SUPPLEMENTARY MATERIAL

The medieval castle of Dun Aros: buildings archaeology and chronological consistency on the shores of the Sound of Mull

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ESM 1.0 – Description of NW Block Core Tumble

The large sections of collapse at Aros Castle allowed examination of cross-sectional volumes of walling to large depths, revealing various aspects of medieval masonry technique. The core masonry at Aros was examined in two main contexts. The first is within a large piece of ex-situ masonry tumble, now lying west of the west wall of the NW Block - from which it very probably derives. This masonry displays a remarkably layered cross-section of wall core, closer inspection of which revealed a number of particular characteristics:

1. The core rubble has been laid in level courses.
2. The core stones themselves are flat-laid upon their largest faces.
3. Each core course has a layer of larger stones at the bottom which make lateral contact with each other.
4. This layer of larger stones is overlaid by smaller pieces of rubble to form a level plane.
5. Vertically, there is no stone-to-stone contact between stone layers.
6. The character of the core mortar is such that this masonry could not have been grouted; the mortar is too coarse to penetrate the voids and it is generally of consistent texture without settling or 'sieving'. It was generally placed before to bed the overlaying layer of core rubble.
7. Notwithstanding 6 above, the 'perp' joints in the core rubble are generally more fine suggesting some settlement in these localised contexts.
8. Core courses in this context average 200-250mm; large core rubble stones average 150 x 200 x 250-300 flat-laid; smaller core 50-100 x 150 flat-laid; temper in mortar/limecrete up to 40mm including probable limestone kiln-relicts to 20-15mm.

This study suggests that a layer of large core rubble stones were laid on a bed of coarse mortar. More coarse mortar was poured over this layer and then smaller stones were pushed into the masonry to level. Each core course, therefore, has a bimodal character.

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ESM 2.0 – Sample Contexts

Although the long axis of the north-west building is oriented slightly SSW-NNE, for the purposes of description the building is considered N-S, with longer walls to the east and west.

The three datum levels:

- The external face of the east wall, 20mm above the top bed of the sill of the complete ground floor slit window.
- The internal face of the east wall, 3160mm above the east wall external datum.
- The external face of the west wall (see figures).

Illus S2.1 (above) - North-West Block; East Wall; Ground Floor; External Datum;

Illus S2.2 (above) - North-West Block; West Wall; Ground Floor; External Datum

ESM 2.1 - Mortar Samples

All fixed mortar samples and one loose sample were from the north-west building. Only ACM.06 was collected from the Enclosure wall as a loose sample of possible core which was representative of that within the structure.

ACM.01: North-west building; East int.; 8530 S of North int; 1300 below datum; 960 back; CORE

ACM.02: North-west building; East ext.; 3710 S of South Jamb of slit window; 850 below datum; 340 back; CORE (unconsolidated).

ACM.03: North-west building; East ext.; 4190 S of South jamb of slit window; 350 below datum; 15-45mm Back; BEDDING of same phase as ACM.02.

ACM.04: North-west building; West ext.; Level with datum; 2340 N of South ext. 1350 Back from west ext.; CORE.

ACM.05: North-west building; West ext.; loose ex-situ.

ACM.06: Enclosure wall; West ex. Loose ex-situ.

ESM 2.2 - Stone Samples

Both stone samples were ex-situ but from contexts associated with the north-west building.

ACM.S 1: East wall; internal face; 15.7 south of internal face of north wall; 350 below datum; 100mm back (detached piece of larger in-situ undressed face stone).

ACM.S2: ex-situ loose of masonry in west (illus 9).

ESM 2.3 - Aggregate Samples

Both beach aggregate samples were collected from the literal cells north-east of the castle site in adjacent contexts at NM 56329 45032 and NM 56324 45060.

ESM 2.4 - MERLF Samples

All MERLF samples were from the north-west building and are listed below.

