

BROOCHES AND BRITANNIA: SUPPLEMENTARY MATERIAL

By H. E. M. Cool and M. J. Baxter

1 Introduction

The supplementary material provided here includes tabular information on the data used in the study and additional analyses that support some of the assertions made in the main text. Where appropriate we have discussed additional aspects of interpretation.

Sections, for the most part, have titles the same as, or similar to, section headings in the main text that they refer to. The exception is Section 5 which provides a brief guide to the computational procedures used. Use of the term ‘text’ in this supplement refers to the main text unless otherwise qualified. References to figures in the text and this supplement are distinguished by the use of the prefix ‘S’ for the latter.

2 Data

Table S1: Concordance between the Mackreth families and types and Groups used in the paper. The start date for each Group is shown. The abbreviations in the family field are those used in Mackreth 2011.

ID	Mackreth Family	Mackreth Type	Start date
1	Late La T	Stead 1	-70
2	Late La T	Stead 2	-50
3	Late La T	Stead 3	-50
4	Nauheim	1	-70
5	ND	1	-50
6	ND	2	45
7	ND	3	20
8	ND	4	20
9	ND	5	45
10	ND	6	1
11	D	1	-70
12	DD	1	10
13	Feugere	11a	-30
14	ROS	1	15
15	ROS	2	-5
16	ROS	4	10
17	ROS	8	10
18	ROS	9	30
19	LEO	5	30
20	LEO	6	25
21	proto LD	5.a	10
22	LD	2.a	10
23	LD	3.a	10
24	LD	7	50

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ID	Mackreth Family	Mackreth Type	Start date	
25		LD	8	50
26		C	1	10
27		C	2	35
28		C	3.1	10
29		C	3.2	10
30		C	3.3	40
31		C	4a	10
32		C	4b	45
33		C	4c	45
34		C	4d	10
35		C	5	10
36		C	6.b	65
37		C	6.e	30
38		C	7.a	40
39	AESICA		2	80
40	AESICA		3	55
41	Mil La T II		1.a	80
42	CD Ha		1.a1	55
43	CD Ha		1.a2	55
44	CD Ha		1.a3	45
45	CD Ha		1.b	70
46	CD Ha		1.c	50
47	CD Ha		1.d	75
48	CD Ha		2.a	60
49	CD Ha		2.c	45
50	CD Ha		2.d	75
51	CD Ha		2.e	55
52	CD Ha		3.a1	60
53	CD Ha		3.a2	75
54	CD Ha		3.b	50
55	CD Ha		4.b	60
56	CD RH		1	55
57	CD RH		3	50
58	CD RH		4	55
59	CD RH		5	45
60	CD RH		6	50
61	CD RH		7	55
62	CD PH		1	60
63	CD PH		2	50
64	CD PH		3	65
65	CD PH		4.a	75
66	CD PH		4.b	85
67	CD PH		4.c	85
68	CD PH		4.d	85
69	CD PH		4.e	100
70	CD PH		4.f	85
71	CD PH		4.i	65
72	CD PH		5.a	65
73	CD PH		5.b	75
74	CD PH		5.d	70
75	CD PH		6.a	50
76	CD PH		6.b	55
77	CD PH		7	60
78	CD PH		8	85
79	CD H		1	85

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Table S1 – *Continued from previous page*

ID	Mackreth Family	Mackreth Type	Start date
80	CD H	3	50
81	CD H	4	50
82	CD H	5	75
83	CD H	6	85
84	CD H	7a	55
85	CD H	7b	70
86	CD H	8	85
87	CD H	9	75
88	CD H	10	45
89	CD H	11	65
90	CD H	12	65
91	CD H	13	85
92	CD H	15	85
93	CD H	16	55
94	CD H	17	85
95	CD H/PH	1	115
96	CD H/PH	2	125
97	Proto HDST	1.b	50
98	Proto HDST	1.d	70
99	Proto HDST	1.e	60
100	Proto HDST	1.f	80
101	Proto HDST	1.g	80
102	Headstud	2	65
103	Headstud	3	55
104	Headstud	4	85
105	Headstud	5	85
106	Headstud	6	80
107	Headstud	8	80
108	Headstud	9	75
109	Headstud	10	80
110	Headstud	11	75
111	WROX	1.a	115
112	WROX	1.b	110
113	WROX	1.c	110
114	CD H/PH 1	1	75
115	TR	1.a	85
116	TR	1.b	80
117	TR	1.2a	115
118	TR	1.2b	75
119	TR	1.2c	110
120	TR	1.3a	85
121	TR	1.3b	80
122	TR	1.5	115
123	TR	2.1	120
124	TR	2.2g	150
125	TR	3.1a	95
126	TR	3.1b	110
127	TR	3.2	110
128	TR	4.1a	80
129	TR	4.1b	80
130	Alesia-Auc	1	-30
131	AVCISSA	all	0
132	HOD HILL	1	35
133	HOD HILL	2	35
134	HOD HILL	3	35

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Table S1 – *Continued from previous page*

