolites in (D.R.Brothwell and E.Higgs eds.) *Science in Archaeology*. London: Thames and Hudson. pp. 244-250.

Helbaek,H. 1950. Tollundmandens Sidste Maltid (The Tollund man's Last Meal). *Arboger for Nordisk Oldkyndighed og Historie*, 1950, 328-341.

Helbaek,H. 1954. Prehistoric Food Plants and Weeds in Denmark: A Survey of Archaeobotanical Research 1923-1954. *Dansk Geologische Undersuchungen*, 2, 250-261.

Helbaek,H. 1958. Grauballemandens Sidste Maltid (The Grauballe Man's Last Meal). *KUML*, 1958, 83-116.

Hesse,B. 1984. Archaic Exploitation of Small Mammals and Birds in Northern Chile. *Estudios Atacamenos*, 7, 42-61.

Heywood,V.H. 1978. *Flowering Plants of the World*. Oxford: Oxford University Press.

Hillman,G.C. 1981.
Reconstructing Crop Husbandry Practices from Charred Remains of Crops, in (R.Mercer ed.) *Farming Practice in British Prehistory.* Edinburgh: Edinburgh University press. pp. 123-162.

Hillman,G.C. 1984.
Interpretation of Archaeological Plant Remains: The Application of Ethnographic Models from Turkey, in (W.VanZeist and W.A.Casparie eds.). *Plants and Ancient Man.* Rotterdam: A.A.Balkema. pp. 1-41.

Hillman,G.C. 1986.
Plant Foods in Ancient Diet: The Archaeological Role of Palaeofaeces in General and Lindow Man's Gut Contents in Particular. In (I.M.Stead, J.B.Bourke, and D.R.Brothwell. eds.) *Lindow Man: The Body in the Bog.* London: British Museum Publications. pp 99 - 115.

Hillman,G.C. 1989.
Late Palaeolithic Plant Foods from Wadi Kubbaniyain Upper Egypt: Dietary Diversity, Infant Weaning and Seasonality in a Riverine Environment. In (D.R.Harris and G.C.Hillman eds.) *Foraging and Farming: The Evolution of Plant Exploitation* London: Unwin Hyman. pp. 207 - 239.

Hillman,G.C. Colledge,S.M. and Harris,D.R. 1989.
Plant-food Economy During the Epipalaeolithic Periods at Tell Abu Hureyra, Syria: Dietary Diversity, Seasonality and Modes of Exploitation. In (D.R.Harris and G.C.Hillman eds.) *Foraging and Farming: The Evolution of Plant Exploitation* London: Unwin Hyman. pp. 207-239.

Hillman,G.C. Madeyska,E. and Hather,J. 1989.
Wild Plant Foods and Diet at Late Paleolithic Wadi Kubbaniya: The Evidence from Charred Remains. In (F.Wendorf and R.Schild eds.) *The Prehistory of Wadi Kubbaniya: volume 2 - Stratigraphy, Paleoeconomy and Environment.* Dallas: Southern Methodist University press. pp. 162-242.

Holden,T.G. 1986.
Preliminary Report on the Detailed Analysis of the Macroscopic Remains from the Gut Lindow Man. In (I.M.Stead, J.B.Bourke, and D.R.Brothwell eds.) *Lindow Man: The Body in the Bog.* London : British Museum Publications. pp. 116-125.

Holden,T.G. 1989.
Preliminary Work on South American Mummies Held at the British Museum. *Paleopathology Newsletter*, 65, 5-9.

Holden,T,G, 1990.
Transverse Cell Patterns of Wheat and Rye Bran and How These Vary Over the Surface of a Single Grain. *Cercaea*, 6(2), 97-104.

Howgate,P. 1979.
Fish. In (J.G.Vaughan ed.) *Food Microscopy*. London and New York: Academic Press. pp. 343-393.

Hrdy,D.B. 1978.
Analysis of Hair Samples of Mummies from Semna South (Sudenese Nubia). *American Journal of Physical Anthropology*, 29, 277-282.

Hughes,J.S. and Swanson,B.G. 1986.
Microstructure of Lentil Seeds (*Lens culinaris*). *Food Microstructure*, 5(2), 241-246.

Hughes,J.S. and Swanson,B.G. 1985.
Microstructural Changes in Maturing Seeds of the Common Bean (*Phaseolus vulgaris* L.). *Food Microsructure*, 4(2), 183-190.

Ignacio,Q. Fernandez,C.A. and Cortes,G.J. 1976.
Contribucion al Estudio Morfologico del Grano de Quinoa. In *Segunda Convencion Internacional de Quenopodiaceas*. Universidad Boliviana Tomas Frias, Comite Departamental, de Obras Publicas de Potosi, Instituto Interamericano de Ciencias Agricolas, Potosi, Bolivia. pp. 58-60.

Jewell,G.C. 1979.
Fruits and Vegetables. In (J.G.Vaughan ed.) *Food Microscopy*. London and New York: Academic Press. pp. 1-34.

Johns,T. 1986.
Detoxification Function of Geophagy and Domestication of the Potato. *Journal of Chemical Ecology*, 12(3), 635-646.

Jones,A.K.G. 1983.
A Coprolite from 6-8 Pavement. In (A.R.Hall, H.K.Kenward, D.Williams, and J.R.A.Grieg eds.) *Environment and Living Conditions at Two Anglo-Scandinavian Sites.* The Archaeology of York 14/4. published for the York Archaeological Trust by the Council for British Archaeology. pp. 225-229.

Jones,A.K.G. 1986.
Parasitological Investigations on Lindow Man in (I.M.Stead J.B.Bourke and D.R.Brothwell eds). *Lindow Man: The Body in the Bog.* London: British Museum Publications. pp. 136-139.

Jones,A.K.G. 1986.
Fish Bone Survival in the Digestive System of the Pig, Dog and Man: Some Experiments. In (D.C.Brinkhuizen and A.T.Claseneds eds.). *Fish and Archaeology: Studies in Osteometry, Taphonomy, Seasonality and Fishing Methods.* British Archaeological Reports, International Series no. 294. pp. 53-16.

Jones,F,W. 1908.
The Pathological Report. *The Archaeological Survey of Nubia, Bulletin,* 2, 55-64.

Jones,F.W. 1910.
Mode of Burial and Treatment of the Body. In (G.Elliot-Smith and F.W.Jones eds.) *Report on the Human remains - Achaeological Survey of Nubia, vol II, Report for 1901-1908.*

Jones,G.E.M. 1984.
Interpretation of Archaeological Plant Remains: Ethnographic Models from Greece. In (W.VanZeist and W.A.Casparie eds.) *Plants and Ancient Man.* Rotterdam: A.A.Balkema. pp. 43-61.

Jones,M. 1981.
The Development of Crop Husbandry. In M.Jones and G.Dimbleby. *The Environment of Man: The Iron Age to the Anglo-Saxon Period.* Oxford: British Archaeological Reports. British Series. No. 87. pp. 85-129.

Kautz,R.R. 1980.
Palynology of Coprolites from Sites in Northern Chile. In (C.W.Meighan and D.L.True. eds.) *Prehistoric Trails of Atacama: Archaeology of Northern Chile.* Los Angeles: Monumenta Archaeologica 7. Institute of Archaeology, University of California. pp. 205-213.

Kellher,J. Walters,M.P. Srinivasan,T.R. Hart,G. Finlay,J.M. and Losowski,M.S. 1984.
Degradation of Cellulose within the Gastrointestinal Tract in Man. *Gut*, 25, 811-815.

Kelsay,J.L. 1978.
A Review of Research on Effects of Fibre Intake on Man. *American Journal of Clinical Nutrition*, 31, 142-159.

Kelsay,J.L. 1981.
Effect of Fibre Level on Bowel Function and Trace Mineral Balances of Human Subjects. *Cereal Chemistry*, 58 (1), 2-5.

Knights,B.A. Dickson,C.A. Dickson,J.H. and Breeze,D,J. 1983.
Evidence Concerning the Roman Military Diet at Bearsden, Scotland, in the Second Century A.D. *Journal of Archaeological Science*, 10, 139-152.

Knoebel,L.K. 1982.
The Gastrointestinel System. In (E.E.Selkurt ed.) *Basic Physiology for Health Sciences.* Boston: Little, Brown and Co.

Knorzer,K.H. 1983.
Aussagemoglichkeiten von Palaoethnobotanischen Latrinenuntersuchungen (The Prospects of the Palaeoethno Botanical Examination of Cesspits). In (W.Van Zeist and W.A.Casparie eds.) *Plants and Ancient Man: Studies in Palaeoethnobotany.* Rotterdam and Boston: A.A.Balkema. pp. 331-338.

Korber-Grohne,U. 1964.
Juncus-Samen und Gramineen-Fruchte. Hildesheim: Agust Lax. Verlagsbuchhandlung.

Korber-Grohne,U. 1981.
Distinguishing Prehistoric Cereal Grains of *Triticum* and *Secale* on the Basis of their Surface Patterns Using the Scanning Electron Microscope. *Journal of Archaeological Science*, 8, 197-204.

Korber-Grohne,U. 1988.
Nutzpflanzen in Deutschland: Kulturgeschichte und Biologie. Stuttgart: Konrad Theiss Verlag.

Korber-Grohne,U. and Piening,U. 1980.
Microstructure of the Surfaces of Carbonised and Non-Carbonised Grains of Cereals as Observed in Scanning Electron and Light Microscopes as an Additional Aid in Determining Prehistoric Findings. *Flora*, 170, 189-228.

Korschgen,L.J. 1971.
Procedures for Food Habit Analysis. In (R.H.Giles ed.) *Wildlife Management Techniques* (Third edition). Washington D.C.: The Wildlife Society. pp. 233-250.

Koyama.T. 1963.
The Genus Scirpus. Linn. Critical Species of the Section Pterolepis. *Canadian Journal of Botany*, 41. 1107-1131.

Kuzayli,M.V. Cowan,J.W. and Sabry,Z.I. 1966.
Nutrative Value of Middle Eastern Food Stuffs: II Composition of Pulses, Seeds, Nuts and Cereal Products of Lebanon. *J.Sci. Fd Agric.*, 17, 82-83.

Lambert,J.B. Szpunar,C.B. and Buikstra,J.E. 1979.
Chemical Analysis of Excavated Human Bone from Middle and Late Woodland Sites. *Archaeometry*, 21(2), 115-129.

Latcham,R.E. 1936.
La Agricultura Precolombiana en Chile y los Paises Vecinos. Ediciones de la Universidad de Chile.

Lersten,N.R. and Gunn,C.R. 1982.
Testa Characteristics in the Tribe Vicieae, with Notes About Tribes Abreae, Cicereae, and Trifolieae (*Fabaceae*). Technical Bullitin No. 1667. Agricultural Research Service. United States Department of Agriculture.

Lewis,D.F. 1979.
Meat Products. In (J.G.Vaughan ed.) *Food Microscopy.* London and New York: Academic Press. pp. 233-272.

Lewis.G.P. and Elias,T.S. 1981
Mimoseae. In (P.H.Raven and R.M.Polhill eds.) *Advances in Legume Systematics : Part I.* Richmond, Surrey: Royal Botanic Gardens, Kew. pp. 155-168.

Liener,I.E. and Kakade,M.L. 1969.
Protease Inhibitors. In (I.E.Liener ed.) *Toxic Constituents of Plant Foodstuffs.* London and New York: Academic Press.

Liversage,D. 1984.
La femme de Huldremose. In (A.Bocquet et al. eds.) *Elements de Pre et Protohistoire Europeenne: Hommages a Jacques-Pierre Millotte.* pp. 639-647.

Llagostera,A. 1989.
Caza y Pesca Maritima. In (J.Hidalgo, V.Schiappacasse, H.Niemeyer, C.Aldunate and I.Solimano eds.) *Culturas de Chile: Prehistoria desde sus Origenes Hasta los Albores de la Conquista.* Santiago: Editorial Andres Bello. pp. 57-80.

Lynch,T.F. 1986.
Climate Change and Human Settlement Around the Late-Glacial Laguna De Punta Negra, Northern Chile. The Preliminary Results. *Geoarchaeology,* 1(2), 145-162.

Macbride,J.F. 1936.
Flora of Peru. Field Museum of Natural History Publications 351. Botanical Series vol XIII. Chicago, U.S.A.

Marquardt,W.H. 1974.
A Statistical Analysis of Constituents in Human Paleofecal Specimens from Mammoth Cave. In (P.J.Watson ed.) *Archaeology of the Mammoth Cave Area.* New York and London: Academic Press. pp. 193-202.

Martin,C.A. and Barkley,W.D. 1961.
Seed Identification Manual. Berkley and Los Angeles: University of California Press.

Martin,P.S. and Sharrock,F.W. 1964.
Pollen Analysis of Prehistoric Human Feces: A New Approach to Ethnobotany. *American Antiquity*, 30, 168-180.

Martins,R. 1976.
New Archaeological Techniques for the Study of Ancient Root Crops in Peru. Unpublished Phd. Thesis. Birmingham University, U.K.

Maurizio,A. 1927.
Die Geschichte unserer Pflanzennahrung von den Urzeiten bis zur Gegenwart. Berlin: Parey.

McCarthy,P. 1985.
A Whiff of the Past. *Science*. April 85, 82.

McK Kliks,M. 1988.
Palaeoparasitological Analysis of Faecal Material from Amerindian (or New World) Mummies: Evaluation of Saprophytic Arthropod Remains. *Paleopathology Newsletter*, 64, 7-11.

Mclaughlin,T. 1971.
Coprophilia. London: Cassell.

Monk,M.A. and Fasham,P.J. 1980.
Carbonised Plant Remains from Two Iron Age Sites in Central Hampshire. Proceedings of the Prehistoric Society, 46, 321-344.

Mostney,G. 1954.
Peine un Pueblo Atacameno. Publicacion no. 4 del Instituto de Geografia Facultad de Filosofia. Universidad de Chile.

Mostney,G. 1957. (ed.)
La Momia del Cerro el Plomo Bulletin del Museo Nacional de Historia Natural Tomo 27(1). Santiago de Chile.

Motulsky,A.G. 1987.
Human Genetic Variation and Nutrition. *American Journal of Clinical Nutrition*,45,1108-1113.

Mueller-Dumbois,D. Ellenberg,H. 1974.
Aims and Methods in Vegetation Ecology. New York: Wiley.

Munoz,M. Barrera,E. and Meza,I. 1981.
El Uso Medicinal y Alimentico de Plantas Nativas y Naturalizadas en Chile. Museo Nacional de Historia Natural, Publicacion Ocasional, No. 33. Santiago de Chile.

Murra,J.V. 1980.
Economic organisation of the Inca State. Greenwich Conecticut: Jai Press inc.

Murray,J.A.H. 1888.
A New English Dictionary on Historical Principles. Oxford: Clarendon press.

Napton,L.K. 1969.
Archaeological and Paleobiological Investigations in Lovelock Cave, Nevada. *Kroeber Anthropological Society, Special Publications*, 2. Berkley.

Napton,L.K. and Heizer,R.F. 1970.
Analysis of Human Coprolites from Archaeological Contexts, with Primary Reference to Lovelock Cave, Nevada. In (R.F.Heizer and L.K.Napton eds.) *Great Basis Lacustrine Subsistence Regime as seen from Lovelock Cave, Nevada - Contributions of the University of California Archaeology Research Facility, Berkley. no. 10. pp. 87-129.*

Napton,L.K. and Kelso, G.K. 1969.
Preliminary Palynological Analysis of Human Coprolites from Lovelock Cave, Nevada. In (L.K.Napton ed.) Archaeological and Paleobiological Investigations in Lovelock Cave, Nevada. *Kroeber Anthropological Society, Special Publications*, 2. Berkley. pp. 19-27.

Netolitzky,F. 1911.
Nahrungs - und Heilmittel der Uragypter (Food and Medication of the Ancient Egyptians). *Die UmschauYours*, 46, 953-956.

Netolitzky,F. 1912.
Hirse und Cyperus ausdem Prahistorischen Agypten (Millet and Cyperus from Prehistoric Egypt). *Beihefte zum Botanischen Centralblatt*, 29, 1-11.

Niemeyer,H. and Schiappacasse,V. 1976.
Los Yacimientos Arqueologicos de Laguna Meniques. *Anales de la Universidad del Norte (Chile)*, 10, 31-57.

Nunez,L. 1976.
Registro Regional de Fechas Radiocarbonicas del Norte de Chile. *Estudios Atacamenos*, 4, 74-123.

Nunez,L. 1981.
Asentamiento de Cazadores-Recolectores Tardios de la Puna de Atacama: Hacia el Sedentarismo. *Chungara*, 8, 137-167.

Nunez,L. 1982.
Temprana Emergencia de Sedentarismo en el Desierto Chileno: Proyecto Caserones. *Chungara*, 9, 80-122.

Nunez,L. 1983.
Paleoindian and Archaic Cultural Periods in the Arid and Semiarid Regions of Northern Chile. *Advances in World Archaeology*, 2, 161-203.

Nunez,L. 1984a.
Pircas: Ocupacion Temprana en el Norte de Chile. *Gaceta Arqueologica Andina*, 11, 8-9.

Nunez,L. 1984b.
El Asentimiento Pircas: Nuevas Evidencias de Tempranas Ocupaciones Agrarias en el Norte de Chile. *Estudios Atacamenos*, 7, 152-177.

Nunez,L. 1986.
The Evolution of a Valley: Population and Resources of Tarapaca over a Millennium. In (J.V.Murra, N,Watchel and J.Revel. eds.). *Anthropological History of Andean Polities*. Cambridge: Cambridge University Press. pp. 23-34.

Nunez,L. 1988.
Analysis Mulidisciplinario de Domesticacion y Crianza Inicial de Camelidos en los Andes del Norte de Chile. Unpublished report of the Instituto de Investigaciones Arqueologicas, Universidad del Norte, San Pedro de Atacama, Chile.

Nunez,L. and Hall,H.J. 1982.
Analisis de Dieta Y Movilidad en un Campamento Arcaico del Norte de Chile. *Bulletin del Instituto Frances de Estudios Andinos*, 11(3-4), 91-113.

O,Connor,T. 1986.
What Vikings Left Behind. *New Scientist*, 1533, 42-47.

Ortiz,J. 1969.
Plantas Silvestres Chilenas de Frutos Comesibles por el Hombre. *Contribuciones Arqueologicas* Museo de la Serena, 8, 5-27.

Osborne,P.J. 1983.
An insect Fauna from a Modern Cesspit and its Comparison with Probable Cesspit Assemblages from Archaeological Sites. *Journal of Archaeological Science*, 10, 453-463.

Oser,B.L. 1965.
Hawks Physiological Chemistry 14th ed. New York: McGraw-Hill Book Co.

Paap,N.A. 1983.
Palaeobotanical Investigations in Amsterdam. In (W.Van Zeist and W.A.Casparie eds.). *Plants and Ancient Man: Studies in Palaeoethnobotany.* Rotterdam and Boston: A.A.Balkema. pp. 339-344.

Paredes,C. and Aspillaga,E. 1984.
Analisis del Contenido Intestinal en Momias. *Estudios Atacamenos*, 7, 323-331.

Pearsall.D.M. 1989.
Adaption of Prehistoric Hunter-gatherers to the High Andes: The Changing Role of Plant Resources. In (D.R.Harris and G.C.Hillman eds.) *Foraging and Farming: The Evolution of Plant Exploitation.* London: Unwin Hyman. pp. 318-332.

Percival,J. 1921.
The Wheat Plant. (facsimile edition 1974). London: Duckworth and Co.

Priston,A.V. 1986.
The Hair. In (I.M.Stead, J.B.Bourke, and D.R.Brothwell. eds.) *Lindow Man: The Body in the Bog.* London: British Museum Publications. pp. 71.

Purseglove,J.W. 1984.
Tropical Crops: Dicotyledons. Third Edition. Harlow, Essex: Longman.

Reed,T. 1910.
On the Anatomy of some Tubers. *Annals of Botany*, 24.

Reiss,W. and Stubel,W. 1880-1887.
The Necropolis of Ancon. Berlin: A.Asher and Co.

Renfrew,J.M. 1973.
Palaeoethnobotany: The Prehistoric Food Plants of the Near East and Europe. London: Methuen and Co L.T.D.

Risi,J.C. and Galway,N.W. 1984.
The *Chenopodium* grains of the Andes: Inca Crops for Modern Agriculture. *Advances in Applied Biology* 10, 145-195.

Riskind,D.H. 1970.
Pollen Analysis of Human Coprolites from Parida Cave. In (R.K.Alexander ed.) *Archaeological Excavations at Parida Cave, Val Verde County, Texas: Papers of the Texas Archaeological Salvage Project,* 19. Austin. pp. 19- 101.

Rivera,M.A. 1980.
Analisis Experimental de Coprolitos Provenientes de los Sitios Azapa 83 Y Azapa 84, Pertenecientes a la Fase Alto Ramirez, Periodo Intermedio Temprano Norte de Chile. *Estudios Arqueologicos,* 5, 13-27.

Rivera,M.A. 1984.
Altiplano and Tropical Lowland Contacts in Northern Chilean Prehistory: Chinchorro and Alto Ramerez Revisited. In (D.L.Browman, R.L.Burger and M.A.Rivera. eds.) *Social and Economic Organisation in the Prehispanic Andes.* Oxford: British Archaeological Reports, International Series, 194. pp. 143-160.

Rivera,M.A. 1987.
Land Use Patterns in the Azapa Valley, Northern Chile. In (D.L.Browman ed.) *Arid Land Use Strategies and Risk Management in the Andes: A Regional Anthropological Perspective.* Boulder and London: Westview Press. pp. 225-250.

Rivera,M.A. and Rothhammer,F. 1986.
Evaluacion Biologica y Cultural de Poblaciones Chinchorro: Nuevos Elementos para la Hipotesis de Contactos Transaltiplanicos, Cuenca Amazonas-Costa Pacifico. *Chungara,* 16-17, 295-306.

Robbins,L.M. 1971.
A Woodland Mummy from Salts Cave Kentucky. *American Antiquity*, 36(2), 200-206.

Robins,D. Sales,K. Odwale,D. Holden,T. and Hillman,G. 1986.
Postscript : Last Minute Results from E.S.R. Spectroscopy Concerning the Cooking of Lindow Man's Last Meal. In (I.M.Stead J.B.Bourke and D.R.Brothwell eds.) *Lindow Man: The Body in the Bog*. London: British Museum Publications. pp. 140-142.

Rosebury,T. 1969
Life on Man. London: Martin, Secker and Warburg Ltd.

Rothhammer,F. Standen,V. Nunez,L. Allison,M.J. and Arriaza.B. 1984.
Origen y Desarrollo de la Trepanosomiasis en el Area Centro-Sur Andina. *Chungara*, 12, 155-160.

Roust,N.L. 1967.
Preliminary Examination of Prehistoric Human Coprolites from Four Western Nevada Caves. *Reports of the University of California Archaeological Survey*. 70. Papers in Great Basin Archaeology, Berkely. pp. 49-88.

