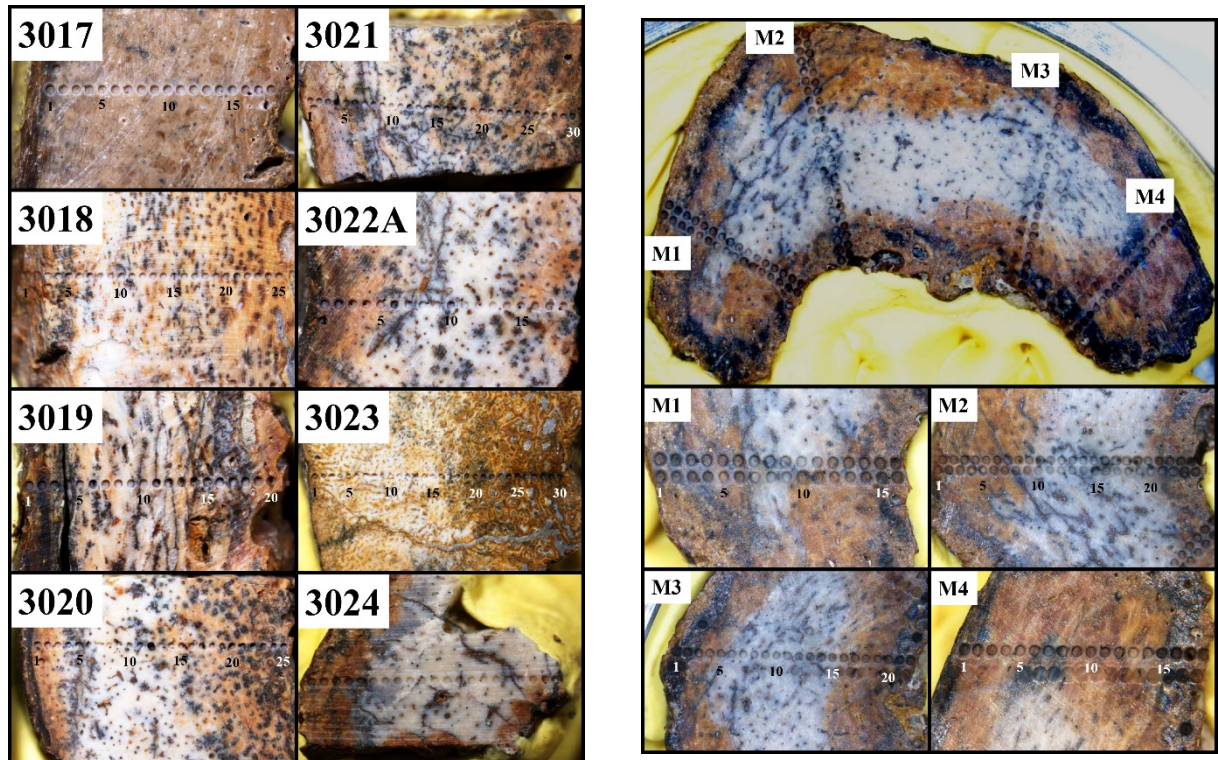




Supplementary Figure 1 | A water buffalo skull hook into a trawl-net of a fishing boat operating at the Penghu Channel in 1995 (left), and examples of large vertebrate fossils collected from the channel (right).



Supplementary Figure 2 | Photos and position of the laser spot analyses on the faunal bones (left) and hominin mandible (right) dredged from the Penghu Channel

Supplementary Table 1 | List of terrestrial vertebrates of the Penghu fauna.

REPTILIA	
Crocodylia	
	Gavialidae
	Tomistominae gen. et sp. indet.
Testudines	
	Geoemydidae
	<i>Chinemys reevesii</i>
	Trionychidae
	<i>Trionyx liupani</i>
MAMMALIA	
Primates	
	Hominidae
	<i>Homo</i> sp. indet
Carnivora	
	Canidae
	<i>Nyctereutes procyonoides</i>
	Ursidae
	<i>Ursus arctos</i>
	Hyaenidae
	<i>Crocota crocuta ultima</i>
	Felidae
	<i>Panthera tigris</i>
Artiodactyla	
	Cervidae
	<i>Elaphurus davidianus</i> (=meziesianus)
	<i>Cervus</i> cf. <i>C. hortulorum</i>
	Bovidae
	<i>Bubalus teilhardi</i>
	<i>Bubalus youngi</i>
	Suidae
	<i>Sus scrofa</i> ?
Perissodactyla	
	Equidae
	<i>Equus ferus przewalskii</i>
Proboscidea	
	Elephantidae
	<i>Palaeoloxodon huaiensis</i> ? (<i>namadicus</i> ?)

Supplementary Table 2 | Occurrence of fossil hyaenids (*Pachycrocuta* and *Crocuta*) from East and Southeast Asia.

Hyaenid taxa	Region	Locality of hyaenid fossils	Estimated age	Refs.
<i>C. crocuta ultima</i>	northern China	Wurji (Inner Mongolia)	late Late Pleistocene	1
		Gezidong cave (Liaoning)	middle Late Pleistocene	2
		Miaohoushan, Benxi (Liaoning)	142–228 ka	3
		Zhoukoudian Loc. 1 (L1-3) (Beijing)	c. 250–500 ka	4–11
	southern China	Shenxian Cave, Lishui (Jiangsu)	11.2 ka (Holocene?)	12
		Dajushan, Huainan (Anhui)	Late Pleistocene	13
		Huanglong Cave, Yunxi (Hubei)	81–101 ka	14,15
		Shuanlong Cave, Jinhua (Zhejiang)	7.815 ka (Holocene?)	16
		Tongzi (Guizhou)	113–181 or 240 ka	17–19
		Guanyindong (Guizhou)	76–115 ka	18,20
		Maba (Guangdong)	129–135 ka	21–23
		Hoshangtung, Fuming (Yunnan)	Middle Pleistocene?	24,25
	Southeast Asia	Phnom Loang (Cambodia)	late Middle Pleistocene	26,27
		Thum Wiman Nakin (Thailand)	>169 ka	26,28
		Thum Phra Khai Phet (Thailand)	late Middle Pleistocene	26,28
		Tam Hang yellow (Laos)	late Middle Pleistocene	26,28; but see 29
		Tam Hang red breccia (Laos)	late Middle Pleistocene	26,28
<i>C. honanensis</i>	northern China	Yushe (Shanxi)	Early Pleistocene	30
		Longdan, Dongxiang (Shaanxi)	Early Pleistocene	13,31
	southern China	Xin'an (= Hsing-an) (Henan)	Early Pleistocene	32,33
<i>P. brevirostris sinensis</i>	northern China	Zhoukoudian Loc. 1 (L5-11) (Beijing)	c. 278–800 ka	4–11,34,35,
		Gonwangling (Shaanxi)	late Early Pleistocene	36
		Nihowan (Shandong)	late Early Pleistocene	37
	southern China	Nanzhao (Henan)	Middle Pleistocene	38
		Huludong, Tangshan, Nanjing (Jiangsu)	127–500 or 207–417 ka	39,40
		Chaoxian (Anhui)	160–200 ka	41–43
		Hexian (Anhui)	387–437, 240–280, or 130–220 ka	44–47
		Changyang (Hubei)	194–196 or 170–220 ka	18,47–49
		Yanjinggou (=Yenchingkou) (Chongqing)	Early/Middle Pleistocene	50,51
		Luokeng, Qiujiang (Guangdong)	late Middle Pleistocene	52
	Southeast Asia	Kudung Brubus, Java (Indonesia)	700–800 ka?	53
<i>P. licenti</i>	southern China	Renzidong, Fanchang (Anhui)	early Early Pleistocene	54
		Yunxian (Hubei)	581 ka	55
		Longgudong Cave, Jianshi (Hubei)	Early Pleistocene	56
		Panxian Dadong (Guizhou)	160–250 ka?	57,58
		Liucheng (Guangxi)	940–1206 ka	25,59