ID	Mackreth Family	Mackreth Type	Start date
135	HOD HILL	4	35
136	HOD HILL	5	35
137	HOD HILL	6	35
138	HOD HILL	7	35
139	HOD HILL	8	35
140	HOD HILL	9	35
141	HOD HILL	10	35
142	HOD HILL	12	35
143	HOD HILL	13	105
144	DURO	1	45
145	DURO	3	-20
146	DURO	5	45
147	DURO	6	35
148	DURO	7	5
149	DURO	8	55
150	AUGEN	1	55
151	PAN	all	65
152	Plate	1	145
153	Plate	2.a	140
154	Plate	2.b	175
155	Plate	2.c	160
156	Plate	2.d	150
157	Plate	2.e	125
158	Plate	2.f	150
159	Plate	2.g	160
160	Plate	3.a	200
161	Plate	3.b	190
162	Plate	4	175
163	Plate	5	120
164	Plate	6	95
165	Plate	7	125
166	Plate	8	125
167	PL CONT	1	65
168	PL CONT	2.a	85
169	PL CONT	2.b	70
170	PL CONT	2.c	125
171	PL CONT	2.d	65
172	PL CONT	2.e	75
173	PL CONT	4	135
174	PL CONT	5	175
175	PL CONT	6	185
176	PL CONT	7	170
177	PL CONT	8	110
178	PL CONT	9	80
179	PL CONT	10	150
180	PL CONT	11	150
181	PL CONT	12	150
182	PL CONT	13	100
183	PL CONT	14	80
184	PL CONT	15	60
185	PL CONT	16	85
186	PL CONT	17	80
187	PL CONT	18	105
189	PL CONT	20	35
190	PL CONT	21	30

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Table S1 – *Continued from previous page*

ID	Mackreth Family	Mackreth Type	Start date
191	PL CONT	22	10
192	PL CONT	23	45
195	Object	1.1	110
196	Object	1.2	115
197	Object	2.1	275
198	Object	4.a	155
199	Object	4.b	150
200	Object	6.a	150
201	DRAG	3	95
202	KNEE Br	1.a	180
203	KNEE Br	1.b	140
204	KNEE Br	2.a	140
205	KNEE Br	2.b	150
206	KNEE Cont	3	150
207	Almgren 101	a-c	110
208	Proto CR	1	200
209	Proto CR	2	170
210	Proto CR	3	210
211	CR	2.ad	215
212	CR	3.1 K1	290
213	CR	3.2 K2	310
214	CR	3.3 K3	340
215	CR	3.4 K4	350
216	CR	3.5 K5	370
217	CR	3.6 K3	400
219	PEN	c1a	50
220	PEN	c2a	0
221	PEN	c2c	undated
222	PEN	c2d	undated
223	PEN	f1	undated
224	PEN	f2	undated
225	PEN	k1b	75
226	PEN	k2	undated
227	PEN	k3	undated
228	PEN	k4	45
229	PEN	k5	45
230	PEN	6	undated
231	PEN	7	undated

Table S2: The data arranged by Group and Region. The regions are EA = East Anglia, N = North, S = South, EM = East Midlands, WM = West Midlands, SW = South-West.

Group	S	SW	EA	EM	WM	N	Total
1	35	8	7	6	0	0	56
2	14	0	2	5	0	0	21
3	40	18	7	13	1	1	80
4	31	8	10	12	3	0	64
5	53	8	16	11	2	0	90
6	53	17	3	2	2	0	77
7	218	37	30	43	11	4	343
8	59	44	8	8	4	0	123
9	7	16	3	1	1	0	28
10	32	11	2	4	2	0	51
11	22	8	8	2	0	0	40

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Table S2 – *Continued from previous page*

Group	S	SW	EA	EM	WM	N	Total
12	98	55	16	43	17	8	237
13	7	11	4	3	0	0	25
14	26	3	9	7	3	0	48
15	24	1	6	3	0	0	34
16	57	5	11	3	0	1	77
17	40	4	6	9	1	0	60
18	14	6	5	6	0	0	31
19	28	4	25	11	1	0	69
20	13	1	3	0	0	0	17
22	84	13	60	25	2	3	187
23	35	3	14	15	4	0	71
24	12	3	6	2	1	0	24
25	12	6	5	0	0	0	23
26	29	2	13	5	4	0	53
27	108	24	38	30	4	4	208
28	47	8	21	19	2	0	97
29	12	5	8	14	2	0	41
30	20	4	20	21	2	2	69
31	13	6	6	4	1	0	30
32	21	10	2	11	0	0	44
33	12	9	3	3	0	0	27
34	73	10	11	16	0	2	112
35	41	8	7	4	4	0	64
36	27	1	1	1	0	0	30
37	13	3	2	3	0	0	21
38	52	4	11	20	3	0	90
39	2	0	49	1	1	1	54
40	12	13	7	8	8	3	51
41	9	3	4	0	5	2	23
42	47	3	40	9	2	1	102
43	34	4	19	14	1	0	72
44	32	5	13	4	0	0	54
45	15	1	6	4	1	0	27
46	26	1	11	4	0	0	42
47	7	1	13	5	1	0	27
48	42	0	49	5	0	1	97
49	33	0	14	4	0	1	52
50	16	6	12	3	0	0	37
51	13	3	4	12	3	0	35
52	6	10	5	4	0	0	25
53	6	15	3	1	2	0	27
54	12	29	0	0	0	0	41
55	14	2	10	6	1	1	34
56	9	3	93	6	3	0	114
57	12	7	51	5	0	0	75
58	11	8	46	6	2	1	74
59	2	2	36	6	0	0	46
60	0	2	25	0	0	0	27
61	3	0	35	1	0	0	39
62	1	15	1	4	8	1	30
63	8	30	0	2	18	1	59
64	4	19	1	3	21	1	49
65	1	4	0	4	11	3	23
66	3	4	0	8	15	1	31
67	3	4	0	2	11	1	21

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Table S2 – *Continued from previous page*

