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THE INTRODUCTION OF *COCHLICELLA ACUTA* AND *COCHLICELLA BARBARA* INTO BRITAIN AND THE EXTINCTION OF *XEROCRASSA GEYERI* IN CORNWALL

Thomas Walker

Department of Archaeology, University of Reading, Whiteknights, Reading, Berkshire RG6 6AB, UK.

Abstract *The introduction into Britain of two helicid species,* Cochlicella acuta *and* C. barbara*, is discussed in the knowledge that old carbon may have influenced the chronology; modern specimens of* C. acuta *from Cornish sand dunes gave radiocarbon dates which are 600–800 years old. The introduction of* C. acuta *is confirmed to the early Bronze Age and it may have been present in the late Neolithic.* C. barbara *arrived in Cornwall prior to its first observation in the 1960s but, in view of the old carbon problem, a precise date cannot be determined.* Xerocrassa geyeri *became extinct in most of southern Britain in the early Holocene, but survived at Gwithian in Cornwall for several more millennia, with radiocarbon dating suggesting that it could have been present there until the later part of the early Bronze Age.*

Key words Cochlicella acuta, Cochlicella barbara, Xerocrassa geyeri, *mollusc introductions, mollusc extinction, Cornwall, radiocarbon dating, old carbon effect.*

Introduction

There are around 100 species of shelled terrestrial molluscs currently extant in Great Britain and Ireland. About 75% of these are considered to be 'native' – that is they have been present in the British Isles from the Late-glacial, prior to the separation of Britain and Ireland from the continent in the early-Mesolithic, around 12,000 BC for Ireland and 7,000 BC for Britain. The remainder, about 25 species, first appeared once Britain and Ireland became islands and are referred to as 'introductions'. There are also a few species which persisted from the Late-glacial but became extinct in the early Post-glacial period, probably being unable to survive rising temperatures. Kerney (1999) considered that two now extinct species, *Trochoidea geyeri* (now *Xerocrassa geyeri*) and *Helicopsis striata* succumbed to the increasing tree-cover in the early Post-glacial period.

The concept that mollusc introductions and extinctions may be of value in establishing the chronology of archaeological sediments is not new. Over 100 years ago Clement Reid (1896) stated 'Land snails are not generally thought to be of much account for fixing the age of deposits; but this is probably a mistake; they are likely to prove extremely valuable historic medals for the periods before coins were used or history written.' Burchell (1958; 1961) and Evans (1969) developed this idea, the former to propose specific chronologies for the south-east of England, and the latter from a more theoretical standpoint.

In order for molluscs to be a valuable tool in establishing chronologies it essential that they be dated. Traditionally this has been contextual and assumes that the shells have remained undisturbed in the sediments in which they were once living. Unfortunately, this is often not the case. Many molluscs are small (less than 1cm) and may be redeposited by the action of external agents, such as wind, rain or animals. If a shell is unexpectedly recovered in a sediment earlier than its accepted introduction, then either the dating model is incorrect, or the shell is intrusive into that sediment. An example of the latter is at Brean Down in Somerset, where *Helix aspersa* (now *Cornu aspersum*), considered to be a Romano-British introduction, appeared in late Bronze Age sediments and was thought to be intrusive, probably due to rabbit burrowing (Bell & Johnson 1990).

This paper discusses three species of terrestrial mollusc in coastal sand dune deposits in Cornwall, south-west England (Fig. 1). The shells were radiocarbon dated to assess the time when two, *Cochlicella acuta* and *Cochlicella barbara*, may have been introduced into Britain, and when one, *Xerocrassa geyeri*, became extinct.

