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Bearsden

A Roman Fort on the Antonine Wall

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Chapter 14

INFRARED ANALYSIS OF CHARRED MATERIAL ADHERING TO POTSHERDS

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The precise identification of ancient wheats, such as the fragments found at Bearsden, is problematic due to the marked degree of overlap which occurs between the species whether the identification is based on gross morphology or histological features (Colledge 1988 and Holden 1990). The morphological identification of wheat, particularly the free-threshing wheats, is heavily dependent on the preservation of mature grains and diagnostic chaff (Hillman 1984; 1985; Jacomet & Schlichtherle 1984; Kislev 1984; Jacomet 1987). Unfortunately ancient samples of free-threshing wheats recovered from archaeological sites are usually found as almost pure grain samples with very little associated chaff. Furthermore, even when the chaff is recovered it may have characteristics of more than one type of free-threshing wheat (Kislev 1984).

The problems associated with identifying ancient wheats lead to a search for an independent method to backup morphological classifications, including the re-examination of those wheats where identifications based on gross morphology or histology were thought to be secure (Hillman et al 1993). Analytical chemistry has provided many techniques which have been applied with increasing success to resolve archaeological enigmas. Past achievements suggested that it was possible that chemical analysis could resolve at least some of the problems associated with the identification of ancient plant material (McLaren et al 1991). Most difficulties associated with the chemical analysis of archaeobotanical material stem from the long unknown history of the specimens. Even the post-excavational treatment is often forgotten. Additionally, the archaeobotanical sample is usually extremely small. For a chemical technique to be of any value to the archaeobotanist it needs; (A) to unambiguously identify a single grain to species or subspecies level and (B) to be sufficiently insensitive for the variation in the viability of the grain not to be a problem to the investigation (McLaren et al 1991).

14.1 THE USE OF INFRARED ANALYSIS

Infrared (IR) analysis was selected as an ideal technique with which to begin examination of archaeobotanical material primarily because it is non-destructive and both the sample and the chemical extracts survive and are available for further study. IR spectra are unique for each different type of organic or inorganic compound. The technique is rudimentary in that IR looks at the overall patterns of the specimen and not the fine detail of each individual component. Consequently, problems associated with archaeological material, such as diagenesis and modern contaminates such as plasticisers, do not generally effect the general IR formations as could be the case with the more sensitive techniques such as Gas Chromatography-Mass Spectroscopy (GC-MS). Another advantage of IR is that if necessary suspected contamination could be screened out. Furthermore, it is one of the most economical chemical techniques, the main costs being machine time and solvents, which may be redistilled for reuse. Like most chemical analyses the main problem are associated with the interpretation of the generated spectra but the morphology limits the possible options in the case of single seeds or plant fragments; for example, the gross morphology will indicate whether the material under analysis is part of a plum stone or a cereal grain.

14.2 WHAT IS THE CHARACTER OF ARCHAEOLOGICAL CHAR?

There is a general consensus of opinion that unless desiccation, waterlogging, mineralisation or mineral replacement is evident the majority of archaeobotanical material recovered in Northern Europe will have survived as a result of charring (Green, F J 1979; Murphy & Wiltshire 1994). Consequently, when archaeobotanists have conducted charring experiments to test the effects of heat on the morphology of seeds, they have tended to concentrate their efforts on high temperature charring to produce distortion patterns (Boardman & Jones 1990; Mason 1988; Charles; unpublished data). In order to test past heat exposures, some ancient material has been examined by Electron Spin Resonance (ESR) (Hillman et al 1985; Fairbairn 1991). When Robins examined the waterlogged bran from Bearsden by ESR he found that the material had been exposed to a temperature of between 180°C–200°C (p 277, Appendix 2). It is unlikely that all the Bearsden chars would have been exposed to the same amount of heat.