Group	S	SW	EA	EM	WM	N	Total
68	2	1	0	3	13	1	20
69	3	1	2	3	12	1	22
70	2	6	2	4	4	3	21
71	1	7	1	1	10	1	21
72	4	31	3	6	17	1	62
73	11	42	2	4	6	1	66
74	2	4	2	4	8	1	21
75	4	4	25	11	0	0	44
76	3	7	24	25	7	2	68
77	3	8	1	1	8	1	22
78	13	21	1	1	2	1	39
79	6	2	37	13	2	0	60
80	8	25	38	8	2	1	82
81	5	15	28	41	3	3	95
82	7	16	15	26	8	0	72
83	7	0	21	45	5	0	78
84	1	4	6	9	0	1	21
85	3	0	11	14	1	10	39
86	0	0	26	12	0	1	39
87	0	1	6	13	0	0	20
88	4	85	3	2	1	0	95
89	1	12	0	1	0	0	14
90	13	61	1	1	0	0	76
91	2	20	0	3	0	1	26
92	4	41	0	0	2	1	48
93	2	35	1	0	0	0	38
94	1	6	3	9	1	11	31
95	4	23	1	2	2	1	33
96	9	37	2	4	6	0	58
97	2	9	0	0	0	0	11
98	2	11	0	0	0	0	13
99	0	13	2	0	0	0	15
100	3	18	0	0	0	0	21
101	1	7	0	0	0	0	8
102	11	4	11	27	11	3	67
103	9	3	6	9	5	11	43
104	3	1	11	9	3	4	31
105	7	7	17	12	6	13	62
106	5	7	13	12	2	9	48
107	5	3	7	7	4	8	34
108	3	7	4	4	2	13	33
109	4	2	5	9	1	10	31
110	3	3	0	7	4	12	29
111	2	1	1	2	5	5	16
112	2	6	2	8	6	9	33
113	8	8	2	4	5	3	30
114	1	25	4	4	1	1	36
115	5	4	29	11	6	54	109
116	7	6	17	12	2	14	58
117	0	1	2	0	6	6	15
118	10	8	18	9	5	18	68
119	0	11	0	8	13	6	38
120	7	33	1	8	9	0	58
121	1	22	2	6	7	6	44
122	2	0	1	7	0	8	18

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Table S2 – *Continued from previous page*

Group	S	SW	EA	EM	WM	N	Total
123	0	1	1	8	7	4	21
124	4	10	1	1	3	0	19
125	5	9	5	3	5	2	29
126	7	2	8	2	1	2	22
127	6	2	7	2	2	3	22
128	1	2	4	9	1	5	22
129	4	3	11	13	3	6	40
130	42	14	9	8	1	2	76
131	78	72	27	27	28	8	240
132	83	43	43	39	10	4	222
133	23	12	7	11	2	1	56
134	47	27	15	11	4	2	106
135	97	93	72	37	15	5	319
136	19	11	6	5	1	1	43
137	14	8	3	3	1	2	31
138	9	10	9	4	0	0	32
139	9	8	3	1	2	0	23
140	5	3	4	4	1	0	17
141	41	21	7	9	3	1	82
142	46	22	12	11	5	2	98
143	9	8	10	1	0	1	29
144	5	69	0	1	1	0	76
145	7	20	0	1	0	1	29
146	6	109	0	0	3	1	119
147	1	16	0	0	0	0	17
148	19	82	2	5	0	0	108
149	12	8	0	5	0	1	26
150	26	7	16	15	3	4	71
151	10	2	5	2	4	2	25
152	11	15	23	4	0	15	68
153	10	4	10	0	0	5	29
154	4	11	18	7	0	3	43
155	4	3	8	2	0	2	19
157	6	1	4	1	0	1	13
159	11	11	21	8	6	19	76
160	19	14	30	12	3	10	88
161	40	18	68	16	11	16	169
162	7	2	2	2	0	0	13
163	7	16	9	9	2	2	45
164	14	8	53	8	3	12	98
165	6	5	18	4	3	7	43
166	6	3	4	4	2	2	21
167	24	7	21	3	1	2	58
168	8	1	9	4	1	0	23
169	5	1	10	0	0	0	16
170	11	7	8	2	0	0	28
171	6	3	12	1	0	0	22
172	9	3	10	1	0	0	23
173	6	6	8	2	3	7	32
174	1	0	2	1	0	0	4
175	12	6	16	0	0	3	37
176	21	11	9	4	2	7	54
177	9	8	11	3	3	6	40
178	6	10	8	3	3	6	36
179	3	1	1	0	1	0	6

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Table S2 – *Continued from previous page*

Group	S	SW	EA	EM	WM	N	Total
180	2	0	0	0	1	0	3
181	2	0	0	1	0	0	3
182	2	3	2	2	1	4	14
183	1	3	3	1	2	0	10
184	2	0	0	2	2	0	6
185	4	1	6	5	0	1	17
186	6	2	5	2	0	0	15
187	3	6	0	1	1	0	11
189	59	21	28	11	2	4	125
190	1	1	0	0	0	0	2
191	3	0	0	0	0	0	3
192	16	3	5	11	0	0	35
195	12	5	10	2	3	3	35
196	10	7	7	0	0	5	29
197	3	11	23	2	2	2	43
198	8	6	10	7	1	2	34
199	5	3	2	2	1	5	18
200	4	4	7	0	1	3	19
201	7	5	12	7	2	59	92
202	15	6	7	6	4	7	45
203	6	1	6	7	1	5	26
204	3	0	5	0	6	7	21
205	1	15	3	5	2	19	45
206	16	6	20	9	2	23	76
207	14	7	12	8	7	5	53
208	9	2	14	2	0	15	42
209	10	3	4	1	0	11	29
210	9	5	15	3	0	19	51
211	33	11	19	8	1	33	105
212	7	0	3	2	1	7	20
213	6	2	5	1	1	3	18
214	3	1	3	1	3	3	14
215	12	6	8	2	5	5	38
216	3	5	5	0	2	0	15
217	7	2	4	2	2	0	17
219	5	11	1	4	4	3	28
220	31	12	33	33	0	3	112
221	3	1	5	14	0	0	23
222	39	11	26	13	2	3	94
223	21	52	4	17	11	3	108
224	4	34	6	6	10	2	62
225	3	7	1	5	0	9	25
226	7	5	2	20	5	29	68
227	7	11	2	3	1	34	58
228	7	10	0	7	9	4	37
229	5	4	0	2	3	2	16
230	20	34	9	12	3	14	92
231	6	27	0	7	7	8	55

Table S3: Regional counts of late Iron Age and Roman brooches by TPQ and period. PEN refers to the undated penannular brooches which cannot be assigned to a period. The regions are EA = East Anglia, N = North, S = South, EM = East Midlands, WM = West Midlands, SW = South-West. The periods are IA = Iron Age, AT = Augusto-Tiberian, CN = Claudio-Neronian, FL = Flavian, TH = Trajanic-Hadrianic, AS = Antonine-Severan, L = Late.

