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Towers, J., Montgomery, J., Evans, J. et al. (2 more authors) (2010) An investigation of the origins of cattle and aurochs deposited in the Early Bronze Age barrows at Gayhurst and Irthlingborough. Journal of Archaeological Science, 37 (3). pp. 508-515. ISSN 0305-4403

https://doi.org/10.1016/j.jas.2009.10.012

Title

An investigation of the origins of cattle and aurochs deposited in the Early Bronze Age barrows at Gayhurst and Irthlingborough

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Keywords

strontium; isotope analysis; tooth enamel; TIMS; intra-tooth sampling

Abstract

The Early Bronze Age round barrows at Irthlingborough, Northamptonshire and Gayhurst, Buckinghamshire contained remarkably large quantities of cattle (Bos taurus) remains. At Irthlingborough, at least 185 skulls with smaller numbers of mandibles, shoulder blades and pelves were found together with a small number of skeletal elements from aurochs (Bos primigenius). In contrast, the remains from Gayhurst are dominated by the limb bones from more than 300 animals. This study employed strontium isotope ratio analysis of cattle tooth enamel from 15 cattle and one aurochs to investigate the diversity of the animals' origins at both sites and provide insights into Early Bronze Age funerary practices. Although strontium results show that most of the cattle and the aurochs included in this study were consistent with local origins, one animal from each barrow was born remotely, most likely in western Britain. In addition, a second Gayhurst animal was consistent with origins in a region of chalk rather than the local Jurassic sediments.

Introduction

Separated by approximately 30 km in central southern England are two of Britain's most remarkable Bronze Age archaeological sites. Early Bronze Age round barrows were discovered during gravel extraction in the 1980s and 1990s at Irthlingborough, Northamptonshire and Gayhurst, Buckinghamshire (Figure 1). They were both dated to around 2000 BC and were notable for the unusually large quantities of cattle (Bos taurus) remains associated with their central human burials.

Irthlingborough

Barrow 1, situated 2 km northeast of the village of Irthlingborough, Northamptonshire, was one of a group of barrows and other monuments on the river Nene floodplain. It was excavated in 1986 as part of the Raunds Area Project (Dix, 1987). The cattle bones found there were mixed with limestone blocks, which are thought to have formed a cairn above a central, wooden, burial chamber. Evidence suggests that the bones and blocks fell into the chamber after the timber had rotted (Davis and Payne, 1993). The chamber contained a skeleton of an adult male human accompanied by various grave goods including a long-necked beaker, a flint dagger, jet buttons, an archer's stone wristguard and an amber ring (Halpin, 1987). These goods indicate links outside the local area. For example, the jet was from Whitby, Yorkshire, the flint dagger was from East Anglia and the amber was from the Baltic Sea region (Parker Pearson, 2005). The skeleton was radiocarbon dated to between 2200 and 1920 cal BC (95% confidence, 3681 ± 47 BP, UB-3148) (Harding and Healy, 2007).

Davis (2009) reported that the cattle bones from Barrow 1 at Irthlingborough include skulls from 185 animals, mandibles and scapulae from between 35 and 40 animals, and pelves from 15 animals (estimated minimum values). Most of the cattle were young adults when slaughtered. A lack of incisor and premolar teeth combined with good preservation of molar teeth suggests that there may have been a period of at least one month between slaughter and incorporation of the skulls into the barrow. This delay would have allowed the smaller teeth to loosen and fall from their sockets. Thus, Davis (2009) speculated that defleshed skulls were incorporated into the cairn and that the presence of fine cut marks on several bones implies the consumption of beef. However, due to the poor preservation of most of the bones, it is not possible to estimate the full extent of feasting that might have taken place. One possible scenario is that around 40 animals were killed and consumed at the site while the remaining skulls were brought as tokens (Davis and Payne, 1993).

Amongst the assemblage were several aurochs (Bos primigenius) remains: five teeth, a fragment of horn core and two possible scapulae. The radiocarbon date of one aurochs tooth suggests it might have been several hundred years old when incorporated into the barrow, whereas radiocarbon date ranges obtained from a second aurochs tooth and two domestic cattle teeth overlap with that of the human skeleton (Harding and Healy, 2007). None of the dated teeth were included in this study.

Gayhurst

Barrow 2, at Gayhurst, Buckinghamshire, was the largest of seven barrows on the floodplain of the river Great Ouse excavated between 1997 and 2002. At the centre of this barrow was a burial of a single adult male in an oak-lined chamber. In this case, the only grave good present was the foreleg of a pig. Oak charcoal from the chamber walls was radiocarbon-dated to between 2200 and 1780 cal BC (95% confidence, 3640 ± 70 BP, Beta-132795) (Chapman, 2007).

The cattle remains found at Gayhurst were in a ring-ditch surrounding Barrow 2. Analysis of the bones suggests a minimum number of 300 animals with a wide-ranging age at death and a female to male ratio of nearly 4:1 (Deighton and Halstead, 2007). Such a demographic composition suggests the slaughter of a herd (or herds) rather than the deliberate selection of particular animals. Variation in bone dimensions indicates that the cattle might have originated from different herds (Deighton and Halstead, 2007).

The assemblage is composed mainly of three bone types – limb bones, skulls and mandibles – indicating deliberate selection of certain body parts. Deighton and Halstead (2007) proposed the following sequence of events:

1) the cattle were slaughtered away from the barrow, perhaps at several locations;
2) some meat was consumed but most of the carcasses were left to rot, a process that may have taken a few weeks or months;
3) after decomposition, limb bones were selected, disarticulated without the aid of a knife and spread across the surface of the barrow mound, in the area above the human burial;
4) they were later raked into the surrounding ditch as a single event.

A sample of cattle bone has produced a radiocarbon date of 2290-2010 cal BC (95% confidence, 3740 ± 50 BP, Beta-218227), which is broadly contemporary with the oak from the central chamber (Chapman, 2007).