The Bearsden pot chars are most likely to have occurred as the result of cooking accidents. While the foods were being cooked a number of chemical reactions were taking place, including the Maillard reaction and caramelisation (Clawson & Taylor 1993). A feature of the Maillard or non-enzymic browning reactions is a brown toasting effect on the food. If the cooking continues unabated then the reaction processes continue as the food dehydrates and darkens until it becomes a char. The char is a surface phenomenon where carbon in its inert form; graphite has foamed with discrete pores (Evans & Biek 1976). At least some of the original chemical component (including long chain hydrocarbons) remain unaltered behind the strong inert wall of carbon.

When investigation began into the possible use of IR analysis on archaeobotanical materials we tested the ability of chemical compounds to survive charring. Fresh grains of wheat and rye including *T. spelta* L. were experimentally charred at a range of temperatures in a variety of open and closed systems (for a periods of up to 21 days). Flour was made into bread to explore the effects of cooking on the chemistry of ancient residues. Examination of the resulting IR spectra showed that charring and cooking had a minimal effect on the IR spectra and suggested that many surviving ancient organic residues were unlikely to have been subjected to high temperatures and critical flash points (McLaren & Evans unpublished data). The IR examination of the chemical components of ancient archaeological specimens continued with material which could be confidently identified by their morphology, eg *Cornus mas* L. stones which are readily recognisable even when in a fragmentary condition. Ancient botanical material was then examined from a wide number of sites ranging from wet land sites of Britain to the relatively arid sites of South-West Asia to see if the source of the material had any effect on the spectra. Happily, results showed that the source of the material appeared to have no effect upon the chemistry. The next stage was to build up a data base of IR reference material which included many typical food plants. However, the investigations have centred around the common cereals particularly the wheats and ryes. At least one sample of modern grain specimens was analysed of all the currently recognised species of wheat and rye. The chaff of selected species was also analysed. Within each species, we examined several different populations (up to 11 in some cases) which represented a broad range of morphological variants and geographical sources. We also examined wheats which we knew were hybrids. The spectra were compared on the basis of 'fingerprint patterns', with particular reference to the position of key peaks on the wave number axis.

It was generally found that variations amongst equivalent spectra from the different modern populations of any one species were very slight, whereas disparities between spectra of separate species (even when closely related) were very marked; ie infra-specific variation in the spectra was consistently exceeded by inter-specific variation. It was therefore clear that species-related differences in IR spectra offered an additional basis for identifying modern wheats and ryes at the species level.

The Bearsden cereal fragments proved an ideal range of ancient material to extend the application of IR in archaeobotany because these fragments derived from pot char and had therefore been processed and cooked. The samples would test whether the chemical signals picked up in the IR spectra of ancient charred grains changed as a result of the additional processing.

14.3 CHEMICAL ANALYSIS OF THE BEARSDEN CHAR

Three char extracts were examined, all taken from the outer surface of the sherds:

Sample A: <0.06 gm; NK75CQ; the granary;

Sample B: 0.06 gm; NK77EA; the gulley south of the officer's quarters of building 7;

Sample C: NK76GN; a pit in 'building 16'.

These samples were extracted in hexane, chloroform and propan-2-ol (McLaren et al 1990) and compared to the library of cereal IR spectra built up mainly from Gordon Hillman's collections of wheats from the 1970s held at the Institute of Archaeology, UCL. The best quality and the most diagnostic spectra were obtained from the propan-2-ol extracts as has been the case with most archaeobotanical material. However, this is not to say that the hexane and chloroform samples were ignored for in some cases the evidence obtained from these spectra revealed equally critical information.

The identification of samples A and C

The IR spectra of the Bearsden samples nos A and C were quite similar to the spectra of individual modern emmers and 'Spanish' spelts but no single match was clear, in contrast to the fingerprint match between Bearsden sample B and durum wheat (see below). It was evident, however, that samples A and C were distinct from the spectra of 'Northern' forms of modern spelt, commonly referred to as European Alpine spelt by Lennart Johnson (1972). Samples A and C were also distinct from emmer/spelt crosses. However when the wave lengths of the main IR peaks in these samples were analysed the results suggested that these samples could be a mixture of emmer and 'Spanish' spelt wheats.