Code	Wall	Elev.	Laterial Pos./mm	Height/mm	Depth/mm	Context
ACM.A	W	EXT	2760 N of SW EXT	510 below datum	1270 back	CORE
ACM.B	W	EXT	1920 N of S EXT	470 below datum	1180 back	CORE
ACM.C	W	EXT	8700 N of S EXT	1410 above datum	1530 back	CORE
ACM.D	W	EXT	14860 N of S EXT	740 above datum	445 back	CORE
ACM.E	W	EXT	11860 N of S EXT	1980 above datum	755 back	CORE

ACM.F CORE	E	EXT	8270 S of N EXT	960 above datum	700 back	
ACM.G CORE	E	EXT	10900 S of N EXT	810 above datum	810 back	
ACM.H CORE	E	EXT	10920 S of N EXT	720 above datum	810 back	
ACM.I	E	INT	7940 S of N INT	20 below datum	480 back	CORE
ACM.J CORE	E	INT	8130 S of N INT	180 below datum	480 back	
ACM.K CORE	E	INT	7780 S of N INT	LEVEL with datum	460 back	
ACM.L CORE	E	INT	19400 S of N INT	730 below datum	280 back	
ACM.M CORE	E	INT	20900 S of N INT	270 below datum	1310 back	
ACM.N CORE	E	INT	20570 S of N INT	1180 below datum	530 back	
ACM.O CORE	E	EXT	3640 S of S jamb	310 below datum	460 back	
ACM.P CORE	LARGE LOOSE EX-SITU CHUNK OF MASONRY TO W					

ESM 3.0 – Thin Section Descriptions

A single thin section was prepared from all samples except mortar sample ACM.01, from which two thin sections were prepared (ACM.01a and ACM.01b)

ESM 3.1 - Mortar Samples

ACM.01a

General Description – 44 x 20mm section dominated by a single subrounded fine-textured blue coloured clast, with longitudinal lenses and some veining. A composite material included with a poorly-sorted mixture of grains survives along one edge to 15 x 2mm.

Carbonate Inclusions – ACM.01a is dominated by a subrounded geogenic polycrystalline clast measuring 44 x 20mm. This clast presents a generally fine-textured fabric dominated by inequidimensional elongate calcite crystals grading up to 0.075mm, with high birefringence, strong cleavage and straight crystal separated by abundant triple-point junctions. This homogeneous fabric is included with a low concentration of quartz and mica intraclasts to 0.05mm, with lenses of more coarse Quartz, calcite and mica up to 0.3mm oriented parallel to the long axis of the main clast, undulating lenses of mica/clay to 1.5mm+, and variously angled veins of more coarse (sparry) calcite up to 1.0mm wide. The calcite veins display evidence of alteration which includes loss of crystal boundaries, cleavage and birefringence, and increased micritization producing a brown cryptocrystalline carbonate.

The composite material in this section is supported by a dark brown carbonate matrix. No biogenic (shell) material was noted.

Non-calcareous Inclusions - The composite material in section ACM.01a contains a poorly-sorted mixture of non-calcareous lithic grains grading up to 2mm diameter. This mixture is dominated by rounded to subrounded grains of basalt, dolerite and gabbro, with more minor subrounded grains micaceous quartzose and quartzofeldspathic (granite?) clasts grading to 2mm, and monomineralic grains of these rocks with subangular monomilleric quartz (1mm) and clinopyroxene.

Carbonaceous Inclusions – None noted.

ACM.01b

General description – Large section measuring 48 x 21mm. This section presents a composite material composed of a fine brown-coloured carbonate matrix supporting a poorly-sorted mixture of calcareous, non-calcareous and carbonaceous inclusions grading up to 5mm.

Carbonate Inclusions – ACM.01b contains a moderate-high concentration of elongate subrounded to irregular geogenic carbonate grains grading up to 5mm. Excepting rare fragments of polycrystalline clasts composed of fine calcite crystals with surviving high birefringence (similar to the main clast in ACM.01a), the carbonate grains in ACM.01b generally present highly altered textures; dominated by micritic brown-coloured carbonate close to optical continuity with the supporting carbonate matrix. Core-rim textural contrasts indicate increased alteration close to grain boundaries which are correspondingly incoherent. Other relict textural features include subrounded oriented cells of micrite, elongate intraclasts

of fine quartz oriented parallel to the long axis of the grain, and probable relict veining (now filled with matrix). No fragments of biogenic (marine shell) materials were noted.

Non-calcareous Inclusions – This composite material is included with a poorly sorted mix of non-calcareous grains grading up to 5mm. This mix is dominated by a high concentration of rounded subrounded mafic grains, including basalt, dolerite and gabbro grading to 5mm. More minor subangular quartzofeldspathic grains of probable granite grading to 5mm and abundant submillimetric subangular to subrounded plagioclase, quartz and clinopyroxene.