The significance of cattle in the Early Bronze Age

Although the Early Bronze Age barrows at Irthlingborough and Gayhurst are unusual with respect to the large size of their cattle bone deposits, the association of cattle remains with human burials in southern Britain appears to have become established centuries before, in the Early Neolithic (Ray and Thomas, 2003). Cattle bones were generally the most common of the various animal species to be deposited in burials, barrow mounds and barrow ditches during the late 3rd and early 2nd millennia BC. Early excavators noted their presence from Early Bronze Age round barrows dug in the 19th century (Greenwell, 1877; Mortimer, 1905; Thurnham, 1869) and they have been recovered from numerous round barrow excavations across southern Britain (e.g. Ainsley, 2005; Clutton-Brock and Jewell, 2005). In some instances, they were placed within the burial pit, as at Hemp Knoll (Robertson-Mackay, 1980) and Durrington Down (Richards, 1990), both in Wiltshire. In others such as Hanborough and Barrow Hills, both in Oxfordshire, they were deposited within the barrow ditches (Barclay and Halpin, 1999; Case et al., 1964-65). However, none of these assemblages are anywhere near as large as those from Irthlingborough and Gayhurst. Mandibles and tooth rows are commonly represented among the cattle bones. Aurochs bones have been found in round barrow contexts at Hemp Knoll, Snail Down, Durrington Down, and Barrow Hills (Barrow 12).

The association of cattle remains with human burials suggests that cattle were symbolically important to the people of the Early Bronze Age. Grant (1991) has speculated that their symbolic significance may have been as important, or perhaps more important, than their economic significance, and that a major emphasis of cattle husbandry was to rear cattle for ritual feasting and funerary deposition. It has also been argued that monument complexes and pastoralism developed in parallel, with woodland clearance allowing not only cattle herding, but also the creation of monument landscapes (Barclay and Hey, 1999). Grazing cattle would enable these open spaces to be maintained.

Little is known about the subsistence economy of the Early Bronze Age since settlements of this period are so poorly known. This lack of evidence for permanent farmsteads may imply a mobile, pastoral lifestyle in which people moved with their cattle herds within broad territories, periodically visiting monuments for burial and feasting (Brück, 1999; Parker Pearson, 2005). Mobility in the Early Bronze Age may have become ‘more formalised in some areas’ than in earlier periods (Whittle, 1997) and evidence for this restriction of mobility in the Early Bronze Age, compared to the Neolithic, has been observed in strontium isotope ratio data from human burials discovered in the Yorkshire Wolds (Montgomery et al., 2007a).

If cattle had a particular symbolic significance in the Early Bronze Age, then the large assemblages of cattle bones at Irthlingborough and Gayhurst indicate that the male skeletons buried at the centres of these barrows were powerful and influential when living (Davis and Payne, 1993). Perhaps these two burials represent different burial customs. Davis’ preferred reconstruction of events at Irthlingborough is that defleshed skulls were brought to the funeral as tokens (Davis, 2009). This allows the possibility that they might have been brought from a wide variety of locations. Alternatively, at Gayhurst, the selection of limb bones may have been deposited as a symbolic feast for the dead (Chapman, 2007).

The large number of animals comprising the Irthlingborough and Gayhurst assemblages leads to speculation regarding the number of herds involved and the geographical diversity of the animals’ origins. These assemblages provide a valuable opportunity to investigate the diversity of the animals’ origins and the role of cattle in Early Bronze Age funerals by means of strontium isotope ratio analysis of tooth enamel.

Strontium isotope ratio analysis of tooth enamel

Tooth enamel is the body tissue of choice for strontium isotope ratio analysis because it is resistant to diagenetic strontium contamination, unlike dentine and bone (Beard and Johnson, 2000; Budd et al., 2000; Hoppe et al., 2003; Trickett et al., 2003).

Herbivores such as cattle and sheep have hypsodont (high-crowned) teeth (Hillson, 1986). During the formation of such a tooth, the enamel is deposited sequentially with the earliest enamel forming at the cusp of the crown and successive bands forming incrementally towards the cervix over time (Zazzo et al., 2005). This enables time-related data to be obtained from a single tooth using intra-tooth enamel sampling, whereby enamel is extracted at a number of positions between the cusp and cervix (Bentley and Knipper, 2005). However, this description of herbivore incremental tooth mineralization is somewhat simplified. It is hypothesized that enamel mineralization may be divided into at least two stages: the matrix formation stage and the maturation stage (Suga, 1982). The maturation stage, when most of the mineralization occurs (Robinson et al., 1995), can also be sub-divided into three phases (Suga, 1982), a complex process such that the timing, rate and degree of mineralization differ between enamel layers (Suga, 1979 cited in Balasse, 2002). In herbivores, the process of molar enamel maturation has been shown to be a complex process both spatially and temporally (Hoppe et al., 2004; Tafforeau et al., 2007). A study measuring the intra-tooth $\delta^{13}C$ values of tooth enamel from cattle that had changed from a C3 to a C4 diet, suggested that each enamel sample took ~6-7 months to mineralize (Balasse, 2002) and there is evidence that for heavier elements such as strontium, very small samples of cattle enamel may contain strontium deposited over a period as long as a year (Montgomery et al., 2009).

Strontium (Sr) has a geological origin and four naturally occurring isotopes: non-radiogenic ^{84}Sr (~0.56%), ^{86}Sr (~9.87%) and ^{88}Sr (~82.53%), and radiogenic ^{87}Sr (~7.04%). ^{87}Sr is formed through the radioactive decay of rubidium (Rb), a naturally occurring element in many rocks and minerals with a half-life of ~$4.88x10^{10}$ years (Capo et al., 1998). It may be demonstrated theoretically that the ^{87}Sr content of a rock is dependent on the ^{87}Rb content and the age of the rock (Dickin, 2005). As a result, the strontium isotope ratio $^{87}Sr/^{86}Sr$ can vary between ~0.703 for recently formed volcanic rocks to >0.74 for very old rocks such as continental granites (Åberg, 1995).

Rocks bearing strontium are weathered to form sediments and soils. Because strontium can substitute for calcium in a variety of physiological and biochemical contexts (Ezzo, 1994), it becomes incorporated into plant tissue and, thence, animal tissue. Although there is no significant fractionation for strontium isotopes in low temperature processes in the geosphere and biosphere (Blum et al., 2000; Capo et al., 1998), the strontium isotope ratio ($^{87}Sr/^{86}Sr$) in body tissues may result from a mixing of several strontium sources (Montgomery and Evans, 2006). The resulting ratio depends on the concentration of strontium in each source and is calculated from the weighted averages of those sources (Montgomery and Evans, 2006). Ratios obtained from tooth enamel correspond to that of the strontium incorporated during tooth crown mineralization.

Strontium isotope ratio analysis of tooth enamel has become an established technique for investigating the mobility and origins of human populations (e.g. Evans et al., 2006a; Ezzo and Price, 2002; Montgomery et al., 2007a; Price et al., 2006), and, to a lesser extent, animal populations (e.g. Balter, 2008; Bentley and Knipper, 2005; Hoppe et al., 1999; Montgomery et al., 2007b).