Supplementary Table 3 | U/Th measurements and ages of the faunal bone samples.^a

3017											
Spot	U (ppm)	Th (ppb)	U/Th	²³⁴ U/ ²³⁸ U	²³⁴ U/ ²³⁸ U error	²³⁰ Th/ ²³⁴ U	²³⁰ Th/ ²³⁴ U error	Age (ka)	+ error	- error	
1	1.54	1.22	1259	1.2049	0.0121	0.1137	0.0078	13.14	0.93	0.92	
2	6.98	6.12	1141	1.1911	0.0039	0.0442	0.002	4.94	0.23	0.23	
3	1.49	3.58	415	1.2184	0.0106	0.3601	0.014	48.04	2.49	2.44	
4	1.08	5.07	213	1.2655	0.0151	0.125	0.0089	14.52	1.12	1.11	
5	0.62	3.72	166	1.2246	0.0157	0.1492	0.0128	17.57	1.82	1.79	
6	0.22	1.19	183	1.3341	0.0267	0.3078	0.0261	39.52	4.29	4.14	
7	0.1	2.96	34	1.3687	0.0508	0.5525	0.0765	83.97	17.53	15.4	
8	0.05	2.38	22	1.5347	0.0862	0.7012	0.1648	119.61	37.5	29.38	
9	0.07	1.92	35	1.3421	0.0588	1.0116	0.1001	301.16	321.97	105.35	
10	0.13	2.85	46	1.283	0.0383	0.4206	0.0476	58.26	6.99	6.59	
11	0.23	0.92	252	1.2207	0.0283	0.2471	0.0323	30.73	4.56	4.39	
12	0.61	1.44	424	1.1778	0.0195	0.0791	0.0107	8.98	1.22	1.21	
13	0.83	1.52	550	1.232	0.0139	0.0769	0.0085	8.72	1.06	1.05	
14	1.2	2.86	421	1.1721	0.0128	0.0553	0.0058	6.2	0.73	0.73	
15	1.44	2.48	581	1.1969	0.0107	0.0431	0.0056	4.8	0.58	0.58	
16	2.61	1.48	1755	1.1556	0.0073	0.0436	0.003	4.87	0.35	0.35	
17	2.97	1.51	1964	1.169	0.0074	0.0505	0.0031	5.65	0.36	0.36	
18	2.59	1.01	2563	1.1634	0.008	0.038	0.0032	4.23	0.36	0.36	
3018											
Spot	U (ppm)	Th (ppb)	U/Th	²³⁴ U/ ²³⁸ U	²³⁴ U/ ²³⁸ U error	²³⁰ Th/ ²³⁴ U	²³⁰ Th/ ²³⁴ U error	Age (ka)	+ error	- error	
1	15.16	1778.26	9	1.2138	0.0043	0.1293	0.0022	15.06	0.28	0.28	
2	14.87	11.81	1259	1.1762	0.004	0.0568	0.0018	6.37	0.21	0.21	
3	12.61	7.4	1704	1.1797	0.0035	0.0412	0.0021	4.59	0.24	0.24	
4	10.27	2.42	4241	1.1659	0.0044	0.0377	0.0017	4.19	0.19	0.19	
5	8.98	6.41	1399	1.1515	0.0043	0.031	0.0015	3.44	0.17	0.17	
6	8.82	4.02	2194	1.1683	0.0046	0.0346	0.0018	3.84	0.21	0.21	
7	8.67	1.9	4563	1.1564	0.0042	0.0237	0.0016	2.62	0.18	0.18	
8	8.65	4.57	1892	1.1672	0.0047	0.0222	0.001	2.45	0.11	0.11	
9	8.2	1.8	4553	1.1493	0.0053	0.0199	0.0016	2.19	0.18	0.18	
10	8.46	3.36	2516	1.1518	0.0052	0.0153	0.0014	1.69	0.15	0.15	
11	8.02	3.13	2563	1.1658	0.0046	0.0165	0.0014	1.82	0.16	0.16	
12	8.58	2.44	3522	1.1574	0.0046	0.0162	0.0013	1.78	0.14	0.14	
13	8.12	1.58	5141	1.1548	0.0041	0.0143	0.0014	1.57	0.15	0.15	
14	8.36	1.74	4811	1.1572	0.0048	0.0148	0.0013	1.63	0.14	0.14	
15	7.35	1.78	4137	1.151	0.0037	0.0127	0.0014	1.4	0.15	0.15	
16	8.22	0.97	8452	1.1452	0.0042	0.015	0.0014	1.65	0.16	0.16	
17	8.04	0.74	10895	1.1485	0.0043	0.0196	0.0011	2.16	0.13	0.13	
18	8.16	0.96	8537	1.1598	0.0041	0.0148	0.0013	1.63	0.14	0.14	
19	8.29	3.4	2433	1.1548	0.0053	0.0161	0.0012	1.78	0.14	0.14	
20	8.05	0.97	8311	1.1633	0.0048	0.0146	0.0013	1.61	0.15	0.15	
21	7.87	2.36	3336	1.1665	0.0045	0.0208	0.0013	2.3	0.15	0.15	
22	8.31	7.38	1126	1.1651	0.0056	0.021	0.0012	2.32	0.13	0.13	
23	8.69	2.87	3026	1.1512	0.0047	0.0276	0.0015	3.06	0.16	0.16	
24	9.61	8.91	1079	1.1592	0.0044	0.0492	0.0018	5.5	0.21	0.21	
25	10.41	5.84	1782	1.1726	0.0039	0.0627	0.0021	7.06	0.25	0.25	

3019

Spot	U (ppm)	Th (ppb)	U/Th	$^{234}\text{U}/^{238}\text{U}$	$^{234}\text{U}/^{238}\text{U}$ error	$^{230}\text{Th}/^{234}\text{U}$	$^{230}\text{Th}/^{234}\text{U}$ error	Age (ka)	+ error	- error
1	10.12	5.52	1835	1.1647	0.0045	0.0442	0.0017	4.93	0.19	0.19
2	8.23	2.89	2844	1.1591	0.0049	0.0429	0.0019	4.78	0.22	0.22
3	8.49	12.21	695	1.1804	0.0048	0.0484	0.0014	5.41	0.16	0.16
4	9.22	6.85	1347	1.1622	0.0045	0.0533	0.0021	5.97	0.24	0.24
5	8.96	3.18	2817	1.1556	0.0046	0.0252	0.0015	2.79	0.16	0.16
6	9.38	4.4	2132	1.1639	0.0039	0.022	0.0013	2.42	0.15	0.15
7	9.05	3.05	2969	1.1587	0.0048	0.0247	0.0013	2.73	0.15	0.15
8	9.33	8.9	1049	1.159	0.0047	0.0267	0.0012	2.95	0.14	0.14
9	9.28	2.36	3927	1.1577	0.0046	0.0307	0.0018	3.41	0.2	0.2
10	10.29	3.64	2823	1.1647	0.0041	0.0466	0.0016	5.2	0.2	0.2
11	10.54	7.01	1504	1.1643	0.0038	0.0539	0.0018	6.04	0.2	0.2
12	11.16	33.51	333	1.1689	0.0039	0.0722	0.0016	8.17	0.19	0.19
13	13.17	25.83	510	1.1729	0.0034	0.1025	0.0024	11.79	0.28	0.28
14	10.82	5.87	1843	1.1765	0.0037	0.0669	0.002	7.55	0.24	0.24
15	9.03	4.16	2173	1.1665	0.0044	0.048	0.002	5.37	0.24	0.24
16	7.94	8.96	886	1.1432	0.004	0.0433	0.002	4.84	0.22	0.22
17	8.78	33.15	265	1.1571	0.0054	0.0411	0.0022	4.58	0.26	0.26
18	8.87	6.28	1412	1.1624	0.0038	0.0436	0.0015	4.86	0.17	0.17
19	9.05	5.24	1727	1.1649	0.0041	0.0411	0.0019	4.57	0.22	0.22
20	8.8	267.73	33	1.1836	0.0063	0.0577	0.0023	6.48	0.25	0.25

3020

Spot	U (ppm)	Th (ppb)	U/Th	$^{234}\text{U}/^{238}\text{U}$	$^{234}\text{U}/^{238}\text{U}$ error	$^{230}\text{Th}/^{234}\text{U}$	$^{230}\text{Th}/^{234}\text{U}$ error	Age (ka)	+ error	- error
1	13.46	6.62	2034	1.1638	0.0046	0.033	0.0012	3.66	0.15	0.15
2	11.96	3.23	3700	1.167	0.0039	0.0226	0.0012	2.5	0.14	0.14
3	12.49	3.41	3662	1.1635	0.0039	0.027	0.0012	2.98	0.13	0.13
4	12.7	4.83	2630	1.1636	0.0037	0.0253	0.001	2.8	0.12	0.12
5	14.06	6.99	2011	1.1734	0.0037	0.0573	0.0015	6.44	0.17	0.17
6	13.46	13.63	987	1.1637	0.0037	0.0625	0.0019	7.04	0.22	0.22
7	12.06	6.16	1958	1.1662	0.0047	0.0473	0.0018	5.29	0.21	0.21
8	11.16	5.13	2174	1.1618	0.0048	0.0393	0.0018	4.37	0.2	0.2
9	10.62	17.87	595	1.1635	0.0056	0.0377	0.0013	4.19	0.16	0.16
10	10.53	18.85	558	1.163	0.0044	0.0316	0.0015	3.5	0.17	0.17
11	9.08	2.49	3654	1.163	0.0049	0.0268	0.0015	2.97	0.17	0.17
12	4.92	10.04	490	1.1596	0.0068	0.0276	0.0023	3.06	0.27	0.27
13	10.46	2.45	4263	1.1778	0.0045	0.0634	0.0018	7.15	0.22	0.22
14	14.59	7.74	1885	1.1632	0.0041	0.0939	0.0021	10.75	0.25	0.25
15	13.88	8.96	1549	1.1757	0.0035	0.0937	0.0023	10.72	0.27	0.27
16	12.54	4.87	2578	1.1601	0.004	0.0841	0.0022	9.57	0.26	0.26
17	8.7	5.43	1601	1.1658	0.0048	0.0408	0.0019	4.55	0.22	0.22
18	10.36	5.53	1874	1.16	0.0046	0.0395	0.0018	4.4	0.2	0.19
19	10.64	8.25	1289	1.1655	0.0042	0.0506	0.002	5.66	0.22	0.22
20	9.66	4.86	1986	1.165	0.0055	0.0505	0.002	5.66	0.23	0.23
21	10.53	8.07	1304	1.1543	0.004	0.0441	0.002	4.92	0.23	0.23
22	10.36	19.6	529	1.1591	0.0048	0.0416	0.0017	4.64	0.19	0.19
23	10.2	4.92	2071	1.1649	0.0049	0.0465	0.0016	5.19	0.19	0.19
24	9.43	11.59	814	1.1644	0.0047	0.0566	0.002	6.36	0.24	0.23
25	9.26	5.09	1818	1.1715	0.0052	0.0539	0.0017	6.04	0.21	0.21