TPQ	S	SW	EA	EM	WM	N	Period
-70	88	24	25	20	3	0	IA
-50	107	26	25	29	3	1	IA
-30	49	25	13	11	1	2	IA
-20	7	20	0	1	0	1	IA
-5	24	1	6	3	0	0	IA
0	141	95	62	64	30	11	AT
5	19	82	2	5	0	0	AT
10	532	119	173	157	37	14	AT
15	26	3	9	7	3	0	AT
20	277	81	38	51	15	4	AT
25	13	1	3	0	0	0	AT
30	56	14	32	20	1	0	AT
35	561	319	247	176	50	26	AT
40	72	8	31	41	5	2	CN
45	203	339	82	54	20	8	CN
50	106	142	190	77	28	8	CN
55	182	98	297	119	34	24	CN
60	68	48	68	22	19	4	CN
65	74	146	55	45	64	10	CN
70	27	17	29	22	10	11	FL
75	106	140	89	90	53	58	FL
80	57	94	130	79	35	70	FL
85	73	145	161	142	63	89	FL
95	26	22	70	18	10	73	FL
100	5	4	4	5	13	5	TH
105	12	14	10	2	1	1	TH
110	58	49	52	37	40	37	TH
115	18	32	12	11	13	25	TH
120	7	17	10	17	9	6	TH
125	38	53	36	15	11	10	TH
135	6	6	8	2	3	7	TH
140	19	5	21	7	7	17	TH
145	11	15	23	4	0	15	AS
150	37	39	34	18	11	50	AS
155	8	6	10	7	1	2	AS
160	15	14	29	10	6	21	AS
170	31	14	13	5	2	18	AS
175	12	13	22	10	0	3	AS
180	15	6	7	6	4	7	AS

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Table S3 – *Continued from previous page*

TPQ	S	SW	EA	EM	WM	N	Period
185	12	6	16	0	0	3	AS
190	40	18	68	16	11	16	AS
200	28	16	44	14	3	25	AS
210	9	5	15	3	0	19	AS
215	33	11	19	8	1	33	AS
275	3	11	23	2	2	2	L
290	7	0	3	2	1	7	L
310	6	2	5	1	1	3	L
340	3	1	3	1	3	3	L
350	12	6	8	2	5	5	L
370	3	5	5	0	2	0	L
400	7	2	4	2	2	0	L
PEN	107	175	54	92	39	93	-

The data in Table S3, expressed as row percentages, form the basis of Table 1 in the text.

3 Regional patterns of use through time

This section provides supporting evidence for assertions made in the the text. Additional comment on some aspects of the statistical techniques is provided.

Correspondence analyses

Correspondence analysis plots, of the kind illustrated in FIG. 4 were used extensively for data exploration, and guided many of the choices made about subsequent methods of analysis and presentation. FIG. S1 shows the results of the initial correspondence analyses undertaken using the data of Table S3. The six regional categories used were determined after undertaking a correspondence analysis based on a finer sub-division of 12 regions, and amalgamating sub-regions whose markers plotted closely together.

The plot based on the first two axes is notable for the three outliers in the lower-left quadrant that pull the South-West away from the other regions; if these are omitted, as in FIG. 4 in the text, the South-West is much less distinctive. As previously, the third axis pulls East Anglia away from other regions. The main interpretation, that the South is ‘early’ and the North ‘later’, with other regions intermediate, is unaffected.

It was noted in the text that if the undated penannular Group was added to FIG. 4 it had a distinctly later ‘flavour’, biased away from the South and East Anglia and more towards the North. The evidence for this is provided in FIG. S2 where the Group is plotted as a solid red circle.

The interpretation outlined in the text need not be repeated here. Unless otherwise stated the density analyses described in the text and below were undertaken omitting the undated penannular Group. Adding this Group, with a range of assumed TPQs and use-lives, only made any visible difference to the patterns observed if a very early

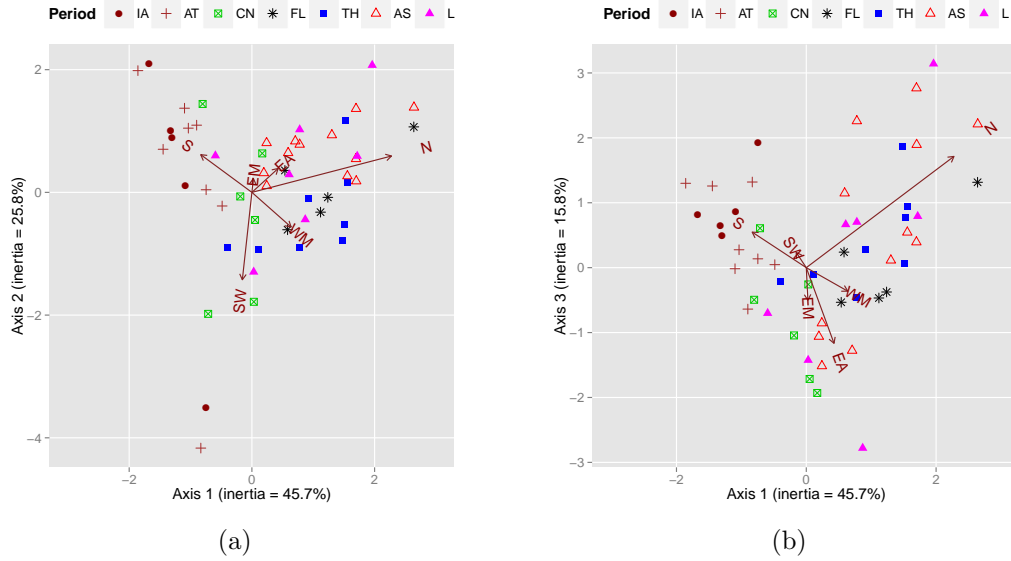


FIG. S1: A correspondence analysis of Table S3. Plots are labelled by period, IA = Iron Age, AT = Augusto-Tiberian, CN = Claudio-Neronian, FL = Flavian, TH = Trajanic-Hadrianic, AS = Antonine-Severan, L = Late.