Rudenko,S.I. 1970.
Frozen Tombs of Siberia. The Pazyryk Burials of Iron Age Horsemen. London: Dent.

Sales,K.D. Oduwale,A.D. Robins,G.V. Hillman,G.C. and Holden,T.G. (in press
An Analysis of the Stomach Contents of Lindow Man with E.S.R. spectroscopy. Paper given at the 7th Symposium of the International Workgroup for Palaeoethnobotany, Cambridge. (J.Renfrew ed.) Edinburgh: University Press.

Salyers,A. Palmer,J. and Balasico,J. 1979.
Digestion of Plant Cell Wall Polysaccarides by Bacteria from the Human Colon. In (G.E.Inglett and S.I.Falkhag eds.) *Dietary Fibers: Chemistry and Nutrition*. London and New York: Academic Press. pp. 193-202.

Sandison,A.T. 1986.
Human Mummification Technique in Ancient Egypt. In (A.R.David ed.) *Science in Egyptology - Proceedings of the Science in Egyptology Symposia.* Manchester: University Press. 1-5.

Santaro,C. 1980.
Estudio de un Yacimiento Funerario Arquelogico del Extremo Norte de Chile, 1300A.C. -1300D.C. Projecto para Optar al Titulo de Arqueologo, Universidad del Norte Antofagasta.

Santoro,C. and Ulloa,L. 1985 (eds.)
Culturas de Arica. Serie Patrimonio Chileno - Coleccion Culturas Aborigenes. Departamento de Extension Cultural del Ministerio de Educacion.

Santoro,C.M. and Nunez,L. 1987.
Hunters of the Dry Puna and the Salt Puna in Northern Chile. *Andean Past*, 1, 57-109.

Scaife,R.G. 1986.
Pollen in Human Palaeofaeces ; and a Preliminary Investigation of the Stomach and Gut Contents of Lindow Man. In (I.M.Stead Bourke,J.B. and D.R.Brothwell eds.) *Lindow Man: The Body in the Bog.* London: British Museum Publications. pp. 126-135.

Schel,J.H.N. Stasse-Wolthuis,M. Katan,M.B. and Willemse,M.T.M. 1980.
Structural Changes of Wheat Bran after Human Digestion. *Mededelingen Landbouwhogeschool Wageningen*, 80-14, 1-9.

Schoenwetter,J. 1974.
Pollen Analysis of Human Paleofeces from Upper Salts Cave. In (P.J.Watson ed.) *Archaeology of the Mammoth Cave Area.* New York and London: Academic Press. pp. 97-105.

Simmonds,N.W. 1965.
The Grain Chenopods of the Tropical American Highlands. *Economic Botany*, 19(3), 223-235.

Sinclare,H.M. and Hollingsworth,D.F. 1969.
Hutchinson's Food and the Principles of Nutrition (twelfth edition). London: Edward Arnold Ltd.

Singh,B. 1953.
Studies on the Structure and Development of Seeds of the Cucurbitaceae. *Phytomorphology*, 3, 224-239.

Spinner,G.P. and Bishop,J.S. 1950.
Chemical Analysis of Some Wildlife Foods in Connecticut. *Journal of Wildlife Management*, 14(2), 175-180.

Stahl,A.B. 1984.
Homanid Dietary Selection Before Fire. *Current Anthropology*, 25, 152-157.

Stahl,A.B. 1989.
Plant Food Processing: Implications for Dietary Quality. In (D.R.Harris and G.C.Hillman eds.) *Foraging and Farming: The Evolution of Plant Exploitation*. London: Unwin Hyman. pp. 171-196.

Standen,V. 1985.
Protocolo de Autopsia de mumias y/o Osteologia de Esqueletas Arqueologicas (Autopsy reports), Unpublished Reports from the Instituto de Antropologia, Universidad de Tarapaca, Arica-Chile.

Stead,I.M. Bourke,J.B. and Brothwell,D.R. 1986. (eds.)
Lindow Man : The Body in the Bog. London: British Museum Publications.

Stead,I.M. and Turner.R.C. 1985.
Lindow Man. *Antiquity*, 59, 25-29.

Stewart,D.R.M. 1967.
Analysis of Plant Epidermis in Faeces: A Technique for Studying the Food Preferences of Grazing Herbivores. *Journal of Applied Ecology*, 4, 83-111.

Stewart,R.B. 1974.
Identification and Quantification of Components in Salts Cave Paleofeces, 1970-1972. In (P.J.Watson ed.) *Archaeology of the Mammoth Cave Area*. New York and London: Academic Press. pp. 41-47.

Stiger,M.A. 1975.
Anasazi Diet: The Coprolite Evidence. Unpublished MA. Thesis, Dept. of Anthropology, University of Colorado.

Stock,J.A. 1983.
The Prehistoric Diet of Hinds Cave. Publication of the Dept. of Anthropology. Texas. A & M University.

Stoertz,G.E. and Ericksen,G.E. 1974.
Geology of the Salares of Northern Chile. U.S. Geological Survey. Professional Paper no. 811, Washington D.C.

Straker,V. 1984.
First Century Carbonised Cereal Grain from Roman London. In (W.VanZeist and W.A.Casparie eds.) *Plants and Ancient Man.* Rotterdam: A.A.Balkema. pp. 323-329.

Strauss,M.S. 1983.
Anatomy and Morphology of Taro, *Colocasia esculenta* (L.) Schott. In (WangJ.K. ed.) *Taro: A review of Colocasia esculenta and its Potentials.* Honolulu: University of Hawaii Press. pp.20-33.

Swift,J. 1728. (reprint 1959)
Gulliver's Travels, London and Glasgow: Collins.

Szpunar,C.B. Lambert,J.B. and Buikstra,J.E. 1978.
Analysis of Excavated Bone by Atomic Absorption. *American Journal of Physical Anthropology,* 48(2), 199-202.

Tapia,M.E. Mujica,S.A. and Canahua,A. 1980.
Origin Distribution Geografica y Sistemas de Production en Quinoa. In *Primera Reunion sobre Genetica y Fitomejoramiento de la Quinoa.* Universidad Nacional de Tecnica del Altiplano, Instituto Boliviano de Tecnologia Agropecuaria, Instituto Interamericano de Ciencias Agricolas, Centro de Investigaciones Internacional para el Desarrollo, Puno, Peru. pp. a1-a8.

Tapp,E. and O'Sullivan,D. 1982.
St. Bee's Man: The Autopsy. *Procedings of the Paleopathology Association - 4th European Meeting.* pp. 178-182.

Tartaglia,L.J. 1980.
An Analysis of the Cultivated Plant Remains from Guatacondo, Chile. In (C.M.Meighan and D.L.True eds.) *Prehistoric Trails of Atacama: Archaeology of Northern Chile.* Los Angeles: Monumenta Archaeologica 7. Institute of Archaeology, University of California. pp. 127-134.

Thompson,K.F. 1976.
Cabbages, Kales etc: *Brassica oleracea* (Cruciferae). In (N.W.Simmonds ed.) *Evolution of Crop Plants*. Harlow: Longman Group Limited. pp. 49-52.

Torres,H.A. and Minaya,I. 1980.
Escarificadora de Quinoa. Diseno y Construccion. Publ. Misc. No. 243. Instituto Interamericano de Ciencias Agricolas, Lima, Peru.

Towle,M.A. 1961.
The Ethnobotany of Pre-Columbian Peru. Viking Fund Publications in Anthropology no 30, Chicago: Aldine Publishing Co.

Trevor-Deutsch,B. and Bryant,V.M. 1978.
Analysis of Suspected Human Coprolites from Terra Amata, Nice, France. *Journal of Archaeological Science*, 5, 387-390.

Troostheide,C.D. 1990.
De Laatsde Maaltyd (2). In W.A.B. (van der Sanden ed.). *Mens en Moeras, Veenlijken in Nederland van de Bronstijd tot en met de Romeinse Tijd (Bog Corpses in the Netherlands from the Bronze Age up to and Including the Roman Period)*. Assen.

Troschel,F.H. 1856-1863.
Gebiss der Schnecken, Berlin: Nicolaische Verlagsbuch handlung.

True,D.L. 1980.
Archaeological Investigations in Northern Chile: Caserones. In (C.M.Meighan and D.L.True. eds.) *Prehistoric Trails of Atacama: Archaeology of Northern Chile*. Los Angeles: Monumenta Archaeologica 7. Institute of Archaeology, University of California. pp. 139-178.

True,D.L. Nunez,L, and Nunez,P. 1970.
Archaeological Investigations in Northern Chile: Project Tarapaca - Preceramic Resources. *American Antiquity*, 35(2), 170-184.

True,D.L. and Crew,H. 1980.
Archaeological Investigations in Northern Chile: Tarapaca 2 in (C.M.Meighan and D.L.True eds.) *Prehistoric Trails of Atacama: Archaeology of Northern Chile.* Los Angeles: Monumenta Archaeologica 7. Institute of Archaeology, University of California. pp. 59-90.

True,D.L. and Gildersleeve,L. 1980.
Archaeological Investigations in Northern Chile: Tarapaca 18. In (C.M.Meighan and D.L.True eds.) *Prehistoric Trails of Atacama: Archaeology of Northern Chile.* Los Angeles: Monumenta Archaeologica 7. Institute of Archaeology, University of California. pp. 37-58.

Turner,R.C. 1986.
Discovery and Excavation of the Lindow Bodies. (In I.M.Stead, J.B.Bourke and D.R.Brothwell eds.). *Lindow Man: The Body in the Bog.* London: British Museum Publications. pp. 10-14.

Turner,R.C. and Briggs,C.S. 1986.
The Bog Burials of Britain and Ireland. In (I.M.Stead J.B.Bourke and D.R.Brothwell eds.). *Lindow Man: The Body in the Bog.* London: British Museum Publications. 181-195.

Tutin,T.G. 1980.
Umbelifers of the British Isles. London: Botanical Society of the British Isles Handbook No 2.

Uhle,M. 1919.
La Arqueologia de Arica y Tacna. *Boletin de la Sociedad Ecuatoriana de Estudios Historicos Americanos.* Quito.

Van Cleave,H.J. and Ross,J.A. 1947.
A Method for Reclaiming Dried Zoological Specimens. *Science,* 105, 318.

Van der Sanden, W.A.B. In press.
Mans en Moeras, veenlijken in Nederland van de Bronstijd tot en met Romeinse tijd. (Bog Corpses in the Netherlands from the Bronze Age up to and including the Roman Period). Assen.

Varriano,E. and DeFrancisco,A. 1984.
Ultrastructure of Quinoa Fruit (*Chenopodium quinoa* Willd.). *Food Microstructure,* 3, 165-173.

Vaughan,J.G. 1970.
The Structure and Utilization of Oil Seeds. London: Chapman and Hall Ltd.

Vaughan,J.G. 1979.
Food Microscopy. London and York and San Francisco: Academic Press.

Vaughan,J.G. and Stubbs,J.A. 1979.
Animal Feeds - Plant Constituents. In (J.G.Vaughan ed.) *Food Microscopy.* London and New York: Academic Press. pp. 393-424.

Veloso,A. and Kalin,M. 1982.
Characteristicas del Medio Fisico. In (E.Bustos and A.Veloso eds.) *El Ambiente Natural y las Poblaciones Humanas en Los Andes del Norte Grande de Chile - Volume 1.* Santiago: Unesco. pp. 5-13.

Vermeer,D.E. 1971.
Geophagy Among the Ewe of Ghana. *Ethnology,* 10, 56-72.

Villagran,C. Armesto,J.J. and M.T.Kalin. 1981.
Vegetation in a High Andean Transect Between Turi and Cerro Leon in Northern Chile. *Vegetatio,* 48, 3-16.

Villagran,C. Kalin,M.T. and Armesto,J. 1982.
La Vegitacion de un Transecto Altitudinal en los Andes del Norte de Chile (18-19 degrees S.). In (E.Bustos and A.Veloso eds.) *El Ambiente Natural y las Poblaciones Humanas en Los Andes del Norte Grande de Chile - Volume 1* . Santiago: Unesco. pp. 13-23.

Voehringer,H. 1979.
Animal Feeds - Animal Constituents. In (J.G.Vaughan ed.) *Food Microscopy.* London and New York: Academic Press. pp. 393-424.

Voyle,C.A. 1979.
Meat. In (J.G.Vaughan ed.) *Food Microscopy975* York: Academic Press. pp. 193-232.

Wakefield,E.G. and Dellinger,S.C. 1936.
Diet of the Dwellers of the Ozark Mountains and its Skeletal Effects. *Annals of Internal Medicine,* 9(10), 1412-1418.

Wales,S. Evans,J and Leeds,A.E. 1989.
The Survival of Waxes in Coprolites: The Archaeological Potential. To be published in the Proceedings of the 1989 Archaeological Sciences Conference held in Bradford, UK.

Warren,S.H. 1911.
On a Prehistoric Interment near Walton-on-Naze. *Essex Naturalist*, 16, 198-208.

Watson,J.A.S. and Moore,J.A. 1962.
Agriculture: The Science and Practice of Farming. Edinburgh and London: Oliver and Boyd.

Watson,P.J. 1974.
Theoretical and Methodological Difficulties Encountered in Dealing with Paleofecal Material. In (P.J.Watson ed.) *Archaeology of the Mammoth Cave Area.* New York: Academic Press. pp. 239-241.

Watson,P.J. and Yarnell,R.A. 1966.
Archaeological and Paleoethnobotanical Investigations in Salts Cave, Mammoth Cave National Park, Kentucky. *American Antiquity*, 31(6), 842-849.

Webber,H.J. and Batchelor,L.D. 1948
The Citrus Industry. Los Angeles: University of California Press.

Weder,J.K.P. 1981.
Protease Inhibitors in the Leguminosae. In (R.M.Polhill and P.H.Raven. eds.) *Advances in Legume Systematics.* London: Royal Botanic Gardens Kew. pp. 533-560.

Wheeler,A. and Jones,A.K.G. 1989.
Fishes. Cambridge: University Press.

White,A. Handler,P. and Smith,E.L. 1973.
Principles of Biochemisty (fifth edition). London: Mcgraw-Hill Kogakusha Ltd.

Wilke,P.J. 1978.
Late Prehistoric Human Ecology at Lake Cahuilla, Coachella Valley, California. *Contributions of the University of California Archaeological Research Facility.* No. 38. May 1978.

Wilke,P.J. and Hall,H.J. 1975.
Analysis of Ancient Feces: A discussion and Anotated Bibliography. Unpublished Article from the Archaeological Research Facility, Department of Anthropology, University of California, Berkley.

Williams,L.R. 1970.
Laboratory Procedures, Methods and Analysis of Northern Chile Coprolites. Submitted as part of a degree for M.A. University of California.

Williams,L.R. 1980.
Analysis of Coprolites Recovered from Six Sites in Northern Chile. in (C.W.Meighan and D.L.True. eds.) *Prehistoric Trails of Atacama: Archaeology of Northern Chile.* Los Angeles: Monumenta Archaeologica 7. Institute of Archaeology, University of California. 195-204.

Williams,P. and Nakkoul,H. 1983.
Some New Concepts of Food Legume Quality Evaluation at ICARDA. In (M.C.Saxena and Varma,S. eds.). *Faba Beans, Kabuli, Chickpeas and Lentils in the 1980's.* An International Workshop, The International Centre for Agricultural Research in Dry Areas, Allepo, Syria. pp. 245-256.

Williams-Dean,G. 1978.
Ethnobotany and Culture Ecology of Prehistoric Man in Southwest Texas. Phd. dissertation, Dept. of Biology, Texas A & M University.

Wilson,D.G. 1975.
Plant Foods and Poisons from Medieval Chester. *Journal of Chester Archaeological Society,* 58, 57-67.

Wilson,H.D. 1981.
Domesticated *Chenopodium* of the Ozark Bluff Dwellers. *Economic Botany* , 35(2), 233-239.

Wilson,H.D. and Heizer,C.B. 1979.
The Origin and Evolutionary Relationship of Huauzontle (*Chenopodium nuttaliae*) Domesticated Chenopod of Mexico. *American Journal of Botany,* 66, 198- 206.

Winter,J.C. and Wylie,H.G. 1974.
Paleoecology and Diet at Clydes Cavern. *American Antiquity,* 39(2), 303-315.

Winton,A.L. Winton,K.B. 1932 and 1935.
The Structure and Composition of Foods: Volumes I and II. New York: John Wiley and sons Inc.

Wright,L. 1960.
Clean and Decent. London: Routledge and Kegan Paul.

Yacovleff,E. and Herrera,F.L. 1934 and 35.
El Mundo Vegetal de los Antiguos Peruanos. *Revista del Museo Nacional, Lima,* 3(3), 244-323, 4(1), 31-102.

Yarnell,R.A. 1969.
Contents of Human Paleofeces. In (P.J.Watson ed.) The Prehistory of Salts Cave, Kentucky. *Reports of Investigations* 16. Springfield: Illinois State Museum. pp.44-55.

Yarnell,R.A. 1974.
Intestinal Contents of the Salts Cave Mummy and Analysis of the Initial Salts Cave Flotation Series. In (P.J.Watson. ed.) *Archeology of the Mammoth Cave Area.* New York: Academic Press. pp. 109-112.

Yiu,S.H. and Mongeau,R. 1987.
Flourescence and Light Microstrucure: Analysis of Digested Oat Bran. *Food Microstructure,* 6, 143-150.

Young,B.H. 1910.
The Prehistoric men of Kentucky. Louisville: *Filson Club Publication* no. 25.

Zeist,W. van 1968.
Prehistoric and Early Historic Food Plants in the Netherlands. *Palaeohistoria* , 14, 41-173.

Zeist,W. van 1981.
Plant Remains from Iron Age Noordbarge, Province of Drenthe, The Netherlands. *Palaeohistoria,* 23, 169-193.

Zeist,W. van 1990.
No title as yet. In W.A.B. van der Sanden (ed.). *Mens en Moeras, Veenlijken in Nederland van de Bronstijd tot en met de Romeinse Tijd (Bog Corpses in the Netherlands from the Bronze Age up to and Including the Roman Period).* Assen.

Zimmerman,M. 1983.
Aleutian and Alaskan Mummies. In (A,Cockburn and E.Cockburn eds.) *Mummies, Disease, and Ancient Cultures* (Abridged). Cambridge: Cambridge University Press. pp. 119-134.

Appendix 1 - Alphabetic Cross-reference of Coprolite Accesions described on Microfiche.

Azapa, Az 6, T-6, Arica, Chile ----------COPTH22

Azapa, Az 71 T230, Arica, Chile ----------COPTH28

Azapa, AZ 141 T-12, Chile ----------COPTH20/6

Azapa, AZ 141 T-26 3A, Chile ----------COPTH20/5

Azapa, AZ 141 T-26 3A, Chile ----------COPTH20/1

Azapa, AZ 141 T-26 3A, Chile ----------COPTH20/3

Azapa, AZ 141 T-28 A3, Chile ----------COPTH20/4

Azapa, AZ 141 T-46, Chile ----------COPTH20/2

Caserones, Tarapaca, North Chile TR-40A ------COPTH02

Camarones, Cam 9 T-13, Chile ----------COPTH23A

Camarones, Cam 9 T-12, Chile ----------COPTH23B

Caserones sur, Cas-Sur T-1B, Tarapaca, Chile -COPTH21/1

Caserones sur, Cas-Sur T-1C, Tarapaca, Chile -COPTH21/2

Cerro Monos 2 T-1, Northern Chile ----------COPTH17

El Morro, Mo 1-6 T-18, Arica, Chile ----------COPTH24/E

El Morro, Mo 1-6 T-22, Arica, Chile ----------COPTH24/F

El Morro, Mo 1-6 T-32, Arica, Chile ----------COPTH24/A

El Morro, Mo 1-6 T-33, Arica, Chile ----------COPTH24/G

El Morro, Mo 1-6 T-46, Arica, Chile ----------COPTH24/I

El Morro, Mo 1-6 T-53, Arica, Chile ----------COPTH24/C

El Morro, Mo 1-6 T-56, Arica, Chile ----------COPTH24/B

El Morro, Mo 1-6 T-U3, Arica, Chile ----------COPTH24/D

El Morro, Mo 1-6 T-U7, Arica, Chile ----------COPTH24/H

Howe of Howe, Orkney, United Kingdom --------COPTH08

Howe of Howe, Orkney, United Kingdom --------COPTH09

Howe of Howe, Orkney, United Kingdom --------COPTH10

Huldremose, Ramten, Djursland, Denmark ------COPTH29

Jarmo, Iraq ----------COPTH04

Kerma, Sudan ----------COPTH07/1-14.

Kerma tombe 45, Kerma, Sudan ----------COPTH13/1

Kerma tombe 64, Kerma, Sudan ----------COPTH13/2

Kerma tombe 80, Kerma, Sudan ----------COPTH13/3

Kerma tombe 89, Kerma, Sudan ----------COPTH13/4

Kerma tombe 118b, Kerma, Sudan ----------COPTH13/5

Kerma tombe 199, Kerma, Sudan ----------COPTH13/6

Lindow II, Lindow moss, Cheshire, U.K. ------COPTH33

Lindow III, Lindow moss Cheshire, U.K. ------COPTH34

Lovelock Cave Nevada, U.S.A. ----------COPTH11

Loughor Castle, Wales, United Kingdom -------COPTH06

Mbi Crater, Bamenda, Cameroon ----------COPTH12

Pircas 2 T-5, Tarapaca, Chile ----------COPTH25

Pircas 2 T-6, Tarapaca, North Chile ---------COPTH01

Playa Millar, Pm 6 T-19, Arica, Chile -------COPTH26

Solcor, Slc 3 T-91 San Pedro, Chile ------COPTH15

Tarapaca, Tr40A, Tarapaca, Chile ----------COPTH27

Tulan, TU57 R-1 EV-6, Atacama, Chile --------COPTH18/1

Tulan, TU57 R-1 E-III, Atacama, Chile -------COPTH18/2

Tulan, TU58 T-4, Atacama, Chile ----------COPTH19

Tulan, Tu58 T-4, Atacama, Chile ----------COPTH31

Tulan, Tu58 T-6, Atacama, Chile ----------COPTH32

Tulan, TU54 C-1 Co-0, Atacama, Chile --------COPTH16C

Tulan, Tu54 C-2 Co-1, Atacama, Chile --------COPTH16D

Tulan, Tu54 C-3 Co-2, Atacama, Chile --------COPTH16H

Tulan, Tu54 C-3 Co-7, Atacama, Chile --------COPTH16J

Tulan, Tu54 C-3 Co-8, Atacama, Chile --------COPTH16K

Tulan, Tu54 C-3 Co-10, Atacama, Chile -------COPTH16I

Tulan, Tu54 C-4 Co-5, Atacama, Chile --------COPTH16E

Tulan, Tu54 C-4 Co-14, Atacama, Chile -------COPTH16F

Tulan, Tu54 C-4 Co-15, Atacama, Chile -------COPTH16G

Tulan, Tu54 C-B3 XVII, Atacama, Chile -------COPTH16L

Tulan, Tu54 C-B3 XXI, Atacama, Chile --------COPTH16M

Tulan, Tu54 C-B3 XXXVIII, Atacama, Chile ----COPTH16N

Tulan, Tu54 C-B3 XL, Atacama, Chile ---------COPTH16O

Tulan, Tu54 Muestra 1, Atacama, Chile -------COPTH16A

Tulan, Tu54 Muestra 2, Atacama, Chile -------COPTH16B

Ventana Cave, Arizona, U.S.A. Z:12:5 --------COPTH03

Wadi Kubaniya, Egypt (modern Jackal scat) ---COPTH05

Zweeloo, Holland ----------COPTH30

Appendix 2 - The Archaeological Identifications in Detail.

a2.1.) Introduction.