3021

Spot	U (ppm)	Th (ppb)	U/Th	$^{234}\text{U}/^{238}\text{U}$	$^{234}\text{U}/^{238}\text{U}$ error	$^{230}\text{Th}/^{234}\text{U}$	$^{230}\text{Th}/^{234}\text{U}$ error	Age (ka)	+ error	- error
1	11.57	7.75	1493	1.1736	0.0037	0.1107	0.0021	12.78	0.25	0.25
2	8.82	9.3	948	1.1593	0.0044	0.0598	0.0023	6.72	0.27	0.27
3	9.04	1.8	5017	1.1753	0.0044	0.0577	0.0021	6.49	0.25	0.25
4	5.78	290.2	20	1.152	0.0052	0.1089	0.0043	12.56	0.52	0.52
5	7.39	23.87	310	1.1575	0.0053	0.0643	0.0025	7.25	0.28	0.28
6	5.98	29.01	206	1.1592	0.0057	0.0502	0.0019	5.62	0.21	0.21
7	8.4	2.38	3531	1.1527	0.0049	0.0417	0.0021	4.65	0.23	0.23
8	7.81	1.05	7431	1.1652	0.0052	0.0483	0.0018	5.4	0.21	0.21
9	8.56	3.92	2181	1.1582	0.0048	0.0389	0.0018	4.33	0.19	0.19
10	8	1.17	6847	1.1668	0.0055	0.0411	0.0016	4.58	0.18	0.18
11	8.23	1.79	4589	1.1478	0.005	0.0375	0.0017	4.17	0.19	0.19
12	8.88	3.08	2883	1.1511	0.0051	0.0396	0.0016	4.41	0.19	0.19
13	8.09	1.21	6712	1.1598	0.0048	0.0446	0.0018	4.98	0.21	0.21
14	7.33	0.44	16633	1.1585	0.0048	0.0469	0.0018	5.24	0.21	0.21
15	7.7	2.72	2830	1.1657	0.0053	0.0374	0.0018	4.16	0.22	0.22
16	7.31	24.09	303	1.1561	0.0046	0.0389	0.0022	4.33	0.24	0.24
17	7.97	38.57	207	1.1435	0.0051	0.036	0.0021	4.01	0.26	0.26
18	8	1.42	5616	1.1577	0.0048	0.0372	0.0017	4.13	0.19	0.19
19	8.01	0.11	70020	1.1643	0.0053	0.0394	0.002	4.39	0.24	0.24
20	7.69	0.69	11082	1.1556	0.0047	0.0357	0.002	3.97	0.23	0.23
21	7.78	1.75	4450	1.1571	0.0057	0.0385	0.0016	4.29	0.19	0.19
22	8.01	1.53	5250	1.1637	0.0046	0.0445	0.0015	4.96	0.17	0.17
23	7.79	1.72	4540	1.1646	0.0046	0.0412	0.0018	4.59	0.21	0.21
24	7.57	2.03	3739	1.1552	0.0042	0.0378	0.002	4.21	0.23	0.23
25	7.17	2.56	2804	1.1546	0.0054	0.0579	0.0022	6.5	0.25	0.25
26	7.7	2.95	2608	1.1564	0.0047	0.042	0.002	4.68	0.22	0.22
27	6.44	60.21	107	1.1512	0.0052	0.044	0.002	4.91	0.24	0.24
28	7.23	9.99	724	1.1524	0.0046	0.0383	0.0018	4.26	0.21	0.21
29	7.63	2.42	3155	1.1535	0.0049	0.0385	0.0018	4.29	0.21	0.21
30	7.19	2.82	2554	1.1608	0.0047	0.0382	0.0019	4.25	0.22	0.22

3022

Spot	U (ppm)	Th (ppb)	U/Th	$^{234}\text{U}/^{238}\text{U}$	$^{234}\text{U}/^{238}\text{U}$ error	$^{230}\text{Th}/^{234}\text{U}$	$^{230}\text{Th}/^{234}\text{U}$ error	Age (ka)	+ error	- error
1	9.36	17.66	530	1.1822	0.0044	0.0328	0.0018	3.64	0.2	0.2
2	9.81	6.65	1475	1.172	0.0052	0.0291	0.0016	3.22	0.17	0.17
3	10.66	5.85	1824	1.1645	0.0042	0.0289	0.0018	3.2	0.2	0.2
4	9.64	4.85	1985	1.1635	0.0036	0.0311	0.0013	3.45	0.15	0.15
5	11.31	2.53	4473	1.1696	0.0044	0.0265	0.0015	2.93	0.17	0.17
6	12.09	5.71	2116	1.1642	0.0033	0.0427	0.0012	4.76	0.14	0.14
7	11.38	5.16	2206	1.1647	0.0044	0.0574	0.0019	6.45	0.22	0.22
8	10.09	8.25	1223	1.1563	0.0041	0.0482	0.0016	5.39	0.18	0.18
9	10.18	2.57	3958	1.1622	0.0044	0.0483	0.0017	5.4	0.2	0.2
10	10.07	5.48	1839	1.1646	0.0044	0.047	0.0017	5.25	0.2	0.2
11	8.72	3.66	2386	1.1743	0.0044	0.0321	0.002	3.56	0.22	0.22
12	9.28	7.04	1317	1.1614	0.0042	0.0339	0.0019	3.77	0.22	0.22
13	8.6	5.24	1642	1.1471	0.0048	0.0287	0.0021	3.18	0.24	0.24
14	8.18	1.69	4855	1.1689	0.0048	0.0312	0.0017	3.46	0.19	0.19
15	8.78	5.2	1687	1.1645	0.0037	0.0359	0.0018	3.99	0.21	0.21
16	9	2.03	4441	1.1528	0.0052	0.0401	0.002	4.47	0.22	0.22
17	9.62	13.68	703	1.1587	0.0053	0.0561	0.0018	6.3	0.21	0.21
18	7.23	5.02	1441	1.1741	0.0067	0.064	0.0026	7.21	0.29	0.29

19	10.42	4.29	2429	1.1749	0.0045	0.0735	0.0022	8.33	0.26	0.26
20	10.32	5.31	1945	1.1716	0.0036	0.0891	0.0023	10.17	0.28	0.28
21	11.15	345.9	32	1.174	0.0039	0.1046	0.0024	12.04	0.28	0.28
22	10.48	344.63	30	1.165	0.0045	0.0984	0.002	11.29	0.24	0.24
23	9.55	10.32	926	1.1719	0.005	0.0623	0.002	7.01	0.24	0.24
24	7.34	7.7	953	1.1641	0.0044	0.0291	0.0019	3.23	0.21	0.21

3023

Spot	U (ppm)	Th (ppb)	U/Th	$^{234}\text{U}/^{238}\text{U}$	$^{234}\text{U}/^{238}\text{U}$ error	$^{230}\text{Th}/^{234}\text{U}$	$^{230}\text{Th}/^{234}\text{U}$ error	Age (ka)	+ error	- error
1	3.78	5.5	688	1.4653	0.0075	0.1335	0.0044	15.53	0.55	0.55
2	4.03	0.65	6171	1.4947	0.0084	0.1502	0.0049	17.62	0.63	0.63
3	3.2	27.97	115	1.4412	0.0148	0.1587	0.0137	18.71	2.9	2.84
4	3.65	2.3	1585	1.4578	0.009	0.1374	0.0042	16.03	0.52	0.52
5	3.96	0.7	5617	1.4645	0.009	0.1457	0.0043	17.05	0.57	0.57
6	3.84	1.46	2635	1.4589	0.0059	0.1559	0.0053	18.35	0.68	0.68
7	3.48	2.24	1552	1.4724	0.0092	0.1563	0.0049	18.4	0.6	0.59
8	2.92	10.24	285	1.4735	0.0105	0.1689	0.0054	20.01	0.74	0.73
9	2.68	0.57	4706	1.4812	0.0106	0.1605	0.0068	18.94	0.92	0.92
10	2.99	0.24	12432	1.5053	0.008	0.1492	0.0052	17.49	0.68	0.67
11	2.8	0.34	8232	1.4555	0.0086	0.1571	0.0051	18.5	0.65	0.65
12	2.96	0.65	4526	1.4392	0.008	0.1484	0.0053	17.4	0.65	0.65
13	2.43	0.74	3266	1.4311	0.0092	0.1643	0.0057	19.42	0.78	0.77
14	2.53	0.91	2800	1.4378	0.0088	0.1456	0.0065	17.06	0.79	0.79
15	2.74	0.57	4797	1.4558	0.0078	0.1432	0.0059	16.75	0.72	0.72
16	2.69	0.02	125896	1.3912	0.0099	0.1322	0.0049	15.38	0.58	0.57
17	2.29	233.26	10	1.3702	0.0093	0.1338	0.0081	15.59	0.95	0.94
18	2.51	4.93	510	1.4071	0.0102	0.1443	0.0067	16.9	0.8	0.8
19	0.74	585.71	1	1.173	0.0146	0.2273	0.017	27.99	2.24	2.19
20	2.26	8.1	279	1.327	0.0076	0.1553	0.0075	18.31	1	0.99
21	2.17	132.33	16	1.3109	0.01	0.1291	0.0058	15.02	0.71	0.7
22	0.62	87.63	7	1.2202	0.0199	0.1382	0.0134	16.17	1.59	1.57
23	1.24	54.39	23	1.3086	0.0143	0.1408	0.0129	16.47	1.93	1.9
24	2.18	32.67	67	1.359	0.0108	0.1621	0.0064	19.17	0.88	0.87
25	2.82	3.31	854	1.287	0.0098	0.1474	0.0051	17.31	0.65	0.65
26	1.56	251.58	6	1.2368	0.012	0.1551	0.0077	18.31	0.95	0.94
27	1.23	86.67	14	1.2947	0.0162	0.1161	0.0119	13.41	1.53	1.51
28	2.29	5.37	426	1.2332	0.01	0.1402	0.0064	16.42	0.79	0.79
29	2.78	1.79	1558	1.3139	0.0103	0.116	0.0073	13.4	0.87	0.86
30	2.73	80.22	34	1.2799	0.008	0.1223	0.0069	14.18	0.84	0.84

3024

Spot	U (ppm)	Th (ppb)	U/Th	$^{234}\text{U}/^{238}\text{U}$	$^{234}\text{U}/^{238}\text{U}$ error	$^{230}\text{Th}/^{234}\text{U}$	$^{230}\text{Th}/^{234}\text{U}$ error	Age (ka)	+ error	- error
1	3.73	1.37	2716	1.2103	0.0067	0.0747	0.0039	8.46	0.45	0.45
2	2.81	0.32	8651	1.1728	0.0078	0.0487	0.0035	5.45	0.4	0.4
3	3.79	0.83	4563	1.1828	0.0073	0.0187	0.0017	2.06	0.19	0.19
4	3.73	0.29	12797	1.1663	0.0071	0.0042	0.0015	0.46	0.17	0.17
5	5.46	0.47	11717	1.1523	0.006	0.0033	0.0012	0.36	0.13	0.13
6	6.65	0.19	34219	1.1561	0.0047	0.0019	0.0009	0.21	0.1	0.1
7	6.4	0.05	116593	1.1624	0.0051	0.0034	0.0011	0.37	0.12	0.12
8	6.86	0.59	11623	1.1625	0.0053	0.0273	0.0037	3.02	0.43	0.42
9	8.53	0.28	30469	1.1568	0.0046	0.001	0.0008	0.11	0.08	0.08
10	6.1	0.43	14070	1.1503	0.007	0.0013	0.0009	0.14	0.11	0.11
11	5.13	0.82	6224	1.1542	0.0057	0.0055	0.0014	0.61	0.15	0.15
12	6.35	3.52	1801	1.1481	0.0066	0.0136	0.0021	1.5	0.23	0.23

13	8.36	1.07	7786	1.1679	0.0093	0.0279	0.0137	3.09	2.28	2.24
14	8.96	1.31	6841	1.1559	0.004	0.0037	0.0008	0.4	0.09	0.09
15	7.73	0.75	10311	1.1509	0.0041	0.0035	0.0008	0.38	0.09	0.09
16	6.38	1.22	5231	1.1567	0.005	0.0022	0.0012	0.24	0.13	0.13
17	6.08	0.18	33854	1.1381	0.0056	0.0031	0.001	0.34	0.11	0.11
18	7.96	0.46	17398	1.1636	0.0056	0.0129	0.0011	1.42	0.12	0.12
19	7.11	0.44	16022	1.1712	0.0059	0.0288	0.0039	3.19	0.52	0.52
20	9.39	11.21	837	1.1973	0.0042	0.0553	0.0029	6.21	0.34	0.34

^a Samples with U-concentrations of <0.5 ppm are marked in red, U/Th ratios of < 50 are in green.