Contact author: t.m.walker@reading.ac.uk

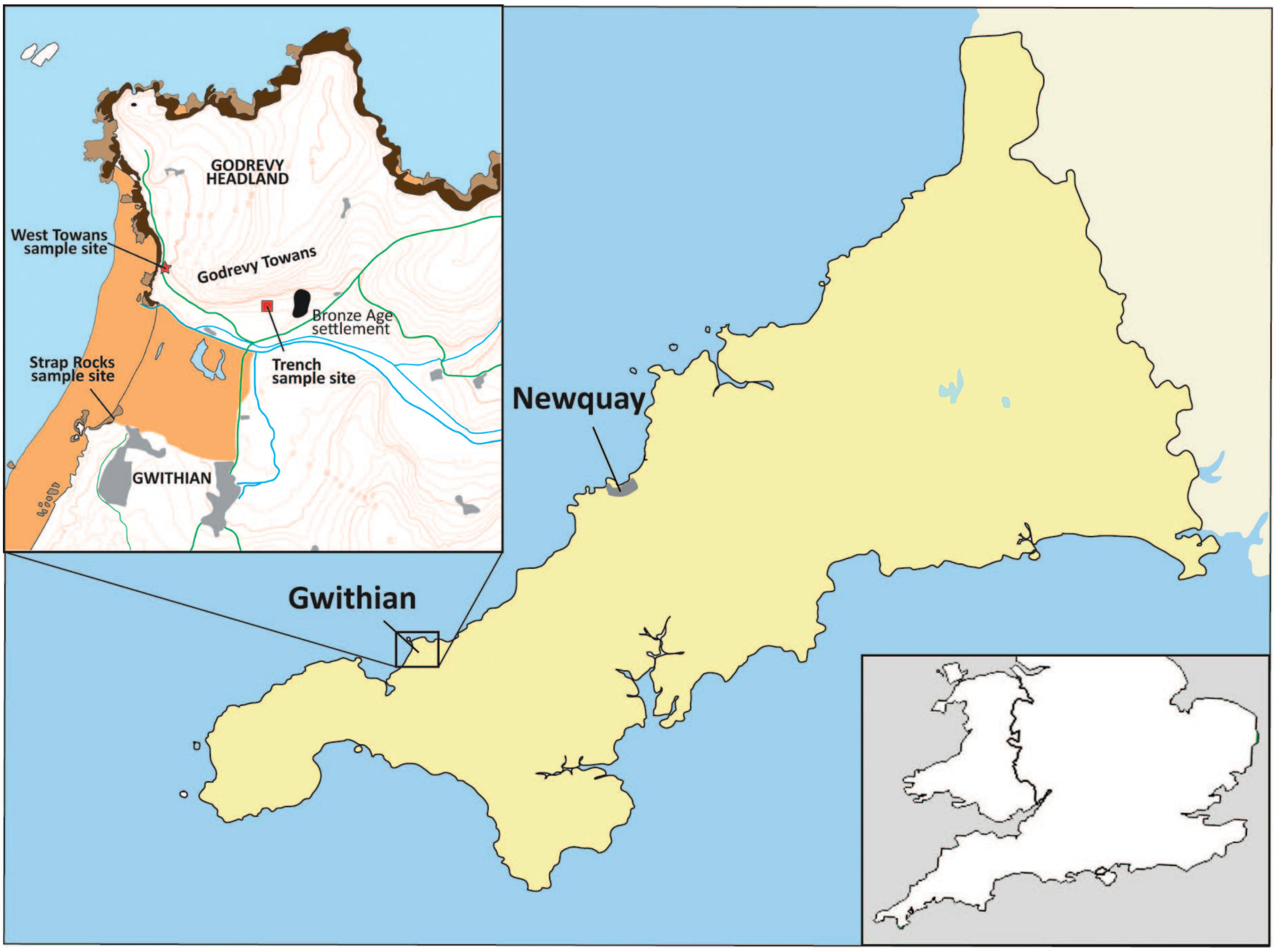

Figure 1 Map to show the sample sites discussed in this paper.

RADIOCARBON DATING OF TERRESTRIAL MOLLUSCS

The principles of radiocarbon dating are well established (e.g. Walker 2005) and do not need repeating. The use of this technique for dating molluscs has recently been reviewed by Douka (2017), although that review concentrated on marine molluscs with little reference to non-marine shells. Pigati (2013) discussed some of the problems associated with the dating of terrestrial shells, in particular the presence of 'old carbon' or the 'limestone effect'. In order to obtain reliable results, it is necessary to ensure that the ^{14}C within the shell is coeval with atmospheric ^{14}C. This is not always the case. Molluscs may obtain some of the carbon in their shells by ingesting 'old' carbon from rasping bedrock such as chalk, limestone or tufa which contain carbon atoms that have already undergone some decay (Yates 1986, 22), leading to erroneously old dates.