Carbonaceous Inclusions - ACM.01b contains a low concentration of elongate, opaque, subangular and crazed probable wood-charcoal inclusions to 1.3mm long.

ACM.02 (x 1 section)

General description – ACM.02 is a large (47 x 22mm) section containing a poorly sorted composite material; composed of a brown coloured carbonate matrix supporting a poorly-sorted mixture of calcareous and non-calcareous lithic grains grading up to 12mm.

Carbonate Inclusions – AMO.02 contains a high concentration of angular to rounded polycrystalline geogenic carbonate clasts grading up to 8mm. The more angular examples present the least altered textures; including polycrystalline grains dominated by submillimetric calcite crystals with surviving high birefringence and strong cleavage. Poorly sorted intraclast distributions of subangular to subrounded quartz and mica lenses are present in undulating orientations and various (but generally low) concentrations, as are veins of carbonate to 0.4mm wide. Increased micritization at grain rims and in veins is also evident, and some very pure grains are in such close optical continuity with the supporting matrix that they can only be recognized through the absence of non-calcareous clasts in subrounded shapes to 8mm. No biogenic carbonate (marine shell) inclusions were noted.

Non-calcareous Inclusions – ACM.02 contains a poorly-sorted mixture of non-calcareous lithic inclusions grading up to 12mm. This mixture includes a high concentration of rounded and elongate subrounded basaltic grains – basalt, dolerite and gabbro – grading up to 12mm; subrounded quartzose and quartzofeldspathic (probable granite) with facetted fragmenting grain boundaries to 3mm, and abundant submillimetric grains of subangular to subrounded monominerallic quartz, plagioclase feldspar, clinopyroxene and olivine.

Carbonaceous Inclusions – No carbonaceous inclusions were noted in this section.

ACM.03 (x 1 section).

General description – This ACM.03 section is elongate and measures 40 x 12mm. The section contains a composite material composed of a brown carbonate matrix supporting a poorly sorted mixture of calcareous and non-calcareous grains grading up to 12mm.

Carbonate Inclusions – ACM.03 contains a high concentration of geogenic carbonate clasts grading up to 4mm. These are often elongate and present a range of textures including: subangular polycrystalline clasts composed of elongate calcite crystals oriented parallel to the long axis of the clast; and more altered subrounded grains dominated by brown micrite but included with elongate and oriented subangular quartz and mica intraclasts.

Non-calcareous Inclusions – This ACM.03 section contains a poorly sorted mix of non-calcareous grains grading up to 12mm. This includes: a high concentration of subrounded

mafic clasts grading up to 4.5mm, including basalt and gabbro; subrounded and often micaceous quartzose and quartzofeldspathic grains grading up to 12mm (more commonly 5mm); and a submillimetric mix of all included rock types together with monocrystalline quartz, plagioclase feldspar, clinopyroxene and amphibole.

Carbonaceous Inclusions – No carbonaceous inclusions were noted in this ACM.03 section

ACM.04 (x 1 section).

General description – The thin section measures 47 x 23mm. The material appears very porous with large transparent areas, but elsewhere displays a composite material composed of a brown carbonate matrix supporting a poorly-sorted mixture of carbonate, non-calcareous and carbonaceous inclusions grading to 14mm.

Carbonate Inclusions – This ACM.04 thin section contains a moderate to high concentration of geogenic carbonate grains grading up to 3mm. All of these often elongate clasts are generally subrounded or irregular, with variously low concentrations of fine quartz and mica intraclasts. All of these grains display evidence of textural alteration, with relict features including incoherent grain boundaries, very fine oriented cells of brown-coloured cryptocrystalline carbonate, and some carbonate veining. Probable quartz reaction-products are also present, but no biogenic carbonate (marine shell) material was noted.

Non-calcareous Inclusions – The thin section contains a poorly sorted mix of non-calcareous lithic grains grading up to 14mm diameter. This includes a high concentration of subrounded mafic grains including basalt and olivine gabbro grading up to 14mm; subrounded grains of micaceous quartzofeldspathic and quartzite/quartzose grains grading up to 3.5mm; and abundant submillimetric grains of subangular to subrounded quartz, plagioclase feldspar and clinopyroxene.

Carbonaceous Inclusions – The section contains a low concentration of opaque probable wood-charcoal inclusions.