Supplementary Table 4 | U/Th measurements and ages of the hominin mandible (Penghu 1).^a

M1											
Spot	U (ppm)	Th (ppb)	U/Th	²³⁴ U/ ²³⁸ U	²³⁴ U/ ²³⁸ U error	²³⁰ Th/ ²³⁴ U	²³⁰ Th/ ²³⁴ U error	Age (ka)	+ error	- error	
1	2.15	24.67	87	1.3459	0.0127	0.2627	0.0113	32.84	1.71	1.68	
2	1.91	17.71	108	1.4101	0.0122	0.2907	0.0155	36.88	2.2	2.16	
3	2.05	14.71	139	1.2136	0.0135	0.1253	0.0085	14.57	1.1	1.09	
4	2.71	3.87	700	1.18	0.0099	0.074	0.0054	8.39	0.63	0.63	
5	5.4	1.78	3033	1.1773	0.006	0.0517	0.0036	5.79	0.4	0.4	
6	5.26	2.23	2356	1.1794	0.0071	0.0671	0.0033	7.57	0.38	0.38	
7	5.55	5.15	1078	1.1685	0.0063	0.0721	0.004	8.16	0.47	0.47	
8	4.84	33.97	142	1.1769	0.0071	0.068	0.0043	7.68	0.54	0.54	
9	6.27	2.88	2174	1.168	0.0071	0.0655	0.004	7.38	0.47	0.47	
10	7.43	1.47	5049	1.1719	0.0065	0.0525	0.0028	5.88	0.32	0.32	
11	8.41	5.83	1442	1.178	0.0052	0.0459	0.003	5.13	0.34	0.34	
12	7.74	6.65	1164	1.186	0.0054	0.0473	0.0027	5.28	0.32	0.32	
13	4.26	14.97	285	1.1866	0.0076	0.1006	0.0049	11.56	0.59	0.59	
14	4.71	6.7	702	1.1781	0.0102	0.0889	0.0048	10.14	0.61	0.61	
15	3.03	15.74	192	1.1953	0.0097	0.1035	0.0059	11.91	0.74	0.74	
16	2.16	455.14	5	1.403	0.013	0.3426	0.0148	44.84	2.33	2.29	
M2											
Spot	U (ppm)	Th (ppb)	U/Th	²³⁴ U/ ²³⁸ U	²³⁴ U/ ²³⁸ U error	²³⁰ Th/ ²³⁴ U	²³⁰ Th/ ²³⁴ U error	Age (ka)	+ error	- error	
1	7.06	0.93	7557	1.1793	0.0062	0.0618	0.0034	6.95	0.4	0.4	
2	7.24	0.6	11984	1.1896	0.0061	0.0565	0.0028	6.35	0.34	0.33	
3	6.74	5.82	1157	1.1827	0.0061	0.0595	0.0032	6.7	0.38	0.38	
4	7.83	2.53	3093	1.1889	0.0071	0.0592	0.0033	6.65	0.4	0.4	
5	8.57	0.92	9266	1.177	0.0063	0.0595	0.0032	6.69	0.38	0.37	
6	8.37	4.35	1924	1.1753	0.0074	0.0597	0.0031	6.72	0.37	0.37	
7	7.96	8.38	949	1.1823	0.005	0.0579	0.0032	6.5	0.38	0.38	
8	9.22	21.33	432	1.1809	0.0064	0.0605	0.0029	6.81	0.35	0.35	
9	9.43	1.82	5193	1.1722	0.0066	0.0544	0.0025	6.1	0.3	0.3	
10	7.7	26.3	293	1.1772	0.0071	0.0497	0.0034	5.56	0.4	0.4	
11	9.46	4.35	2175	1.1774	0.0066	0.0559	0.0029	6.28	0.33	0.33	
12	10.32	5.47	1887	1.1802	0.0052	0.0518	0.0025	5.8	0.28	0.28	
13	10.11	1.3	7796	1.1762	0.0053	0.0526	0.0022	5.9	0.26	0.26	
14	9.83	0.76	12980	1.1763	0.0063	0.0539	0.0025	6.05	0.29	0.29	
15	10.62	2.25	4721	1.1622	0.0069	0.054	0.0022	6.06	0.26	0.26	
16	9.45	55.58	170	1.1696	0.0068	0.0504	0.0023	5.64	0.28	0.28	
17	8.58	81.47	105	1.1818	0.0062	0.0447	0.0026	4.99	0.3	0.3	
18	7.88	33.93	232	1.1761	0.0066	0.055	0.0033	6.17	0.38	0.37	
19	5.45	57.42	95	1.1721	0.0064	0.0713	0.0033	8.06	0.42	0.41	
20	6.46	13.5	478	1.1866	0.0065	0.0525	0.0032	5.88	0.36	0.35	
21	7.14	3.64	1966	1.1803	0.0072	0.0719	0.0032	8.13	0.37	0.37	
22	5.45	11.09	492	1.1938	0.0073	0.1005	0.0041	11.54	0.51	0.51	
23	4.01	18.14	221	1.2053	0.0081	0.1279	0.0067	14.89	0.82	0.82	
24	3.05	2517.85	1	1.4354	0.0126	0.5544	0.0328	83.94	8.24	7.73	
M3											
Spot	U (ppm)	Th (ppb)	U/Th	²³⁴ U/ ²³⁸ U	²³⁴ U/ ²³⁸ U error	²³⁰ Th/ ²³⁴ U	²³⁰ Th/ ²³⁴ U error	Age (ka)	+ error	- error	
1	2.65	40.14	66	1.544	0.0117	0.3475	0.0087	45.4	1.42	1.4	
2	0.75	6.02	124	1.4959	0.0245	0.4145	0.0284	56.57	5.59	5.36	
3	4.89	4.91	996	1.2094	0.0064	0.1006	0.0044	11.55	0.53	0.53	
4	7.2	1.71	4201	1.1728	0.007	0.0768	0.0043	8.72	0.51	0.51	
5	7.4	1.95	3789	1.181	0.0078	0.0653	0.0035	7.37	0.41	0.41	
6	8.3	1.21	6862	1.177	0.0068	0.0652	0.0029	7.35	0.35	0.35	
7	8.59	0.87	9830	1.1771	0.0072	0.058	0.0026	6.51	0.31	0.31	
8	8.93	2.05	4353	1.1698	0.0066	0.0558	0.0031	6.27	0.35	0.35	
9	9.76	4.31	2265	1.1717	0.0055	0.0534	0.0027	5.99	0.32	0.32	
10	9.48	0.3	31623	1.1755	0.0059	0.052	0.0029	5.82	0.34	0.34	
11	9.88	2.35	4202	1.1704	0.0055	0.0554	0.0027	6.21	0.32	0.32	

12	8.77	0.35	24893	1.1749	0.006	0.0548	0.0024	6.14	0.28	0.28
13	7.75	1.88	4128	1.178	0.0064	0.0566	0.003	6.36	0.38	0.38
14	6.84	39.37	174	1.1747	0.0069	0.045	0.0029	5.03	0.33	0.33
15	9.23	12.03	767	1.16	0.0055	0.0515	0.0028	5.76	0.32	0.32
16	7.83	6.31	1242	1.1723	0.006	0.0591	0.0027	6.65	0.34	0.34
17	7.41	3.9	1902	1.1835	0.0065	0.0541	0.0029	6.06	0.34	0.34
18	8.2	2.19	3750	1.1759	0.0068	0.0548	0.003	6.15	0.35	0.35
19	7.49	2.68	2801	1.1757	0.0064	0.0466	0.0021	5.21	0.26	0.26
20	8.52	47.08	181	1.188	0.007	0.0676	0.0032	7.64	0.39	0.39
21	1.14	9.75	117	1.2019	0.0164	0.193	0.0188	23.28	2.6	2.55
22	3.06	36.39	84	1.2791	0.0102	0.1806	0.0094	21.6	1.26	1.25
M4										
Spot	U (ppm)	Th (ppb)	U/Th	$^{234}\text{U}/^{238}\text{U}$	$^{234}\text{U}/^{238}\text{U}$ error	$^{230}\text{Th}/^{234}\text{U}$	$^{230}\text{Th}/^{234}\text{U}$ error	Age (ka)	+ error	- error
1	4.78	80.96	59	1.4199	0.008	0.2573	0.0079	32	1.11	1.1
2	7.15	133.66	54	1.2097	0.0075	0.1029	0.0041	11.82	0.53	0.53
3	8.64	6.26	1380	1.1977	0.0068	0.0897	0.0029	10.24	0.35	0.35
4	8.16	2.44	3340	1.1775	0.006	0.0693	0.0031	7.83	0.36	0.36
5	8.79	3.07	2865	1.1874	0.0052	0.073	0.003	8.26	0.36	0.36
6	8.43	6.21	1359	1.183	0.0065	0.0769	0.0032	8.72	0.38	0.38
7	9.1	1.61	5665	1.1763	0.0064	0.0681	0.003	7.69	0.34	0.34
8	8.94	2.82	3173	1.1724	0.0056	0.0648	0.0025	7.3	0.28	0.28
9	7.99	1.34	5965	1.173	0.0061	0.0668	0.0024	7.54	0.28	0.28
10	7.76	1.83	4245	1.1707	0.0055	0.0702	0.0031	7.94	0.37	0.37
11	7.06	1.34	5253	1.1798	0.0073	0.0606	0.0034	6.82	0.4	0.4
12	6.09	12.9	472	1.1829	0.0082	0.0644	0.0028	7.26	0.32	0.32
13	6.81	10.33	659	1.1646	0.0063	0.0491	0.0029	5.49	0.33	0.33
14	5.66	4.57	1238	1.1712	0.0066	0.0455	0.0028	5.08	0.32	0.32
15	3.16	5.77	547	1.1725	0.0089	0.08	0.007	9.09	0.85	0.85
16	0.82	9.35	88	1.2758	0.0203	0.3008	0.0227	38.56	3.61	3.5
17	1.84	191.46	10	1.4806	0.0154	0.362	0.0138	47.81	2.15	2.11
18	2.52	21.94	115	1.4232	0.0114	0.2836	0.0089	35.81	1.36	1.35

^a Samples with U-concentrations of <0.5 ppm are marked in red, U/Th ratios of < 50 are in green.