This section outlines the criteria that have been used for the identification of the archaeological remains discussed in the text. Where previous work published work has been carried out, this has been cited at the beginning of each category of debris. Where no previous data are available, items have been described in detail so that they may be used in the future as base references for identifications of specific classes of material. Important, but as yet unidentified items have also been described in full so that it will be possible to reassess the data at a later stage. By adopting this approach of documenting fully, the identifications made, with either a full description or by referring back to other published descriptions and it is hoped to avoid a constantly recurring problem associated with much earlier bio-archaeological work. That being, the mis-identification of archaeological remains with no way of re-evaluating them in the light of a new techniques or knowledge.

The description and illustrations are therefore presented below following the order used by Heywood (1978). The nature of the material is such that most descriptions are

as observed in surface view and all micrographs are light micrographs, taken in surface view, except where stated otherwise.

a2.) Plant Tissue.

a2.2.1) Bryophytes.

Sphagnum sp. (Sphagnum moss).

Leaf: Identification was based upon the distinctively "s" shaped cells of the leaf. These have been illustrated in Holden 1986.

a2.e2.2.) Cactaceae.

Opuntia cf. *atacamensis* Phil. (Cume, Cactus).

a) Seed and enclosing endocarp: The seeds of this species measured approximately 2.5-3.0 mm. in diameter and were enclosed within a fibrous endocarp. The endocarp formed a robust pale/dark coloured layer around each seed and showed a distinctive patterning on its surface. This formed a series of concentric rings or ridges radiating from a point just off centre and towards the embryo notch (plate 15:3,4). This notch was a pronounced feature surrounded by a thickened area and was located between the radicle tip and the body of the seed. In some samples there was additional fibrous tissue associated with the endocarp. Whether the presence of this fibrous material

was related to the state of maturity, or the processing techniques used to prepare the food is not yet fully understood. The seeds themselves had a testa which was dark brown and made up of cells with sinuous walls over the major part of the surface but more rectangular cells around the margin (plate 15:5,6).

b) Fruit epidermis (Winton and Winton 1935:791): Two types of epidermal tissue were recovered from some samples. The first of these originated from the top flattened part of the swollen receptacle and possibly also from other areas of the fruit (plate 1:1,2). It consisted of a tissue of roughly polygonally shaped cells which showed a similarity to some cork tissues. They differed from these, however, in that they had a highly pitted upper surface. The second tissue consisted of a number of layers and made up the endocarp. This was made up of approximately polygonal cells and the subepidermal tissues were packed with druse crystals.

c) Areoles and spines: This category of debris was recovered largely, although not exclusively, from flotation samples and were easily identified as small thickened cupules from which whole or fragmentary spines and glochidia (structures that are indicative of the tribe Opuntieae) protruded.

a2.2.3.) Caryophyllaceae.

Spergula arvensis L. (corn spurrey).

a) (Berggren 1981:53, Helbaek 1958: plate 6): A number of whole seeds were identified on the basis of there gross morphology. This was not, however, possible in most cases. The majority of the samples, were identified on the basis of the characteristic sinuous and heavily pigmented cells of the testa (plates 25:6-9, 30:1). With the Huldremose sample some of these were possibly immature since they were pale in colour and cell pattern could be clearly discerned. Darker examples, however had to be cleared in Jeffry's solution in order for the detailed cell patterns to be seen. The size range of the Huldremose seeds was between 1-1.2mm.. This feature, together with the lack of club shaped papillae on the testa surface would indicated that they were not *S.arvensis* var. *maxima* which has a diameter of between 1.4 and 2.2mm (Berggren (1981:53,187). The dull and minutely tubercled surface (Clapham *et. al.* 1962:259), however, suggested that they were *S. arvensis* var. *sativa* rather than *S.arvensis* var. *arvensis*

A number of the inner parts of the seed, including examples of the coiled embryo were also recovered. These were enclosed within the thin and relatively featureless inner layer of the testa.

b) Capsule fragments (Helbaek 1950): Numerous fragments of the capsule teeth were identified (plate 25:4). Some of the larger examples were identified on the basis of their gross morphology but the characteristic cell patterns were used for more fragmentary remains. These consist of sinuously shaped cells with regularly occurring ribs (plate 25:5). Towards the edges the cells were more compressed and overlain by thick walled and longitudinally elongated cells.

Some fragments of the basal part of the capsule were also recovered. These consisted of degraded cupules in which an outer area of sclerenchyma around the circumference were held rigid by a network of radially arranged vascular material.

c) Stem, leaf and axillary fragments. A substantial amount of each of these classes of debris were recovered from the Huldremose body. This debris matched well with modern reference material but in the absence of other more diagnostic fragments of it would probably not have been possible to make a specific identification. In the context of quantities of seed and capsule material that were also recovered from the same sample these were, however, identified as *S. arvensis*.

a2.2.4.) Amaranthaceae.

Amaranthus cf. *caudatus* L.(*Kiwicha*).

Seed and Utricle (Berggren 1981:47): These pale to dark brown seeds were recovered from one sample that may not, in fact, be of gut origin (AZ141 T-28). The seeds were up to 1.25mm. in diameter and had a slight depression that runs around the circumference and marking the position of the embryo (see section 3.4.1.5.14). In the paler coloured seeds the embryo was often a slightly different colour from the the body (perisperm) of the seed. Only in one case were there any remains of a utricle present. The characteristic oval shaped cupule of these with three protruding stigmas remaining at the apex were easily recognised and confirmed the identification made on the basis of the seeds.

a2.2.5.) Chenopodiaceae.

Chenopodium sp. South American type. (possibly *quinoa*).

a) Seed fragments (Winton and Winton 1932:325, Wilson 1981, Varriano and DeFrancisco 1984): Only in a few cases did the embryo or perisperm remain undigested. Fragments of testa and adherent inner epidermal layers were, however, recovered from some samples. Two distinct classes of seeds were recovered:

i) Dark seeded type: From some samples whole seeds were recovered, these had a diameter of approximately 1.5mm. They had the characteristic shape associated with *Chenopodium* seeds and had a testa that was somewhat thicker and more robust than that of most modern cultivated varieties (plate 16:1-4). The colour of the seeds varied from black to dark red. The cell patterns of the testa could be observed under light microscopy after clearing. These were found to differ from those of other closely related species such as *Amaranthus* and *Atriplex* and consisted of a thick layer of angular to wavy walled cells containing numerous "stalactite-like rods". This pattern varied over the "beak" of the seed where they tended to run in rows. This patternation was most similar to samples of a dark seeded species cf. *C.quinoa* provided, for comparative purposes, from grave goods from the Valley of Tarapaca (plate 16:5-7).

ii) ii) Pale seeded type: The cell patterns of the testa were confused and not clearly discernible. The majority of these seeds were therefore identified from the gross morphology. Most of the samples showed a lenticular shape in cross section but those from sample (Mo 1-6 T-07) showed a definite barrel shape (ie. with more squared ends).

The darker seeds exhibited certain characteristics that are generally presumed to have been selected against

during the cultivation of *quinoa* (eg. thick resinous testa and small size - see, for example, Wilson 1981). Risi and Galwey (1984:150 citing Tapia *et al.* (1980), however, noted that cultivated species from the "salares" (salt flats) of southern Bolivia frequently have black seeds. In the same paper Risi and Galwey (1984:159 citing Ignacio *et al.* 1976) put the seed size of *quinoa* at between 2.6 to less than 1.8 mm. From these details it becomes clear that even today some populations of cultivated *quinoa* retain certain "primitive" seed characteristics and that the species as a whole can be very variable in many respects. They are apparently also closely related to the weedy species *C.quinoa* var. *melanospermum* and *C. hircinum* (ie. they will produce fertile hybrids, Wilson and Heiser 1979:201). Archaeologically, Pearsall (1989:322) has also recorded *Chenopodium* species with small average seed diameters from an early cave site at Panaulauca, Junin, Peru and discusses the possibilities of these being wild or domesticated species. These darker seeds could be the remains of a small seeded species of cultivated *quinoa* their poor state of preservation, small size and dark colour would make it difficult to distinguish them from both, the other cultivated species *C. pallidicaule* (*canihua*), and the closely related weedy species *C.hircinum* and *C. quinoa* var. *melanospermum* any one of which could also have been used as dietary components in the Chilean past.

Chenopodium album L. (Fat hen).

Fragments of the seeds (Berggren 1981:38, Clapham *et al.* 1962:275, Winton and Winton 1932:322): The dark black pigmentation of these seeds made observation under transmitted light microscopy somewhat difficult. However, after clearing for 48 hours in Jeffry's solution a slight reduction in the dark colour just allowed the form of the polygonal to slightly wavy edged cells of the testa to be discerned (plate 29:5,6). The structures referred to as "stalactite-like rods" by Winton and Winton (1932:323) could also be observed.

Atriplex sp. South American. (*Cachiyuyo*).

a) Seeds: A number of seeds and occasionally their enclosing bracteoles were recovered from sample TR-40 T-6. Where enclosed within bracteoles, these were identified as *A. atacamensis* since the shape of these (plate 15:8) and the cell patterns on the seed testa matched those of modern reference material. Where seeds were recovered without enclosing bracteoles they were not identified to species level since these may be confused with other commonly occurring species of *Atriplex* in the North Chilean desert.

b) Leaves: Both whole leaves from flotation samples and fragmentary ones from faecal samples were identified. The overall leaf shape varied from oval to rounded up to

3cm in length. As with the bracteoles they appeared not to have a continuous epidermis but exhibited a roughened surface resembling loosely packed parenchyma cells or scales. The vascular material was embedded within the mesophyll which contained concentrations of druse crystals along the vein margins. These could clearly be seen under cross polarised light. Although many desert plants also contained the crystals it is felt that even in this fragmentary state a number of the ancient samples resembled *Atriplex.* sufficiently for a tentative identification to be made.

a2.2.6.) *Portulacaceae.*

Calandrinia sp. Kunth.

Seed: The seeds of this genus were small (0.7-1mm. diam.) with a lustrous black seed coat (plate 18:3-5). They bore a general similarity to small *Chenopodium* seeds. Many such seeds were recovered from the Tulan flotation sequence and most were associated with an organic matrix that possibly represented bird or rodent droppings.

The species identified as *C.borchersi* Phil. (Kew gardens collection) would be the most obvious source of these seeds. This small herb grows in abundance on the quebrada slopes around modern Tulan.

a2.2.7.) Polygonaceae.

Polygonum cf. lapathifolium L. (pale persicaria)

a) Whole and fragmentary nutlets (Berggren 1981:30, Martin and Barkley 1961:149) Whole nutlets were identified on the basis of their gross morphology. A number of fragments were also recovered which matched well with reference material prepared from this species. They had a pericarp that consisted of a layer of elongated "palisade" cells with considerably thickened cell walls. These overlay a less distinctive, brown, pigmented layer. From the material available to the author it would seem that *P. persicaria* and *P. hydropiper*, while having the same general arrangement, had a slightly thinner pericarp than *P. lapathifolium.* If this can be taken as being a generally applicable criterion, then most fragments recovered, matched best with *P.lapathifolium*, however, at this stage, the unqualified identification of such fragments to species has not been made.

Polygonum convolvulus L. (black bindweed).

Pericarp (Winton and Winton 1932:314): This had a distinctive outer layer comprising of cells with deeply convoluted cell walls and cuticular warts (plate 27:4-6). The inner layers were strongly pigmented and composed of several layers, the organisation of which could not be discerned.

Rumex L. sp. (Docks).

Nutlet fragments (Winton and Winton 1932:319): Pale golden/brown fragments of the nutlets were recovered. The outer layer (the epicarp) consisted of a layer of cells with sinuous and strongly thickened cell walls (plate 28:1). Despite this, the lack of pigment in these cells made it difficult to see them clearly using transmitted light. The darker brown and elongated cells of the mesocarp could be observed in places. A number of this genus show the same anatomical features and therefore could not be separated on the basis of the small fragmentary remains available in these samples.

a2.2.8.) Linaceae.

Linum cf. *usitatissimum* L. (cultivated flax).

Seed fragments (Dickson 1988:124, Helbaek 1950: figs.18-19, Winton and Winton 1932:525, Vaughan 1970:41): The seed testa was composed of several layers of which the most prominent was the outer epidermis. This was composed of rounded cells and directly overlay a layer of fibres which were orientated parallel to the long axis of the seed (plate 30:2,3). The distinctive and irregularly pigmented brown layer, with more-or-less quadrilaterally shaped cells was also occasionally present. The cf. qualification to the identification to species level has been added since it was doubtful whether *L. usitatissimum* could, in fact, be distinguished from other members

of the same genus, given the small and fragmentary nature of the material recovered.

a2.2.9.) Malvaceae.

Malvaceae sp.

Seed: A number of seeds of this type were recovered from flotation samples. They were commonly 1.5mm x 1mm. x. 0.4mm. with a sharp radicle tip that projected at an acute angle from the main body of the seed (fig. 10:4). The author collected two species of Malvaceae with this type of seed from the area of San Pedro de Atacama. Both of these were to be found in or around the agricultural fields but neither has yet been identified to the species level.

a2.2.10.) Crucifereae.

Brassica sp. (rape or mustard).

A single layer of small palisade cells with thickened walls which overlay a pigmented layer of much larger cells could be seen. In surface view these appeared as a layer of small, thick walled cells under which, darker outlines of the pigment layer could be seen (plate 30:4).

Camelina cf. *sativa* (L.) Crantz (Gold of Pleasure).

a) Seeds fragments (Berggren 1981:134, Helbaek 1950:329,

Vaughan 1970:62): The seeds consisted of a relatively thick testa with thick walled cells varying in shape but commonly hexagonal or pentagonal and between 40-70um in diameter. Overlying this layer was a diaphanous layer with papillae. These could be seen as regular, circular structures in surface view or as short broad papillae in places where the testa was folded (plate 25:1-3).

b) Siliqua fragments: (Berggren 1981:34, Helbaek 1950:329). Some of the outer layers were commonly digested away leaving an outer surface of loosely anastomosing vascular material underneath which were several layers of fibres that run along the length of the siliqua (plate 26:2,3). The innermost layer consisted of thin walled and transversely elongated, interlocking cells. (plate 26:4).

Although Helbaek recorded both of these two structures from the gut of the Tollund man (Helbaek 1950, figs. 14-15) as *C. linicola* it would seem likely that these, and the closely related members of this genera could not be distinguished from the small fragments available from the Huldremose body.

cf. *Raphanus* sp. (Radish).

Testa fragments (Gassner 1973:49): This species has a very similar structure to that of the *Bassica/Sinapis* group, however, some of the fragments from the gut of the

Lindow III bog body more resembled the testa of *Raphanus* (Prof. J.Vaughan pers. comm.) which showed thinner palisade cell walls (plate 29:1-3) in surface view.

cf. *Sisymbrium* L. sp. (Rockets).

a) Seeds and testa fragments: Where seeds were recovered from flotation samples they were commonly oval shaped with a depression in the embryo position. The seeds were approximately 1.5mm. long by 1mm. broad and covered with small but regularly spaced papillae (plate 19:1-3). Where recovered from coprolite material they were commonly fragmentary with none of the starchy interior remaining but could be identified by the structure of two layers of the testa. The first of these, the outermost, was defined by roughly hexagonally shaped cells with a central circular structure (the papillae) (plate 19:5,6). Below this layer the cells were of the order of 0.04mm. in diameter and polygonal to elongated in shape. They were clearly defined, with thick cell walls. This arrangement matched most closely with European species of *Sisymbrium*. Unfortunately, no seeds of Chilean species of this genus were available for comparison but the author did, however, collect a single specimen of a crucifer growing in the quebrada of Tulan, Salar de Atacama in 1987. This matched well with species of South American *Sisymbrium* species such as *S.intricatissimum* (held at Kew gardens). No seed material was available during any of the collecting trips made in 1987 or in subsequent

seasons. It would seem likely that the heavy grazing of sheep and camelids rapidly depletes this species in the Tulan area. In support of this Aldunate *et al* (1981:216) recorded the species *Sisymbrium philippianum* Johnst. growing in the nearby area of Toconce and that this was principally used as fodder for sheep.

a2.2.11.) Rosaceae.

Rubus fruticosus agg. (blackberry, bramble).

Whole seeds: The identification was made on the basis of their gross morphology (van Zeist in press.) although some fragmentary remains were also recovered (plate 30:5).

a2.2.12.) Leguminosae.

Prosopis cf. alba/chilensis. (*algarrobo*).

a) Legume (Gunn 1984:68): Evidence of algarrobo pod consumption was recorded in various forms. The most distinctive debris were the osseous segments of the endocarp (fig. 9:4) which had been largely unaffected by the action of digestion. In some cases, however, these had been broken open, presumably by the action of chewing, such that the seeds themselves and fragments of the testa were also present in samples. These were recognised by their dark brown/red colour and the characteristic arrangement of palisade cells so typical of many legume

seeds (see for example Winton and Winton 1935:293). Below the palisade layer, the "hourglass" cells could be seen and fragments of the pod epidermis (or epicarp) and pod fibre (fig.9:3) were also recovered. The first of these, the epicarp (plate 15:7), survived as a layer of roughly quadrilaterally shaped cells which ran in parallel rows in places. This arrangement was broken by the presence of stomata, which were surrounded by numerous subsidiary cells with unevenly thickened cell walls. There were also structures (possibly resinous) that ran between the rows of cells. The fibre was quite distinctive being arranged along the length of the pod so forming a complex network. In cross section individual bundles appeared as a "U" shaped sheath of fibres (*sensu stricto*) surrounding lighter coloured vascular elements. Arrangements of elongated parenchyma commonly linked sections of parallel fibres.

b) Flower (Burkart 1952:126, Lewis and Elias 1981:164): A number of floral fragments were recovered. These consisted of separated calyces, each with five fused sepals. Five highly degraded petals could also be discerned in more complete specimens, (fig. 9:1,2). The woolly inner faces of these petals were highly characteristic of *Prosopis*.

c) Leaflets: Individual leaflets commonly 0.7cm. in length were recovered from a few samples. A primary vein ran along the long axis of the leaflet while smaller but

distinctive secondary veins ran parallel to the leaf margin at varying distances from the edge. The edge of the leave had occasional small hairs.

Two wild species of *Prosopis sp.* that produce these flattened algarrobo pods are common in the modern flora of Northern Chile (Burkart 1976). These are *P. alba* and *P.chilensis* which are difficult to distinguish even with fresh flowering specimens. No attempt was therefore been made to distinguish the two species on the basis of these degraded remains.

Legume indet..

One sample (AZ141 T-12) from gut of an infant from the Azapa valley revealed a mass of pulpy material from this a quantity of highly degraded, dark brown palisade tissue from an as yet unidentified legume seed was recovered (plates 17:6,7 21:8,9). The individual cells were frequently detached from the rest of the palisade tissue. The large number of species of edible tree and cultivated legumes in this area have not been surveyed in detail it was therefore not possible to identify these fragments further at this stage. Nb. Based upon palaeopathological data A.Aufderheide suggests that this infant might have been the victim of acute bacterial colitis.

a2.2.13.) Corylaceae.

Corylus avellana L. (hazel).

a) Testa (Vaughan 1970:45, Winton and Winton 1932:405): The testa was composed of several layers of parenchyma, the innermost of which was compressed and contained a brown pigment. A series of distinctive, broad, sinuous vascular bundles ran through this layer (plate 29:4).

Fragments of testa that exactly matched the modern equivalents were recovered from the gut of the Lindow III body. In addition to this, quantities of the disorganised brown parenchyma of the inner layer of the pericarp was also present.

a2.2.14 *Krameriaceae.*

cf. *Krameria cistoidea* H. et A.

This class of debris was highly degraded and had a tendency to disintegrate on rehydration. Nevertheless a number of fragments of what appeared to be highly sclerenchymatised endocarp with a thin meso/epicarp. In more complete specimens, this retained a number of scars on the surface. These matched with modern reference material of *Krameria* fruit after the removal of the barbed spines that cover the surface.

a2.2.15.) Solanaceae.

Capsicum L. sp. (Chili pepper)

a) Seed (Winton and Winton 1935:423): The ancient examples match modern specimens of *Capsicum* (pepper). The cells of the testa had the same overall shape and highly sclerenchymatised, sinuous cell walls. They commonly measured 4.0mm. across the longest diameter.

The sole example from Tulan also matched the general form of the other ancient material but this had a diameter of only 3mm. and was therefore considerably smaller then any of the cultivated examples in the authors reference collection. For this reason the identification was given a cf. qualification.

Cacabus prostratus (L'Henit) Benth.

Seed: These seeds, had the characteristic form of many seeds of the Solanaceae (with a thickened and raised sinuous cell walls on the surface and a roughly kidney shaped outline). This small herb grows in the vicinity of the site of Tulan 54 today and probably represented a wind blown addition to the ancient midden material.

Solanaceae indet..

Seed: The flotation samples yielded a number of small seeds that were characteristic of members of the family Solanaceae. They were up to 2mm. in length and were

somewhat elongated but with a shape that was reminiscent of a very small tomato seed (plate 20:2). The surface sculpturing was very distinctive with cells having thickened and sinuous cell walls (plate 20:3,4).

a2.2.16.) *Verbenaceae.*

cf. *Verbena* L. sp.

Seed (Martin and Barkley 1961:194): The seed was approximately 2mm. long and oblong in shape with a rounded to triangular cross section and a veined dorsal surface. A cf. qualification was kept because no modern reference was available for comparison.

Acantholippia riojana Hier. et. Mold. (*Rica rica*).

a) Fruits (Shizocarp): These were approximately oblong with rounded ends (2mm. x 1mm.x.1mm.). There was a distinctive groove on the underside of the fruit at the attachment point of the two mericarps.

b) Leaf: The small (aprox. 1 x 1 x 1.5mm) succulent and distinctively shaped leaves of this species were easily recognised (plate 19:4) (fig. 10:5).

This woody shrub matched the specimen of *A. riojana* at Kew Gardens but from other sources the common name *rica rica* is also referred to as *A. punensis* Botta., *A. deserticola* (Phil.) Mold., *Verbena origenes* Phil., *V.*

salsoloides Griseb. and other species of either *Acantholippia* or *Verbena*. There is evidently some confusion regarding the nomenclature of this/these species but it is probable that they all refer to the same species. *Rica rica* grows in abundance in the San Pedro de Atacama region in many of the seasonally dry quebradas between 2400m and 3000m. It is used widely as a fuel and was probably brought onto habitation sites for this purpose although Castro *et al.* (82:165) and Aldunate *et al.* (1981:204, 1983:125) also state that it also has medicinal properties.

a2.2.17.) *Labiateae.*

Galeopsis type.