Sample preparation and analysis

Pairs of adjacent second and third domestic cattle molars, together with a single aurochs third molar, were selected from the Irthlingborough material for this study. For each pair, both molars were associated with a bone fragment and were therefore from the same animal. Because the Irthlingborough domestic cattle remains could not be separated to individual on the basis of context, left maxillary molars were utilised in all but one case to maximise the number of different animals included. Table 1 shows which teeth were analysed for each animal. A single right mandibular second molar was also analysed (Table 1: Animal ID = IRTH 8). However, oxygen and carbon isotope results (Towers, 2008), together with the strontium isotope results described below, suggest that IRTH 8 was a distinct animal. Pairs of second and third molars were also obtained from the Gayhurst material. Unfortunately, consistency in sampling with respect to tooth position (mandibular or maxillary, left or right) was not possible (Table 1). However, there were different contexts and sampling was carried out across these contexts. Oxygen, carbon and strontium isotope results suggest different animals, apart from two, designated GAY 2 and GAY 4, for which all three isotope results are very similar (Towers, 2008); i.e. it is possible that GAY 2 and GAY 4 were the same individual.

In order to investigate cattle origins, samples of second molar cuspal enamel, which forms during the months immediately following birth (Brown et al., 1960), were obtained from seven animals from Irthlingborough (less than 4% of the 185 cattle) and at least five animals from Gayhurst (less than 2% of the >300 cattle). The greater the number of animals represented, the easier it is to estimate the local strontium isotope ratio range. Therefore, since the enamel from additional second molars was poorly preserved, cuspal enamel samples were obtained from several third molars. For one animal from each site, on the basis of their second molar strontium results, intra-tooth sampling was carried out in order to investigate animal movement over time. Intra-tooth samples were also obtained from an aurochs third molar from Irthlingborough.

Initial sample preparation was carried out at the University of Bradford. Each molar was cleaned using a toothbrush under running water to remove loose material. Using a diamond dental burr, tooth cementum was removed and the exposed enamel surface was cleaned. Samples of enamel were obtained from the crown using a flexible diamond edged rotary dental saw. Any dentine attached to the enamel samples was removed using the dental burr to avoid contamination. Samples were sealed in containers and transferred to the clean laboratory suite at the NERC Isotope Geosciences Laboratory at Keyworth, Nottinghamshire (NIGL). In order to prevent contamination, the chemical procedures were performed under laminar flow conditions using high purity deionised water and reagents. The samples were cleaned first in acetone and then ultrasonically, in high purity water. They were weighed into acid-cleaned Teflon beakers and spiked with a known amount of ^{84}Sr, then dissolved in Teflon-distilled 8M HNO_3. Strontium was extracted from the samples using cation exchange chromatography, which used quartz columns containing Dowex AG 50W-X12 resin. Full details of the method of preparation described above are given in Montgomery (2002).

Strontium concentrations and isotope ratios were measured using a Thermo Triton multicollector thermal ionisation mass spectrometer (TIMS). In addition to enamel samples, analysis also included procedural blanks, NIST-1486 solution samples and machine standards (NBS987).

All ^{87}Sr/^{86}Sr data were normalised during run time to ^{86}Sr/^{88}Sr = 0.1194 to correct for fractionation. In order to correct for instrument drift during the period of analysis, the data were also normalised to a value for the standard reference material NBS987 of 0.710250. External precision for ^{87}Sr/^{86}Sr was ± 0.001% (1σ, n = 5), obtained from NIST-1486 solution standards. External precision for strontium concentration was ±

0.5% (1σ, $n = 5$), also obtained from NIST-1486 solution standards. Procedural blank values, at ≤ 80pg, were sufficiently low to be considered insignificant.

Results and discussion

Strontium results are shown in Table 1.

Determination of local range of strontium isotope ratios

In order to assess whether the cattle from Irthlingborough and Gayhurst were born locally or were from diverse geographical origins, the local range of strontium isotope ratios expected for each site must be estimated. One approach is to use local biosphere strontium data from other archaeological sites of the same geology as a local proxy with which to compare the Irthlingborough and Gayhurst data. Both Irthlingborough and Gayhurst are located within a swathe of Jurassic geology running from Dorset through Central England, the East Midlands to North East Yorkshire. The geological drift and bedrock components common to both Irthlingborough and Gayhurst localities are also present at Ketton, Rutland, where strontium data have been obtained (Evans and Tatham, 2004). Of particular interest are strontium isotope ratios measured for plant leaves and soil water leachates from Ketton. Values range from 0.70829 to 0.71041 and from 0.70812 to 0.71004 for plant leaves and soil water leachates respectively (Evans and Tatham, 2004). In addition, mineral water from an area of Jurassic geology gives a ratio of 0.70846 (Montgomery et al., 2006) and Evans et al. (in press) have proposed a strontium biosphere range of 0.709 to 0.710 for regions of Jurassic sediments in central England.. However, a less restricted range of 0.70812 to 0.71041, derived from the Ketton data, is taken to be the proxy local range for this study, as indicated in Figures 2, 4 and 5.

Investigation of the diversity of cattle origins at Irthlingborough

Figure 2 is a plot of strontium isotope ratio versus the inverse of strontium concentration for all Irthlingborough enamel samples together with the proposed local biosphere range obtained from Ketton, Rutland. By plotting all Irthlingborough results, it is possible to determine, by the manner in which they cluster, which results are likely to be local. All but four results are consistent with the estimated local range. Although it is theoretically possible that the cattle producing these results originated from any location in Britain with Jurassic Series geology, or other lithologies that produce a similar biosphere range, the likelihood is that they spent all or most of the first two years of life, the period of second and third molar formation, locally to Irthlingborough. It is not possible to determine precisely the extent of the geographical area inferred by the term ‘local’ in this context, but the Jurassic geology extends for a minimum of 25 km in all directions (Figure 1). Figure 2 also shows that the three intra-tooth isotope ratios for the aurochs, IRTH B, lie within the locally defined group. Therefore, it is likely that this animal was from the local area.