Supplementary Table 5 | Trace element measurements (wt%) for the bone samples from the Penghu Channel.

	No.	Taxon	Portion	N ^a	F/P ₂ O ₅		Na ₂ O/P ₂ O ₅	
					Mean	S.D.	Mean	S.D.
1	1	<i>Palaeoloxodon</i>	radio-ulna	20	0.100	0.019	0.026	0.003
2	2	<i>Palaeoloxodon</i>	skull	13	0.079	0.013	0.021	0.004
3	3	<i>Palaeoloxodon</i>	humerus	11	0.098	0.018	0.027	0.009
4	4	<i>Bubalus</i>	horn core base	8	0.089	0.011	0.022	0.003
5	5	<i>Bubalus</i>	horn core base	24	0.078	0.010	0.026	0.004
6	6	<i>Bubalus</i>	horn core base	43	0.076	0.012	0.036	0.006
7	8	<i>Palaeoloxodon</i>	femur	56	0.071	0.011	0.030	0.005
8	F0021877	<i>Sus</i>	humerus shaft	12	0.088	0.008	0.028	0.004
9	F051720	<i>Sus</i>	humerus	9	0.105	0.012	0.067	0.048
10	F03829	<i>Elaphurus</i>	horn core base	27	0.077	0.011	0.025	0.005
11	F028268	<i>Elaphurus</i>	horn core base	10	0.083	0.009	0.027	0.004
12	F0020761	<i>Elaphurus</i>	horn core base	25	0.083	0.010	0.023	0.002
13	F051436	<i>Cervus</i>	distal tibia	8	0.047	0.010	0.023	0.002
14	F051444	<i>Cervus</i>	distal tibia	6	0.080	0.014	0.033	0.006
15	F051445	<i>Cervus</i>	distal femur	22	0.049	0.009	0.026	0.004
16	F051694	<i>Equus</i>	distal radius	21	0.098	0.009	0.015	0.002
17	F051695	<i>Equus</i>	distal tibia	3	0.054	0.004	0.014	0.003
18	F030057	<i>Equus</i>	metatarsal	49	0.087	0.011	0.018	0.002
19	F051708	<i>Ursus</i>	distal femur	57	0.035	0.012	0.035	0.004
20	F051710	<i>Crocota</i>	mandible 1	46	0.091	0.008	0.024	0.002
21	F051710	<i>Crocota</i>	mandible 2	38	0.095	0.010	0.022	0.003
22	Penghu 1	<i>Homo</i>	mandible	50	0.084	0.010	0.026	0.006

^a Number of the spots used to calculate the average values reported in the right columns.

Supplementary Table 6 | Comparative mandibular and dental samples.^a

Sample name and taxon ^b	Description	Age (Ma)	Portion	Composition	Data source
<i>H. habilis</i>	<i>H. habilis sensu lato</i>	2.2-1.6	Mand.	KNM-ER 817, 1483, 1501, 1801, 3734, 1805, 1811;	Original
				KNM-ER 60000, 62003	Ref. 60
			M ₂	OH 13, 37	Original
				KNM-ER 1805, 2597, 60000, OH 7, 13, 16	Ref. 60,61
Dmanisi	EP <i>Homo</i> from Dmanisi, Georgia	1.75	Mand.	KNM-ER 1802, OH 37	Original
				L628-10; Omo75-14	Refs. 61,62
			M ₂	D211, 2600	Cast, ref. 63
				D211, 2600, 2735	Ref. 64
<i>H. ergaster</i>	EP post- <i>habilis</i> <i>Homo</i> from Africa	1.7-0.9	Mand.	KNM-ER 730, 731, 819, 992, 1506, 1808, 3950;	Original
				OH 22, 23, 51;	Original
			M ₂	KGA10-1	Cast, ref. 65
				KNM-ER 730, 806, 992, 1808, KNM-WT 15000; SK15	Ref. 61
Jianshi (? <i>H. erectus</i>)	EP <i>Homo</i> from Jianshi, China	EP	M ₂	KNM-ER 1506; OH 22;	Original
				KGA10-1	Cast
			M ₂	PA504	Cast, Ref. 66
Early Javanese <i>H. erectus</i> (older)	EP <i>Homo</i> from Sangiran (Grenz/Sang. levels)	≥1.2-1.0	Mand.	Sangiran 1b, 5, 6a, 8, 9, 22; Bk7905, Bk 8606	Original
			M ₂	Sangiran 1b, 5, 9, 22; Bk 7905	Original
Early Javanese <i>H. erectus</i> (later)	EP <i>Homo</i> from Sangiran (Bapang-AG levels)	1.0-0.8	Mand.	Sangiran 21; Sb8103	Original
			M ₂	Sb 8103, Ng 8503	Original
IEP Europe (<i>Homo</i> sp.)	Late EP <i>Homo</i> from Europe	1.2-0.8	Mand.	ATE9-1; ATD6-96	Refs. 67,68
			M ₂	ATE9-1; ATD H1, 6-96	Refs. 67-69
eMP Africa (<i>Homo</i> sp.)	Early MP <i>Homo</i> from East and North Africa	0.8-0.4	Mand.	KNM-BK 67, 8518	Original
			M ₂	Tigehnf 1, 2, 3; Thomas Quarry	Cast
Chinese <i>H. erectus</i>	Early MP <i>Homo</i> From Zhoukoudian and Lantian	0.75-0.4	Mand.	Tighenif 1, 2, 3; KNM-BK 67, 8518	Ref. 70, Original
				Lantian; Zhoukoudian PA86	Original
			M ₂	Zhoukoudian A1, G1, H1, H4, K1, M2	Cast
				Zhoukoudian 43, 44, 45, 106, 107, 108, 109/110, 111, 138' Lantian	Ref. 71
Hexian (? <i>H. erectus</i>)	MP <i>Homo</i> from Hexian, China	0.4	Mand.	PA831	Ref. 72
			M ₂	PA839	Original
Late archaic China (<i>Homo</i> sp.)	Late MP-LP archaic <i>Homo</i> from China	?0.1-0.3	Mand.	Xujiayao 14 (PA 1497)	Ref. 73
			M ₂	Dingcun, Huanglong Cave	Refs. 42,74
MP Europe	MP <i>Homo</i> from Europe	0.6-0.2	Mand.	AT-1, 75, 250, 300, 505, 605, 888, 950	Cast, ⁷⁵⁻⁷⁷
			M ₂	Mauer; Arago 2, 13; Montmaurin	Refs. 78,79
Neanderthal	Terminal MP-LP archaic <i>Homo</i> from Europe and West Asia	0.14-0.05	Mand.	Krapina G, H, J; Spy 1; La Ferrassie 1;	Cast, Ref. 80
				La Quina 5, 9; Regourdou; Banyolas;	
			M ₂	Subalyuk; St. Cesaire; Amud 1; Kebara 2;	Refs. 79-82
				Tabun 1; Shanidar 1, 2, 4	
early <i>H. sapiens</i>	LP <i>H. sapiens</i> from Asia, Australia, and Europe	?0.1-0.01	Mand.	Krapina G, H; Spy 1; La Quina 5, 9; Regourdou;	Original, Refs. 83,84
				Subalyuk; Amud 1; Kebara 2; Tabun 1; Shanidar 2, 6	
				Zhiren 3; Tyanyuan;	
				Zhoukoudian UC 101, 104, 108, 109;	
				Minatogawa 1, A, B, C;	
				Wajak 1, 2; Kow Swamp 1, 5; Nacurrie;	
early <i>H. sapiens</i>			Mand.	Skhul 4, 5; Qafzeh 9; Kostenki 14;	Original, Ref. 85
				Cro-Magnon 1; Abri Pataud;	
				Combe Chapelle; Obercassel 1, 2	

^a Data for the maxillary teeth are same with the mandibular teeth, or from refs. 42,87-91.^b EP, Early Pleistocene; MP, Middle Pleistocene; LP, Late Pleistocene.

Supplementary Table 7 | Definitions of mandibular measurements and indices.

Superior mandibular length	Distance from infradentale to the line connecting mid-condyles.
Bicondylar breadth (M65)	Maximum breadth across the condyles.
Mandibular shape index	Ratio of the superior mandibular length to the bicondylar breadth.
Alveolar arcade index (M ₂)	Arcade length–breadth ratio. Breadth, distance between right and left intersection points of distal contour of M ₂ and midline of the molar row. Length, distance from infradentale to the line tangential to distal faces of right and left M ₂ crowns.
Alveolar arcade index (last molar)	Same as 'alveolar arcade index (M ₂)'. The two indices are identical in cases of M ₃ agenesis (Penghu 1, Lantian, and Minatogawa A in our sample).
Symphyseal/corpus heights	Minimum distance from basal contour to lateral alveolar margin, being perpendicular to alveolar line.
Symphyseal/corpus width	Taken perpendicular to long axis of corpus cross section that includes two landmarks of corpus height.
Ramus height (M70)	Distance between condyle and gonion.
Ramus height (M70a)	Condylar height measured perpendicularly from the corpus base.
Least ramus A-P width (M71a)	Minimum anteroposterior length of the ramus.
Condylar length (M71b)	Maximum mediolateral diameter of the condyle.
I ₁ -I ₂ alveolar lengths	Distances between the midpoints of interalveolar septa across the two incisors on either side.
P ₁ -P ₂ alveolar lengths	Distances between the midpoints of interalveolar septa across the two premolars on either side.

Supplementary Table 8 | Mandibular measurements of Penghu 1 and comparative *Homo* samples.