Testa: Fragments of a yellow coloured testa with very prominent, regularly occurring crystal inclusions within hexagonally shaped cells with thin but easily distinguishable cell walls (plate 27:2,3).

a2.2.18.) *Compositae.*

Tessaria absinthioides (H. et A.) DC. (Brea, Sorona)

a) Leaf (Gajardo and Alliende 1986): Fragments of these leaves were recovered showing the edge patterning of rarely dentate and approximately rhomboid shaped leaves. The surface pattern of small hairs and occasional resin ducts was also characteristic.

a2.2.19.) Cyperaceae.

Schoenoplectus americanus (Pers.) Volkart.. syn. *Scirpus americanus* Pers. (*unquillo*, three square bullrush, sword grass) and *Schoenoplectus* type.

Although much of the older literature use the generic name *Scirpus*, I have put these into a *Schoenoplectus* category following the present nomenclature of the Royal Botanic Gardens, Kew. These two names can therefore be considered to be synonymous for the purposes of this thesis.

a) Epidermis and sub-epidermal fibre layer: Fragments of fibrous material was recovered from some coprolite samples. These were interpreted as fragments of the epidermis and associated fibre layer of a cyperaceous tuber/rhizome. This identification was made on the basis of the following features:

a) layers of dark/pale brown fibrous tissue several layers thick;

b) presence of localised radial thickenings in the fibre layer that match well with nodal thickenings of modern reference material (plate 20:5);

c) presence of adventitious root scars, typical of many monocotyledonous vegetative storage organs (plate 20:6);

d) presence of thickened areas adjacent to rhizome detachment scars.

All of these features compare favourably with modern samples of *Schoenoplectus* although from such often fragmentary remains it would be difficult state with absolute certainty that they had not derived from of any one of a number of closely related genera. The most obvious candidate, however, was *Schoenoplectus americanus* a species that occurs in widely throughout the americas (Koyama 1963:1112, Macbride 1936:289) and has been collected by the author in several parts of Northern Chile. Koyama (1963:1116), in fact, indicates that *S.americanus* subsp. *monophillus* has an inland variety (var. *longisetis*) that is restricted to the desert lands of the central Andes. It is most likely that this is the variety represented by both the modern reference material collected and their archaeological counterparts. Where more fragmentary remains were recovered, in the absence of whole equivalents from flotation deposits, they have been recorded as *Schoenoplectus* type. Flotation samples from Tulan, yielded many of the tubers that were almost complete and showed clearly the triangular apical scar and associated ridges characteristic of modern reference material (fig. 10,1). These have been identified to species. Also present in some of these samples were the leaf sheaths and fragments of the rhizome.

In some of the flotation samples complete and fragmentary charred tubers were recovered. Three categories of this

material were sorted: i) Samples with diagnostic features such as root scars, rhizome detachment scars, on the endodermal surface, ii) Samples with an obvious inner parenchyma and adherent epidermis but with none of the above distinctive features, iii) Samples showing only parenchymatous tissue but with no other features.

b) Achenes (Martin and Barkley 1961:137): These were up to 2.5mm. in length and were identified in accordance with the features referred to by Martin and Barkley and by comparison with modern reference material.

a2.2.20.) Gramineae.

Avena L. sp. (Oats).

Testa fragments (Dickson 1987:99 Helbaek 1958: plate 1, Winton and Winton 1932:158) : These consisted of thin walled, colourless and transversely elongated cells which were organised into rows that often made up a herring bone pattern in surface view (plates 28:4,5 30:7,8). Although it is normally a simple matter to distinguish between the testa of *Avena* and other large cereals/grasses, highly degraded fragments were recovered in which this distinction becomes less certain (plate 28:3). In such samples the general herring bone pattern was present but evidence of other associated, highly degraded layers make the identifications more tenuous.

Bromus L. sp. (Brome grass).

Testa fragments (Dickson 1987:101, Helbaek 1958: plate 2, Korber-Grohne 1964, Winton and Winton 1932:186) : The testa was composed of relatively thin walled, elongated and interlocking cells. This layer had a darker brown pigmentation than the bran of other cereals and the cells made a characteristic fan pattern which radiated outwards from a point at the apical end of the hilum (plate 28:2).

The samples from the Zweeloo body showed a cellular arrangement with dark pigmentation. The low number of fragments recovered and the lack of any fragments showing the cellular pattern characteristic of the apical end of the grain made it necessary to qualify the identification to the level of cf. *Bromus* sp. (plate 30:6).

Cortaderia Stapf. sp. (cola de Zorro, pampus grass).

Leaf fragments: This was characterised by a relatively thick monocotyledon lamina with a parallel veined organisation. These veins were darker than the surrounding tissues and were often "squared" in cross section and appeared as ridges on the leaf's surface. The thinner examples were often curled (presumably pieces from closer to the tip of the lamina) and had a series of spines at regular intervals along both the edges of the blade and on the dorsal nerve of the abaxial surface.

Members of this genera grow in abundance in the quebradas of Northern Chile today. The presence of *Cortaderia* sp. leaf fragments most probably represents post depositional contamination of samples, these having presumably become incorporated from detached pieces of the funery garments.

Hordeum L. sp. (Barley).

a) Testa fragments (Dickson 1987:99, Helbaek 1958: plate 1, Holden 1986:121, Winton and Winton 1932:269) : The pericarp of barley is rarely recovered from archaeological material, however, the two layers of what Winton and Winton (1932:274) call the spermoderm and perisperm are occasionally recovered. These appear as overlapping layers of rectangular and thin walled cells (plates 28:6, 29:8,9, 31:6). Many of these had a dark brown pigmentation. Such fragments can not be identified beyond the level of genus.

b) Rachis internodes: These were identified as such since they had relatively straight, parallel sides with a smooth/glossy abaxial surface and a distinctive detachment scar. (see fig. 11;4).

c) Light chaff: A substantial quantity of light cereal chaff was recovered from the Lindow II sample. Much of this material was identified as being fragments of rachillas, lemmas and paleas of barley (see fig 11 1-6). The lemma of barley forms a fork-like structure at its

base with the flattened and often hairy rachilla positioned in its axis (fig. 11 6). When fragmented, the lemma and palea form thin slivers with thickened basal areas. The rachillae look superficially similar although they often have hairs. This material and fragmentation pattern most closely resembled a modern reference sample of crushed barely that had been prepared for a coarse museli.

Hordeum/Secale indet. (barley/rye).

a) Rachis fragments: The upper part of the rachis was, in this case, recovered. This consisted of a relatively parallel sided structure with a coarse hairy margin. The upper part was much degraded though enough was present to show that it was a rachis fragment of either barley or rye but the normally distinctive pattern of the glume attachment scars was not clearly defined.

Panicum miliaceum L. (broom-corn millet).

a) Floret ie. lemma and palea (Renfrew 1973:36, Winton and Winton 1932:122) : Whole florets were identified on the basis of their gross morphology and size (Van Zeist in press). More fragmentary pieces could easily be related to these complete examples.

b) Testa fragments (Winton and Winton 1932:122) : Only one fragment of this was recovered from the Zweeloo bog

body. It was characterised by elongated, sinuous and thin walled cells that made up a translucent and delicate layer (plate 30:9).

Secale cereale L. (rye).

a) Pericarp and testa fragments (Colledge 1988, Dickson 1987:100, 1988:123, Holden 1990, Korber-Grohne 1981, Korber-Grohne and Piening 1980, Winton and Winton 1932:256): A substantial quantity of rye bran (pericarp and testa) was recovered from the Huldremose body. This included low quantities of the degraded longitudinal cell layer (plate 26:5,6) of the pericarp and larger quantities of the testa and adherent transverse and tube cell layers of the pericarp. These testa fragments were relatively dark in colour. The transverse cell layer showed marked thickening of the end walls of the cells (plate 26:7,8,9); strong concentrations of pigment towards the ends of the cells and cells, in a central position on the grain were generally 15-20um in breadth and 55-100um. in length. This thickening of the end wall of the transverse cell layer of the pericarp would seem to be a feature that is distinctive of rye. It was on this basis that some of the Huldremose bran has been identified. Where testa fragments were recovered with no adherent pericarp layers these could not be distinguished from those of wheat. They have been discussed in the *Triticum/Secale* group below.

b) cf. Glume fragments. Two fragments of glume from the Huldremose body were probably of rye and were identified on the basis of there gross morphology.

Setaria cf. *viridis* (L.) Beauve. (green bristle grass).

The whole floret was identified on its gross morphology. Length 1.75mm. breadth 1mm.

Stipa L. sp. (ichu).

a) Spikelet: The extremely hairy spikelets of approximately 0.5mm in length were identified on the basis of there general shape and more particularly on the form of the sharp rachilla and associated backward pointing bristles.

Triticum diocccum Schubl. (emmer wheat).

No further samples of T.dicoccum were identified from these samples. However 2 glume bases were identified by Hillman (1986) from the original sample studied in the preliminary survey of the Lindow II bog body.

Triticum spelta L. (spelt wheat) glume base/rachis.

A number of fragments of the glume base and rachis were recovered. These were identified on the basis of their size and patterns of veination.

Triticum indet. glume bases/rachis fragments.

A substantial number of split and fragmentary glume bases or rachis fragments were recovered from all of the Lindow II samples. These were, however, so degraded that a more specific identification could not be made.

a) Pericarp (Colledge 1988, Dickson 1987:100, 1988:123, Holden 1986:119, 1989, Korber-Grohne 1981, Korber-Grohne and Piening 1980, Pomeranz 1971:56, Schel *et al.* 1980, Winton and Winton 1932:191) : The outermost layer of the pericarp consisted of one or more layers of longitudinal cells which were not considered to be of any diagnostic value. These layers are not commonly recovered from ancient samples. Below this, however, the transverse cell layer can be of diagnostic importance but its survival in faecal material varies considerably (plate 28:7, 31:1,2).

Rye and some more primitive species of wheat (eg. spelt) would seem to be virtually inseparable on the basis of the cellular characteristics of the bran. Criteria related to the cell size of the transverse layer can be misleading (Holden 1990) but, the pronounced thickening of the end cell walls of the transverse cell layer does seem to be a characteristic that rye alone possesses. In the light of data such as those provided by Colledge (1988) it would appear, however, that not all varieties of rye show this feature, neither is it a feature that is

consistent over the surface of individual grains. The absence of this thickening cannot therefore be used to identify the presence of wheat. For this reason such fragments have been put into a rye/wheat category.

Testa fragments (Dickson 1987:100, 1988:123, Helbaek 1958: plate 1, Holden 1986:119, 1989, Winton and Winton 1932:191): The testa was composed of two overlying layers of elongated, pigmented cells with thin walls. They presented a characteristic chequer-board pattern when seen in surface view (plate 28:8,9, 29:7, 31:3). These layers are characteristic of both *Triticum* and *Secale* and can not, therefore, be used to distinguish between the two.

Zea mays L. (maize).

Pericarp and Caryopsis base (Gassner:1973:62, Hayward 1938:111, Vaughan 1970:91, Winton and Winton 1932:62): Some samples yielded small fragments of maize grains. These were primarily pieces of rachilla and the thickened basal part of the caryopses onto which pieces of the darker pericarp was frequently adherent. These basal parts were between 1-2 mm. across. Also surviving in some samples were fragments of pericarp (plate 17:8,9) showing a number of layers (up to twelve according to Winton and Winton 1932:68 see ch.3) of elongated cells with strongly pitted cell walls. These pericarp samples were, however, substantially thinner than modern maize

species from Peru and Chile and closely matched samples recovered from grave goods from tombs in the Tarapaca valley, Chile (plate 17:1,2, 18:1-3).

a2.2.21.) Other.

Cork Layer indet.

A few fragments of plant tissue that resembled the cork layer of either a plant root or stem were recovered. These consisted of a layer of storied, polygonal, or occasionally elongated cells (plate 17:3-5). This arrangement is typical of the cork (phellem) of many plant stems and roots during the early stages of secondary growth. As such, it is a commonly occurring feature on stem tubers and other edible storage organs. Martins (1976) has investigated the value of both cellular and subcellular organisation of a number of species of South American tubers with a view to identifying features of diagnostic value. Using this work and modern reference material, samples recovered from Pircas 2 T-5 and others matched well with the cork layers of *Solanum tuberosum* (potato). Stone cells were also recovered from a number of these samples but these could have derived from a number of sources and and are thought to be of only limited diagnostic value. Experiments on the differential digestion of different plant tissues (see section 3.4.1.5.1.) indicated that if potatoes were to be consumed little would survive digestion apart from the cork layer (if they were eaten unpeeled) and the stone cells

of the cortex. In this respect the Tarapaca material was in agreement with the expected results, however, an unqualified identification was not made. There is still an incomplete knowledge of how the anatomy of tissues like this cork layer vary with maturity or environmental conditions. It is also probable that many other species show the same cellular arrangement.

Fleshy stem/root indet.

This category of debris consisted of a group probably consisting of more than one species of plant but all exhibiting similar features. None of these were thought to be diagnostic of any particular species. Larger fragments showed a loose connection between several layers of rounded to rectangularly shaped parenchyma and bundles of fibres with thick and pitted cell walls (plate 21:1-3). No starch was present and the extremely fragile nature of most of this type of debris might suggested that these associations only survive where passage through the gut has been faster than normal thus preventing total digestion.

Pericarp/Geoffroea type. (COPTH16K-1).

The outer layer of this structure was composed of a number of layers of storied cells that resembled cork tissue. These stories (stacks) of cells appeared as lines when observed under low power. Below this layer

was a layer of degraded parenchyma containing occasional cells with dark chromatophore inclusions. Embedded within this second layer was a two dimensional network of anastomosing vascular tissue. This tissue in many ways resembled the pericarp of *Geoffroea decorticans* but there are certain obvious differences that can not be reconciled at present. No identification has, as yet, been made.

Seed testa/Pericarp indet.

Type I (Lindow II) - A number of small fragments of this type of seed testa were recovered. This consisted of a tissue made up of rounded cells with fluted thickening of the walls (plate 27:8).

Type II (Lindow II) - Fragments of this dark brown testa/pericarp were recovered from the Lindow II samples. They were made up of a dense arrangement of thick walled and irregularly shaped cells (plate 27:7).

Epidermal tissue indet.

Type I (zweeloo)- Two fragments of what appear to be leaf cuticle were recovered from the Zweeloo bog body. This consisted of degraded remains of an epidermal tissue in which the cell patterns could just be discerned and the remains of stomata seen (plate 31:4,5). No identification was possible.

Type II (AZ6 T-6) - One sample revealed an epidermal tissue in which the constituent cells were irregularly shaped with thick beaded cell walls (plate 21:4,5). No identification has been possible as yet

Leaf tissue indet.

Sample Cam 9 T-13 produced a number of fragments that resemble leaf tissue. The veination and a certain amount of degraded ground tissue were still present no samples of the epidermis was recovered (plate 21:6.7). No identification has been possible as yet.

a2.3.) Animal tissue.

a2.3.1.) Marine invertebrates.

Ceolenterata. cf. Hydrozoan.

Two samples of regularly segmented and tubular coelenterates were recovered from two samples. The had a consistency not unlike that of fish bone and had a branch on each segment of the body. One example measuring 2.5mm. in length consisted of four segments. It would seem most likely that these were not in fact dietary items but contaminants of other marine foods.

Marine invertebrate indent.

At least two samples yielded samples of what appeared to be a colonial marine invertebrate. These had a brittle calcium based skeleton (plate 24:1,2) but none of the fragments could be identified. In any event, is probable that this item was a contaminant of other marine foods rather that a deliberately consumed food species.

a2.3.2.) Mollusca.

cf. *Chlorostoma* sp. (Top shells).

The radula ribbon was approximately 1mm. in diameter and highly degraded with both the lateral and marginal teeth missing. However, the shape of the rachidian teeth (the single central row) indicate that it was a rhipidoglossan type of radula (eg. Fretter and Graham 1962:171) and it matched with those indicated by Trochel 1856-1863 (vol. II plate 23) of the genera *Chlorostoma* (plate 23:1,2).

Chlorostoma cf. atra Lesson. (Top shells).

The radula ribbon was approximately 2mm. in diameter but in a good condition with both the 5 lateral teeth and numerous (20 +) marginal teeth still present (plate 23:3-6). The form and arrangement of these teeth indicate that this is also a rhipidoglossan radula and matches well with reference material of *C. atra* (J. Taylor pers. comm.) held at the British Museum of Natural

History. There are, however, at least 3 other species of *Chlorostoma* that inhabit the waters of Northern Chile (Basly 1982) for which no reference material was available.

Snail shell indet.

Some flotation samples from the Tulan area yielded low numbers of very small terrestrial/river snails. These were not thought to have been of great importance with respect to human subsistence and were not identified above the level of phylum. They could have been either brought on to the site with other resources eg. *Schaenoplectus* tubers or could actually have been living in and around the habitation sites.

2.3.3.) Insects.

Beetle larvae: Sample Pircas 2 T-6 produced the remains of a beetle larva that was identified by Mrs E.Peacock (British Museum of Natural History) as belonging to the Family Dermestidae possibly either *Trogoderma sp.* or *Cryptorhopalum* sp.. This was made on the basis of the characteristically spear shaped hairs that occur over the bodies of members of these genera (plate 24:3-6). Many members of the family Dermestidae are both scavengers and crop pests it is therefore not possible to determine whether they had entered the body as food contaminants or as post depositional intrusions.

Body parts indet: Some samples yielded occasional fragments of insects. These were never recovered in quantity and there was never any evidence to suggest that these were of any dietary importance. It was not therefore considered necessary to identify all fragments. The majority of insect parts are thought to have been either contaminants of food during preparation/storage etc. or post depositional intrusions.

Pupae/Puparia indet: Fragments of these were regularly recovered from the flotation samples from Tulan. They were not considered to be of great significance to the major objectives of the project and could have become incorporated into the assemblages either at the time of deposition or at a later stage by burrowing insects.

a2.3.4.) Acarid mites.

Lardoglyphus robustisetus Baker.

This species was, in fact, new to science prior to its discovery in sample Cas-sur T-1B and is described fully in the publication by Baker (in press.). The feeding preferences of this genera is for dry, high protein foods and others have been recovered for mummified human remains (Mck. Klicks 1988). It is possible that they were attracted by the body itself but it would seem more likely that they were taken in as part of the food since they were present in such large quantities in the gut contents.

a2.3.5.) Fish Remains.

a) Bone: These bones were commonly fin rays and spines although some samples (see Mo 1-6 T-18) produced large numbers of pharyngeal bones. Fish bone has a consistency that is easily distinguished from mammal or bird bone being occasionally almost translucent and yellow/orange colour. The absence of modern reference material prevented specific identifications being made.

b) Scales: Most of the scales recovered were in a highly degraded state and could not be used for any accurate identification (A. Wheeler pers. comm.).

c) Otoliths: These were recovered from one sample only. They were highly degraded, presumably due their passage through the gut, but retained sufficient structure to suggest that they were most probably otoliths (A.Wheeler pers. comm.) With such degraded specimens it would seem unlikely that any further information relating the species concerned could be deduced.

Most of the fish material recovered was thought to be of marine origin even when recovered from sites as far inland as Tarapaca (30Km. inland). In these regions the present water flow is not sufficient to maintain any substantial fish population. To the authors knowledge there was no evidence to show that the flow during any part of the holocene would have been able to support such population.

a2.3.6.) Birds.

a) Bones: A substantial quantity of fragmentary bone material was recovered from the site of Tulan. A quantity of this was hollow, of very slight construction and was considered to have belonged to a small species of bird. (NB. Hesse 1984 has already identified *Metriopelia* sp. ground dove) from Tulan 54.

b) Feathers: A number of samples revealed quantities of bird feather but it was not possible, within the scope of this project, to identify these with any accuracy.

c) Beak: One sample of a bird beak was recovered from a flotation sample. The lack of modern reference material and expertise prohibited the making of an identification.

a2.3.7.) Mammalian Remains.

a) Bone: A substantial quantity of fragmentary bone material was recovered from the site of Tulan 54. Even though most of this was too small to identify with any certainty, but much was of a size range suggestive of from small rodent. Hesse (1984) has already analysed a number of rodent and bird bone samples from Tulan 54 and indicated that in addition to the dominating *Lagidium/Chinchilla* (Viscacha/Chinchilla) group, bones of *Ctenomys fulvus* (the *Tuco tuco* or *Cholulo*) and *Phylottis* sp. (leaf eared mouse) were also present.

b) Hair: Animal hair was not a common component of the coprolites although a number of samples from Tulan 54 contained considerable quantities. There being no specialist help nor reference material available for consultation these were divided into two main categories.

i) Rodent type: This group consisted of fine hairs with a pronounced profile and frequently a laddered medulla (plate 22:4,5,7-9). (Appleyard 1978).

ii) Camelid type: This group consisted of hairs with a much greater diameter with a smooth profile and an intermittent to non-existent medulla (plate 22:6). (Appleyard 1978).

A more detailed examination of the hair samples from Tulan is being carried out by P.Dransart (pers. comm.).

c) Teeth: A number of rodent teeth were recovered from the Tulan 54 samples. The lack of an adequate reference collection made a more detailed identification impractical.

a2.3.8.) Amphibian.

Bone: One coprolite sample from Tulan revealed a number of very small animal bones. On the basis of the structure of the bones and the fused nature of the lumber vertebrae. These were identified (K.Dobney and B.Irving

pers. comm.) as being the bones of a species amphibian (probably a juvenile).

a2.3.9.) Animal indet.

a) Epithelial tissue: Thin layers of diaphanous tissue which have definite elastic properties. Although showing a "cellular" nature the general texture of these fragments indicate that they were animal in origin (plate 27:1).

b) Cartilage/tendon Tissue: Fragments of brown almost lustrous material with a rubbery consistency were recovered. Attempts were made to section, stain and mount such samples using standard anatomical techniques, however, these did not stain selectively and no detailed anatomy could be discerned.

c) Muscle fibres (Meat/Jarky): In a number of samples notably COPTH16K/3 (plate 22:1-3) meat fibres with the same distinctive, striated pattern were recovered. It is unlikely that it will be possible to identify such samples to a more detailed level than animal indet.

a2.3.10.) Animal droppings.

cf.Insect droppings.

This class of material was most commonly charred and characterised by small discrete or agglutinated masses

(aprox. 1mm. in length) that were normally cylindrical in shape with a granular texture (plate 20:1).

cf. Bird droppings.

These were discrete cylindrical, granular accumulations of organic material that commonly showed a longitudinal twist. In many of these *Calandrinia* sp. seeds were recovered from the organic matrix.

Rodent droppings.

These consisted of organic concretions that although cylindrical in cross section tapered towards each end. They were smaller than camelid droppings and larger than those of insects.