The results for second molar cuspal enamel (Figure 2: triangular symbols), which formed within a few months of the animals’ births, indicate that all but one of the Irthlingborough cattle were born locally. However, the result for animal IRTH 6, lying outside the local group has an isotope ratio of 0.71172, which is higher than expected for Jurassic geology. If enamel takes ~6-7 months to mineralize (Balasse, 2002) and animal IRTH 6 moved to Irthlingborough within its first year of life, then it is possible that the value 0.71172 results from a mixing of strontium from both the animal’s birthplace and the Irthlingborough area. Under those circumstances, with local values appearing to be less than ~0.7106, the isotope ratio of strontium ingested at the animal's birthplace would have been greater than 0.71172. A location for the animal's birthplace on chalk-based geology can be ruled out immediately. Strontium isotope ratios from chalk areas tend to fall between two end-members, ~0.7075 (chalk) and ~0.7092 (rainwater), as has been found for archaeological human communities (Evans et al., 2006b; Montgomery et al., 2007a). Figure 1 shows the bedrock geology of Britain. The birthplace of animal IRTH 6 seems not to have been in central and south-eastern Britain, regions dominated by Cretaceous and Jurassic geology. Rather, a location in western Britain with a more radiogenic geology is more likely. Mineral water strontium ratios are ≥ 0.7117 in Devon, Somerset, the Malvern Hills, much of Wales, Derbyshire, Cheshire, the Lake District and parts of Scotland (Montgomery et al., 2006), suggesting one of these regions as a possible birthplace for animal IRTH 6. In addition, Evans et al. (in press) have proposed a strontium biosphere range of 0.711 to 0.712 for Carboniferous coal measures in the West Midlands. At ~65 km from Irthlingborough, one of these areas is the nearest possible place of origin for animal IRTH 6.

Figure 3 displays sequential intra-enamel isotope ratios for second and third molars on a single time-related x-axis for animal IRTH 6, derived using the chronology of cattle tooth crown formation given in Brown et al. (1960), measured crown heights and predicted unworn crown heights. The unworn crown heights were predicted from wear stage and crown height data for 221 Irthlingborough second and third molars compiled by Davis (2009). It has been assumed for simplicity that the rate of crown formation (mm/month) is uniform but this may not be the case (Hoppe et al., 2004). Note that the isotope ratios are plotted against the time of initial enamel matrix formation relative to that of the cervical enamel of the second molar, which is taken to be a fixed reference point in time, designated 0 months; i.e. 0 months is not the time of birth. Note also that the isotope ratio for each intra-enamel sample represents an average of perhaps six or seven months of mineralization (Balasse, 2002).

The plot suggests that the animal was brought to the Irthlingborough area sometime before the mineralization of the cervical half of the second molar, broadly during the first year of its life. From the wear stage of the second molar and the fact that the third molar crown was not fully formed, it is predicted that this animal was slaughtered during the second year of its life. Therefore, it appears that the animal came to the Irthlingborough area on the hoof well before it was slaughtered and its skull was not brought as a token from its place of origin. There is insufficient evidence to determine whether or not this animal was killed and consumed at a funerary feast or if its skull was brought as a token from the local area. The movement of this animal suggests that there were long-distance communication and trade links between communities in the Early Bronze Age. Such contact with outside communities would have allowed the regular input of fresh bloodlines into the local herds, as is necessary in the keeping of livestock (Pryor, 2004).

Within the proposed local group defined in Figure 2, attention is drawn to a tight cluster of three results corresponding to animals IRTH 3, IRTH 8 and IRTH 9, for which the range in strontium isotope ratio is only ~5×10^{-5}. This range is far narrower than that observed in a single herd of modern cattle (Lakin, 2004), which was ~0.0005. Therefore, there is a possibility that these animals were born in the same location and belonged to the same herd, though not necessarily at the same time. In fact, on the basis of comparison with the modern herd data, two further animals (IRTH 4 and IRTH A), plotting close to the tight cluster in Figure 2, may also have been members of the herd.

Investigation of the diversity of cattle origins at Gayhurst

Compared to the Irthlingborough cattle (Figure 2), the proposed local group for Gayhurst (Figure 4) has a larger strontium concentration range, which may indicate a more varied diet (Evans et al., 2007). However, the strontium isotope ratio ranges for both proposed local groups are similar: 0.00158 for Gayhurst and 0.00125 for Irthlingborough. Mean isotope ratios are also similar: 0.70973 for Gayhurst and 0.70971 for Irthlingborough. Two results, encircled in Figure 4, correspond to animals GAY 2 and GAY 4. As discussed earlier, it is possible that these results derive from a single individual, given the similarity between strontium, oxygen and carbon isotope results (Towers, 2008).

Of the Gayhurst animals investigated for place of birth, two show second molar cuspal enamel results (Figure 4: triangular symbols) that are distinct from the locally defined group with respect to concentration (GAY 3) or ratio (GAY 1). GAY 3 has a strontium isotope ratio of 0.70847, which falls within the biosphere range as defined by proxy data from Ketton. However, it is the lowest ratio obtained in this study ($\approx 2\sigma$ below the mean value of 0.70973 ± 0.00063 (1σ) of the proposed local group). In addition, it has the lowest strontium concentration ($1/\mathrm{Sr} \times 10^3 = 12.05$ which is $>2\sigma$ above the $1/\mathrm{Sr} \times 10^3$ mean value of 5.31 ± 1.96 (1σ) of the proposed local group). On this basis, it is possible that this animal was not part of a locally raised herd. The strontium isotope ratio is consistent with origins on Cretaceous Chalk (Bendrey et al., 2009), which lies ~25 km to the south and west.

In contrast to animal GAY 3, there is little doubt that the origin of animal GAY 1 was non-local. The strontium isotope ratio of the second molar cuspal enamel, 0.71303, is quite unusual for England. Following the arguments used when considering the origin of animal IRTH 6 above, geological regions producing isotope ratios ≥ 0.7130 must be sought for potential birthplaces of animal GAY 1. Mineral water values (Montgomery et al., 2006) indicate that the Malvern Hills, certain areas of Wales, the Lake District and parts of Scotland are possibilities within Britain. The enamel oxygen isotope ratios for GAY 1 also differ to those of the other animals from Gayhurst and provide additional support for origins in the west of Britain (Towers, 2008).