ACM.05 (x 1 section)

General Description – ACM.05 is dominated by a single angular grey-coloured fine-textured clast measuring 19 x 18mm, which displays a well-defined rim of yellow material 1.5-2.0mm wide and veining up to 0.5mm wide. A layer of composite material, 1.1mm wide, survives on two edges of the main grain.

Carbonate Inclusions – This ACM.05 thin section is dominated by a polycrystalline geogenic carbonate clast which displays a core of fine calcite crystals with some (relict) third-order birefringence, strong cleavage and tight triple-point junctions. Sparry probable calcite veining up to 0.5mm is also visible, although the crystals here and in the clast rims have lost all birefringence and almost all crystal structure.

Non-calcareous Inclusions – The volume is too small characterise.

Carbonaceous Inclusions – None noted but the volume is very small.

ACM.06 (x 1 section)

General Description - Large thin section measuring 50 x 25mm, displaying a composite material composed of brown coloured carbonate matrix supporting a poorly sorted mixture of calcareous and non-calcareous grains grading up to 7mm.

Carbonate Inclusions – This ACM.06 thin section contains a moderate-high concentration of geogenic carbonate clasts to 3mm. This includes subangular polycrystalline fragments to 1.5mm composed of calcite crystals with surviving high birefringence, with fine quartz and probable mica intraclasts. Most of the carbonate inclusions in this section, however, are larger subrounded and highly altered grains grading up to 5mm, which are dominated by brown micrite close to optical continuity with the supporting carbonate matrix, with incoherent grain boundaries and variable concentrations of oriented quartz and quartzose lenses. No biogenic carbonate (shell) fragments were noted.

Non-calcareous Inclusions – This ACM.06 thin section contains a poorly sorted mixture of non-calcareous large rounded non-calcareous lithic clasts grading up to 7mm. This mixture contains a high concentration of rounded to subrounded mafic grains, from basalt to gabbro grading up to 6mm; subrounded irregular grains of micaceous quartzose (schist) and quartzofeldspathic (granite) grains grading up to 7mm; as well as abundant submillimetric mix of quartz, plagioclase feldspar, clinopyroxene, olivine and amphibole.

Carbonaceous Inclusions – No carbonaceous inclusions were noted in this section.

ESM 3.2 - Stone Samples

ACM.S1 (x 1 section)

General description – Large section measuring 43 x 22mm and containing a homogenous dark brown medium-textured granular material with some layering/orientation parallel with the long axis of the slide.

Magnified view in polarized light – This is a subfeldspathic sandstone. The thin section is dominated by moderately poorly sorted angular-subrounded quartz grains with more minor fractions of feldspar and mica and rare rock grain fragments (mica-schist, quartzite). Grains range from 0.05-0.6mm with low compaction. High (and locally very high) concentrations of iron oxides, clay and organic material have resulted in some matrix-supported textures.

ACM.S2 (x 1 section)

General Description **–** Large section measuring 42 x 23mm and containing a homogenous, fine-textured, transparent material.

Magnified view in polarized light – This is a porous compact quartz arenite dominated by poorly-sorted and rounded-subrounded quartz grains from 0.2 to 1.6mm in a grain-supported texture. The quartz displays undulose extinction and is often fractured. No feldspar or mica was noted and only very low levels of iron oxide are present.

ESM 3.3 - Aggregate Samples

ACM.B1 (x 1 section)

General description – This is a large thin section measuring 50 x 21mm and containing a poorly-sorted mixture of differently coloured grains grading to 12mm.

Magnified view in XPL – This ACM.B1 section is dominated by a poorly-sorted mixture of rounded to subrounded mafic grains, including basalt and gabbro grading up to 12mm, but also includes significant volumes of micaceous quartzofeldspathic (granite) and quartzose (schist) grains. Some abraded feldspar-rich cemented materials was also noted but no biogenic carbonate (marine shell) of monomineralic grains were present.