Camelid droppings.

These were easily recognisable by virtue of their shape which was generally spherical/cylindrical slightly tapering at one end and commonly over 1cm. in diameter. The matrix was composed of finely comminuted vegetable material.

Plate 15.

1) Opuntia cf. atacamensis Philippi. (Cume). Epidermis/cork tissue from the fruit x 50. Taken from a flotation sample from Tulan 54, Chile (Tu54 cf 33b).

2) Opuntia cf. atacamensis Philippi. (Cume). Epidermis/cork tissue from the fruit x 85. Taken from a flotation sample from Tulan 54, Chile (Tu54 cf 33b).

3) Opuntia cf. atacamensis Philippi. (Cume). Tough endocarp that surrounds the seed x 50. From a coprolite from Tulan 54, Chile (COPTH16E).

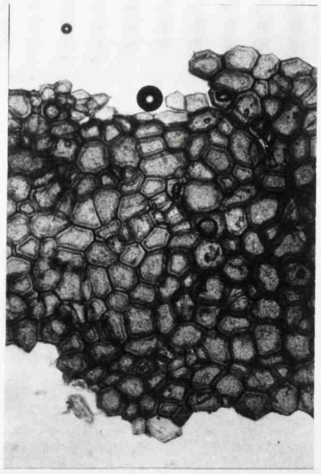
4) Opuntia cf. atacamensis Philippi. (Cume). Tough endocarp overlying the testa x 50. From a coprolite from Tulan 54, Chile (COPTH16E).

5) Opuntia cf. atacamensis Philippi. (Cume). Testa from the central part of the seed x 50. From a coprolite from Tulan 54, Chile (COPTH16E).

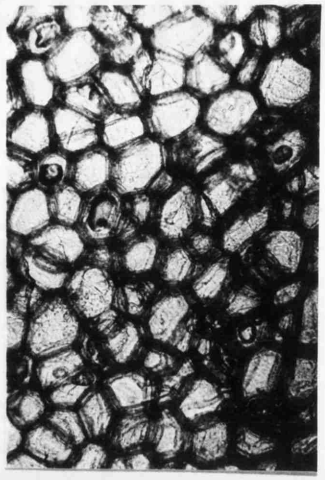
6) Opuntia cf. atacamensis Philippi. (Cume). Testa from the edge of the seed x 50. From a coprolite from Tulan 54, Chile (COPTH16E).

7) Prosopis L. sp. (Algarrobo). Legume epidermis. From the gut contents of a human body from the Tarapaca valley, Chile (COPTH02).

8) Atriplex atacamensis (Cachiyuyo). Seed enclosed within the bracts x 5. From the gut contents of a human body from the Tarapaca valley, Chile (COPTH02).

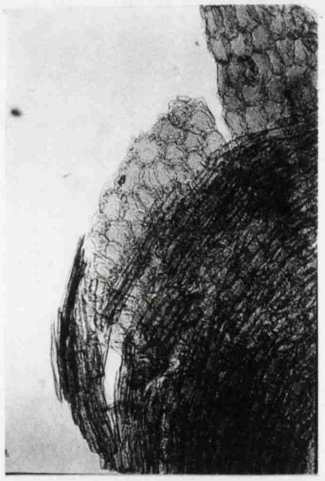


1

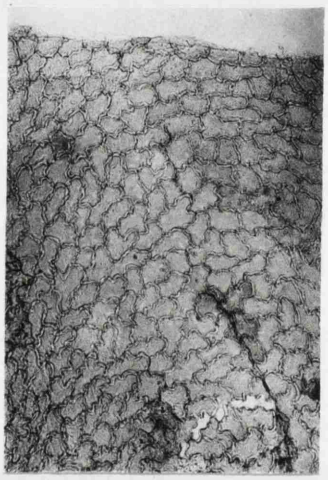


2

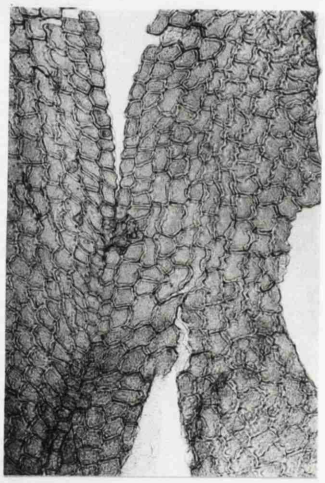
3



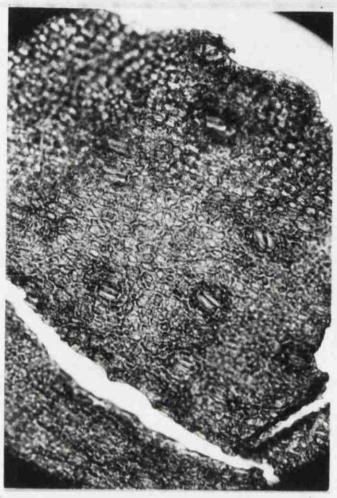
4



5



6



7

8

Plate 16.

1) Chenopodium L. sp. (quinoa or yuyo). Scanning electron micrograph of a dark seeded variety in which much of the testa broken away. From the gut contents of a human body from Pircas 2, Tarapaca, Chile (COPTH01).

2) Chenopodium L. sp. (quinoa or yuyo). Scanning electron micrograph of a dark seeded variety in which much of the testa broken away - close-up of the radicle. From the gut contents of a human body from Pircas 2, Tarapaca, Chile (COPTH01).

3) Chenopodium L. sp. (quinoa or yuyo). Scanning electron micrograph of the degraded testa of a dark seeded variety. From the gut contents of a human body from Pircas 2, Tarapaca, Chile (COPTH01).

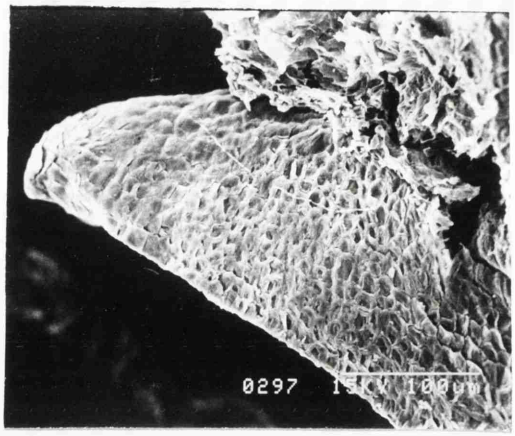
4) Chenopodium L. sp. (quinoa or yuyo). Scanning electron micrograph of the embryo area of a dark seeded variety in which much of the testa has been broken away. From the gut contents of a human body from Pircas 2, Tarapaca, Chile (COPTH01).

5) Chenopodium L. sp. (quinoa or yuyo). The cell patterns of the testa x 325. Grave offerings from a tomb in the Tarapaca valley, Chile.

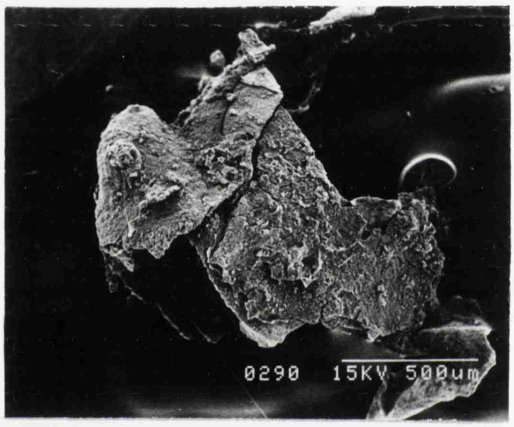
6) Chenopodium L. sp. (quinoa or yuyo). The cell patterns of the testa x 325. Grave offerings from a tomb in the Tarapaca valley, Chile.

7) Chenopodium L. sp. (quinoa or yuyo). The cell patterns of the testa x 85. Grave offerings from a tomb in the Tarapaca valley, Chile.

1

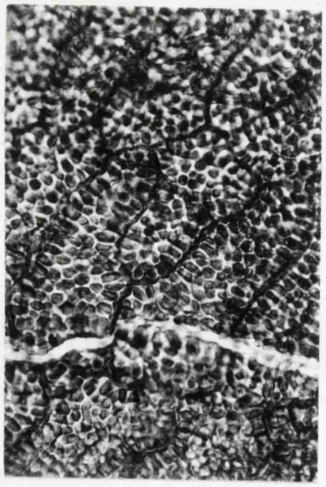


2

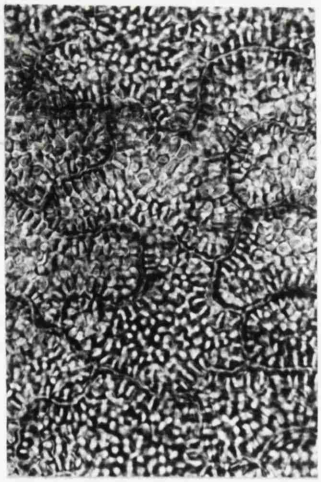


3

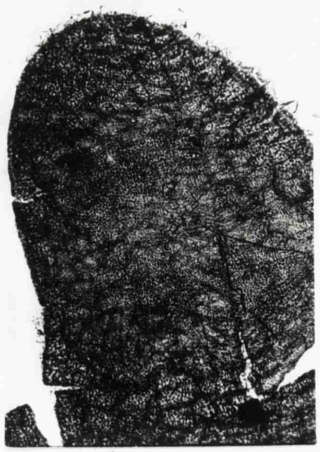
4



5



6



7

Plate 17.

1) Zea mays L. (Maize). The elongated cells of the epicarp x 325. Grave goods from a tomb in the Tarapaca valley, Chile.

2) Zea mays L. (Maize). The elongated cells of the epicarp x 85. Grave goods from a tomb in the Tarapaca valley, Chile.

3) Cork layer indet. x 85. From the gut of a human body from Camarones, Chile (COPTH28).

4) Cork layer indet. x 85. From the gut of a human body from the Azapa valley, Chile (COPTH28).

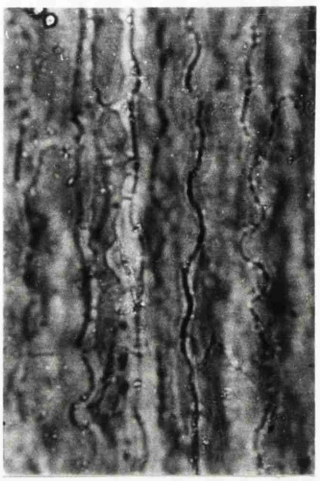
5) Cork layer indet. x 325. From the gut of a human body from Pircas 2, Tarapaca, Chile (COPTH25).

6) Legume indet. Palisade layer. x 85. From the gut of a human body from the Azapa valley, Chile (COPTH20/6).

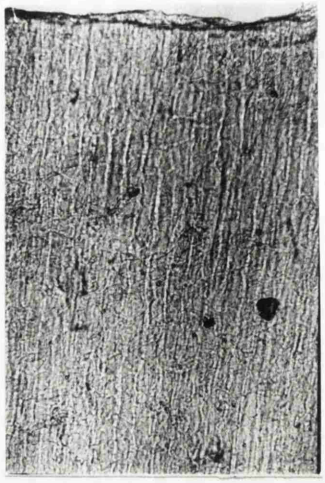
7) Legume indet. Palisade layer. x 325. From the gut of a human body from the Azapa valley, Chile (COPTH20/6).

8) Zea mays L. (Maize). The elongated cells of the epicarp x 85. From the gut of a human body from Camarones, Chile (COPTH23a).

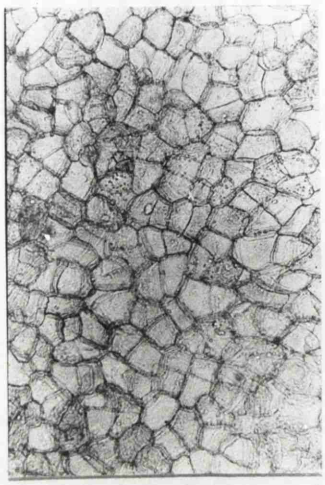
9) Zea mays L. (Maize). The elongated cells of the epicarp x 85. From the gut of a human body from Camarones, Chile (COPTH23a).



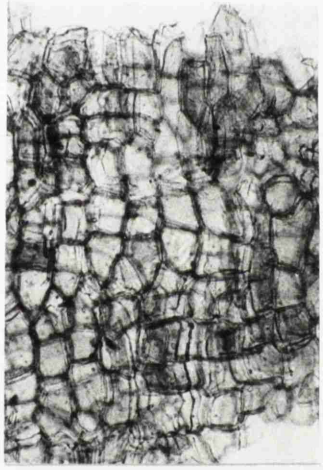
1



2

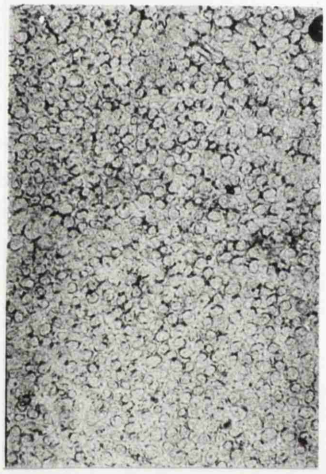


3

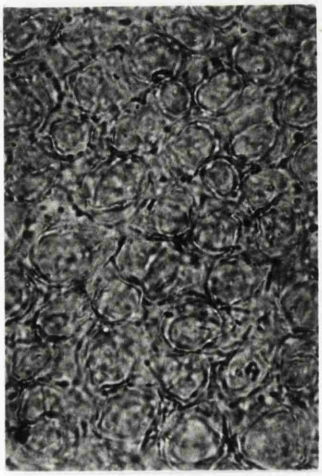


4

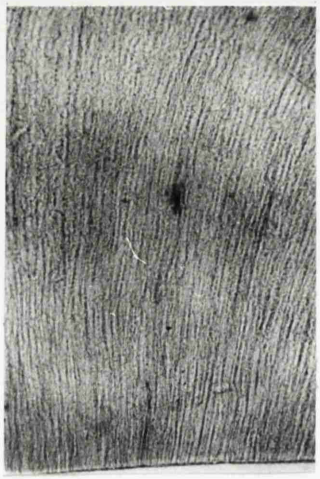
5



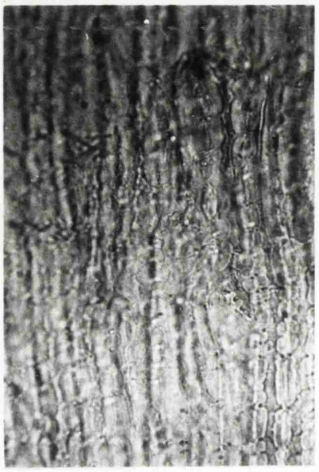
6



7



8



9

Plate 18.

1) Zea mays L. (Maize). Scanning electron micrograph of the surface of the epicarp. Grave offering from the Tarapaca valley, Chile.

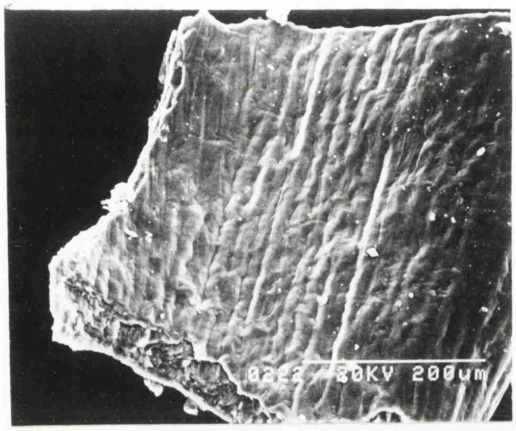
2) Zea mays L. (Maize). Scanning electron micrograph showing the elongated cells of the epicarp overlying the transverse and tube cell layers. Grave offering from the Tarapaca valley, Chile.

3) Zea mays L. (Maize). Scanning electron micrograph showing the aleurone layer overlying the transverse and tube cell layers. Grave offering from the Tarapaca valley, Chile.

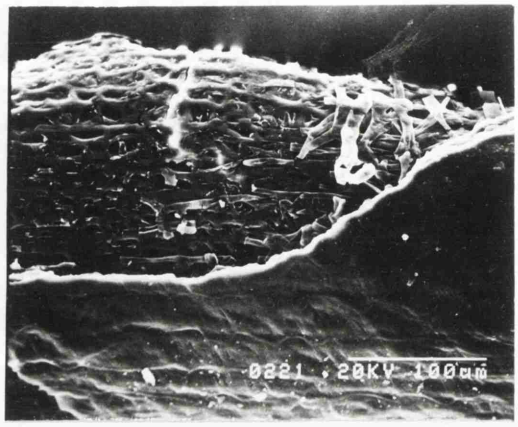
4) Calandrinia borchersi Phil. (balsamo). Seed. From a flotation sample from Tulan 54, Chile (Tu54 cf 17).

5) Calandrinia borchersi Phil. (balsamo). Distorted seed. From a flotation sample from Tulan 54, Chile (Tu54 cf 17).

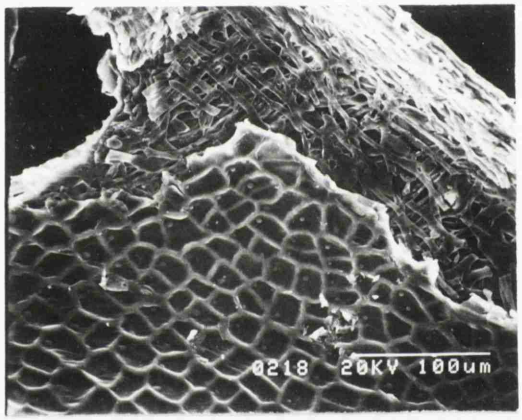
6) Calandrinia borchersi Phil. (balsamo). Seed testa showing cell patterns over the edge of the seed. From a flotation sample from Tulan 54, Chile (Tu54 cf 17).


20KV 200um

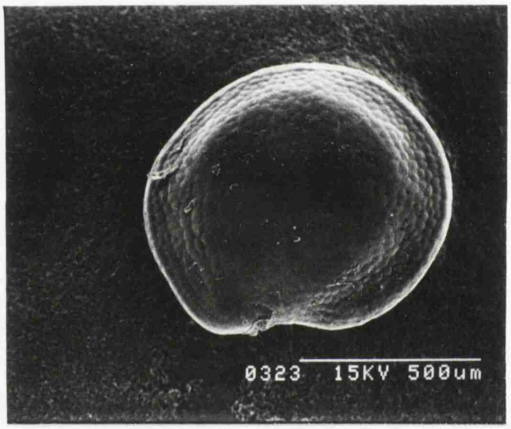
1


0321 20KV 100um

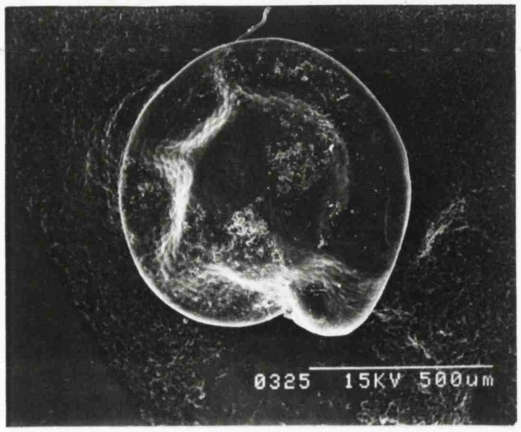
2


0218 20KV 100um

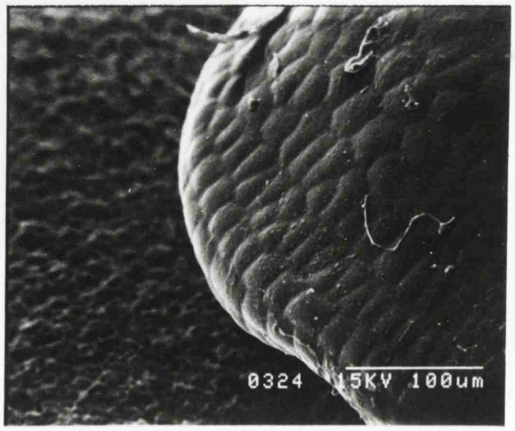
3


0323 15KV 500um

4


0325 15KV 500um

5


0324 15KV 100um

6

Plate 19.

1) cf. Sisymbrium L. sp.. Scanning electron micrograph of the whole seed. From a flotation sample from Tulan 54, Chile (Tu54 cf 17).

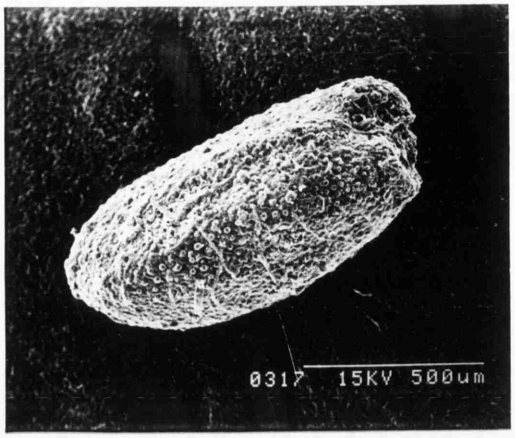
2) cf. Sisymbrium L. sp.. Scanning electron micrograph of the testa. From a coprolite from Tulan 54, Chile (COPTH16A).

3) cf. Sisymbrium L. sp.. Scanning electron micrograph of the testa. From a coprolite from Tulan 54, Chile (COPTH16A).

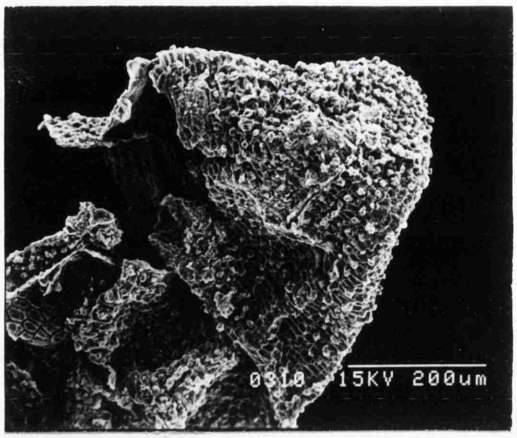
4) Acantholippia riojana Hier. et. Mold. (Rica rica). Scanning electron micrograph of the adaxial leaf surface. From a flotation sample from Tulan 54, Chile (Tu54 cf 17).

5) cf. Sisymbrium L. sp.. Testa surface showing papillae and underlying cell patterns x 325. From a coprolite from Tulan 54, Chile (COPTH16A).

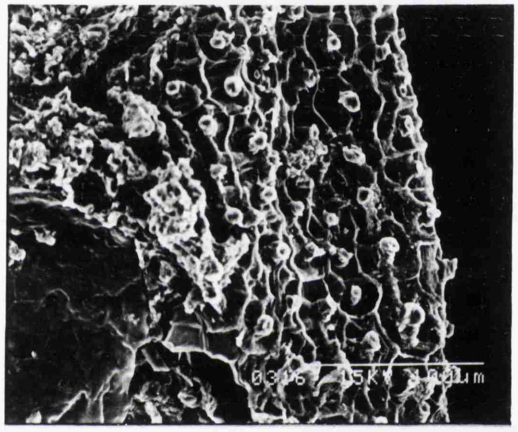
6) cf. Sisymbrium L. sp.. Testa surface showing papillae and underlying cell patterns x 50. From a coprolite from Tulan 54, Chile (COPTH16A).