TPQ and short use-life was assumed. FIG. S2 suggests that such an assumption is quite untenable on statistical as well as archaeological grounds.

Density analysis

The ‘density analysis’ discussed in this section refers to the kernel density estimates (KDEs) used to visualise the temporal distribution of brooch loss across regions. In the text FIGS. 5 and 6 are the examples of such analyses. They provide a more nuanced display of regional differences in the temporal distribution of brooch use than correspondence analysis, allowing for a use-life. Assumptions have to be made about the use-life and the pattern of brooch loss; a 100 years use-life with brooch loss peaking at and symmetrically distributed about the half-life of 50 years was assumed (i.e. $\alpha = \beta = 2$ in the beta distribution used to model random dates). We asserted that results were surprisingly insensitive to these assumptions. This was based on extensive experimentation with different use-life and brooch loss assumptions, at the extreme allowing both to vary between Groups. Some illustrative examples are offered below to support this contention. Baxter and Cool (2016) provides a detailed account of the methodology used.

In FIG. S3 a use-life of 60 years is assumed, with brooch loss modelled using a beta distribution with $\alpha = 2$ and $\beta = 4$. In archaeological terms this models the idea that peak brooch loss occurs a quarter of the way through the use-life, or after 15 years in this example.

The interpretation of these plots is much the same as that of FIG. 5. The main difference is the appearance of two modes for the North after A.D. 150. If Table S3 is examined it can be seen that for the North, relative to the years around them, there

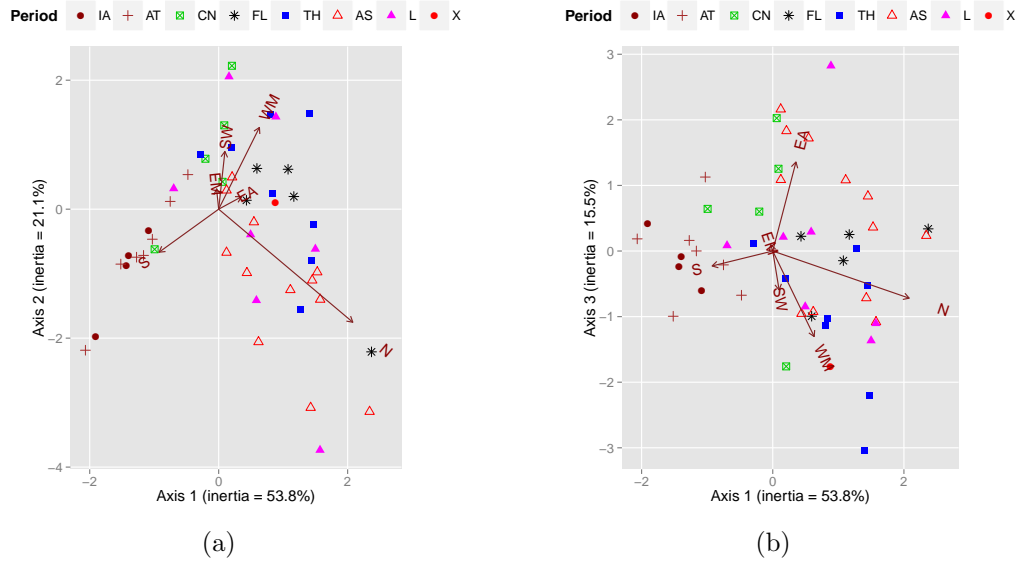


FIG. S2: A correspondence analysis of Table S3 after removing three outliers. This is FIG. 4 in the text with the addition of a supplementary point for the undated penannular brooch Group. Labelling is as in FIG. S1 with X corresponding to the undated penannular brooches, represented by a single solid red circle.

is an increase in brooch loss for Groups with TPQs about A.D. 150 and A.D. 190–215. The modelling assumptions ‘smear’ these brooches over a period of 60 years from their TPQs but with a strong bias towards loss in the early part of this period. This means there will be very little overlap in the simulated dates for the time periods involved and hence the peaking reflects the rise in brooch loss apparent for the two periods. If, as in FIG. 5, a longer use-life is assumed and dates are not biased towards an early loss then there is far more scope for dates from the earlier Groups to overlap with those from the later Groups, and the peaks coalesce and are undifferentiated.

This is an intra-regional difference not seen in FIG. 5; inter-regional comparisons are not affected. It is interesting to ask what these patterns mean. One possibility suggested by FIG. S3 is that the sharp decline in brooch use in the first half of the second century A.D. is arrested and reversed for a period in the second half of the century before experiencing another decline in the last quarter of the century and then another recovery in the early part of the third century. That is, there is a hiatus in brooch use rather than the simple decline observed in most other regions (the East Anglian ‘bump’ centered on about A.D. 200 is discussed in the text).