	Bycondylar breadth	Sup. mand. length	Mand. shape index (length/breadth)	Alv. arc. index (M2)	Alv. arc. index (last molar)	
<i>H. habilis</i>	136 (1)	121 (1) ^b	89 (1)	98 (3: 95-102) ^a	121 (3: 117-126) ^a	
Dmanisi	133 (1)	133 (1)	100 (1)	101 (2: 101-102)	123 (2: 123-123)	
<i>H. ergaster</i>	-	-	-	81 (1)	98 (1)	
Jav. <i>H. erectus</i> (older)	-	-	-	92 (2: 92-92)	107 (2: 107-108)	
Jav. <i>H. erectus</i> (later)	-	-	-	-	-	
IEP Europe	-	-	-	-	-	
eMP Africa	140.5 (2: 126-155)	122 (1)	79 (1)	89 (3: 83-97)	103 (3: 98-113)	
Chinese <i>H. erectus</i>	127 (1)	98 (1)	77 (1)	80 (2: 75-85)	87 (2: 85-88)	
Hexian	-	-	-	-	-	
Xujiayao	-	-	-	-	-	
MP Europe	135.3 (3: 131-142)	111.3 (3: 105-120)	82 (3: 76-92)	76 (5: 68-84)	89 (5: 79-101)	
Neanderthal	139.3 (8: 123-155)	109.7 (7: 96-120)	78 (7: 66-88)	68 (8: 59-82)	81 (8: 72-95)	
early <i>H. sapiens</i>	122.0 (10: 109-135)	101.1 (8: 95-108)	83 (8: 77-96)	76 (14: 65-89)	89 (13: 77-100)	
Penghu 1	139 ^a	103.5 ^a	74 ^a	88 ^a	88 ^a	
	Symphyseal height	Symphyseal width	Symph. robusticity (width/height)	Corpus height (at M1)	Corpus width (at M1)	Corpus rob. ind. (width/height)
<i>H. habilis</i>	34.2 (2: 25-43)	20.6 (5: 18-25)	58.9 (2: 49-69)	31.9 (8: 25-38)	19.9 (7: 18-23)	62.1 (7: 53-70)
Dmanisi	36.2 (2: 28-45)	19.8 (2: 18-22)	56.4 (2: 49-64)	32.9 (2: 26-40)	18.8 (2: 18-20)	58.8 (2: 50-67)
<i>H. ergaster</i>	31.2 (4: 29-35)	19.3 (5: 18-20)	62.1 (4: 58-68)	33.7 (7: 29-40)	20.3 (9: 17-26)	63.9 (6: 56-70)
Jav. <i>H. erectus</i> (older)	39.0 (2: 36-42)	17.0 (2: 16-18)	43.8 (2: 43-45)	36.6 (6: 29-48)	19.8 (7: 16-27)	54.3 (5: 48-59)
Jav. <i>H. erectus</i> (later)	-	-	-	-	16.5 (1)	-
IEP Europe	33.5 (1)	15.3 (1)	45.7 (1)	29.3 (2: 29-30)	16.8 (2: 17-17)	57.5 (2: 57-58)
eMP Africa	32.9 (4: 28-37)	17.6 (5: 16-19)	52.8 (4: 48-63)	31.5 (7: 28-35)	17.4 (7: 14-20)	55.4 (7: 44-70)
Chinese <i>H. erectus</i>	33.1 (3: 33-34)	13.1 (4: 12-14)	39.9 (3: 38-43)	27.8 (6: 26-33)	16.2 (7: 15-19)	58.8 (6: 56-63)
Hexian	-	-	-	32 (1)	20.7 (1)	64.7 (1)
Xujiayao	-	-	-	-	-	-
MP Europe	32.8 (11: 27-37)	15.5 (11: 14-19)	47.6 (11: 41-60)	31.5 (13: 27-37)	16.5 (13: 14-22)	52.7 (13: 45-70)
Neanderthal	33.6 (8: 28-39)	15.9 (7: 13-21)	47.6 (7: 41-62)	32.1 (15: 28-36)	15.3 (14: 14-19)	47.6 (14: 41-54)
early <i>H. sapiens</i>	32.0 (22: 25-41)	15.1 (18: 13-18)	46.7 (18: 34-58)	31.2 (22: 26-37)	14.0 (23: 11-17)	45.1 (22: 38-59)
Penghu 1	30.5	17.8	58.4	27.3	20.7	75.8
	Ramus height (M70)	Ramus height (M70a)	Least ramus A-P width	Condylar length (M-L)	I1-I2 alv. length	P1-P2 alv. length
<i>H. habilis</i>	-	89 (1)	47.0 (1)	-	10.8 (3: 9-13)	16.9 (9: 15-19)
Dmanisi	-	83 (1)	48.0 (1)	23.6 (1)	11.3 (2: 10-12)	16.8 (1)
<i>H. ergaster</i>	-	73.5 (1)	50.2 (2: 50-51)	25.0 (2: 24-26)	10.6 (4: 10-12)	17.8 (6: 16-19)
Jav. <i>H. erectus</i> (older)	-	-	-	-	10.3 (2: 10-11)	17.5 (5: 16-19)
Jav. <i>H. erectus</i> (later)	-	63 (1) ^c	-	26.6 (1)	-	-
IEP Europe	60 (1)	-	40.6 (1)	-	-	-
eMP Africa	71.8 (3: 68-75)	78.2 (3: 73-86)	46.8 (3: 44-52)	26.2 (2: 24-28)	10.5 (5: 10-12)	16.6 (6: 14-18)
Chinese <i>H. erectus</i>	60.9 (2: 55-67)	68.3 (2: 63-74)	40.8 (2: 40-41)	20.7 (2: 18-23)	11.5 (2: 11-12)	15.7 (7: 12-18)
Hexian	-	-	-	-	-	-
Xujiayao	-	-	44.5 (1)	-	-	-
MP Europe	60.5 (4: 57-64)	64.0 (2: 60-68)	44.2 (3: 38-52)	23.6 (4: 22-25)	11.6 (3: 11-12)	15.8 (4: 14-18)
Neanderthal	59.7 (3: 59-61)	64.9 (5: 54-69)	41.2 (10: 35-46)	25.0 (4: 22-27)	11.4 (6: 10-13)	13.1 (6: 13-14)
early <i>H. sapiens</i>	59.2 (10: 50-69)	60.6 (11: 50-72)	38.6 (18: 29-46)	21.7 (12: 19-24)	10.5 (17: 8-12)	14.1 (16: 12-16)
Penghu 1	55.4	60	43.0	19.6	13.0	17.6

^a Measurements of KNM-ER 60000 based on a CT-based reconstruction illustrated in Supplementary Notes 8 and 10 of ref. 60.^b Estimate based on a distorted, damaged ramus of Sangiran 21.

Supplementary Table 9 | Diagnostic mandibular and dental characters of Penghu 1 within *Homo*

	Group	Penghu 1	Early Pleistocene					IEP Europe
			<i>H. habilis</i>	Dmanisi	<i>H. ergaster</i>	<i>H. erectus</i> Java (older)	<i>H. erectus</i> Java (later)	
			2.2-1.6 Ma	1.75 Ma	1.7-0.9 Ma	1.2-1.0 Ma	1.0-0.8 Ma	
Age	late MP							
Mand. length/breadth (Fig. 4a-c)		short/wide	(long/mod.)	(long/mod.)	?	?	?	?
Dental arcade shape (Fig. 4d-e)		mod.-wide	narrow	narrow	(mod.)	narrow	?	?
Chin development (ref. 67)		Rank 1	Rank 1-2	Rank 2-3	Rank 1-2	Rank 1-2	?	(Rank 2)
Corpus height (Fig. 4g)		low	mod.	mod.	mod.	high	?	mod.
Symph. width/height (Fig. 4h)		thick	(thick)	thick	thick	thin	?	(thin)
Corpus width/height (Fig. 4i)		very thick	thick	thick	thick	mod.	?	mod.
Ment. foram. number (refs. 69)		sing.	sing.	sing.	sing.	sing.-mult.	?	sing.-mult.
Mental foram. position (ref. 68)		P₁/P₂	P₂	P₂	P₂	P₂	?	P₂
Lat. superior torus		strong	mod.-stro.	mod.-stro.	mod.-stro.	mod.-stro.	(weak)	(weak)
Lat. prominence position (refs. 68,69)		mes. M₂	mid. M₂	M₂	dist. M ₂	mes. M₂	(M ₂ /M ₃)	?
Extramolar sulcus (ref. 69)		wide	mod.-wide	mod.-wide	mod.-wide	mod.-wide	narrow-mod.	(mod.)
Retromolar space extensive (ref. 68)		no	no	(no)	no	(no)	(no)	(no)
Ramus height (Fig. 4k-l)		low	(low)	?	very high	?	(low)	?
Ramus breadth (Fig. 4b)		mod.	?	(broad)	broad	?	?	?
Condylar ML length (Fig. 4n)		short	?	(long)	long	(very long)	?	(mod.)
I ₁ -I ₂ alv. length (Fig. 4o)		very long	(very short)	mod.	short	short	?	?
P ₁ -P ₂ alv. length (Fig. 4p)		long	long	(long)	long	long	?	?
M ₂ size (Fig. 4b)		large	very large	mod.	mod.-large	large	small	small
M ₂ ling. contour markedly rounded		yes	no	no	no	no	no	(no)
M3 agenesis		present	present	present	absent	absent	absent	absent