Other possible sources of 'old carbon' could be the ingestion of carbonate derived from older dead shells incorporated into the sediments from which the living mollusc obtains its nutrients. These may be terrestrial shells which have been redeposited by wind or animal action into sediments accessible to the living mollusc. The study sites discussed below are all coastal, and some marine shells (and coralline algae) will inevitably have been blown onto the dunes and also be available for browsing. The 'marine reservoir effect' must therefore be considered, whereby marine shells/algae contain old carbon from deep water; this results in a measured radiocarbon age for molluscs in the North Atlantic being about 400 years older than their true age (Walker 2005, 26).

There are two methods whereby the reliability of radiocarbon dating of land molluscs can be assessed. First, comparison can be made with other dated material from the same archaeological sediments, most frequently organic material such as wood, plants, seeds or charcoal. Second, radiocarbon dating of modern or recently dead specimens of the same species of mollusc collected from the same location as the archaeological specimens will allow assessment of accuracy (Burleigh & Kerney 1982; Pigati 2013; Preece 1980). If the modern sample provides a date contemporary with the date of collection, then this is good evidence that the species has not ingested old carbon, and the dating of the archaeological specimens is likely to be reliable, at least at that location. Should the modern shells produce an earlier radiocarbon date, then the discrepancy in ages can be determined and allowance made in the evaluation of archaeological molluscs. There is also the question of 'uniformitarianism' to consider: were the conditions in which the old shells lived the same as that of modern shells, and did they behave in the same way, such as in their diet?

DATING OF MODERN MOLLUSCS

Specimens of modern *Cochlicella acuta* were submitted for radiocarbon dating to assess the possible old carbon effect. These were obtained from exactly the same location at Gwithian, Cornwall, as the archaeological samples of this species discussed below. The first shells (OxA-40936) were dead shells obtained from the ground surface that still had their periostracum intact, suggesting recent death. The second shells (OxA-43531) were obtained live and were submitted for dating after the flesh had been rotted out, so that only the shell remained.

The radiocarbon dates on these modern shells (Table 1) are greatly at variance with the time at which they died – by around 600 years for the first sample, and over 800 years for the second sample – and clearly indicate the presence of old carbon. Even if a marine reservoir effect of 400 years is allowed for, this still gives ages which are too old by 200–400 years.

Both samples were collected from among grass growing on the surface of blown sand. The underlying bedrock, at a depth of 3m below ground surface, is Mylor Slate Formation of slate and siltstone; there is no limestone or chalk in the vicinity. However, the blown sand on which the modern specimens were collected contains large numbers of dead shells of a variety of species. These may derive from various depths, having been moved by winnowing and redeposition, and it seems likely that the modern shells may have obtained some of the carbonate by browsing on these older shells. The diet of *C. acuta* is primarily decomposing organic matter (Baker *et al.* 2012) but it may be that the molluscs need to obtain some of their carbonate for shell-building from dead shells, either terrestrial or marine, which are abundant in their surroundings.

The $\delta^{13}C$ values measured at the time of ^{14}C dating may also suggest that there is a problem with the dates. $\delta^{13}C$ is the ratio between the stable isotopes ^{13}C and ^{14}C, and the value is a reflection of the diet of an organism – lower values indicate a greater vegetable diet as plants have a low $\delta^{13}C$. In the present study the values vary substantially between the modern and archaeological specimens of *Cochlicella acuta* – less than 9.3‰ for the recent shells and as high as -3.5‰ for the same species radiocarbon dated to 2570–2345 cal BC from the same site (Table 2). Similar differences in the $\delta^{13}C$ between modern and ancient shells has been observed. Colonese *et al*. (2007; 2010) found that the values were considerably lower in living specimens of *Helix ligata* from southern Italy compared to those in Late-glacial and Holocene shells, and which they considered may be due to differences in CO_2 atmospheric concentration, vegetation or environmental stress.

Does this then invalidate the radiocarbon dates obtained on the archaeological specimens discussed below? There do not seem to be any previous data on $\delta^{13}C$ values of *Cochlicella acuta*, but it would appear likely that the discrepancy between modern and archaeological specimens

Table 1 Radiocarbon dates for modern *Cochlicella acuta* shells.

Lab. number	$\delta^{13}C$	Radiocarbon date (BP)	Calibrated date (2σ)	Comment
OxA-40936	-9.85‰	518±18	cal AD 1400–1440	recently dead shells collected on 25/6/2016
OxA-43531	-9.36‰	867±20	cal AD 1150–1225	living shells collected on 5/7/2022

Table 2 Radiocarbon dates for the samples from the basal sediments on Godrevy Towans.