Another possible interpretation is that the modelling assumptions are not plausible; that it is reasonable to expect a smoother, more ‘continuous’ pattern of brooch use; and that the assumption of a longer use-life, not biased towards early loss, better reflects this, as in FIG. 5. The statistical analysis cannot arbitrate between different interpretations, but has the merit of drawing attention to (intra-regional) phenomena that arise from quite explicit assumptions about brooch lives, that invites what may or may not be a ready archaeological explanation. As noted in the text, currently while the different pattern seen in brooch decline in the north seems a real phenomenon, a simple explanation

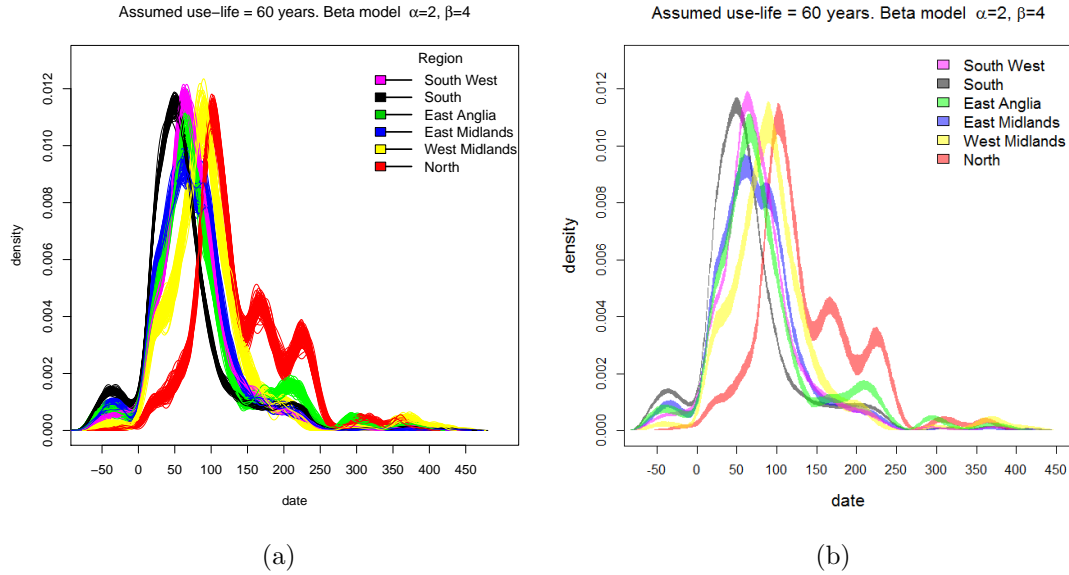


FIG. S3: Density plots of brooch use from 99 simulations assuming a use-life of 60 years, modelled using a beta distribution with $\alpha = 2$ and $\beta = 4$. The plot to the right shows an 80% ‘envelope’ for the simulated distributions in the plot to the left – see the text for details.

that is reflecting different use patterns by the military cannot be sustained.

The plot in FIG. S3b is basically the same as that of FIG. S3a, omitting the more extreme simulated results. It can be thought of as an ‘80% simulation envelope’ where the 20% most extreme simulations have been jettisoned¹. Transparent colours are used in the plot to allow for the potential of considerable overlap in the envelopes. It’s not really needed here since FIG. S3a adequately reveals patterns, but is of greater value when the simulations exhibit more variation.

Another assumption made in the above analyses is that the use-life is constant across brooch Groups, which is unrealistic. Unfortunately what would be ‘realistic’ is problematic to specify. We avoided this problem by simulating dates allowing each date-assemblage to have a different use-life. If a *maximum* use-life, M , is assumed each date-assemblage is randomly assigned a use-life between 0 and M , from a uniform distribution, retaining the same model of brooch loss (which can, however, also be varied).

FIG. S4a shows the results of allowing use-life to vary up to a maximum of 80 years, assuming brooch loss peaks half way through the use-life. This implies that for a quarter of the date-assemblages brooch loss will peak at 20 years or somewhat less. FIG. S4a shows more variability than previous plots, but stripping out the more extreme, and probably seriously unrealistic simulations, with transparency (FIG. S4b), makes it easier to see the regions of overlap. Interpretation in terms of inter-regional differences is much as before which suggests that conclusions about regional differences are robust, even in the face of what are possibly unrealistic assumptions.

¹More technically, for each region 99 sets of simulated dates are generated and plotted as kernel density estimates (KDEs). The plotted curves are derived from 512 plotting positions on the date axis. At each plotting position the 10th and 90th percentiles are obtained and these form the boundaries of the envelopes in the figure.