ACM.B2 (x 1 section)

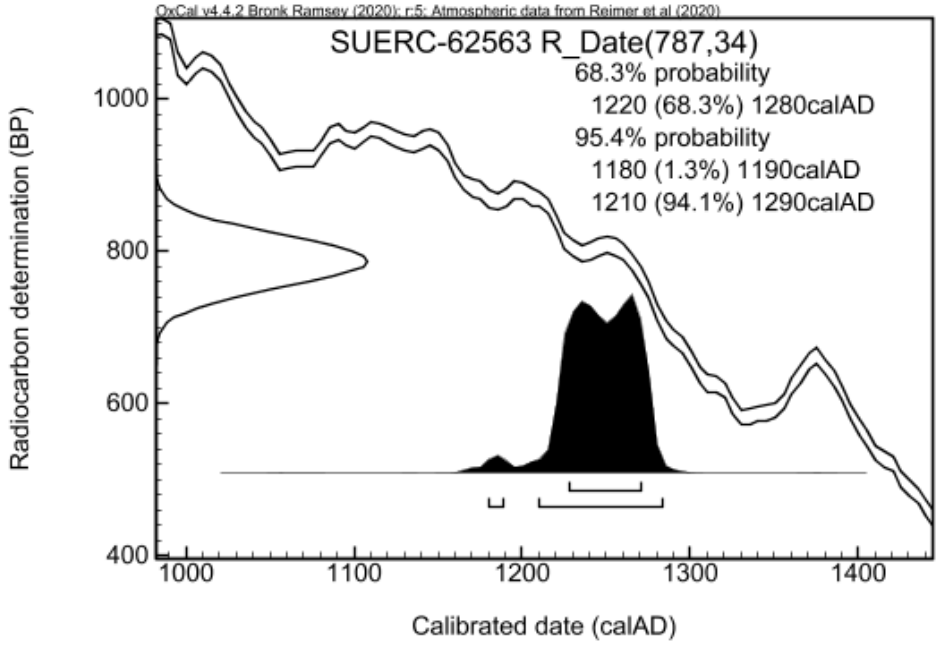
General description – This is a large thin section measuring 50 x 22mm and containing a moderately well sorted mixture of grains displaying a range of different textures and grading up to 1-2mm.

Magnified view in XPL – The section displays a well sorted mixture clasts grading to 4mm including subrounded mafic grains of gabbro, dolerite and basalt to 3mm, more irregular subangular to subrounded micaceous quartzose and quartzofeldspathic grains to 4mm, rare abraded cemented quartz-rich grains to 2mm and monomineralic quartz to 2mm. No biogenic carbonate (marine shell) material was noted.