Lab. number	Depth (m)	Material	$\delta^{13}C$	Radiocarbon date (BP)	Calibrated date (2σ)
OxA-28967	2.88–3.00	*Cochlicella acuta* shell	-6.45‰	3187±27	1505–1415 cal BC
OxA-28966	3.10–3.32	*Cochlicella acuta* shell	-3.52‰	3957±29	2570–2345 cal BC
Beta-280906	3.32	*Prunus* sp. charcoal	-23.80‰	3950±40	2575–2305 cal BC

is also due to differing environmental and dietary causes. It is clear that the findings discussed below need to be treated with caution.

COCHLICELLA ACUTA (MÜLLER, 1774)

This species has long been known in Britain and Ireland, its first description being by Martin Lister who recorded it in his *Historiae animalium Angliae* nearly 350 years ago. It is a xerophile mollusc frequently found in grassy calcareous areas and sand dunes enriched with calcium from dead shells. Its modern range is mainly on the west and south coasts of Britain and all around Ireland, although with a few inland locations (National Biodiversity Network). It is frequently found in coastal archaeological excavations, especially in blown sand deposits.

Few studies have explored the question of when this species first appeared in Britain. Lewis (1968, 307) argued that the earliest *Cochlicella acuta* at Gwithian in Cornwall formed a 'founder population'; it was not present on the earliest stable land surface in his trench, but first appeared in early Bronze Age blown sand. Spencer (1975) also found it in abundance in early Bronze Age sand at Gwithian. At Brean Down in Somerset, Bell and Johnson (1990) did not find it until the late Bronze Age levels, and even then had some doubts, in that the molluscs in this horizon may have been intrusive from later sediments. Evans considered that *Cochlicella acuta* was certainly in Britain by the Iron Age (1979) and established that it did not reach the Outer Hebrides of Scotland until the 'Iron Age II' horizons (1972, 293; 2004), although it has also been claimed that it was present there in the late Bronze Age (Thew 2003, 163).

Shells obtained at Gwithian may now suggest an earlier introduction, in the Neolithic. In 2008 a mollusc column 350cm in height was obtained from an exposed dune scarp at the extreme western end of Godrevy Towans ('towan' is Cornish for 'sand dune') as part of a project to study the palaeoenvironment of the area (Walker 2014; 2018, 141). *Cochlicella acuta* was abundant in the basal blown sand, a palaeosol stabilisation horizon at 3.10–3.32m below the ground surface (132 specimens in a 2kg subsample), with a few on the surface of the underlying old land surface at 3.32m (13 shells in 2kg). There was also charcoal on the old land surface, and both the charcoal and *C. acuta* were submitted for radiocarbon dating (Table 2). Above the basal palaeosol there was a horizon of blown sand, overlain by another stabilisation layer of sand representing second buried soil (2.88–3.00m), from which a further sample of *C. acuta* was dated.

The almost exact overlap of the charcoal and basal shell dates suggests the *C. acuta* date is reliable and may not be influenced by old carbon. It also implies that this shell is very likely to be in its original position and is not intrusive from more superficial sediments. However, the old carbon effect must be considered. The difference in $\delta^{13}C$ values between the two *C. acuta* samples shown in Table 2 suggests that there was some change in environmental conditions between the two deposits, and that this was also different from the modern environment.

It therefore remains possible that *Cochlicella acuta* was present in Cornwall in the late Neolithic, somewhat earlier than the previously proposed introduction date in the early Bronze Age, even when allowance is given for old carbon offset. Whether Cornwall was the location of the initial colonisation of *Cochlicella acuta* in Britain cannot be determined. There do not seem to have been any studies exploring its introduction to coasts between Cornwall and the Outer Hebrides but the evidence suggests that is was present in Cornwall first, so south-west Britain seems the more likely location for its introduction. How it arrived is open to speculation. It is a species that is currently very widely distributed on the Atlantic coasts of Europe and throughout the Mediterranean (Welter-Schultes 2012, 497) and in prehistoric times it may have been inadvertently transported by early travellers across the English Channel.