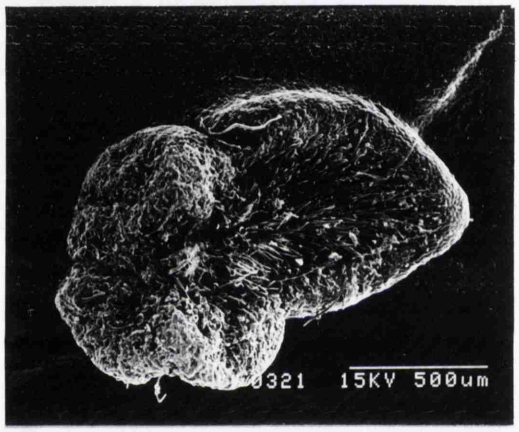
1



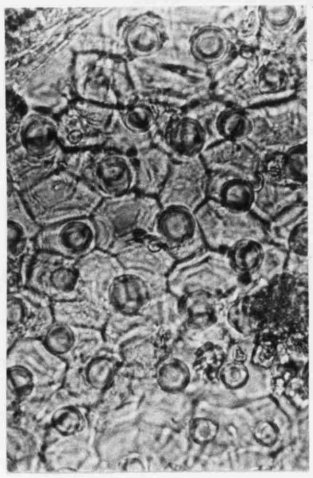
2



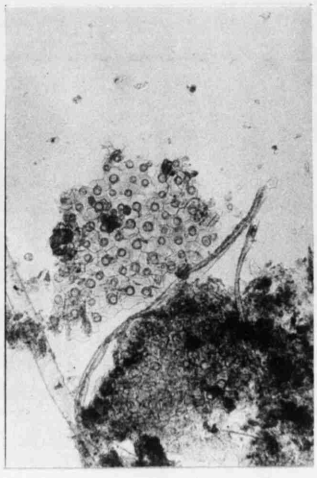
3



4



5



6

Plate 20.

1) Scanning electron micrograph of an indet. item - possibly a charred insect dropping. From a coprolite from Tulan 54, Chile (COPTH24H).

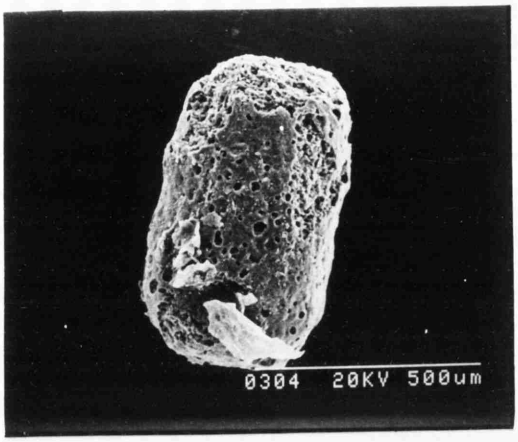
2) cf. Solanaceae sp. Scanning electron micrograph of the seed. From a coprolite from Tulan 54, Chile (COPTH24H).

3) cf. Solanaceae sp. Scanning electron micrograph of the seed. From a coprolite from Tulan 54, Chile (COPTH24H).

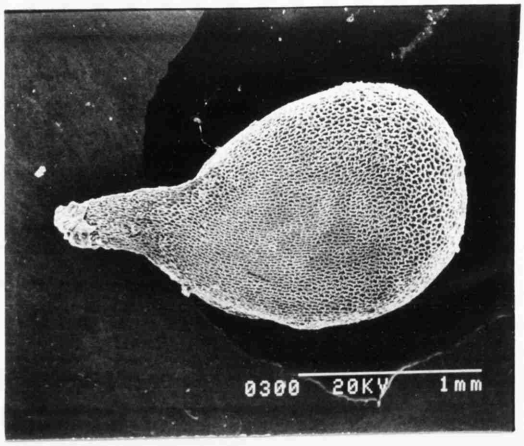
4) cf. Solanaceae sp. Scanning electron micrograph of the seed. From a coprolite from Tulan 54, Chile (COPTH24H).

5) Schoenoplectus cf. americanus (Pers.) Volkart. Scanning electron micrograph of a small fragment of the epidermis and fibre layer showing a portion of a radial thickening. From the gut of a human body from Pircas, Tarapaca, Chile (COPTH01).

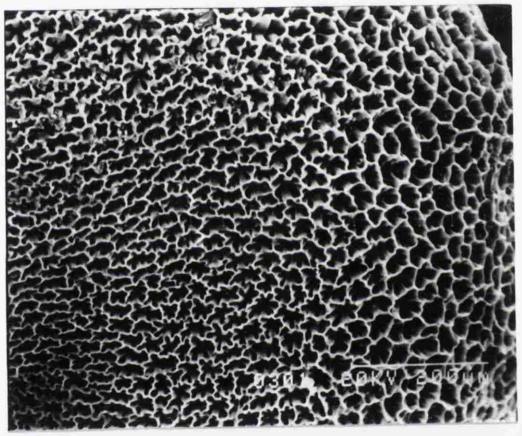
6) Schoenoplectus cf. americanus (Pers.) Volkart. Scanning electron micrograph of a small fragment of the epidermis and fibre layer with a typical thickening around the point of root attachment. From the gut of a human body from Pircas, Tarapaca, Chile (COPTH01).


0304 20KV 500um

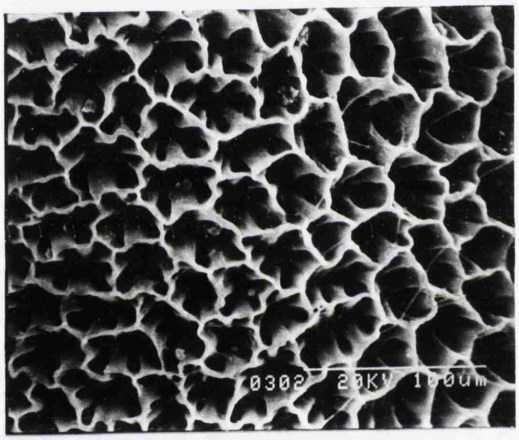
1


0300 20KV 1mm

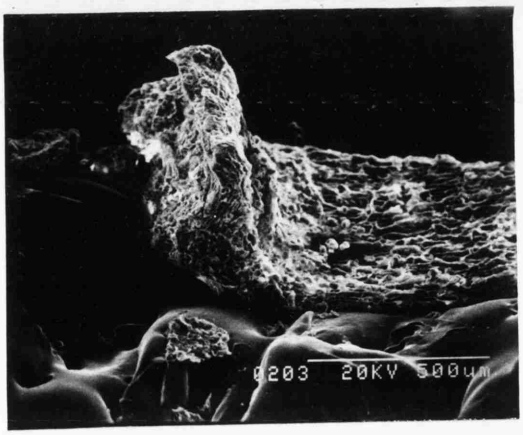
2



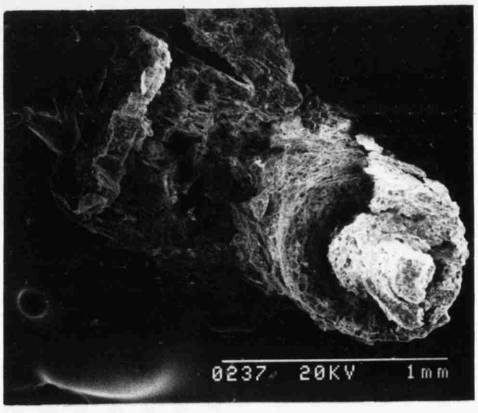
3


0302 20KV

4


0203 20KV 500um

5


0237 20KV 1mm

6

Plate 21.

1) Stem/Root tissue indet. Parenchyma with associated fibres x 60 From the gut of a human body from Camarones, Chile (COPTH23b).

2) Stem/Root tissue indet. Parenchyma with associated fibres x 50. From the gut of a human body from Arica, Chile (COPTH24H).

3) Stem/Root tissue indet. Parenchyma with associated fibres x 85. From the gut of a human body from Arica, Chile (COPTH24H).

4) Epidermal tissue indet. x 85. From the gut of a human body from the Azapa valley, Chile (COPTH22).

5) Epidermal tissue indet. x 325. From the gut of a human body from the Azapa valley, Chile (COPTH22).

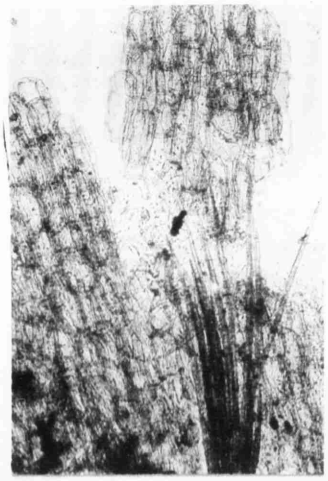
6) Leaf tissue indet. x 50. From the gut of a human body from Camarones, Chile (COPTH23a).

7) Leaf tissue indet. x 50. From the gut of a human body from Camarones, Chile (COPTH23a).

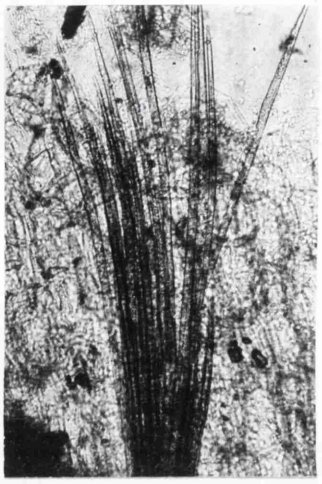
8) Legume indet. Disaggregated cells from the palisade layer of a legume x 325. From the gut of a human body from the Azapa valley, Chile (COPTH20/6).

9) Legume indet. Disaggregated cells from the palisade layer of a legume x 85. From the gut of a human body from the Azapa valley, Chile (COPTH20/6).

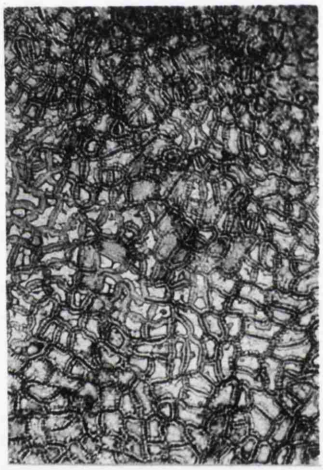
1



2

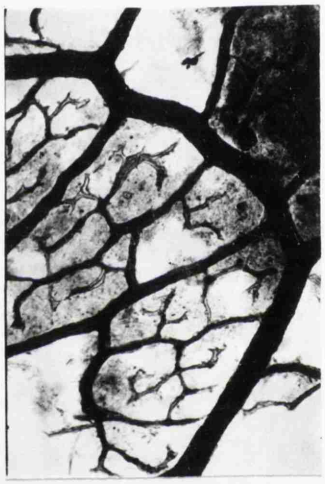


3

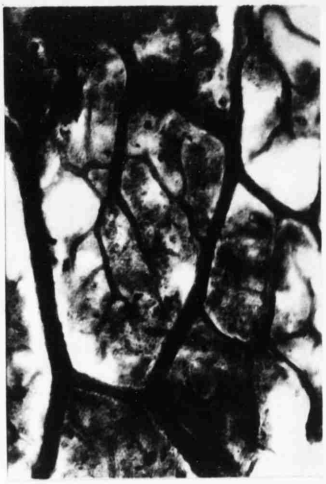


4

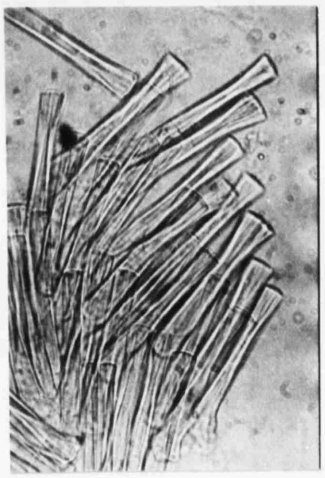
5



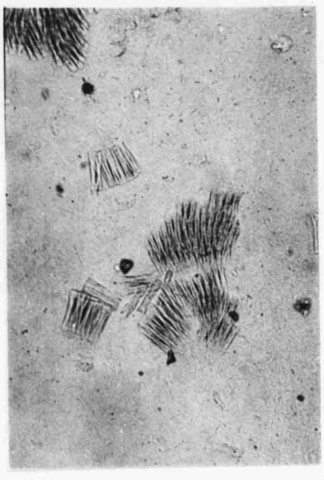
6



7



8



9

Plate 22.

1) Striated muscle fibres. x 325. From a coprolite from Tulan 54, Chile (COPTH16K/3).

2) Striated muscle fibres. x 325. From a coprolite from Tulan 54, Chile (COPTH16K/3).

3) Striated muscle fibres. x 50. From a coprolite from Tulan 54, Chile (COPTH16K/3).

4) Hair x 325. From the gut of a human body from Arica, Chile (COPTH24a).

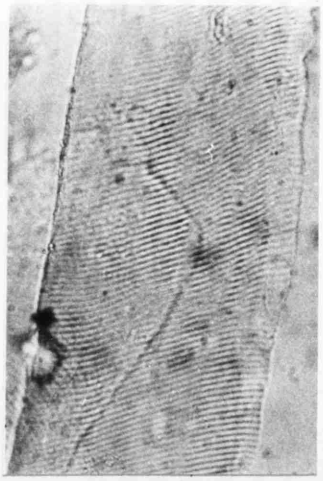
5) Hair x 85. From the gut of a human body from Arica, Chile (COPTH24a).

6) Camelid hair (fine) x 85. From a coprolite from Tulan 54 (COPTH16N/3).

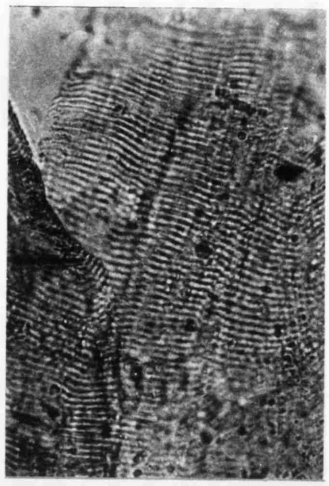
7) Rodent type Hairs x 325. From a coprolite from Tulan 54 (COPTH16G/1).

8) Rodent type Hair x 325. From a coprolite from Tulan 54 (COPTH16G/1).

9) Rodent type Hair x 325. From a coprolite from Tulan 54 (COPTH16I/1).

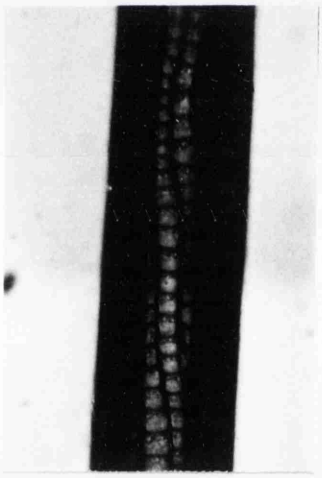


1

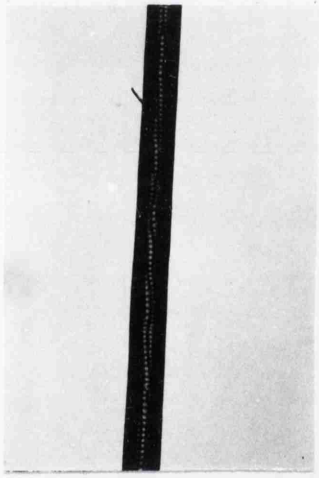


2

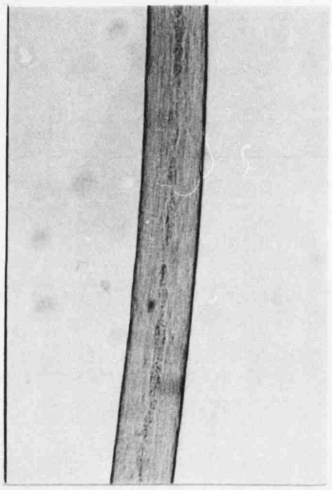
3



4

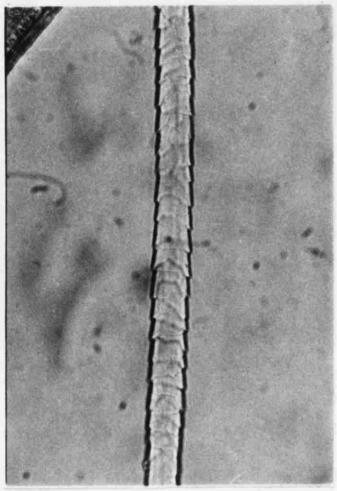


5

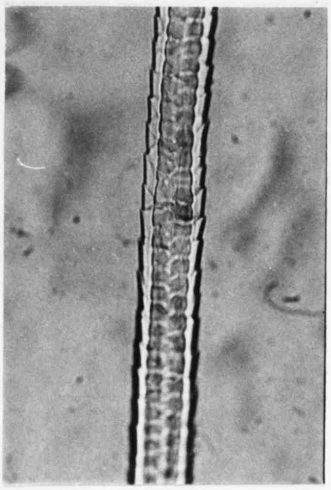


6

7



8



9

Plate 23.

1) cf. Chlorostoma sp. (Top shell). Scanning electron micrograph of the radula. From the gut of a human body from Arica (COPTH24E).

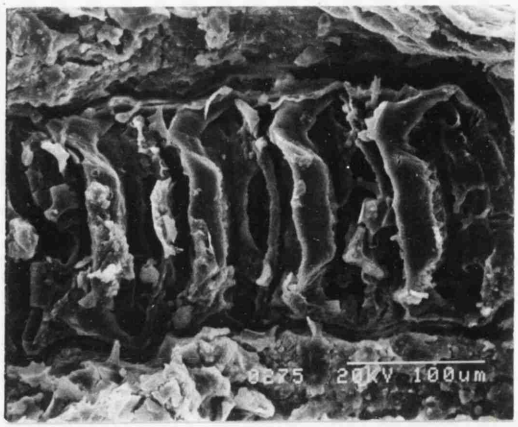
2) cf. Chlorostoma sp. (Top shell). Scanning electron micrograph of the radula. From the gut of a human body from Arica (COPTH24E).

3) Chlorostoma cf. atra Lesson. (Top shell). Scanning electron micrograph of the radula. From the gut of a human body from Arica (COPTH24E).

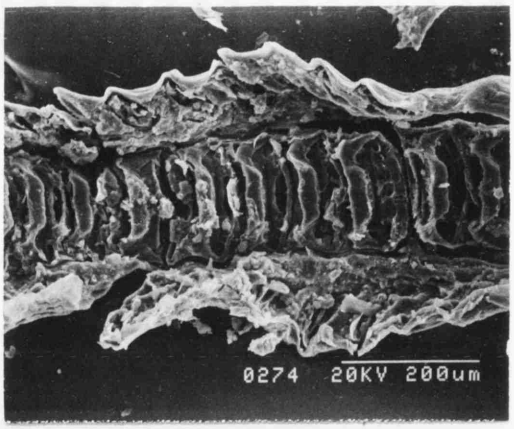
4) Chlorostoma cf. atra Lesson. (Top shell). Scanning electron micrograph of the radula. From the gut of a human body from Arica (COPTH24E).

5) Chlorostoma cf. atra Lesson. (Top shell). Scanning electron micrograph of the radula - detail on rachidian tooth. From the gut of a human body from Arica (COPTH24E).

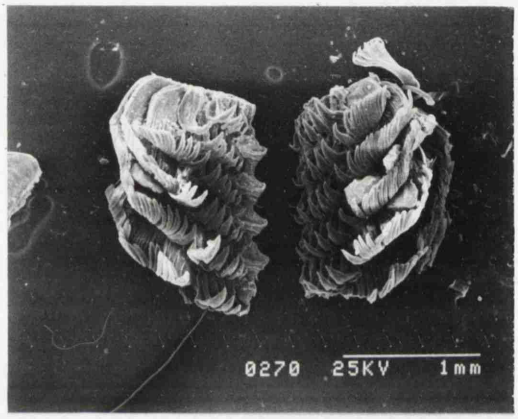
6) Chlorostoma cf. atra Lesson. (Top shell). Scanning electron micrograph of the radula - detail on lateral teeth. From the gut of a human body from Arica (COPTH24E).


0275 20KV 100um

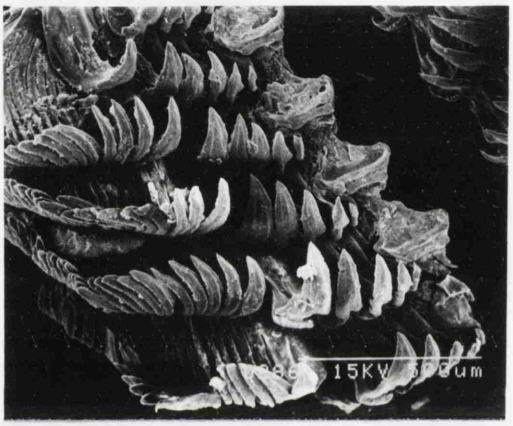
1


0274 20KV 200um

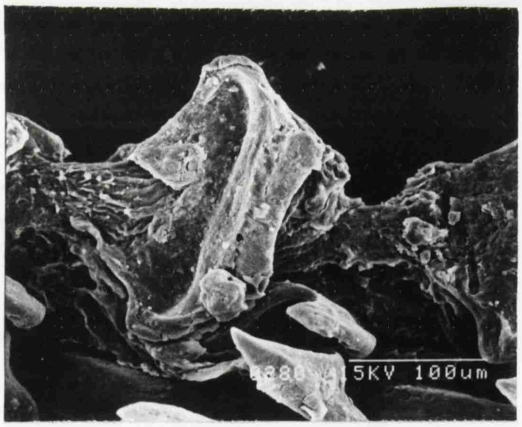
2


0270 25KV 1mm

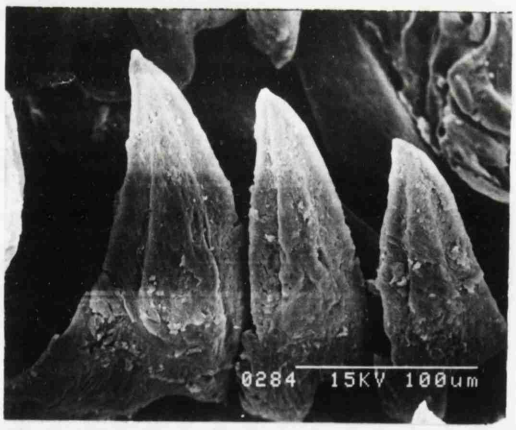
3


15KV

4


15KV 100um

5


0284 15KV 100um

6

Plate 24.