Intra-tooth results for animal GAY 1 produce a mixing line, as shown in Figure 5. Such a phenomenon occurs when the strontium composition of a set of samples results from different combinations of the same two sources of strontium with different isotope ratios and concentrations (Faure, 1986). A best-fit line has been added to the plot. Its R^2 value approaches unity, indicating a very good fit to the data. For geological mixing processes, the goodness of fit to a straight line “is a test for the validity of the mixing hypothesis and of the assumption that neither the strontium concentration nor the $^{87}Sr/^{86}Sr$ ratios were modified after mixing had occurred” (Faure, 1986). If this argument holds true for biological processes, then the goodness of fit of the GAY 1 data to a straight line implies that there were only two major sources of strontium in the animal’s diet, equivalent to the end-members of the straight line. These are likely to have been the food sources at the animal's birthplace and at the location to which it was brought in the Gayhurst area. Since there appears to have been little influence from a third food source, the animal was probably brought directly to Gayhurst from its place of birth and provides further evidence for the long-term averaging, i.e. c. 12 months, of strontium in cattle molar enamel (Montgomery et al., 2009).

The intra-tooth strontium data for GAY 1 is displayed versus time in Figure 6. It is predicted that the animal was brought to the Gayhurst area sometime before the matrix formation of the third molar cervical enamel, during the animal's second year of life. It was slaughtered several years later, as determined by the wear stages of its second and third molars, and, thus, was brought to the Gayhurst area alive.

Conclusions

The strontium isotope data obtained in this small-scale study from Early Bronze Age cattle do not reflect the marked difference in skeletal composition of the assemblages excavated from the barrows at Irthlingborough and Gayhurst. For both sites, the results have shown that most of the cattle included in the study, including the aurochs from Irthlingborough, were likely to be of local origin. However, at each site, one animal of non-local origin was identified and in both cases the strontium ratio points to origins on radiogenic rocks, which in Britain are found to the west and north of Irthlingborough and Gayhurst. Intra-tooth strontium isotope ratio analysis combined with tooth wear stages indicate that the non-local animals in both assemblages were brought to the local area on the hoof at an early age, well before they were slaughtered, indicating that they were probably not long-distance funerary gifts.

Rather, they were traded in long-distance exchange networks, suggesting that Early Bronze Age people knew the importance of a regular input of fresh bloodlines into their livestock.

A second Gayhurst animal may have been born in a region of chalk geology, the nearest being the Chiltern Hills about 25 km to the southeast. Because the sample size was small for both sites, it is not possible to predict the proportion of cattle originating from outside the local area.

Three of the Irthlingborough animals’ strontium values are close enough to suggest that they may have belonged to the same herd. However, for both Irthlingborough and Gayhurst, there is insufficient evidence to know whether members of more than one herd were slaughtered, and thus whether the animals were provided by guests or those hosting the funerary rites. On current evidence, it would appear that the sources of cattle used in funerary events at Irthlingborough and Gayhurst were local and not long-distance.

Acknowledgements

We would like to thank Northamptonshire Archaeology and English Heritage for permission to sample the cattle teeth in their collections; particularly Andy Chapman, Frances Healy and Claire Tsang for locating and selecting samples. Many thanks to Professor Julia Lee-Thorp, University of Bradford, and Dr. Andrew Millard, Durham University, for their useful comments.

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Figures

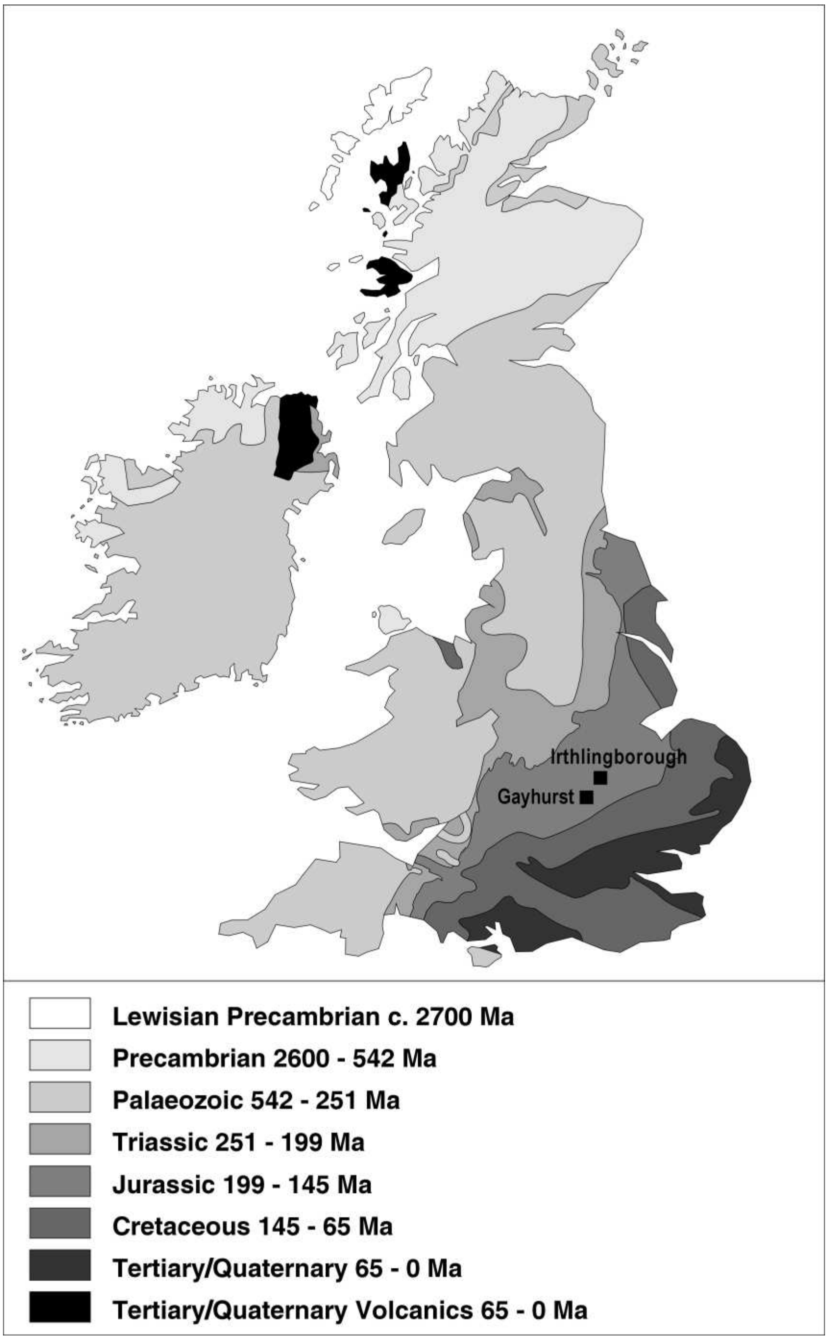

Figure 1. Simplified geology map of Britain showing the locations of Irthlingborough and Gayhurst.