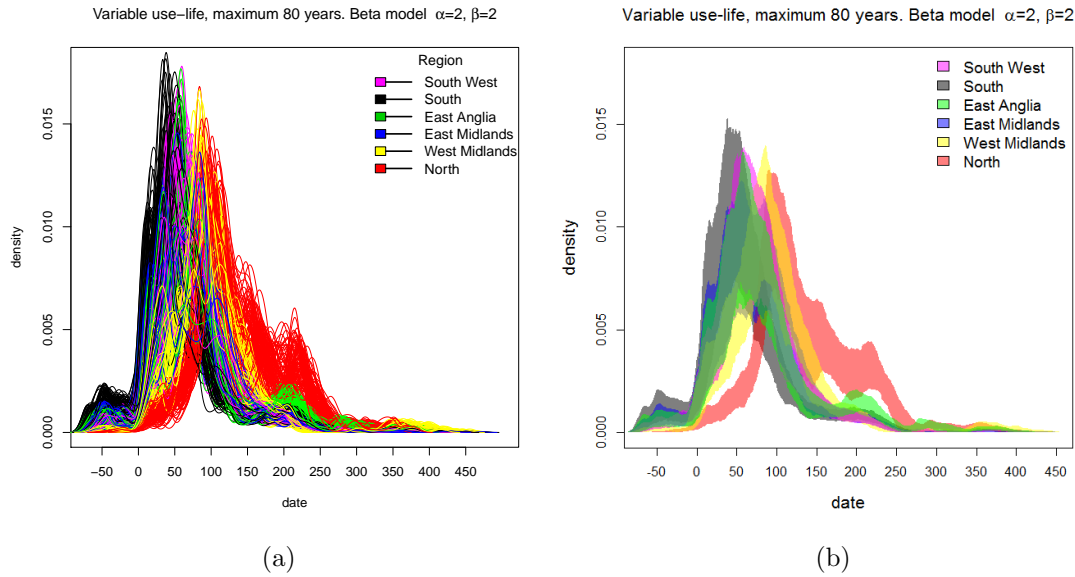


FIG. S4: Density plots of brooch use from 99 simulations assuming a variable use-life with a maximum of 80 years, modelled using a beta distribution with $\alpha = 2$ and $\beta = 2$. The plot to the right shows an 80% ‘envelope’ for the simulated distributions in the plot to the left – see the text for details.

The point to emphasise is that the differences in patterns of inter-regional brooch use that can be seen are surprisingly insensitive to the different beliefs concerning use-life and brooch loss that might reasonably be embodied in the modelling assumptions. This, in retrospect, is not too surprising. If each brooch is simply associated with the TPQ of the date-assemblage to which it belongs the picture obtained is difficult to interpret and suggests regular hiatuses in brooch use. If a use-life of more than minimal duration is assumed this allows the use-life of brooch Groups to overlap with that of others having a different TPQ, resulting in a smoother and more realistic pattern of brooch use/loss.

4 Regional patterns in the later first to second centuries

Density maps were used to explore, in more detail, regional patterns within a shorter window of time than covered by the full data set, for reasons explained in the text. FIGS. 8–10, as well as FIG. 2 are examples of density maps based on two-dimensional KDEs. Our applications use functions from the `spatstat` package for R (Section 5) which map the *intensity* of the point pattern. The intensity of a point-pattern over a region is just the number of points divided by the areal extent; to produce the maps, ‘localised’ intensities over a unit area are computed at a fine grid of pixels and it is this *intensity function* that the KDE represents.

We have, for the most part, used the defaults in the software; it is possible to vary the bandwidths used for the KDEs and this was experimented with, but one has to depart in a major way from the defaults to get a seriously different picture which either breaks up the pattern observed (under-smoothing) or obscures any pattern there may be (over-smoothing). Similarly, the default colour palette was mostly used; it shows nicely

the broad gradation in intensity as one moves about the country. The colour scheme is relative to the individual map (it is based on densities) and in comparing two maps it should be borne in mind that it cannot be used to draw conclusions about absolute densities.

FIG. 2 in the text illustrates this. There are about two and three-quarters as many rural settlement sites as there are brooch sites so, other things being equal (which they are not) the intensity of the settlement sites would be uniformly greater than that for the brooch sites. Exactly the same picture is obtained if the settlement sites are randomly sampled to get the same number as the brooch site. What is going on can be seen readily by inspecting a map of the point scatter, as in FIG. 2a (which is an obligatory starting point in any event). For example, the obviously less dense brooch site distribution in the South-West and West, compared to the settlements, is not reflected in the maps in FIG. 2b. What's really interesting about this figure, when all maps are compared, is that East Anglia in the two maps for FIG. 2b, is quite differently coloured, reflecting, in the case of the brooches, that it is the region most densely populated with brooch sites. What's striking – it is neither inevitable nor to be expected – is that inspection of FIG. 2a shows that the region is more densely populated with brooch sites, in absolute terms, than with rural settlement sites. It was this observation, possibly more than Mackreth's frequent worry about the eastern bias his data might show, that first alerted us to the fact that there might be something rather peculiar about the nature of brooch finds in the region.

We departed from the defaults when it came to looking at trumpet brooch distributions. FIG. 9 is a subset of FIG. S5, based on all 15 trumpet brooch groups for which data were available. We opted for a more 'shouty' rainbow colour palette; it makes it easier to compare a large number of maps than the more nuanced gradations of the default palette allows. A little care is needed in reading these since some of the sample sizes are quite small, so inspection of the actual point patterns (not shown) should be undertaken in conjunction with this; essentially, though, what the shouting's about – it's being trumpeted if you wish – is that trumpet brooch groups are both differently and regionally distributed.

FIG. S5 is particularly interesting because the patterns seen in the Groups not included in FIG. 9 of the main text again point to the problems of bias towards colour in metal-detecting assemblages. Groups 123 and 124 are both plain types and show no major area of density in East Anglia. All of the others are enamelled and do. This leads in the case of Group 125 (Mackreth TR Type 3.1a, also known as the Alcester brooch) to a most peculiar density pattern. These are large, handsome brooches, frequently retaining silver trim as well as enamel. They are a type that is very collectable and provide a very good example of how metal-detecting may disrupt meaningful patterns in the data.

5 Computational and related matters

Statistical analyses were undertaken using the open-source software R (R Core Team, 2015). This is an extremely powerful package for statistical analysis, greatly extended by the availability of, literally, thousands of user-contributed packages that implement less standard methodologies or enhance facilities bundled with R. The packages need to