COCHLICELLA BARBARA (LINNAEUS, 1758)

The naming of this species has led to confusion in the past. The taxon named by Linnaeus *Helix barbara* was used by many early authors for the species now recognised as *Cochlicella acuta* (e.g. Kennard & Woodward 1920). The first published record of modern populations of 'true' *Cochlicella barbara* in Britain was in December 1975, when they were discovered at Torquay in Devon by Edward Bishop (Kerney 1976). An earlier unpublished record, in 1966, is given on the NBN database, with the species being found on Kenfig dunes, Glamorganshire, by Janet Boyd, with the identification confirmed by Michael Kerney. In recent decades the 'true' *Cochlicella barbara* has been described at several sites in Cornwall (including the Isles of Scilly) and Devon, along the South Wales coast, at a few coastal sites in mid-Wales and on the Lleyn peninsula in north Wales (National Biodiversity Network). It does not, however, seem to have been reported in archaeological deposits.

In 2014 the author was asked to perform an assessment of the molluscs in sediments obtained from an excavation on land at Tregunnel Hill, Newquay, (Randall 2022) on the north Cornish coast (Fig. 1). The site is immediately east of a known Bronze Age settlement and an Iron Age cemetery at Trethellen (Nowakowski 1991) on a south-facing slope between the dunes above Fistral Bay and the River Gannel. The Tregunnel excavation revealed numerous pits cut into the natural substrate of shillet and slate inclusion, some containing pottery from the early Neolithic to the Iron Age; in two pits there were charred hazelnut shells radiocarbon dated to the early centuries of the 4^{th} millennium BC. The natural substrate was overlain by sandy silt and ploughsoil up to 0.9m in thickness (Sheldon 2011).

Palaeoenvironmental samples were obtained from numerous pit fills (both prehistoric and superficial) and mollusc assessment was performed on subsamples from 59 of the pits. The molluscs clearly demonstrated that the majority of the analysed sediments were of historic date, in that 54 subsamples contained *Cernuella virgata* and of these 39 also contained *Xeroplexa intersecta*. Both of these species are considered to have been introduced to Britain during the Romano-British or later times (Evans 1972, 179; Kerney 1999, 179, 181).

Cochlicella acuta was present in every subsample, often in large numbers, both in prehistoric levels and in the upper windblown sands. In the upper windblown sand deposits of six of the pits there were also specimens of *Cochlicella barbara*, albeit in small numbers (one to five per subsample), and always with specimens of *C. virgata* and *X. intersecta*. It appeared unlikely that the colluvial sands were very recent, in that three of the *C. barbara* sediments were in sandy fills beneath the modern topsoils although the other three were in plough soil. There were no shells of *C. barbara* in prehistoric sediments. The site is downhill from a line of terraced houses built in the 1930s, which would probably have restricted large quantities of sand moving downhill from the higher dunes after their construction. It therefore seemed probable that these *C. barbara* pre-dated the construction of the houses, but there was no evidence of the timing for the colluvial movement of the sand. Two specimens of *C. barbara* from different pits were submitted to radiocarbon dating (Table 3). Despite one sample being considered at the time of excavation to be from modern plough soil, the radiocarbon dates suggest that both samples are contemporary and from the late medieval period.

Subsequent searching uphill of the excavation site revealed a population of *Cochlicella barbara* limited to Mount Wise graveyard, 150–200m

Table 3 Radiocarbon dates on *Cochlicella barbara* shells from Tregunnel Hill.

Lab. number	Sediment	$\delta^{13}C$	Radiocarbon date (BP)	Calibrated date (2σ)
OxA-35379	plough soil	-8.60‰	488±25	cal AD 1410–1450
OxA-35380	single fill of shallow pit	-9.48‰	511±26	cal AD 1330–1445

directly uphill from the sample site. Live shells were found, as well as recently dead and older dead specimens. The area immediately to the east and west of the graveyard is built up, but no specimens of *Cochlicella barbara* were found a short distance further to the west on open grassy dune sands, where *C. acuta* was abundant.

The radiocarbon dates open the question of whether this species may have been in Britain for considerably longer than previously thought. Although first observed in the late 20th century it is evident that, at Newquay, it may have been present up to 600 years ago. The *caveat*, though, is that old carbon may be leading to erroneously old dates, as with *Cochlicella acuta* discussed above. Radiocarbon dating of modern specimens of *C. barbara* was attempted but failed to produce a result. The $\delta^{13}C$ values of both the archaeological specimens of *C. barbara* are similar to those of the modern specimens of *C. acuta*, which would make some old carbon effect probable. It is, therefore, not possible to determine with certainty when this species first appeared at Newquay. They were almost certainly present before the construction in the 1930s of the houses uphill from the excavation site and may well have been present for some hundreds of years prior to this.