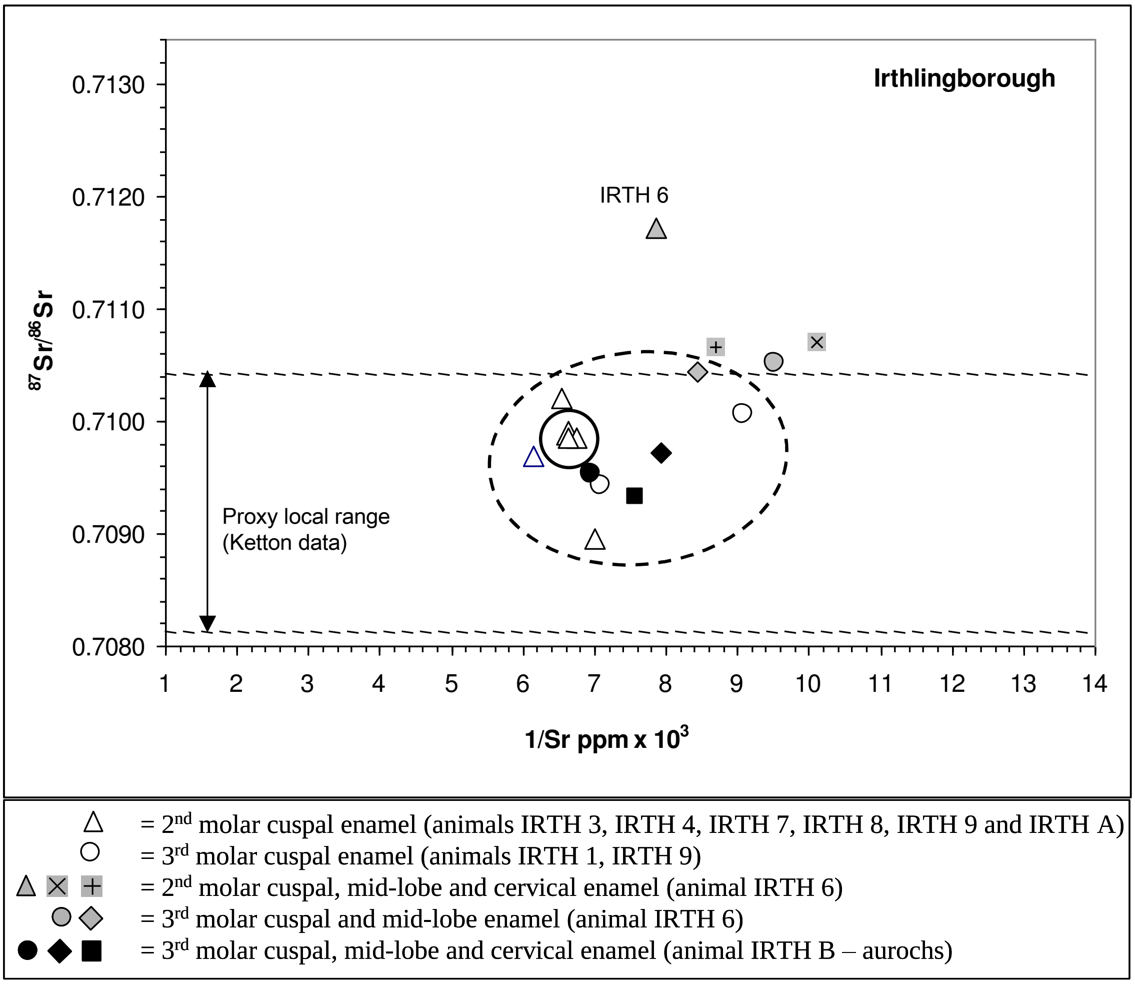

Figure 2. $^{87}Sr/^{86}Sr$ versus the inverse of strontium concentration for Irthlingborough second and third molar enamel samples. 2σ errors for $^{87}Sr/^{86}Sr$ are contained within the symbols. The dashed oval indicates the proposed local group and the circle draws attention to a cluster of results. They have no statistical significance. (Figure includes data from Evans and Tatham, 2004).

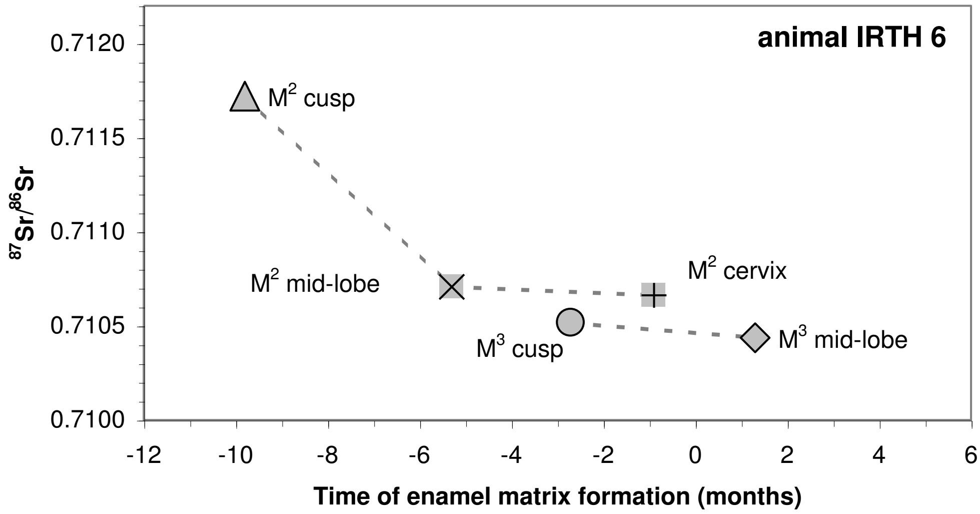

Figure 3. Combined plot of $^{87}Sr/^{86}Sr$ versus time of matrix formation for IRTH 6 second and third molar enamel. Time of matrix formation is months before (-ve) or after (+ve) matrix formation of the second molar cervix. 2σ errors for $^{87}Sr/^{86}Sr$ are contained within the symbols.