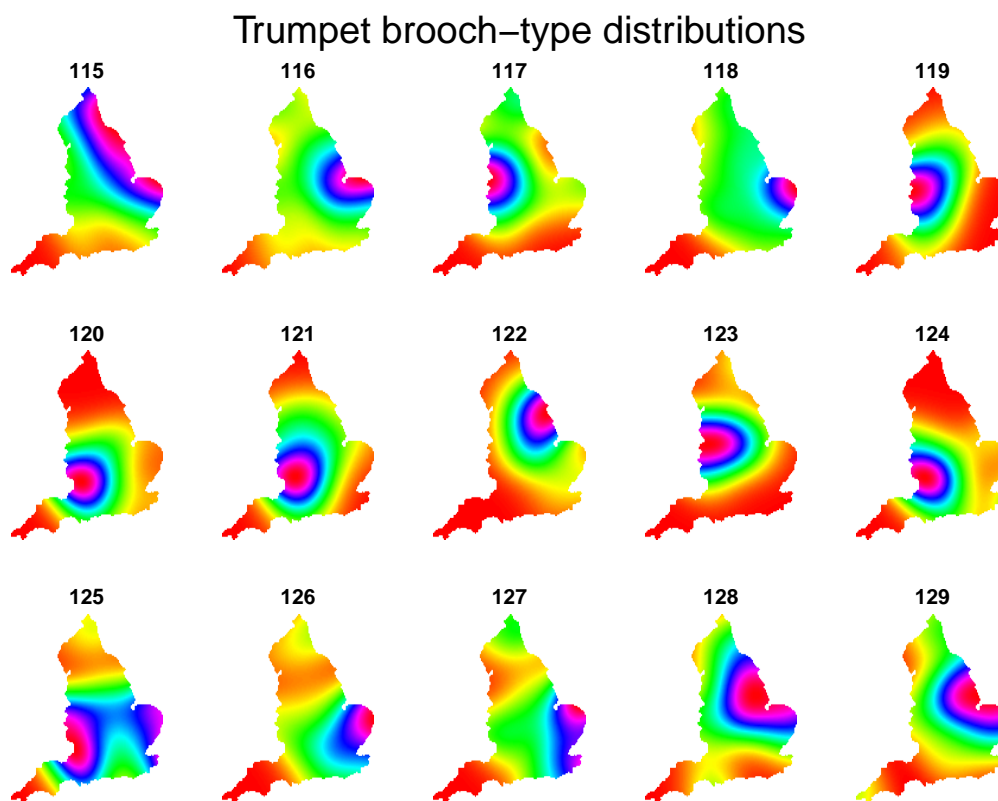


FIG. S5: Density maps showing the distribution of trumpet brooch-groups with a start date between A.D. 70 and A.D. 125 (inclusive).

be imported into R before they can be used. Baxter (2015b) is an introductory guide to the use of R for archaeological data analysis and describes how this is done. For a more detailed account of some of the methods to be described, intended for an archaeological readership, see Baxter (1994, 2003, 2015a) and Shennan (1997).

Correspondence analysis

Several packages in R are available for carrying out correspondence analysis; the `ca` function from the package with the same name was used. Create an R object, `X`, which is the 51 table of counts (Table S3), with row names given by the TPQ, and an analysis can be undertaken using `plot(ca(X))` which is more than adequate for exploratory purposes. For presentational purposes FIGS. 4, S1 and S2 were produced using the enhanced graphical facilities of the `ggplot2` package (Wickham 2009), using information

derived from the initial correspondence analysis.

Density analysis

The plots contrasting the regional patterns over time of brooch loss (FIGS. 5, 6, S3, S4) were based on kernel density estimates (KDEs) of simulated dates. The building block is the simulation model

$$D = \text{TPQ} + L \times E$$

where E is randomly sampled from a beta distribution. In R this is easily accomplished using the `rbeta` function. Thus, for the Group of 88 brooches from the South with a TPQ of 70 B.C., and an assumed use-life, L of 100 years, $\alpha = 2$ and $\beta = 5$, 88 random dates are generated using

```
D <- -70 + 88 * rbeta(88, 2, 5)
```

A KDE for the dates can be plotted using `plot(density(D, bw = 8))` where `bw = 8` is the bandwidth which controls the level of smoothing; there is a sensible default if `bw` is not specified. The value 8 was used in our analyses, chosen after some experimentation, but the choice is not that important unless one goes to extremes.

For a single simulation for the South, 3349 dates need to be generated as the TPQ varies, with assumptions about L , α and β also varied if wished. This then needs to be repeated 99 times (in our analyses) and the resultant KDEs overlaid. The process is repeated for other regions with the KDEs overlaid on the same plot. A little programming effort is needed to achieve this, which we shall not go into but which is not particularly onerous.

Cluster analysis

The hierarchical cluster analysis of FIG. 7 used the `chclust` function from the `rioja` package, based on the data as given in Table 3. The following code does this

```
D <- dist(X, method = "manhattan")
plot(chclust(D), labels = date, xvar = date, cex = .75)
```

Here `X` is the table of percentages and `date` a column containing the TPQs. The first line calculates the distances between rows `X` using Manhattan distance; the second line executes the analysis and plots the resultant dendrogram, with leaves labelled according to the values held in `date`. The `xvar = date` argument is optional, but spaces the leaves according to their actual TPQs (the default is equal spacing); `cex` is similarly optional, but controls, in the interests of readability, the size of the labels.

Density maps

The density maps in FIGS. 2, 8–10 and S5 were produced using the `spatstat` package (Baddeley *et al.*, 2015). The time-consuming aspect of an analysis is setting up the necessary data structures. These consist, in effect, of three columns of data – the coordinates of the brooch/site locations and a set of *marks* defining, for example, the brooch group or other classifying variable of interest, and a window that delineates the region within which points lie. See the references or the `spatstat` documentation for details.

We used a map of England derived, with a little effort, from David Lucy's `blighty` package. With this done things become a lot easier

Call the resultant structure `X.ppp`. If this consists of the combined brooch and rural settlement sites with the marks distinguishing between the two, `plot(split(X.ppp))` produces the upper plot in FIG. 2; `plot(split(density(X.ppp)))` produces the lower plot. For FIG. S5 the coordinates corresponded to trumpet brooch locations, marks to brooch Groups, and the additional argument `col = rainbow` was used to change the default palette.

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Barbican Research Associates
hilary@coolarchaeology.com

Nottingham Trent University (Emeritus)
michaelj.baxter@btconnect.com