Xerocrassa geyeri (Soós, 1926)

This species was first reported in Britain by Sparks (1952) (as *Helicella geyeri*) who observed it in Pleistocene sections at Barrington in Cambridgeshire. He later (1953) described its presence at a number of sites in Kent and Essex. However, examination of specimens in the British Museum (now Natural History Museum) led Sparks to demonstrate that it had earlier been described in Kent by Kennard and Woodward (1922) but that those authors had confused it with *Helicella striata* (Müller, 1774). Sparks considered that it did not survive the Pleistocene, although there are reports of its presence in the Late-glacial: near Ventnor in the Isle of Wight (Preece *et al.* 1995) and at Hambledon Hill, Dorset (Bell *et al.* 2008).

Xerocrassa geyeri has never been found alive in Britain but post-Pleistocene records do exist. The first Holocene occurrence of the species was reported by Kerney (1963), who described it in three Late-glacial deposits in Kent, at Holborough, Upper Halling and Oxted, and extended its presence to around 8,000 BC. Since then, there have been further reports of *X. geyeri* in early Holocene deposits. Additional sites in Kent include the Cray Valley near Sevenoaks (Davis 1954), at Aylesford near Maidstone (Burchell & Davis 1957) and at Boxley (Stafford 2006); elsewhere it has been found at Thatcham, Berkshire (Holyoak 1983) and at Durrington Walls, Wiltshire (Evans 1971).

At only one location in Britain has it been found in deposits later than the early Post-glacial: at Gwithian on the east side of St Ives Bay on the north Cornish coast (Fig. 1). Mollusc analysis of sediments from excavations in the late 1950s of a Bronze Age settlement included shells described as *Helicella caperata* (Spencer 1975); that species, now named *Xeroplexa intersecta*, is generally considered not to have been introduced into Britain until the Romano-British period. Review of Spencer's specimens by Milles (1991, 2–8) determined that the shells in question were actually *Xerocrassa geyeri* (named by her *Trochoidea geyeri*). Milles also found numerous specimens in her own samples from Gwithian below sediments radiocarbon dated to 3250±103 BP (1860–1270 cal BP). Lewis (1968), in his research on the banding of *Cochlicella acuta*, found large numbers of what he named *Helicella caperata* at the base of a trench at Gwithian; in the light of current knowledge these were almost certainly *Xerocrassa geyeri*.

The opportunity arose in 2012 to obtain a more accurate dating for the persistence of *Xerocrassa geyeri* at Gwithian. Samples were obtained from a small trench close to a field system within the meadow about 100m west of the Bronze Age settlement site (Walker 2018, 118) (Fig. 1). The trench, 1.00m deep, included two buried soil horizons at 0.60–0.70m and 0.85–0.94m, the latter overlying the old land surface. Windblown sand was interposed between these soil horizons and also overlay the upper soil up to the modern ground surface. OSL dating of the buried soils gave dates of 940–640 BC (upper: Aber-203/GWT-12–2) and 1290–910 BC (lower: Aber-203/GWT-12–4), establishing these horizons as middle/late Bronze Age and late Bronze Age/early Iron Age respectively.

Numerous specimens of *Xerocrassa geyeri* were found in these sediments, both within the buried soils and in the intervening blown sand. In view of the previous confusion in the identification of this rare species, confirmation was sought