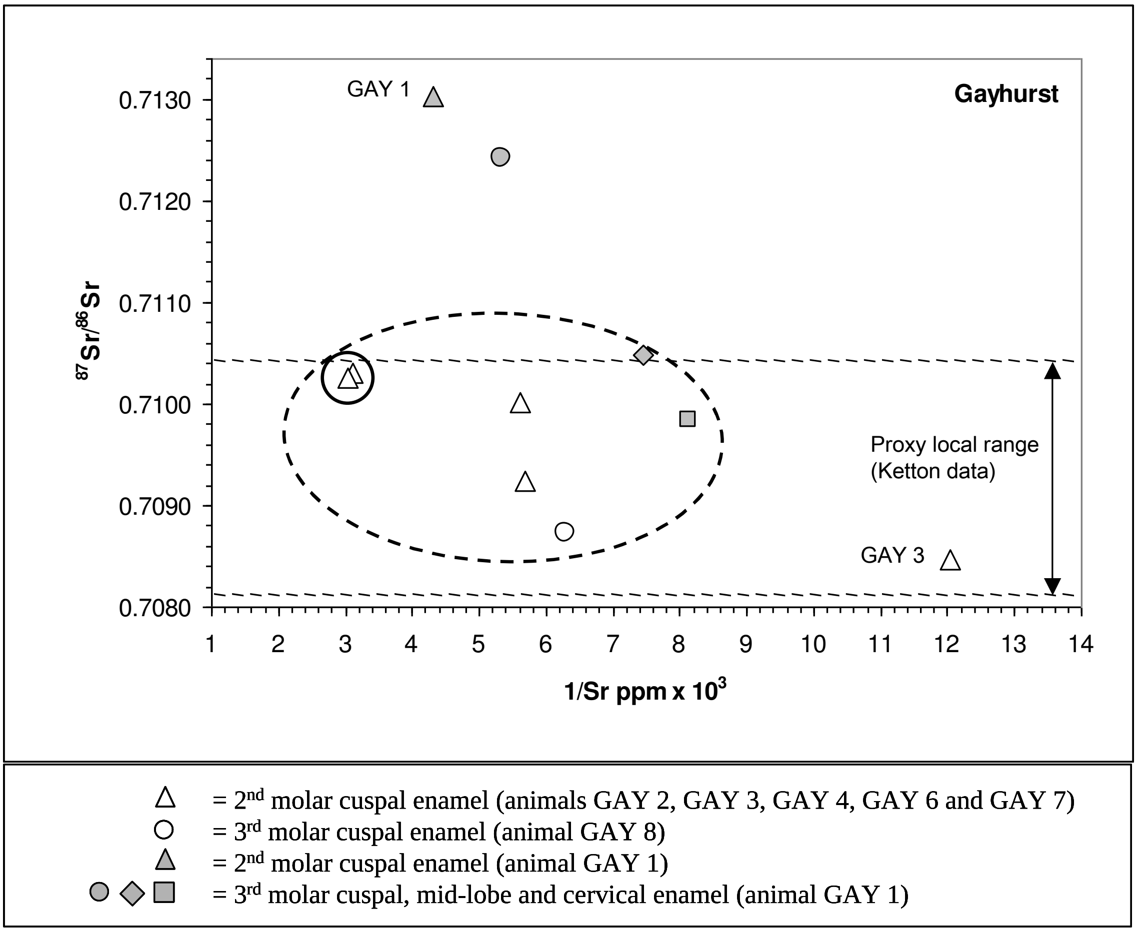

Figure 4. ^{87}Sr/^{86}Sr versus the inverse of strontium concentration for Gayhurst second and third molar enamel samples. 2σ errors for ^{87}Sr/^{86}Sr are contained within the symbols. The dashed oval indicates the proposed local group and the circle draws attention to a pair of very similar results, GAY 2 and GAY 4. They have no statistical significance. (Figure includes data from Evans and Tatham, 2004).