1) cf. A species of colonial marine invertebrate. Scanning electron micrograph of the calcareous 'skeleton'. From the gut of a human body from Camarones, Chile (COPTH23a).

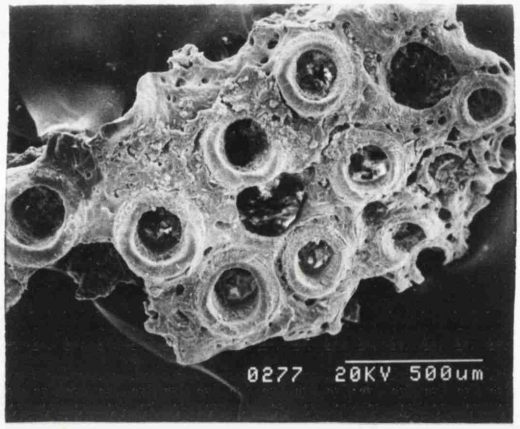
2) cf. A species of colonial marine invertebrate. Scanning electron micrograph of the calcareous 'skeleton'. From the gut of a human body from Camarones, Chile (COPTH23a).

3) Dermestid beetle larva (Either Trogoderma sp. or Cryptorhopalum sp.) x 85. From the gut of a human body from Tarapaca, Chile (COPTH02).

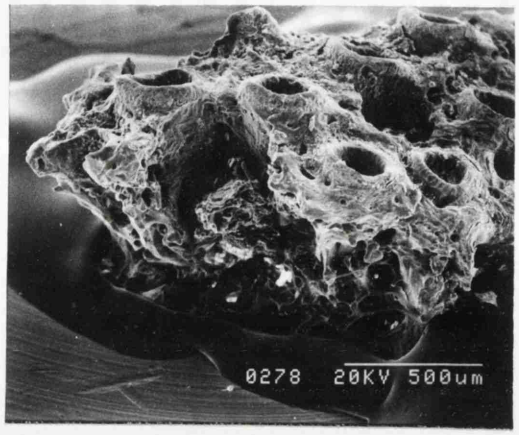
4) Dermestid beetle larva (Either Trogoderma sp. or Cryptorhopalum sp.) x 50. From the gut of a human body from Tarapaca, Chile (COPTH02).

5) Dermestid beetle larva (Either Trogoderma sp. or Cryptorhopalum sp.) x 85. From the gut of a human body from Tarapaca, Chile (COPTH02).

6) Dermestid beetle larva (Either Trogoderma sp. or Cryptorhopalum sp.) x 325. From the gut of a human body from Tarapaca, Chile (COPTH02).



1



2

3

4

5

6

Plate 25.

1) Camelina cf. sativa. (L.) Crantz. (Gold of Pleasure). Testa showing thick walled cells of the testa overlain by an almost translucent layer with papillae x 85. From the gut of Huldremose bog body.

2) Camelina cf. sativa. (L.) Crantz. (Gold of Pleasure). Testa showing thick walled cells of the testa overlain by an almost translucent layer with papillae x 100 (second focal position of the same fragment as in no. 1). From the gut of Huldremose bog body.

3) Camelina cf. sativa. (L.) Crantz. (Gold of Pleasure). Testa showing thick walled cells of the testa overlain by an almost translucent layer with papillae. These can be more clearly seen where the fragment is folded over x 85. From the gut of Huldremose bog body.

4) Spergula arvensis L. (Corn Spurrey). The tip of one of the 'teeth' of the capsule x 50.

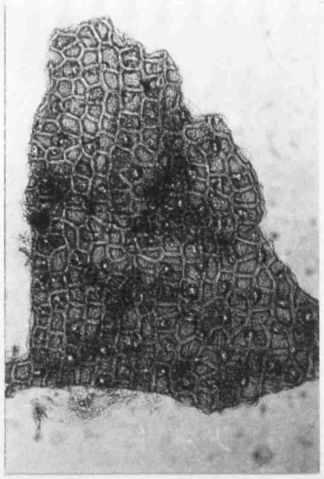
5) Spergula arvensis L. (Corn Spurrey). The cell patterns on one of the 'teeth' of the capsule x 85.

6) Spergula arvensis L. (Corn Spurrey). The cell patterns of the testa x 85. From the gut of Huldremose bog body.

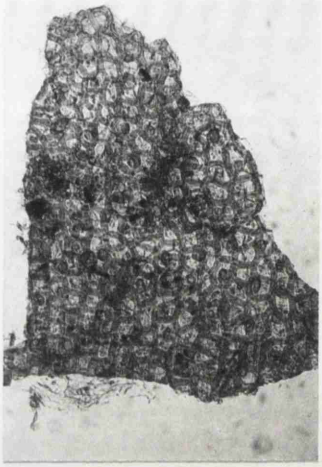
7) Spergula arvensis L. (Corn Spurrey). The cell patterns of the testa x 85. From the gut of Huldremose bog body.

8) Spergula arvensis L. (Corn Spurrey). The cell patterns of the testa x 85. From the gut of Huldremose bog body.

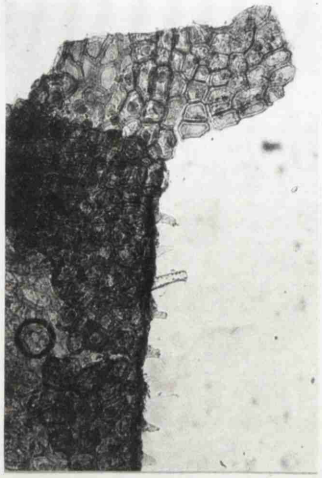
9) Spergula arvensis L. (Corn Spurrey). The cell patterns of the testa x 325. From the gut of Huldremose bog body.



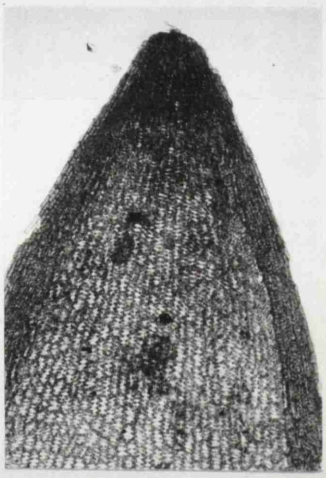
1



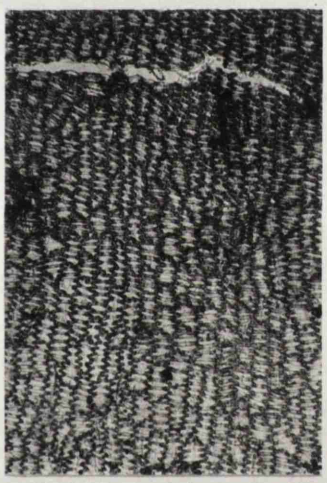
2



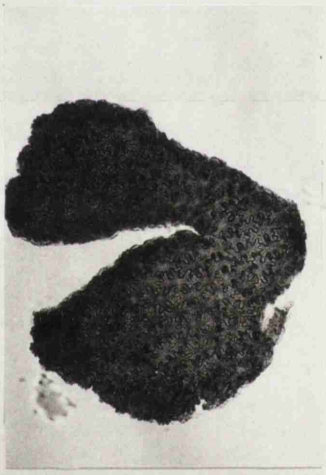
3



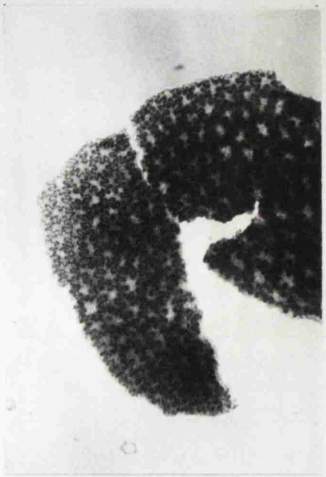
4



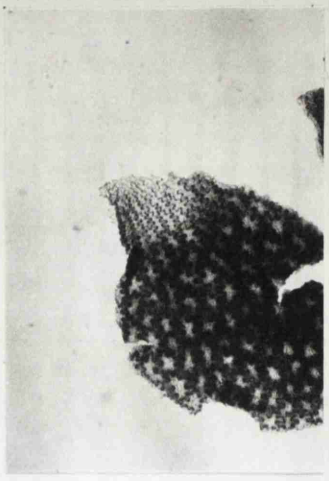
5



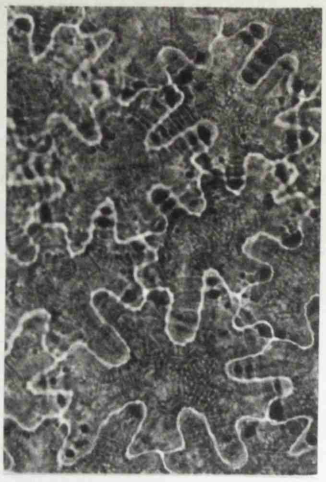
6



7



8



9

Plate 26.

1) Cork material. Probably stem tissue of Spergula arvensis x 85. From the gut of Huldremose bog body.

2) Camelina cf. sativa (L.) Crantz. (Gold of pleasure). Fragments of the siliqua showing a layer of interlocking and elongated cells overlying a layer of fibres and a network of loosely anastomosing vascular tissue. From the gut of Huldremose bog body x 50.

3) Camelina cf. sativa (L.) Crantz. (Gold of pleasure). Fragments of the siliqua showing a layer of interlocking and elongated cells overlying a layer of fibres and a network of loosely anastomosing vascular tissue. From the gut of Huldremose bog body x 85.

4) Camelina cf. sativa (L.) Crantz. (Gold of pleasure). Fragments of the siliqua showing a layer of interlocking and elongated cells overlying a layer of fibres. From the gut of Huldremose bog body x 50.

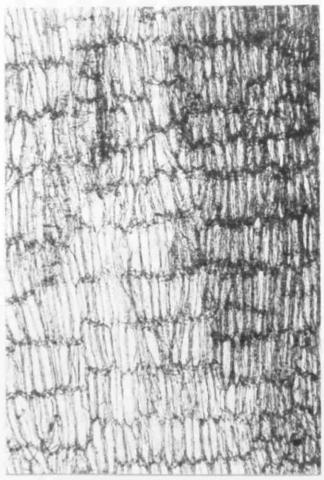
5) Cereal indet. (Probably Rye). A detached fragment of the degraded longitudinal cell layer of the pericarp x 85. From the gut of Huldremose bog body.

6) Cereal indet. (Probably Rye). A detached fragment of the degraded longitudinal cell layer of the pericarp x 325. From the gut of Huldremose bog body.

7) Secale cereale L. (Rye). The transverse layer of the pericarp showing dark patches at the ends of the cells and thickened end cell walls x 85. From the gut of Huldremose bog body.

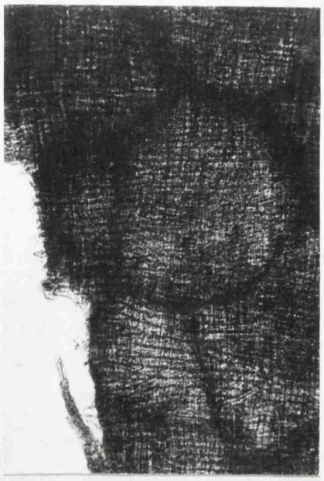
8) Secale cereale L. (Rye). The transverse layer of the pericarp showing the distinctive thickened end cell walls x 325. From the gut of Huldremose bog body.

9) Secale cereale L. (Rye). The transverse layer of the pericarp showing dark patches at the ends of the cells and distinctively thickened end cell walls x 10. From the gut of Huldremose bog body.

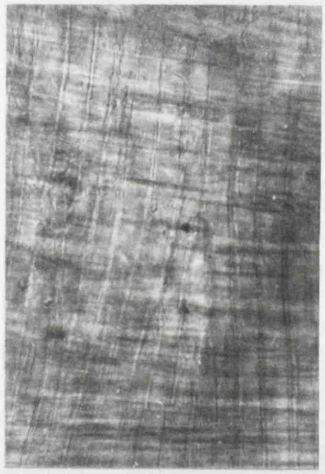


1

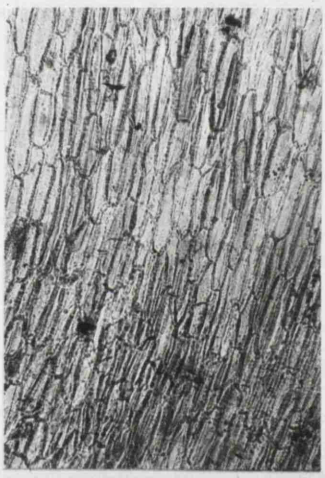
2



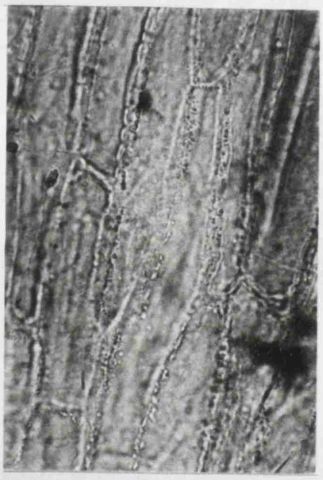
3



4

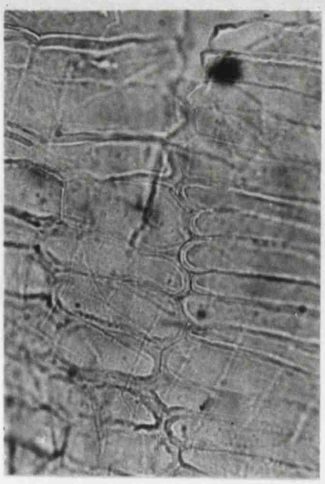


5

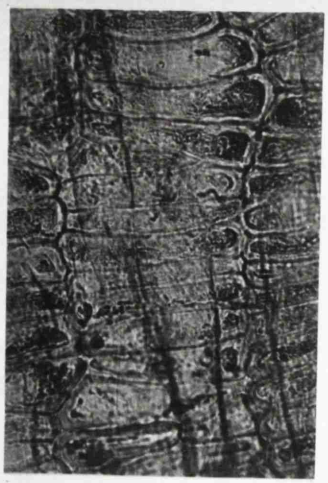


6

7



8



9

Plate 27.

1) cf. Connective tissue x 6. From the gut of Huldremose bog body.

2) cf. Galeopsis sp. Testa with crystal inclusions x 85. From the gut of the Lindow II bog body.

3) cf. Galeopsis sp. Testa with crystal inclusions x 325. From the gut of the Lindow II bog body.

4) Polygonum convolvulus L. (Black bindweed). Testa x 325. From the gut of the Lindow II bog body.

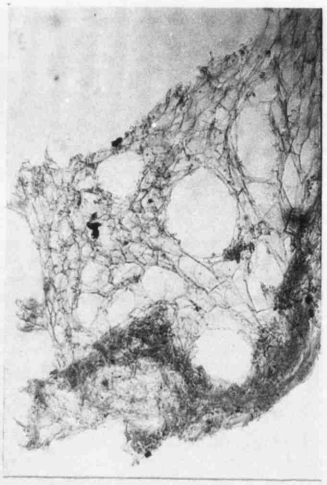
5) Polygonum convolvulus L. (Black bindweed). Testa x 325 (at a second focal position). From the gut of the Lindow II bog body.

6) Polygonum convolvulus L. (Black bindweed). Testa x 325 (at a third focal position). From the gut of the Lindow II bog body.

7) Testa indet. x 325. From the gut of the Lindow II bog body.

8) Testa indet. x 85. From the gut of the Lindow II bog body.

9) Polygonum convolvulus L. (Black bindweed). Testa x 85. From the gut of the Lindow II bog body.



1

2

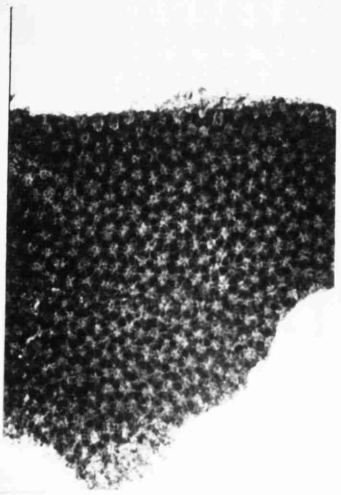
3

4

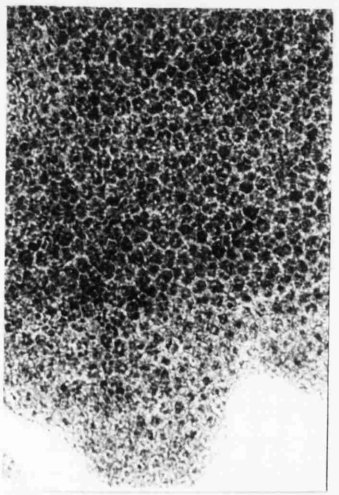
5

6

7



8



9

Plate 28.

1) Rumex acetosella L. agg. (Sheep's sorrel). Testa x 325. From the gut of the Lindow II bog body.

2) Bromus sp. (Brome grass). Testa x 50. From the gut of the Lindow II bog body.

3) Highly degraded fragment of cereal testa - probably Triticum/Secale (Wheat/Rye) x 85. From the gut of the Lindow II bog body.

4) Avena L. sp. (Oat). Testa fragment with an adherent parasite egg x 85. From the gut of the Lindow II bog body.

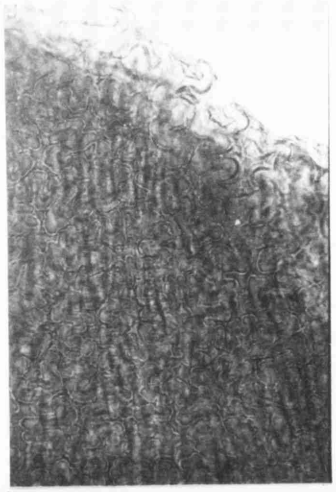
5) Avena L. sp. (Oat). Testa fragment x 85. From the gut of the Lindow II bog body.

6) Hordeum sp. (Barley). Testa fragment x 85. From the gut of the Lindow II bog body.

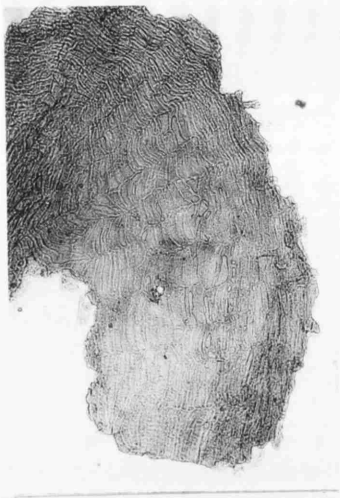
7) Triticum/Secale sp. (Wheat rye). Fragment of the testa with an adherent, degraded fragment of the transverse layer of the pericarp x 85. From the gut of the Lindow II bog body.

8) Triticum/Secale sp. (Wheat rye). Fragment of the testa x 85. From the gut of the Lindow II bog body.

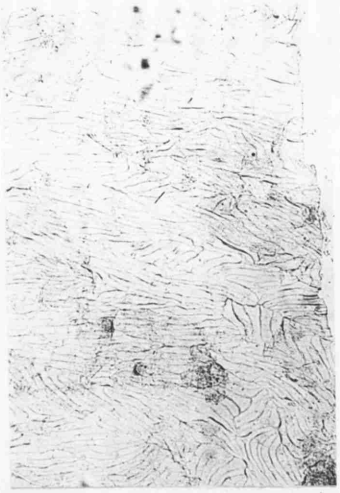
9) Triticum/Secale sp. (Wheat rye). Fragment of the testa x 325. From the gut of the Lindow II bog body.



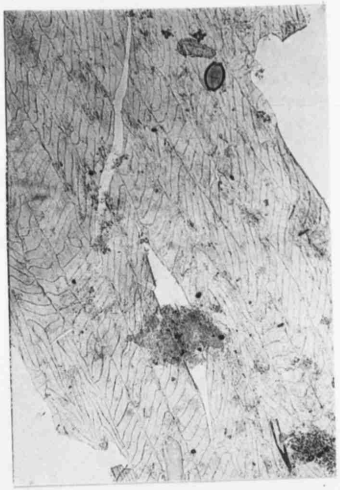
1



2



3



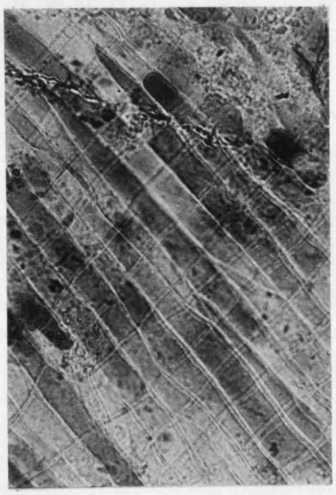
4

5

6

7

8



9

Plate 29.

1) cf. Raphanus L. (Radish) sp. The testa showing smaller palisade cells overlying the much larger pigmented cells x 85. From the gut of Lindow III bog body.

2) cf. Raphanus L. (Radish) sp. The testa showing smaller palisade cells overlying the much larger pigmented cells x 325. From the gut of Lindow III bog body.

3) cf. Raphanus L. (Radish) sp. The testa showing smaller palisade cells overlying the much larger pigmented cells x 400 (as no 2 but different focus). From the gut of Lindow III bog body.

4) Corylus avellana. L. (Hazel). A fragment of the testa x 50. From the gut of Lindow III bog body.

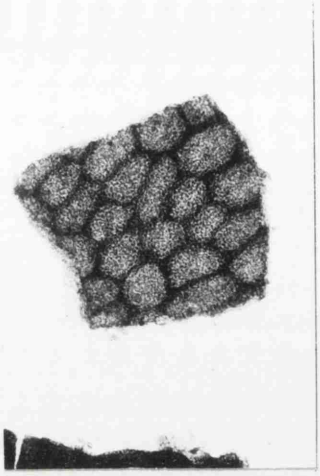
5) Chenopodium album L. (Fat hen). A fragment of the testa after partial clearing in Jeffry's solution x 85. From the gut of Lindow III bog body.

6) Chenopodium album L. (Fat hen). A fragment of the testa after clearing in Jeffry's solution x 85. From the gut of Lindow III bog body.

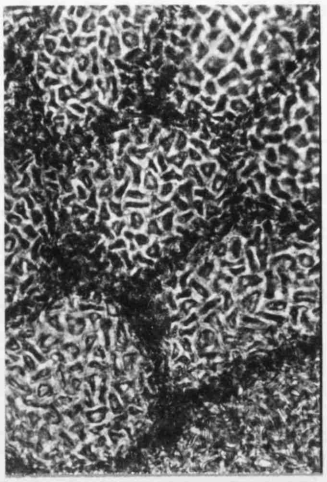
7) Triticum/Secale (Wheat/rye). A fragment of the testa x 85. From the gut of Lindow III bog body.

8) Hordeum L. sp. (Barley). A fragment of the testa x 325. From the gut of Lindow III bog body.