In order to confirm the presence of a mixture, samples A and C were compared to samples of emmer and spelt using differential spectroscopy (Martin 1966). If identical amounts of the same compound are placed into the two separate light paths of an IR doublebeam spectrometer, then a straight line spectrum emerges; any small differential bands reflect a variation between the total quantities of each sample extract. The spectrum produced by comparing ancient charred material with modern plant sources by differential spectroscopy is unlikely to produce a completely straight line because the ancient charred extract contains an unknown volume of the extract. What can be assumed, however, is that if no major differentiated bands were present then this would suggest that the charred material and the plant source/s were identical.

On this basis the differential IR analysis confirmed that the propanol spectra of Bearsden samples A and C were the same as a spectrum of a mixture of two Spanish wheat samples, the tetraploid *T. turgidum* subsp *dicoccum* (Schrank) Thell. (traditionally called *T. dicoccum* Schübl. commonly called emmer) and the hexaploid *T. aestivum* (L.) Thell. subsp *spelta* (L.) Thell. (traditionally called *T. spelta* L. commonly called spelt)

The antiquity and origin of the spelt/emmer crop

Prior to modern farming practices, wheat crops generally consisted of mixed land races, which often included not only different varieties but also wheats of different ploidy levels. Archaeological evidence shows that emmer wheat, a readily identifiable glume wheat, was the stalwart of a South-West Asian wheat crop assemblage and maintained this position as farming spread west throughout prehistoric Europe (Zohary & Hopf 1993). Which wheat species were developed to spread throughout the temperate world were largely determined by the methods used by farmers for harvesting their crops and selecting grain for the next crop. They would have had a choice of either selecting specific wheat heads for seed corn or putting aside a more random proportion of the harvest for future sowing (for a more detailed discussion on the origins and spread of wheat farming see the paper by Hillman & Davies 1990). If the farmers continually selected for specific wheats then these plants would eventually dominate the crop. This method of seed selection is still used today in Eastern Turkey according to Dr Sencer (Hillman, pers comm). However, if the farmers constantly selected a random proportion of their harvest for future propagation then any crop would continually produce more or less the same land race mixture as before, provided no other factors altered.

As farming began to spread from the Neolithic nuclear areas of the Fertile Crescent through the temperate regions of the Old World, so wheat crops came into contact with some of their wild grass relatives, notably the *Aegilops* species. When this encounter occurred the close affinity between the crop and *Aegilops* enabled them to cross readily to form fully fertile hybrids. Spelt is one such successful hybrid and generally thought to be the result of a successful cross which occurred when a cultivated *T. turgidum* came into contact with *Aegilops squarrosa* L. = *Ae tauschii* Coss. The initial contact between the parent species is thought to have occurred when farming was introduced into the south-west corner of the Caspian belt because at present there is no evidence that *Ae. squarrosa* and wild emmer (*T. dicoccoides* (körn) ever overlapped in distribution (Zohary & Hopf 1993). *Aegilops* species are extremely variable in their ecological demands and consequently there are a number of different forms which can be found in a variety of habitats ranging from desert margins through to the elevated plateaux of Iran and Afghanistan (van Zeist 1976). When crosses occurred between *Ae. squarrosa* and a wheat, the parent *Aegilops* introduced a wider degree of climatic tolerance into the genetic make up of the progeny. Gradually these new wheats began to form an integral part of the crop as wheat farming continued to spread out to new environments.By the time wheat cultivation reached Neolithic Britain, the standard crop probably contained a number of wheat species (derived from all ploidy levels). Generally the hulled wheat species would probably have been found growing together and correspondingly the free threshing wheats (Zohary, pers comm, 1995). A typical example of an ancient free threshing wheat crop pattern can be seen in the wheats recently found at the Neolithic site of Balbridie (Fairweather & Ralston 1993; McLaren unpublished data).