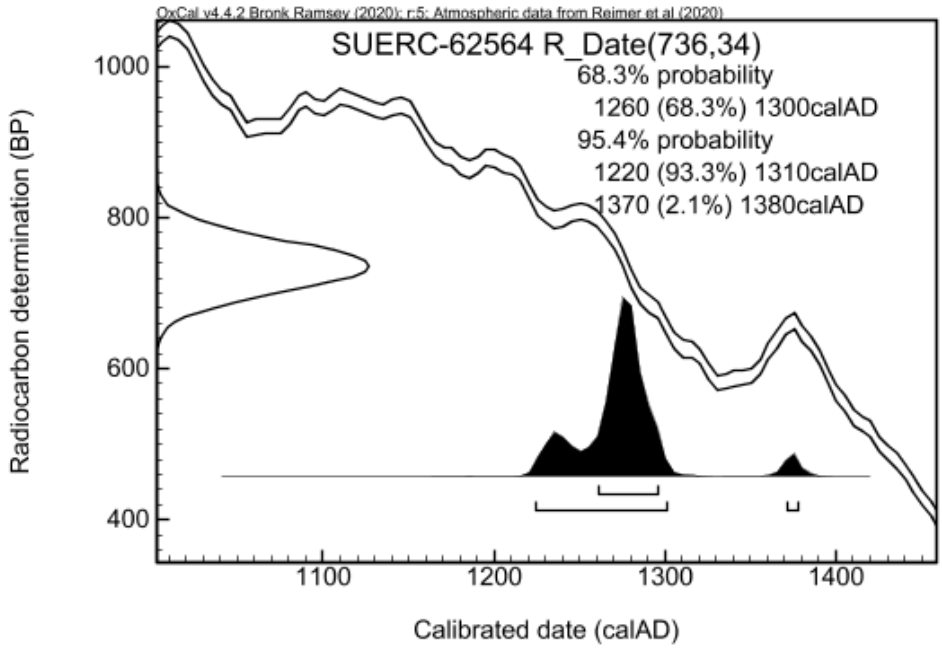
ESM 4.0 – Radiocarbon Analysis

ESM 4.1 - Radiocarbon Calibration

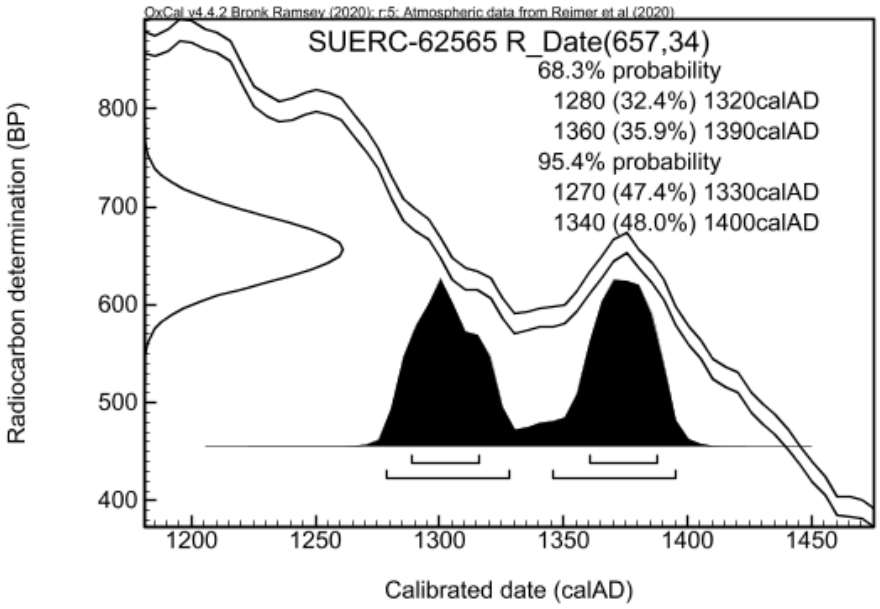
All determinations were calibrated in OxCal 4.4 (Bronk Ramsey 2009) against the IntCal.20 calibration curve (Reimer et al 2020) and results were rounded out to 10 years.



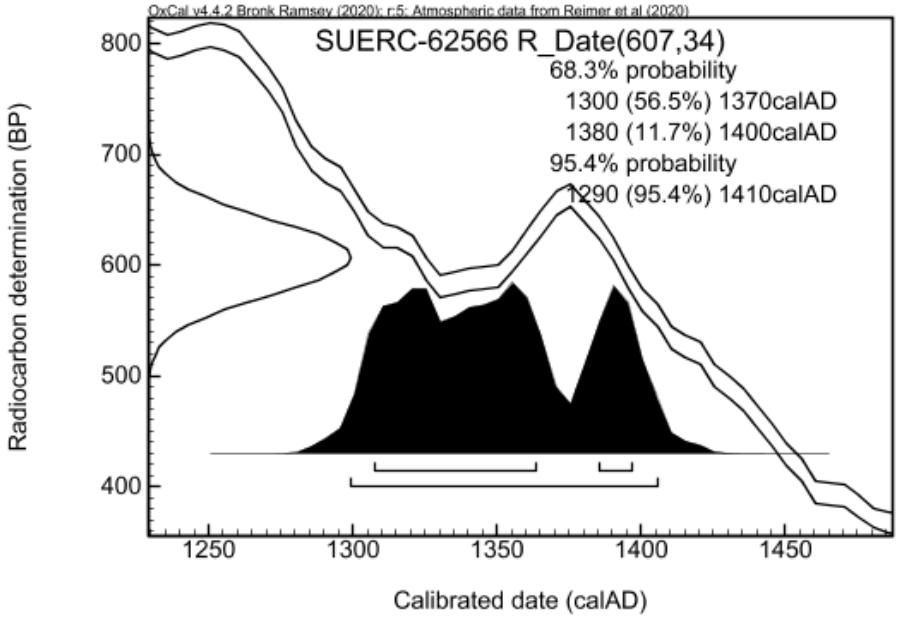
Illus S4.1 (above) – Calibration of determination SUERC-62563; Aros Castle MERLF sample ACM.A.