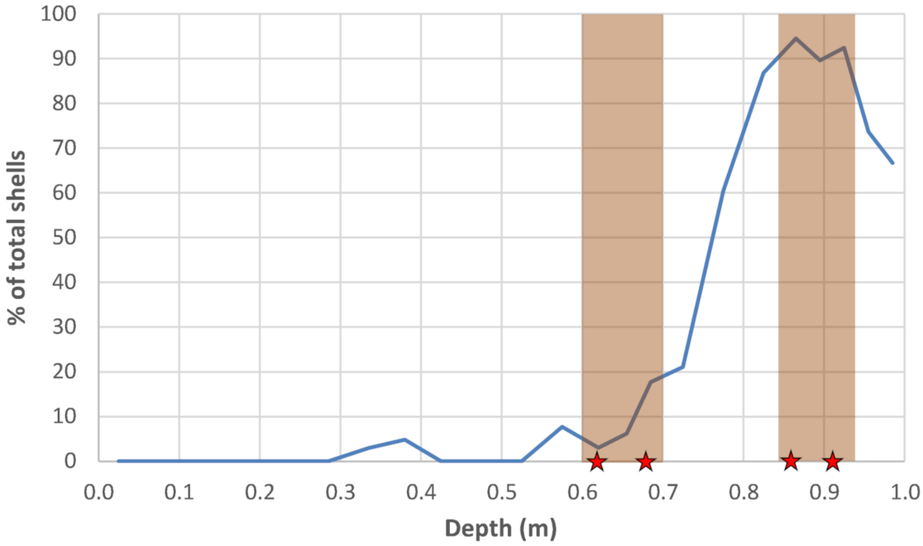

Figure 2 The proportion of *Xerocrassa geyeri* in the trench samples. The buried soil horizons are shaded. The stars show the depths from which the molluscs for dating were obtained.

Table 4 Radiocarbon dates for the *Xerocrassa geyeri* shells in the trench.

Lab. number	Depth (m)	$\delta^{13}C$	Radiocarbon date (BP)	Calibrated date (2σ)	Context
OxA-28965	0.60–0.64	-6.46‰	3599±28	2030–1890 cal BC	top of upper buried soil
OxA-28964	0.67–0.70	-6.23‰	3537±28	1950–1770 cal BC	bottom of upper buried soil
OxA-28963	0.67–0.70	-6.53‰	3515±29	1925–1750 cal BC	
OxA-28962	0.85–0.88	-6.38‰	3576±29	2025–1785 cal BC	top of lower buried soil
OxA-28961	0.91–0.94	-7.22‰	3558±29	2015–1775 cal BC	bottom of lower buried soil

from Professor Edmund Gittenberger of Leiden University, Netherlands, who declared ‘The shells are very well preserved and very typical *geyeri* indeed, i.e. in sculpture, shape (globularity), roundish very open umbilicus, and size.’ (*in litt.* 29 January 2013). In the lower palaeosols *X. geyeri* was the strongly dominant species (93% of 315 shells in three 1kg samples) (Fig. 2); numbers dropped markedly in the overlying blown sand between 0.80 and 0.70m, there being relatively few specimens of this species in the upper palaeosol (7% of 4185 shells). It is probable that the few shells above 0.60m (six shells in total) are extraneous.

Radiocarbon dates were obtained on five of the *Xerocrassa* shells which confirmed their Bronze Age origin (Table 4). Interestingly, all the dates are contemporary, despite being from the two different buried soil horizons. The $\delta^{13}C$ values of the upper four shells are very similar which implies that the shells in these subsamples may derive from two buried soils which formed within a short time of each other, with an intervening deposit of blown sand.

A second site, about 1km south-west of the trench, was also examined in 2012. This is on the south side of Gwithian Bay, in the cliffs adjacent to Strap Rocks. A line of large stones had been noticed eroding out of the blown sand above the cliffs which suggested a man-made wall, but it was unclear whether this was prehistoric and contemporary with Bronze and Iron Age settlement sites in the vicinity, or associated with Industrial Age mine workings. A mollusc column (1.30m in depth) was obtained in the hope that the assemblages would resolve this (Walker 2018, 145). *Xerocrassa geyeri* was found in the lower samples. There were 75 specimens confined to the lowest horizons, there being none of this species above 0.94m (Fig. 3). Two *X. geyeri* specimens were submitted to radiocarbon dating which confirmed a Bronze Age date (Table 5). The uppermost level