	Group	Middle Pleistocene			Late Pleistocene			
		eMP Africa	<i>H. erectus</i> China	Hexian	MP Europe	Xujiayao	Neanderthal	<i>H. sapiens</i>
		0.8-0.4 Ma	0.75-0.6 Ma	0.4 Ma	0.6-0.2 Ma	~0.1 Ma	0.14-0.05 Ma	0.1-0.01 Ma
Mand. length/breadth (Fig. 4a-c)		(long/wide)	(short/mod.)	?	mod./mod.	?	short/wide	short/narrow
Dental arcade shape (Fig. 4d-e)		mod.	wide	?	wide	?	wide	wide
Chin development (ref. 67)		Rank 1-2	Rank 2	?	Rank 1-2	?	Rank 1-3	Rank 4-5
Corpus height (Fig. 4g)		mod.	low	(mod.)	mod.	?	mod.	mod.
Symph. width/height (Fig. 4h)		mod.	thin	?	thin	?	thin	thin
Corpus width/height (Fig. 4i)		mod.	mod.	(thick)	mod.	(thin?)	thin	thin
Ment. foram. number (refs. 69)		sing.-mult.	mult.	(mult.)	sing.-mult.	?	sing.-mult.	sing.
Mental foram. position (ref. 68)		P₂	P₂	(P ₂ -M ₁)	M ₁	?	M ₁	P₂
Lat. superior torus		mod.-stro.	mod.-stro.	?	mod.-stro.	?	weak-stro.	weak-mod.
Lat. prominence position (refs. 68,69)		dist. M ₂	M ₂ /M ₃	?	M ₃	?	M ₃	M ₂ /M ₃
Extramolar sulcus (ref. 69)		mod.-wide	narrow	?	mod.	(narrow)	narrow-mod.	narrow-mod.
Retromolar space extensive (ref. 68)		no	no	?	yes	(yes?)	yes	no
Ramus height (Fig. 4k-l)		high	mod.	?	mod.	(mod.)	mod.	very low
Ramus breadth (Fig. 4b)		mod.	narrow	?	narrow	(mod.)	narrow	very narrow
Condylar ML length (Fig. 4n)		very long	short	?	long	?	long	mod.
I ₁ -I ₂ alv. length (Fig. 4o)		short	mod.	?	mod.	?	mod.	mod.
P ₁ -P ₂ alv. length (Fig. 4p)		mod.	mod.	?	mod.	?	very short	short
M ₂ size (Fig. 4b)		mod.	small	large	very small	?	very small	very small
M ₂ ling. contour markedly rounded		no	no	(yes)	no	?	no	no
M3 agenesis		absent	present	?	absent	?	absent	present

^aAverage or dominant condition for each sample is indicated. Bold face means that the sample range encompasses or similar to the Penghu morphology. The parentheses indicate that the observation is based on a single specimen. Abbreviations: mod., moderate; mult., multiple; sing., single.

Supplementary Note 1. Penghu 1 and its discovery.

Penghu 1

Access No.: NMNS006655

Catalogue No.: F051911

Portion: Right hemi-mandible with four teeth

Repository: National Museum of Natural Science, Taichung

Taxon: *Homo* sp. indet.

Mr. Kun-Yu Tsai, a citizen of the Tainan City, obtained the Penghu 1 mandible from a local antique shop around February 2008, before he submitted it to the current repository. This mandible was one of the vertebrate fossils collected from the Penghu Channel, 20 km off the harbors of Tainan (Fig. 1). A large number of terrestrial vertebrate fossils have been dredged by fishing boats operating at this place (Supplementary Fig. 1; see also Supplementary Note 2), and are being sold to such antique shops.

The external surface of the Penghu 1 mandible was originally covered with remains of marine invertebrates as is always the case with fossil bones from the channel. Mr. Tsai removed these attachments. The hominin status of Penghu 1 was first noticed by M. Takai and C. Chang in 2009 based on its photographs. With Mr. Ted Chen's financial support and encouragement, Mr. Tsai kindly donated this specimen to the National Museum of Natural Science, Taiwan.

Supplementary Note 2. Penghu submarine channel, fossil fauna and its chronology

Penghu channel and taphonomy of its faunal assemblage. The Penghu submarine channel is located between the Penghu Islands and the main-island of Taiwan. The channel is 100–120 m deep in its northern half and gradually deepens southward (Fig. 1). Although the formational history of the channel is not fully understood⁹², the only possible explanation for the high density of well-preserved terrestrial vertebrate fossils, known as “Penghu fauna,” at the northern part of the channel (encircled in Fig. 1) is that they were accumulated on the riverbeds (or estuaries) by fluvial action when this area was mostly or entirely exposed above the sea-level. Such fossil accumulation would have most effectively occurred when the sea-level was at its lowest, c. –130 m, but may also have been possible whenever it was lower than c. –60 m (Fig. 1).

Studies of the past sea-level fluctuation suggest that, during the past 450,000 years, sea level lowering of >60 m occurred 10–70, 130–190, 225, 240–280, (?300), 335–360, and 425–450 ka (events >100 m occurred for short terms within these periods around 20 ka [MIS 2–4], 140 ka [MIS 6], 250 ka [MIS 8], 340 ka [MIS 10], and 440 ka [MIS 12])^{93–95}. Theoretically it is possible that the Penghu faunal assemblage includes terrestrial animal remains from more than one of these different phases, but a reasonable expectation is that the dominant component is from the later of these phases, primarily 10–70 ka and secondarily 130–190 ka. This is because 1) the Penghu Channel may not have been present as it is today in more remote past, and 2) if the fluvial force was the prime cause of the fossil accumulation as hypothesized above, there are greater chances for more recent fossils to be collected by trawling nets because the fossils accumulated by previous sedimentation events are likely more damaged, swept away, or overlain by later sedimentation events. However, this hypothesis of taphonomy and chronology needs to be tested by other evidence as examined below.

Penghu fauna: composition and palaeoenvironmental implication. Since the

initial study by Shikama et al.⁹⁶, several researchers have investigated aspects of the Penghu fauna^{97–103}. Fossils from the channel are scattered in different research institutions and private collections in Taiwan. In addition to literature survey, we examined large collections of the original fossil materials housed at the National Museum of Natural Science in Taichung, two local museums in Tainan, and some other private collections.

Supplementary Table 1 shows all the terrestrial animal taxa that we confirmed based on our own observation of the original fossils or published photographs/figures. There are two reptilian orders with 2 families, 3 genera and 3 species, and five mammalian orders with 10 families, 11 genera and 12 species. Previous researchers mentioned some additional taxa such as *Capricornis*, *Rangifer* and *Muntiacus*^{97–99}, but we could not find them in our sample. Supplementary Table 1 does not include these taxa, but inclusion or exclusion of these extant genera does not affect the following discussion of biochronology. The existing Penghu faunal assemblages are clearly biased toward large-sized taxa because they were collected by trawls. The smallest taxon we observed was *Nyctereutes* (raccoon dog), and small animals such as rodents are lacking.

Previous studies showed that all the mammalian taxa from the Penghu Channel occur in the Middle to Late Pleistocene of Chinese mainland. The fauna from these two regions show general similarities in body size and morphology, and there are no evidence of dwarfism often observed in insular environments^{100–103}. Therefore, the Penghu fauna can be described as a regional element of the Asian mainland fauna that distributed on the continental shelf during the sea-level lowstand.

Many of the Penghu mammal taxa, such as *Palaeoloxodon*, *Elaphurus*, *Ursus arctos*, *Crocota crocuta ultima* and *Nyctereutes*, are common to the relatively high-latitude areas of mainland China^{4,5,104–106}, but these also occur in southern China. The Penghu fauna lacks two important

elements of the Middle to Late Pleistocene northern Chinese fauna, *Coelodonta* (woolly rhinoceros) and *Mammuthus* (mammoth). It also lacks middle- to large-sized mammal taxa that characterize the Middle to Late Pleistocene southern Chinese fauna, such as *Ailuropoda* (giant Panda), *Stegodon* (an extinct elephant group), *Tapirus* (tapir), and *Pongo* (orangutan). Overall, the Penghu fauna is comparable to the mid-latitude, Middle to Late Pleistocene mainland fauna but is not similar to the southernmost Chinese fauna despite their latitudinal equivalence. This is consistent with the above taphonomic expectation that the Penghu fauna is from a glacial period(s). Most of these animals migrated from the mid-latitude regions southward, rather than from the southernmost China or Southeast Asia eastward, to the Taiwan area in colder climate.

Coexistence of two kinds of turtles, *Chinemys* (pond turtle) and *Trionyx* (softshell turtle), and semiaquatic mammals such as *Bubalus* (water buffaloes) as well as *Elaphurus* (Père David's deer), both of which prefer marshlands in a hot and humid climate, suggests relatively wet environments with rivers, ponds and/or lakes. Postcranial and craniodental remains of *Bubalus* and *Palaeoloxodon* (an extinct straight-tusked elephant) are dominant in the fossil assemblage. *Bubalus* contains two extinct species, *B. teilhardi* and *B. youngi*, which are distinguished from each other by cranial and horn morphology. Both of these species were widely distributed in mainland China and Southeast Asia during the Middle to Late Pleistocene¹⁰⁷⁻¹⁰⁹. It is generally accepted that the former is more primitive and appeared slightly earlier than did the latter¹¹⁰. *B. teilhardi* is also known from the late Early/early Middle Pleistocene Chochen fauna, southern Taiwan¹¹¹. *Palaeoloxodon* fossils are represented by a single species, *P. heaiensis*, which was also widely distributed in mainland China. The presence of these large-bodied terrestrial herbivorous mammals with laterally extensive horns or long straight tusks suggests that the Penghu area had been relatively open, wet woodland.

Biochronology. Previous researchers suggested either Late Pleistocene or late Middle Pleistocene

ages for the Penghu faunal assemblages^{97,100-103}. Among the taxa listed in Supplementary Table 1, *Crocota crocuta ultima* (extinct subspecies of spotted hyena) is particularly useful for biochronology in East and Southeast Asia because of the known replacement event from *Pachycrocota* to this taxon^{2512,27-30,50,53,112,113}.

At least seven cranio-mandibular specimens in addition to some postcranial elements of hyaenid are known from the Penghu faunal assemblage¹⁰³. These are easily allocated to the genus *Crocota* as oppose to *Pachycrocota* (previously described as *Hyaena*¹¹⁴), based on the upper and lower carnassial teeth and other dental morphology^{101,103}. They can be distinguished from the Early Pleistocene subspecies, *Crocota honanensis*¹¹⁵ in showing much larger sizes, and are identified as *Crocota crocuta ultima*^{30,33,103}.

Tseng and Chang¹⁰³ previously discussed chronology of Asian hyaenids and suggested that the age of Penghu *Crocota* is late Middle Pleistocene. We compiled published data to further examine this possibility. Supplementary Table 2 lists East Asian localities that have yielded four hyaenid species or subspecies: *C. c. ultima*, *C. honanensis*, *P. licenti*, and *P. brevirostris sinensis*. Here, “northern China” and “southern China” mean the areas north and south of the Qinling Mountains, respectively.