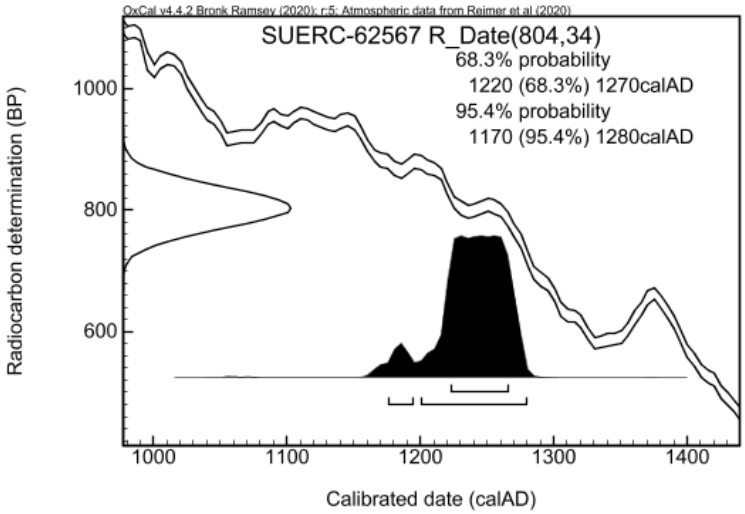
Illus S4.2 (above) – Calibration of determination SUERC-62564; Aros Castle MERLF sample ACM.B.



Illus S4.3 (above) – Calibration of determination SUERC-62565; Aros Castle MERLF sample ACM.E.



Illus S4.4 (above) – Calibration of determination SUERC-62566; Aros Castle MERLF sample ACM.M.



Illus S4.5 (above) – Calibration of determination SUERC-62567; Aros Castle MERLF sample ACM.O.

ESM 4.2 - Bayesian Modelling

Model 1 Script (Oxcal 4.4 (Bronk Ramsey 2009) against IntCal.20 (Reimer et al 2020))

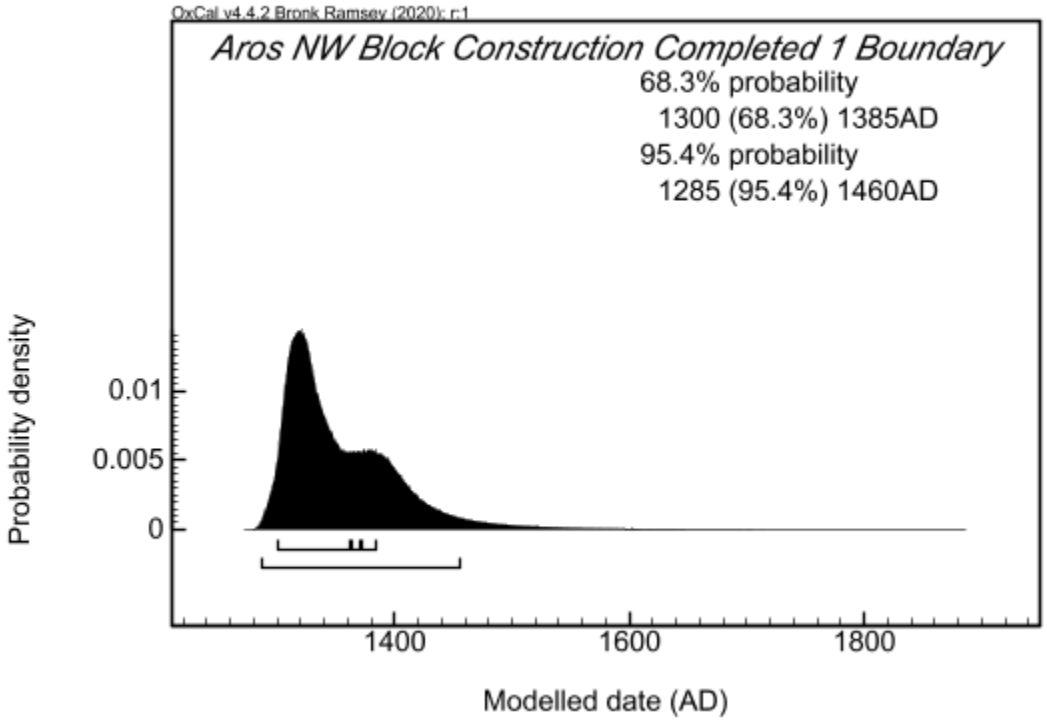
```
Options()
 {
  Resolution=1 year;
  kIterations=20000;
 };
 Plot()
 {
  Sequence("Aros Castle NW Block")
  {
   Tau_Boundary("Aros NW Block Woodland Growth");
   Phase(" Aros Castle NW Block Primary Phase ")
   {
    R_Date("SUERC-62566", 607, 34)
    {
    };
    R_Date("SUERC-62565", 657, 34)
    {
    };
    R_Date("SUERC-62564", 736, 34)
    {
    };
    R_Date("SUERC-62563", 787, 34)
    {
    };
    R_Date("SUERC-62567", 804, 34)
    {
    };
    Last("Aros NW Lowest IA MERLF 1");
   };
   Boundary("Aros NW Block Construction Completed 1");
  };
  Order("Post Elgin Bar Tracery Probability 1")
  {
   C_Date("Elgin Bar Tracery Potential TPQ", 1270, 0.05);
   Date("=Aros NW Block Construction Completed 1");
  };
  Order("Pre Fordun Chronicle Probability 1")
  {
   Date("=Aros NW Block Construction Completed 1");
   C_Date("Fordun Chronicle Potential TAQ", 1385, 0.05);
  };
 };
```