During the 1930s the central issue of debate on the origin of free threshing hexaploid wheats (*T. aestivum* subsp *vulgare* (Vill.) Mackey also called *T. aestivum* L., *T. sativum* L. or *T. vulgare* Host) was whether the precursor of free threshing wheats was spelt (*T. aestivum* subsp *spelta* (L.) Thell.) or alternatively, was spelt a later mutant evolved from the free threshing crops once they had become established in Europe (Kuckuck 1973). During the 1950s the agriculturalist Kuckuck collected and examined a number of spelts from Shahr-Kord (a high plateau near Isfahan) where spelt had ceased to be grown as a crop during the previous 15 years although emmer was still grown. Kuckuck found that the spelt complex contained a range of morphological features and possessed other characteristics such as both winter and summer types. In this complex Kuckuck detected a number of parallel transitional spelt forms leading up to the free threshing wheats and so he felt able to refute the idea that spelt was a later European crop. The association between spelt and emmer crops is quite common in south-west Asia because of the similarity in their harvesting regimes (Zohary, pers comm, 1995). Bor (1970) erroneously described Kuckuck's Iranian spelts as wild when in reality they were probably tolerated as an element of the harvest and would not have survived unless they were part of a farming regime. Morris and Sears (1967) also carried out a programme of genetic research into the history of spelt. They also found a wide diversity of spelt genotypes which confirmed Kuckuck's observations on the origin of spelt. Not everyone has agreed with the proposition of a multiple origin for spelt. Lennart Johnson (1972), for example, on the basis of his analysis of wheat protein profiles, suggested that both the hulled and the free threshing hexaploid wheats were much more uniform than had been previously supposed. He felt that all the bread wheats probably derived from a single (monophyletic) origin rather than several (polyphyletic) origins.

IR analyses of a range of spelts

The IR spectra of the modern samples of European spelt wheats fell into two clusters; European Alpine spelts and the Spanish spelt. Analysis of a series of prehistoric British spelts found at the Iron Age sites of Thetford and Danebury (unpublished data) compared well to very primitive varieties of European Alpine spelt called *T. spelta* L. var. *Capruleum* B and *T. spelta* L. var. *duhumelianum* respectively.In contrast, the Bearsden spelt compared well with the spectra derived from modern Spanish spelts recently collected by Peña Chocarro (Peña Chocarro and Lamont, in preparation). Her collections included a field where a crop consisting primarily of spelt with emmer inclusions had been continuously grown together for some years specifically for bread production. When Hillman (pers comm) morphologically examined the Spanish spelt he observed many primitive features in the ears. The IR spectra indicate that a certain amount of introgression has occurred between the emmer and spelt over the years, particularly from spelt into emmer, ie cultivated spelt and emmer have crossed at some point in the past and produced fertile progeny. The fertile hybrids began to back cross with emmer and so each new generation looked morphologically more and more like the parent emmer while retaining some genetic components from spelt. The IR analysis of two Bearsden samples suggest that these same patterns of introgression probably occurred in the Roman crops.

The divergence between the IR spectra of a range of Alpine spelts and the southern Spanish spelts is quite distinct, however, at present it is impossible to say anything further about these two forms separated by IR. For example, no inferences can be made about possible separation into Mediterranean type spelt and Alpine type spelt because at present insufficient studies have been performed. The results at present indicate that by examining more than one chemical component of the plant, IR may signify more about plant relationships than would be the case by just analysing one chemical fraction such as the proteins. However, the exact origins of different forms of spelt must be considered provisional until more detailed analyses have taken place to elucidate the situation.

The identification of sample B by IR

The three spectra from this sample produced an excellent match with *T.turgidum* conv. *durum* (Desf.) MacKey (syn. *T. durum* Desf. commonly called durum wheat). Sample B also produced a fine match with Bronze Age ancient grains from the sites of Shotughai in Afghanistan (Willcox 1991) and Peñalosa in Spain (Contreras et al 1991). At present (1995) the Bearsden sample B is the first evidence for *durum* wheat in the British Isles.