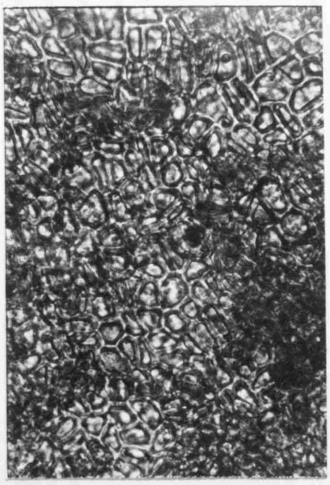
9) Hordeum L. sp. (Barley). A fragment of the testa x 10. From the gut of Lindow III bog body.



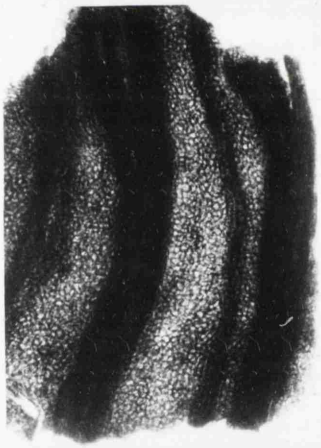
1



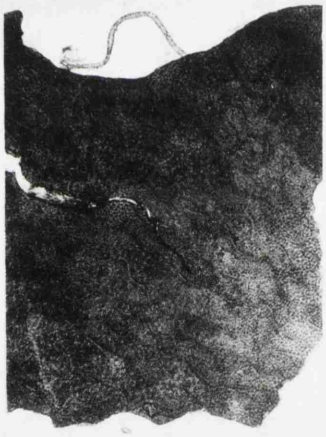
2



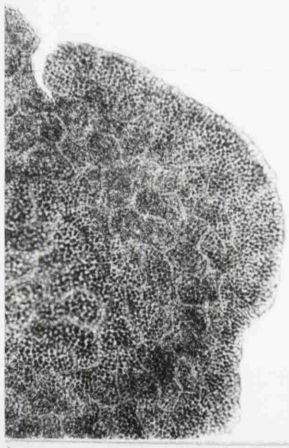
3



4



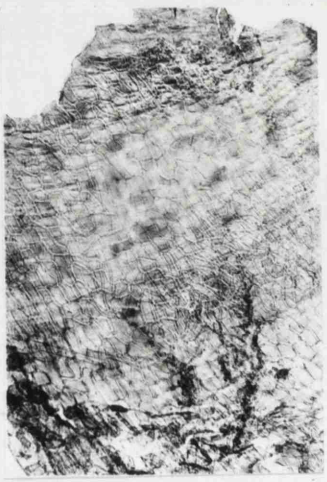
5



6

7

8



9

Plate 30.

1) Spergula arvensis L. (Corn Spurrey). The cell patterns of the testa x 325. From the gut of Zweeloo bog body.

2) Linum cf. usitatissimum L. (Linseed). A fragment of the seed x 50. From the gut of Zweeloo bog body.

3) Linum cf. usitatissimum L. (Linseed). A fragment of the seed x 50. From the gut of Zweeloo bog body.

4) Brassica sp. A fragment of the testa x 85. From the gut of Zweeloo bog body.

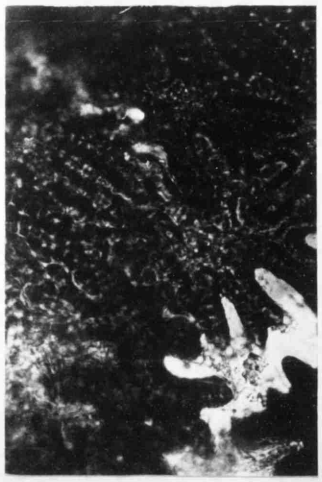
5) Rubus fruticosus L. agg. (Blackberry). A fragment of the seed testa x 85. From the gut of Zweeloo bog body.

6) cf. Bromus sp. L. (Brome grass). A Fragment of the testa x 85. From the gut of Zweeloo bog body.

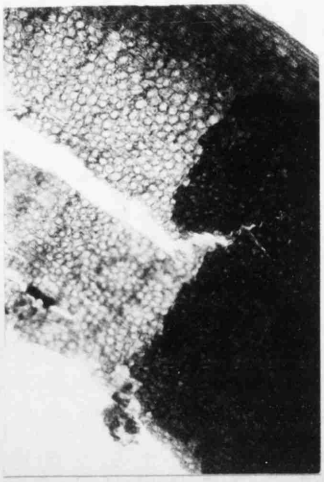
7) Avena L. sp. (Oat). A Fragment of the testa x 85. From the gut of Zweeloo bog body.

8) Avena L. sp. (Oat). A Fragment of the testa x 325. From the gut of Zweeloo bog body.

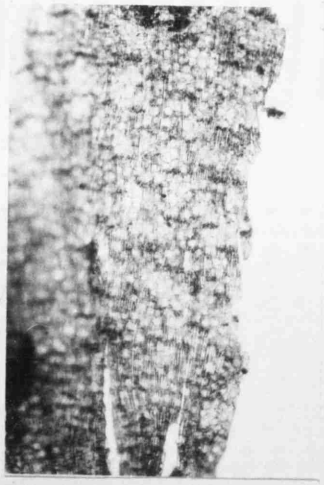
9) Panicum miliaceum L. (Common millet). A Fragment of the testa x 85. From the gut of Zweeloo bog body.



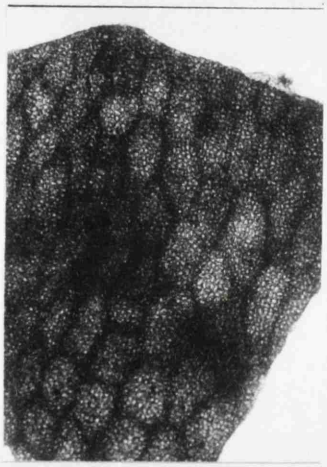
1



2

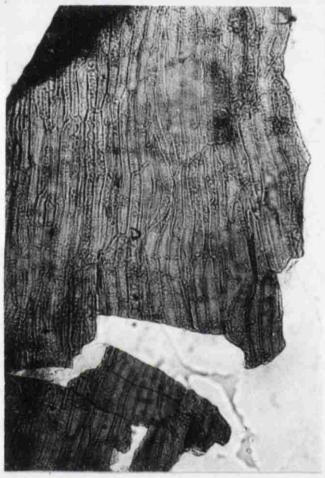


3



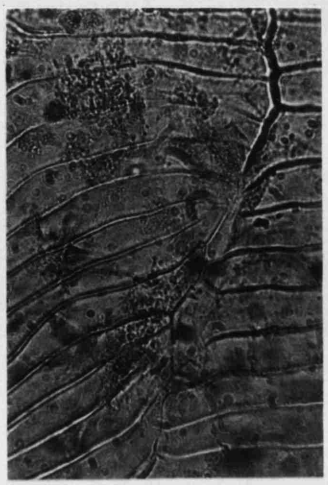
4

5



6

7



8

9

Plate 31.

1) Triticum/Secale (Wheat/Rye). A fragment of testa with faint traces of the transverse cell layer of the pericarp x 85. From the gut of Zweeloo bog body.

2) Triticum/Secale (Wheat/Rye). A fragment of testa with faint traces of the transverse cell layer of the pericarp x 325. From the gut of Zweeloo bog body.

3) Triticum/Secale (Wheat/Rye). A fragment of testa x 325. From the gut of Zweeloo bog body.

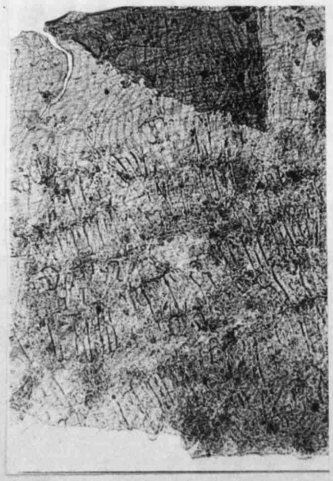
4) cf. leaf epidermis/cuticle indet. x 85. From the gut of Zweeloo bog body.

5) cf. leaf epidermis/cuticle indet. x 325. From the gut of Zweeloo bog body.

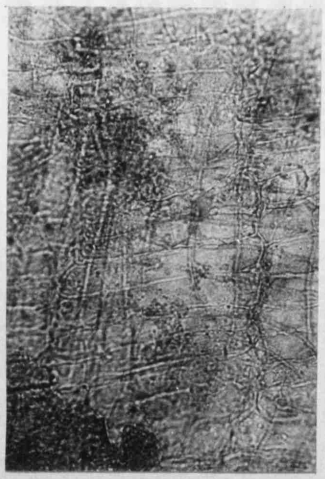
6) Hordeum L. sp. (Barley). A fragment of highly degraded testa x 10. From the gut of Zweeloo bog body.

7) Animal hairs indet. x 325. From the gut of Zweeloo bog body.

8) Animal hairs indet. x 325. From the gut of Zweeloo bog body.

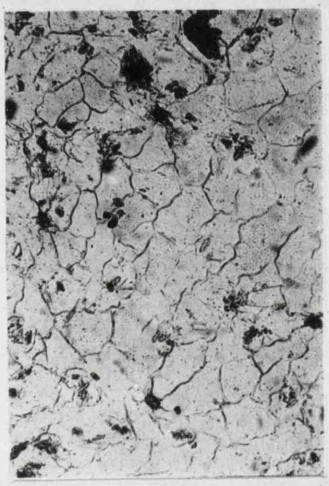


1

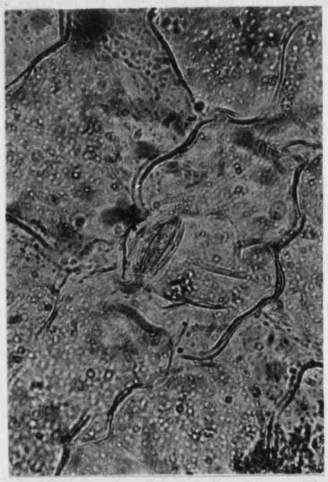


2

3

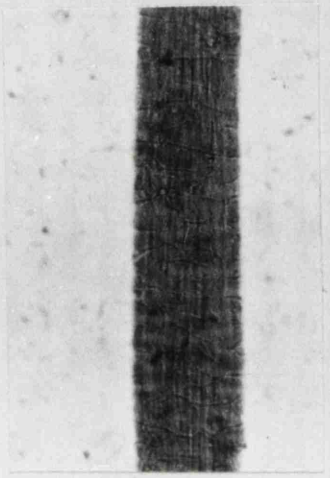


4

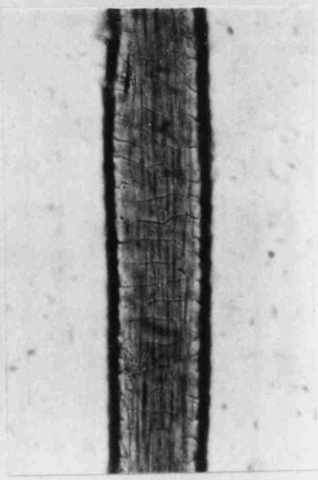


5

6



7



8

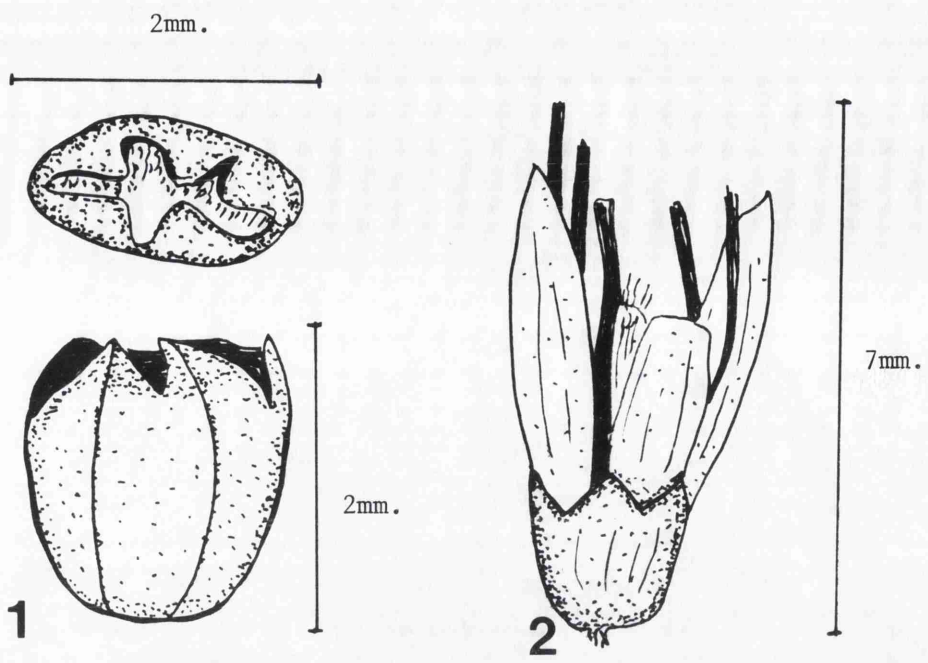
Fig. 9

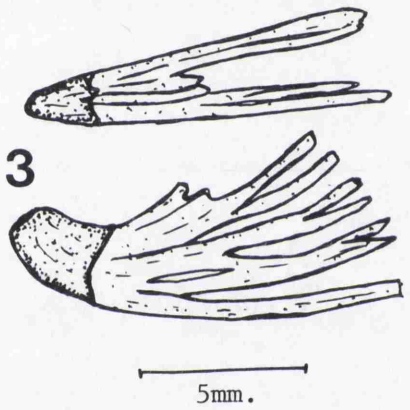
1) The calyx of Prosopis sp. recovered from a sample from the gut of a body from Cas-sur T-1C, North Chile.

2) A complete floret of Prosopis sp. recovered from a sample from the gut of a body from Cas-sur T-1C, North Chile.

3) The basal part of a legume of Prosopis sp. from the gut of a body from TR-40 T-6, N. Chile.

4) Segments of the endocarp of Prosopis sp. from the gut of a body from TR-40 T-6, N. Chile.


2mm.
2mm.
1
7mm.
2


3
5mm.

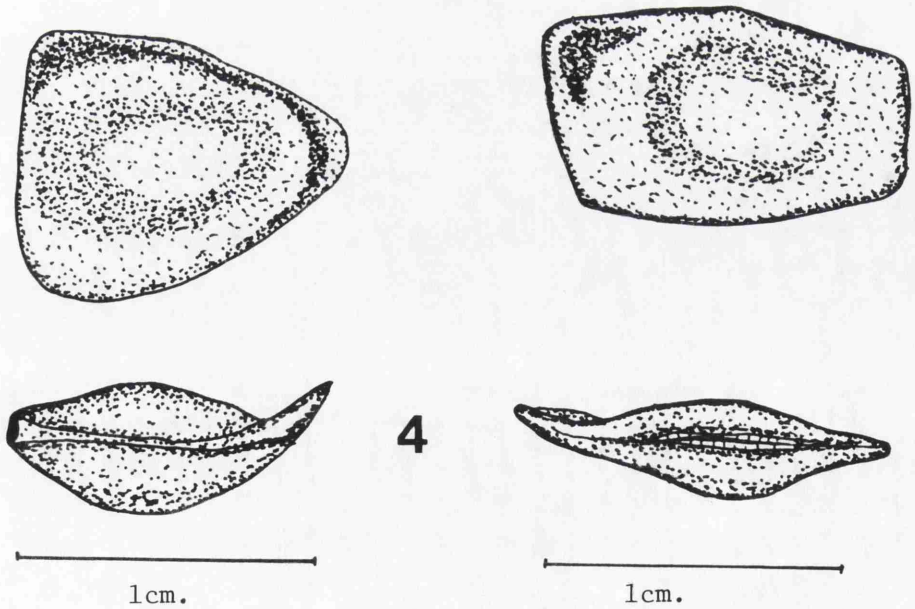

4
1cm.
1cm.

Fig. 10

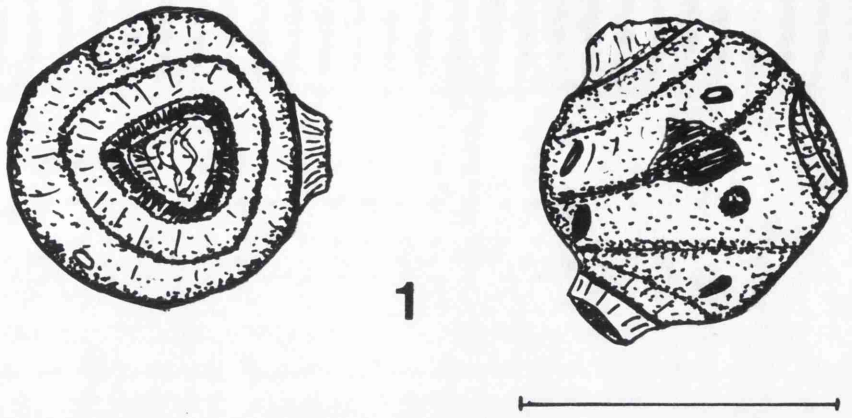
1) A tuber of Schoenoplectus americanus from a flotation sample from Tulan 54.

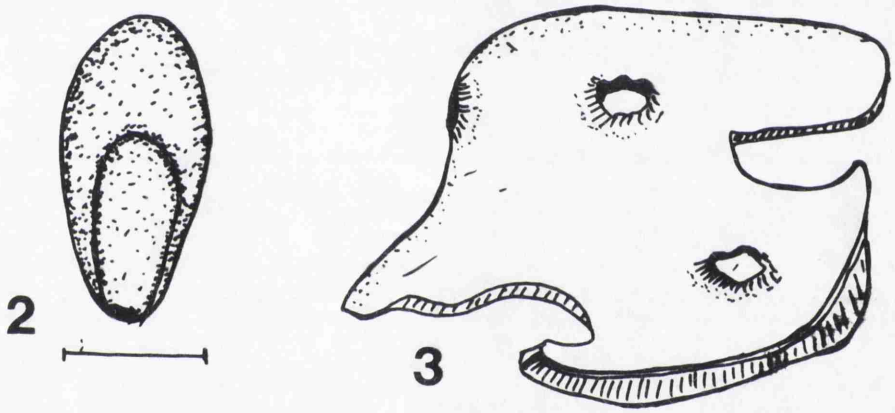
2) The seed of Acantholippia riojana recovered from a flotation sample from Tulan 54.

3) The pericarp of a fruit which resembles that of Krameria cistoidea recovered from the gut of a body from Tulan 58.

4) A seed of a species of Malvaceae from the flotation samples from Tulan 54.

5) A leaf from Acantholippia riojana (rica rica) recovered from the flotation samples from Tulan 54.


1


2
3

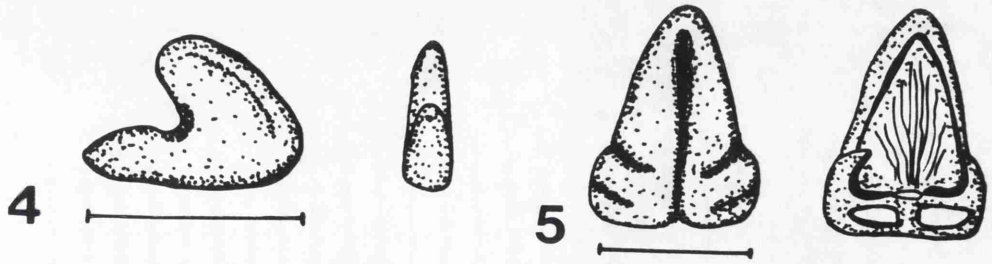

4
5

Fig. 11

1) A sliver of the lemma of Hordeum sp. from the gut of the Lindow II bog body.

2) A rachilla of Hordeum sp. from the Gut of the Lindow II bog body.

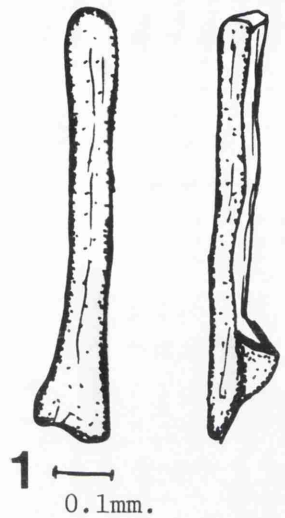
3) A rachilla of Hordeum sp. from the Gut of the Lindow II bog body.

4) A rachis fragment of Hordeum sp. from the gut of the Lindow II bog body.

5) A sliver of the lemma of Hordeum sp. from the gut of the Lindow II bog body.

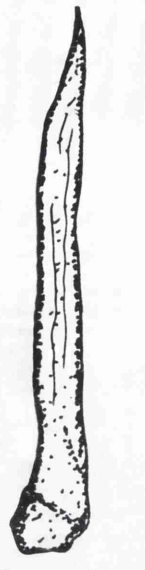
6) The basal part of the lemma of Hordeum sp. with an adherant fragment of rachilla, from the gut of the Lindow II bog body.

7) An the basal part of the lemma of an unidentified spcies of grass, from the gut of the Lindow II bog body.



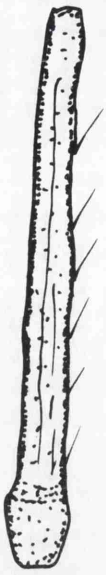
1

0.1mm.



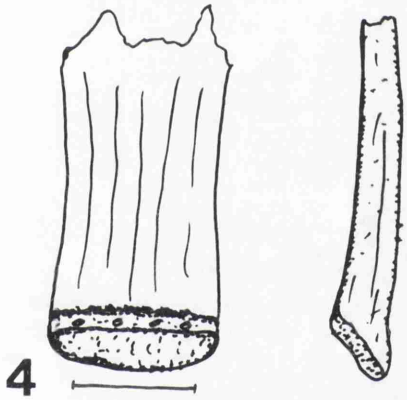
2

0.2mm.



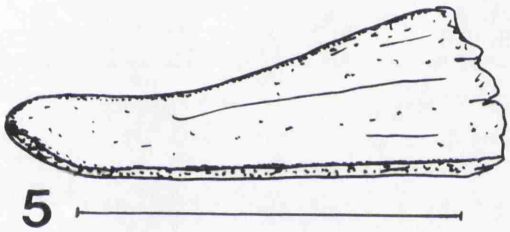
3

0.2mm.



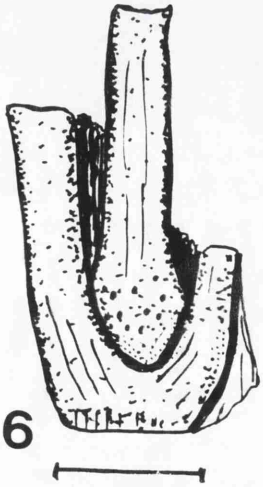
4

1mm.



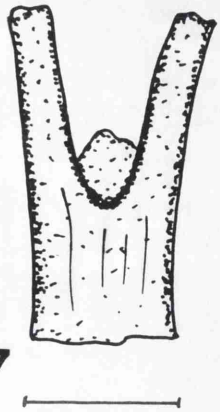
5

3mm.



6

0.2mm



7

0.3mm