Model 1 Table of Results

Name: Aros Castle Model 1	Unmodelled (BC/AD)						Modelled (BC/AD)						Indices Amodel 77.7 Aoverall 78				
	from	to	%	from	to	%	from	to	%	from	to	%	Acomb	A	L	P	C
Sequence Aros Castle NW Block																	
Tau_Boundary Aros NW Block Woodland Growth							1215	1310	68.268949	1055	1360	95.449974					99.8
Phase Aros Castle NW Block Primary Phase																	
R_Date SUERC-62566	1305	1400	68.268949	1295	1410	95.449973	1290	1340	68.268949	1280	1400	95.449973		94			100
R_Date SUERC-62565	1285	1390	68.26895	1275	1400	95.449974	1280	1325	68.268949	1275	1395	95.449973		99			100
R_Date SUERC-62564	1235	1300	68.268949	1220	1380	95.449974	1265	1295	68.268949	1225	1380	95.449974		106.1			100
R_Date SUERC-62563	1225	1275	68.26895	1180	1285	95.449974	1235	1280	68.268949	1215	1285	95.449974		101.4			100
R_Date SUERC-62567	1220	1265	68.268949	1175	1280	95.449973	1230	1275	68.268949	1180	1280	95.449974		103.3			100
Last Aros NW Lowest IA MERLF 1							1295	1380	68.268949	1290	1395	95.449974					99.9
Boundary Aros NW Block Construction Completed 1							1300	1385	68.268949	1285	1460	95.449974					99.7
Order Post Elgin Bar Tracery Probability 1																	
C_Date Elgin Bar Tracery Potential TPQ				1265	1270	95.449974	1265	1270	68.268949	1265	1270	95.449974		70.7			100
=Aros NW Block Construction Completed 1							1300	1385	68.268949	1285	1460	95.449974					99.7
Order Pre Fordun Chronicle Probability 1																	
=Aros NW Block Construction Completed 1							1300	1385	68.268949	1285	1460	95.449974					99.7
C_Date Fordun Chronicle Potential TAQ				1380	1385	95.449974	1380	1385	68.268949	1380	1385	95.449974		70.8			100

Table S4.1 (above) – Model 1 Table of Results. All figures rounded out to 5 years.

Model 1 – End Boundary Distribution



Illus S4.6 (above) –Model 1 End Boundary Distribution (rounded out to 5 years).

Model 1 – Aros End Boundary Post Elgin Bar Tracery (1270) Probability

Order	Elgin Bar Tracery Potential TPQ	Aros NW Block Construction Completed 1
Elgin Bar Tracery Potential TPQ	0	1
Aros NW Block Construction Completed 1	0	0

Table S4.2 (above) –Table of Aros Model 1 End Boundary Post Elgin Bar Tracery Probability.

Model 1 – Aros End Boundary Pre Fordun Chronicle (1385) Probability

Order	Aros NW Block Construction Completed 1	Fordun Chronicle Potential TAQ
Aros NW Block Construction Completed 1	0	0.7619
Fordun Chronicle Potential TAQ	0.23812	0

Table S4.3 (above) – Table of Aros Model 1 End Boundary Pre Fordun Chronicle Probability.