The antiquity and origin of durum wheat

As a free-threshing wheat the presence of *durum* in an archaeobotanical sample is extremely difficult to establish. Zohary and Hopf (1993) applied genetic and environmental evidence to argue that *durum* wheat was the first established free-threshing wheat because all the necessary elements to create this domesticated cereal could be found in the fertile crescent. In contrast to spelt, *durum* wheat is generally regarded as a typical Mediterranean-type wheat since many *durum* types tend not grow well in cool oceanic climates particularly because they can be intolerant of frost (Percival 1974). Greig (1991) when reviewing the agriculture of mediaeval Britain came to the conclusion that mediaeval *durum* wheats were imports. Although, there is the slim chance that the occupants of Bearsden introduced a hardy variety of Mediterranean-type durum into the Britain Isles, this option is unlikely given the environment of the site and the relatively short period of occupation.

14.4 HOW CAN WE INTERPRET THE BEARSDEN WHEATS?

It is tempting to suggest that the presence of the durum wheat indicates that these Roman wheats were imported from Spain. The spelt/emmer crop needs more analytical study before anything can be implied about this match. At present IR has produced no evidence that any similar wheat mixtures were grown in Prehistoric or Roman Britain. The wheats from the Neolithic site of Balbridie are probably the best comparative example of what wheat types could be expected to form a typical British prehistoric wheat crop mixture (Fairweather & Ralston 1993; McLaren, unpublished data).

Unfortunately Classical authors do not provide any helpful clues about the growth of different wheats. The Romans simply divided wheats into two groups; the glume wheats and the naked free-threshing wheats (Percival 1974). Although they recognised and discussed a variety of wheat crops, including three specific references to spelt (Jasny 1944), their use of only colloquial names and habit of describing different crops by the name of a nearby town, such as Pliny's assertion that the best bread was made from a mixture of white Pisan and red Campanian wheat limits the usefulness of their information (Jasny 1944). Why would the Roman occupants of Bearsden import wheat? There may have a shortage of wheat in northern England. We have no good evidence for spelt wheat grown in Scotland at this time and emmer wheat was probably only produced on a small scale at favourable coastal localities. Roman millers had one consuming ambition – to produce fine white flour (eg the adverse comments of Galen outlined in Hillman 1985). This obsession resulted in many detailed commentaries on the technology of crushing, grinding and processing cereals for flour (Moritz 1958). Spelt wheat produces a light coloured flour in contrast to the dark flours of durum, emmer and einkorn (Jasny 1944; D'egido et al 1993; Boyacioglu & D'Appolonia 1994). In view of the current use of the spelt/emmer crop in Spain, together with C Dickson's (1990) morphological evidence which suggested that the waterlogged bran in the sewage could be partly from bran made from two or more wheat types, it is likely that brown loaves were being produced at Bearsden. The flour could not have been white because it was rich in bran; brown cork deposits in the bran show it to have been brown bread.

The popular name for durum wheat is macaroni wheat and as this name implies it is a very good wheat for making pasta. Durum is a hard wheat and when the flinty kernels are crushed they do not reduce to the very fine particle size of the soft bread wheats but form middlings or semolina, which are more suitable for porridge or pasta (Moritz 1958). Durum can be turned into good breads especially when mixed with other wheats (Percival 1974; Boyacioglu & D'Appolonia 1994) but the Bearsden durum wheat does not appear to be part of a cereal mixture. Both the Italians and the Chinese lay claim to the invention of pasta or noodles. However, the origins of pasta making are probably lost in the mists of time because every cooking tradition (including Near Eastern) has an element of boiled dough cookery (Tannahill 1988). It is therefore possible that some of the Bearsden cereals were used not only for bread but also for a pasta or even a porridge. IR analysis is non-destructive and therefore these extracts are available for further analysis. Analysis of the Bearsden char has shown that IR signature of food chars are not significantly different from the IR signature of the raw grains. Therefore, it will be possible to trace chemically the technology of food preparation from harvested seed to the final product. It is anticipated that further chemical investigations, particularly into the protein content of the Bearsden chars may throw light on the Roman army's use of cereals at Bearsden. Greig (1991) wondered why the Romans in Britain appeared to be so reliant on the standard British prehistoric crops of emmer and spelt when they obviously imported olive oil and the exotic fruits found in Roman London (Willcox 1977) to maintain their Mediterranean life style. The charred material indicates that at least some Mediterranean wheats found their way to Bearsden.