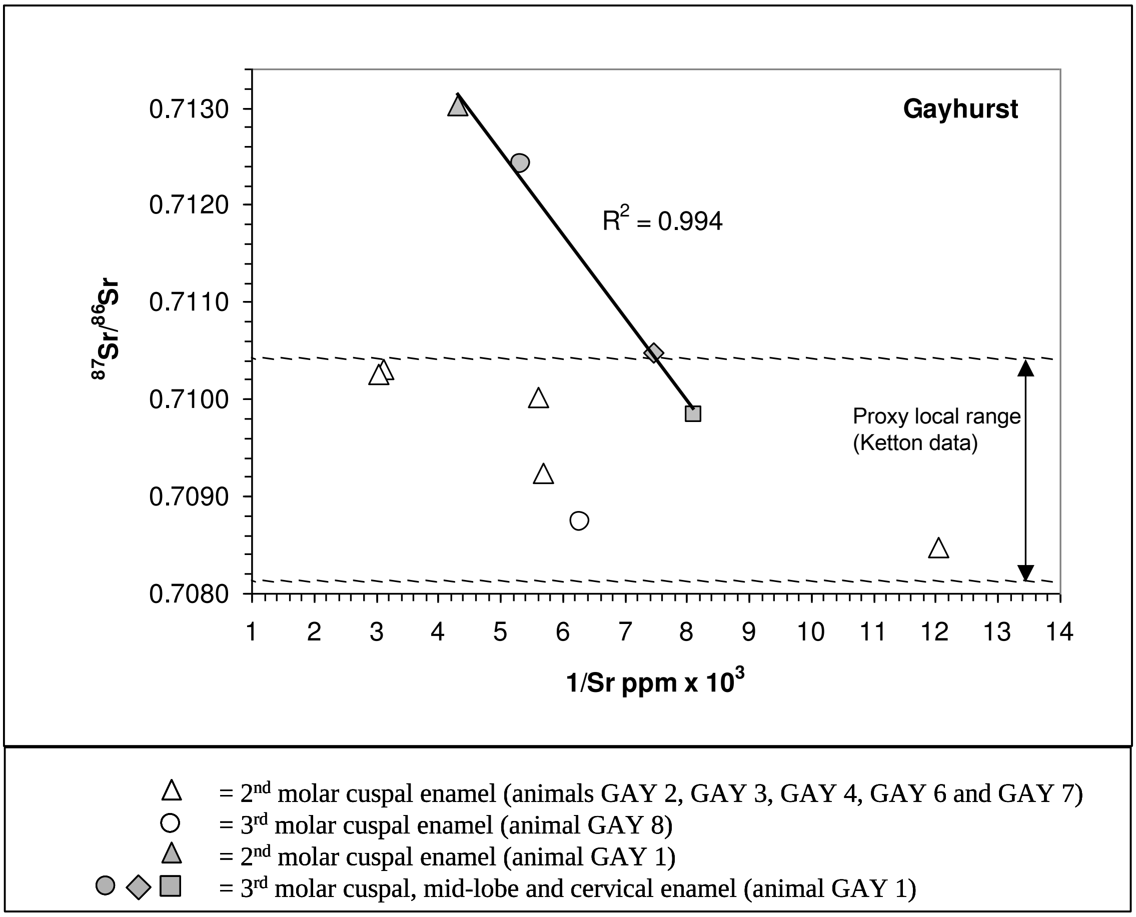

Figure 5. $^{87}Sr/^{86}Sr$ versus the inverse of strontium concentration for GAY 1 enamel samples. 2σ errors for $^{87}Sr/^{86}Sr$ are contained within the symbols. (Figure includes data from Evans and Tatham, 2004).

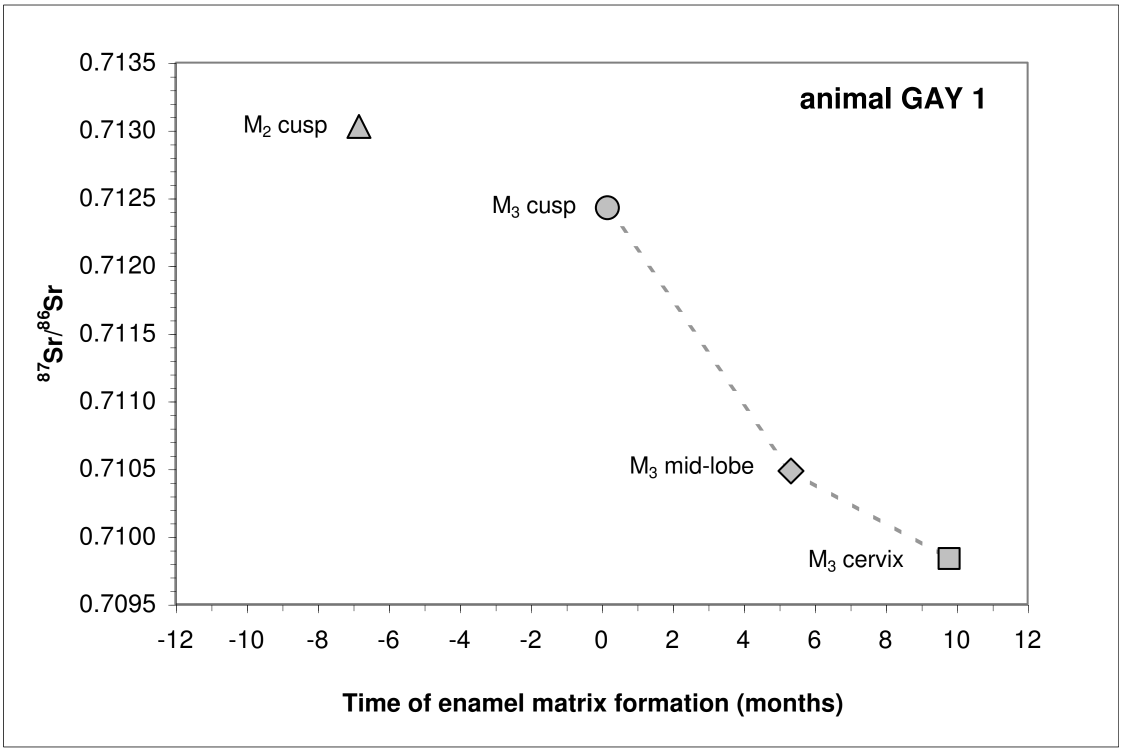

Figure 6. Combined plot of ^{87}Sr/^{86}Sr versus time of matrix formation for GAY 1 second and third molar enamel. Time of matrix formation is months before (-ve) or after (+ve) matrix formation of the second molar cervix. 2σ errors for ^{87}Sr/^{86}Sr are contained within the symbols.

Tables

Table 1. Strontium isotope ratios and concentrations from Gayhurst and Irthlingborough cattle tooth enamel. Mandibular 2nd and 3rd molars are designated M_2 and M_3, maxillary 2nd and 3rd molars are designated M^2 and M^3. L = left, R = right.

Sample ID	**Animal ID**	**Tooth**	**Position on tooth lobe**	**Sr concentration (ppm)**	**$^{87}Sr/^{86}Sr$ normalised**
IRTH 131	IRTH 1	M^3L	cusp	141	0.709424
IRTH 321	IRTH 3	M^2L	cusp	151	0.709901
IRTH 421	IRTH 4	M^2L	cusp	153	0.710205
IRTH 621	IRTH 6	M^2L	cusp	127	0.711720
IRTH 622	IRTH 6	M^2L	mid-lobe	99	0.710707
IRTH 623	IRTH 6	M^2L	cervix	115	0.710662
IRTH 631	IRTH 6	M^3L	cusp	105	0.710515
IRTH 632	IRTH 6	M^3L	mid-lobe	119	0.710437
IRTH 721	IRTH 7	M^2L	cusp	143	0.708954
IRTH 821	IRTH 8	M_2R	cusp	148	0.709853
IRTH 921	IRTH 9	M^2L	cusp	151	0.709856
IRTH 931	IRTH 9	M^3L	cusp	110	0.710053
IRTH A21	IRTH A	M^2L	cusp	163	0.709687
IRTH B31	IRTH B	M^3R	cusp	144	0.709537
IRTH B32	IRTH B	M^3R	mid-lobe	126	0.709718
IRTH B33	IRTH B	M^3R	cervix	132	0.709326
GAY 121	GAY 1	M_2R	cusp	232	0.713028
GAY 131	GAY 1	M_3R	cusp	187	0.712421
GAY 132	GAY 1	M_3R	mid-lobe	134	0.710484
GAY 133	GAY 1	M_3R	cervix	123	0.709830
GAY 221	GAY 2	M_2L	cusp	322	0.710303
GAY 321	GAY 3	M_2L	cusp	83	0.708473
GAY 421	GAY 4	M_2R	cusp	329	0.710264
GAY 621	GAY 6	M^2L	cusp	178	0.710018
GAY 721	GAY 7	M_2R	cusp	176	0.709235
GAY 831	GAY 8	M_3R	cusp	159	0.708723