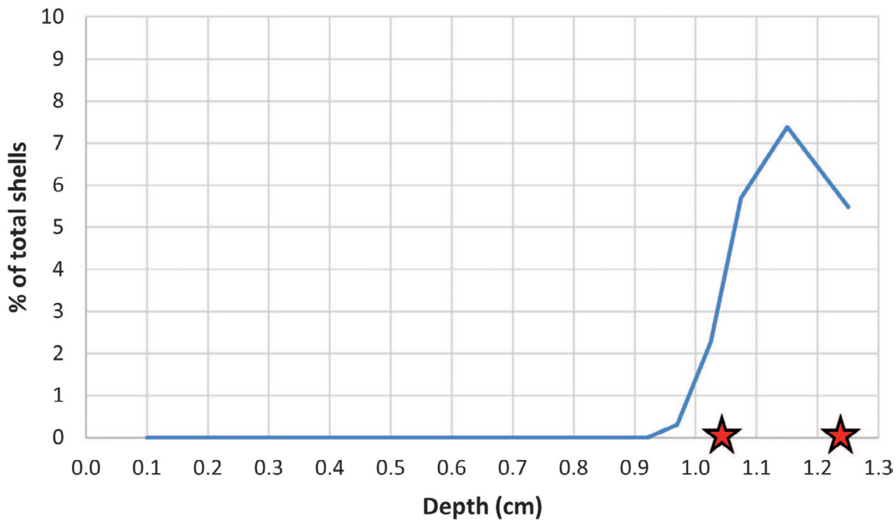

Figure 3 The proportion of *X. geyeri* in the Strap Rocks samples. The stars show the depths from which the molluscs for dating were obtained.

Table 5 Radiocarbon dates for the Strap Rocks molluscs.

Lab. number	Species	Depth (m)	$\delta^{13}C$	Radiocarbon date (BP)	Calibrated date (2σ)
OxA-28971	*Xerocrassa geyeri*	1.00–1.05	-6.23‰	3290±29	1635–1500 cal BC
OxA-28970	*Xerocrassa geyeri*	1.20–1.30	-6.53‰	3650±29	2135–1940 cal BC

at which the wall stones were encountered in the mollusc column was at 1.05m, clearly indicating the presence of early Bronze Age field walls on the south side of Gwithian Bay (Fig. 1).

It is not possible to determine whether these dates have been influenced by old carbon, as no living shells exist for dating. The dates shown in Table 5 suggests its presence at Strap Rocks as late as the early Bronze Age, but if these were affected by old carbon then this would bring its persistence even later, perhaps into the middle Bronze Age.

What is not explained is why this species should have survived into the Bronze Age at Gwithian, when it appears to have become extinct elsewhere in southern Britain several millennia earlier. The present-day European range of *Xerocrassa geyeri* is limited to scattered populations from eastern Spain to central Europe and Gotland in the Baltic Sea (Magnin 1993; Welter-Schultes 2012, 522), but its Pleistocene distribution is likely to have been far more extensive. Pfenniger *et al.* (2003) produced evidence that this species was capable of surviving in cryptic refugia during major climatic changes but with limited dispersal abilities. Could this microclimate theory explain its survival in Cornwall?

Kerney (1999, 184) stated 'In general it died out very early in the Post-glacial period as suitable open habitats were covered by forests', but did not provide any evidence. Pollen analysis at Gwithian (Batchelor 2018) indicates that the environment was relatively open in the early Bronze Age suggestive of an anthropogenically modified landscape. However, there is no evidence for the local environment in the Mesolithic (despite much evidence locally of human activity) and Neolithic, or whether tree cover was extensive in this area as elsewhere. Another, rather simplistic, suggestion is that it has just not been recovered or recognised in Neolithic or Bronze Age sites outside Cornwall, but that would seem unlikely in light of the attention given to environmental analyses in recent decades.

Conclusions

The radiocarbon dating of modern terrestrial shells has highlighted the problem of the old carbon effect. While this is usually considered to be the result of ingestion of limestone, the present study implies that a discrepancy of several hundred years can be caused by molluscs obtaining carbonates with which to build their shells from older dead shells within the sediments in which they live, although the present study only obtained modern dates for *Cochlicella acuta*. It is likely that the same old carbon effect might apply to other species where there are older shells on which to browse. $\delta^{13}C$ values may reflect differences in the environment at different periods but does not help in determining whether it is necessary to apply a carbon offset to archaeological mollusc samples. What is clear is that calibrated radiocarbon dates should not necessarily be taken at face value.

Even allowing for old carbon, the introduction of *Cochlicella acuta* into Britain has been established certainly to the early Bronze Age, and perhaps as early as the late Neolithic. Whichever is correct, it is possible that the 'founder populations' of this species were in Cornwall.

With regard to *Cochlicella barbara*, it has not been possible to establish the time of its introduction to Britain; it is almost certainly prior to the 1930s and may have been several hundred years earlier.

The extinction of *Xerocrassa geyeri*, although early in the Post-glacial in most of Britain, has been shown to have been delayed until the Bronze Age at Gwithian, confirming the archaeological evidence from excavations in the 1950s and later. How it was able to survive in this very local area for millennia after its disappearance at other sites remains unanswered.

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