Supplementary Table 2 shows that, in southern China, *P. brevirostris* is documented from the Early to Middle Pleistocene contexts. This species had survived until the terminal Middle Pleistocene (150–200 ka) in this region, but was then replaced by *C. c. ultima* that appeared around that time (130–240 ka or 130–200 ka if we exclude one of the possible ages from Tongzi [240 ka] that substantially overlaps with the above age for *P. brevirostris*) and continued probably until the early Holocene. In northern China, the hyaenid replacement event is clearly recorded in the successive sediments at the Locality 1 of Zhoukoudian, the famous *Homo erectus* sites. Here, *P. b. sinensis* is known from the lower stratigraphic levels (the Layers 5–11), whereas *C. c. ultima* from the upper levels (Layers 1–3)^{4,5,34},

suggesting that the replacement occurred around the age of Layers 3–4⁵. These layers are dated by different researchers to c. 250–400 ka^{6–9} or c. 400–500 ka^{10,11} (also see ref. 116). These varying age estimates as well as dates from other sites lead us to a broad conclusion that the hyaenid replacement event may have occurred more or less earlier in northern (250–500 ka) than in southern China (130–200 ka). The same hyaenid replacement event did occur in Southeast Asia, but the available limited chronological data allow us to draw only a broad inference that it was sometime during the Middle Pleistocene.

Conclusions. The above palaeogeographic and taphonomic considerations led us to hypothesize that the Penghu terrestrial faunal assemblage had been accumulated primarily 10–70 ka but it may also include fossils from 130–190 ka. Older low-sea-level events, 225, 240–280, (?300,)

335–360, and 425–450 ka cannot be completely excluded, but such a situation requires explanation for unusual distribution of *C. c. ultima*, preservation through repeated sedimentary events, and long-term geomorphological stability of the Penghu Channel. The above chronology (10–190 ka) is supported by the presence of the younger hyena species (*Crocota crocota ultima*) and the absence of the older one (*Pachycrocota brevirostris sinensis*) in Penghu fauna. Our U-series analyses of bone samples (Supplementary Note 3) returned ambiguous results (≤ 60 ka) but at least they do not contradict with the proposed Late Pleistocene age. Furthermore, our trace element analyses of bone samples (main text) support contemporaneity between *C. c. ultima* and Penghu 1. To conclude, the above series of evidence suggest that the age of Penghu 1 is somewhere in 10–70 ka or 130–190 ka.

Supplementary Note 3. U-series dating of Penghu 1

We have applied U-series analysis on a range of bones. A first set consisted of eight faunal bones that were found by dredging the Penghu channel, i.e. there is nothing further known as with respect to exact location or burial conditions. It is thought that the bones were most likely deposited on the surface of the Penghu channel before early Holocene sea level rise (see Supplementary Note 2). Samples 3017 to 3023 were bovid bones and 3024 that of a hyena. A second sample was a cross cut of the hominin mandible (Penghu 1).

Details of how laser ablation U-series analysis is carried out at RSES, including a detailed description of the equipment, sampling strategies, and data reduction, has been given by Grün et al¹¹⁷. The cortical bone samples were cut by a thin diamond cutter and analysed along cross sections using laser spot analysis (see e.g. ref. 118).

For the interpretation of the U-series data one has to keep in mind that the U-series ages are indications of when uranium migrated into the skeletal tissue. Firstly, there can be a long delay between the deposition of a bone or tooth and the U-uptake. Secondly, there may be several consecutive overprinting uptake phases in the skeletal tissue (see e.g. ref. 117, and several samples below). Thus, apparent U-series ages have to be regarded as minimum age estimates. Furthermore, there may be U-leaching processes which may lead to older apparent ages. Leaching is usually associated with lower U-concentrations in the affected domains compared to their surroundings in the bone.

For this study it is of importance to know that the sea water $^{234}\text{U}/^{238}\text{U}$ ratio is between 1.14 and 1.15¹¹⁹. Generally, the $^{234}\text{U}/^{238}\text{U}$ changes little across a bone¹²⁰, as long as the source for the uranium stays the same. If the source changes, so may the $^{234}\text{U}/^{238}\text{U}$ ratio.

Laser ablation is not a particularly sensitive method. In Supplementary Tables 3 and 4, we have marked those samples with U-concentrations of lower than 0.5 ppm in red, as these results may be

unreliable. Samples that had elemental U/Th ratios of < 50 are marked green and these are not further discussed as these samples may contain considerable amounts of detrital ^{230}Th . This can be seen, for example, for spot 17 of transect M4 in the hominin mandible where the U/Th ratio of 10 yielded a significantly higher age than the surrounding spots. Other samples showed less age response to low U/Th ratios.

For convenience it is most straightforward to discuss the results of each transect separately. The bones and measurement sequence were orientated that spot 1 is closest to the outside of the bone. The photos in Supplementary Fig. 2, which shows the positions of the transects and spots for the fossil samples, were orientated accordingly.

Faunal bones

Sample 3017 (bovid). The centre of the bone (spots 6 to 11) contains little uranium. Only spots 16 to 18 have $^{234}\text{U}/^{238}\text{U}$ ratios close to seawater whereas the other spots have significantly higher values. This indicates some seawater secondary overprint lowering the outside values. Whether the result of spot 3 (48.0 ± 2.5 ka) is meaningful is difficult to ascertain, however, spots 1, 4 and 5 indicate an earlier U-uptake that took place in the later Pleistocene around 13 to 18 ka.

Sample 3018 (bovid). The U-concentrations in this bone are high throughout. Only spots 1 to 3 and 25 have $^{234}\text{U}/^{238}\text{U}$ ratios different from seawater. The low U/Th ratio discounts the result of Spot 1, which may indicate a late Pleistocene age. All other results are Holocene, although there is a clear trend of older apparent ages with higher $^{234}\text{U}/^{238}\text{U}$ ratios (spots 2, 3, 4, 25). Rather than indicating an age sequence, the cross section is the result of mixing of an earlier U-uptake and one of seawater perhaps around 2,000 years ago.

Sample 3019 (bovid). The U-concentrations are high throughout. Most spots have $^{234}\text{U}/^{238}\text{U}$ ratios slightly higher than seawater, which may indicate an earlier U-uptake. Spot 12 to 14, with the highest U-concentrations seem a remainder of the earlier

U-uptake which may have taken place in the late Pleistocene and was overprinted around 3,000 years ago.

Sample 3020 (bovid). The sample shows the same behaviour as 3019. The U-concentrations are high throughout. Most spots have $^{234}\text{U}/^{238}\text{U}$ ratios slightly higher than seawater and in the centre (spots 13 to 16) there is a domain with increasing U-concentrations slightly higher $^{234}\text{U}/^{238}\text{U}$ ratios and latest Pleistocene ages. The overprint may have taken place around 4 to 5 ka ago.

Sample 3021 (bovid). U-concentration as well as $^{234}\text{U}/^{238}\text{U}$ ratios are quite uniform, except for spots 1 to 4. It seems that spot 1 indicates a late Pleistocene uptake phase. The main marine signature derives from an uptake event around 4 to 5 ka ago.

Sample 3022 (bovid). The U-concentrations are high throughout. Most spots have $^{234}\text{U}/^{238}\text{U}$ ratios slightly higher than seawater. This may indicate a very late overprint with sea water uranium. A late Pleistocene age is only indicated in the B section (spots 19 to 24, not shown in Supplementary Fig. 2). The sea water U-uptake phase took place between about 3 and 6 ka.

Sample 3023 (bovid). The U-concentrations are throughout significantly lower than in 3018 to 3022. The brownish section from spot 19 onwards seems to contain large amounts of detrital Th, the pores seem to be filled with sediment (see Supplementary Fig. 2). Most spots have $^{234}\text{U}/^{238}\text{U}$ ratios slightly lower than seawater and all spots give late Pleistocene ages of around 15 to 20 ka, older than all other faunal samples. This suggests a unique history of taphonomy and/or exposure to seawater for this sample.

Sample 3024 (*Crocota crocuta ultima*). There is a U-gradient increasing from spot 1 to 6. The ages in the centre of the bone are the youngest of all samples, most of them significantly less than 1,000 years. The higher $^{234}\text{U}/^{238}\text{U}$ ratios at the outside (spots 1 to 4 and 18 to 19) are associated with higher ages. However, none is indicating a Pleistocene age.

Penghu 1

Four transects were run. In the first attempt, the laser energy decreased during the run (the holes in transect 4 are significantly shallower than in transect 1). This session was abandoned and parallel transects were run a month later.

Transect M1. U-concentrations vary throughout the bone. Spots 1 to 4 and 13 to 16, located in the brown coloured domains have lower U-concentrations, but higher $^{234}\text{U}/^{238}\text{U}$ ratios. This may indicate leaching. The central part yielded Holocene ages. None of the $^{234}\text{U}/^{238}\text{U}$ ratios indicate sea water. The central part indicates an U-uptake event around 5 to 7 ka ago.

Transect M2: There are little differences in the U-concentrations from spots 1 to 20, but a clear gradient towards lower concentrations in spots 22 to 24, located in the dark brown section. The latter also have the highest $^{234}\text{U}/^{238}\text{U}$ ratios. The central part indicates an U-uptake event around 6 ka ago.

Transect M3. The characteristics are the same as for transect M1. Again the lower U-concentrations in the outer spots (1 to 3 and 21, 22), located in the brown domain, are associated with higher $^{234}\text{U}/^{238}\text{U}$ ratios and older ages. The central part indicates an U-uptake event around 6 ka ago.

Transect M4. The characteristics are similar to the others. Lower U-concentrations in the outer spots (1 and 15 to 18), located in the brown domain, are associated with higher $^{234}\text{U}/^{238}\text{U}$ ratios and older ages. The central part indicates an U-uptake event between 5 to 8 ka ago.

Summary and Discussion

The faunal bones all show an earlier, mostly late Pleistocene, U-uptake phase followed by a seawater overprint. The Pleistocene ages show similar $^{234}\text{U}/^{238}\text{U}$ values as Penghu 1, which in turn show no evidence of complete replacement by seawater-derived U. Many spots show mid- or late-Holocene U-Th ages and $^{234}\text{U}/^{238}\text{U}$ values similar to seawater. This may indicate the time of the initial seawater submergence, but alternative, more likely explanation is that the bones had

experienced continual (and spatially variable) seawater overprint since early Holocene.

It is tempting to use the older outside results to approximate the age of Penghu 1. These domains seem heavily altered, as indicated by the brown color, and have lower U-concentrations. This raises the question whether the lower U-concentrations are due to loss of bone material

(reduced surface area for U to adsorb on) or leaching. Since the latter process cannot be excluded, these older age estimates are not very meaningful. It should be noted that, however, none of the spots indicate Early/Middle Pleistocene U-Th ages. This observation is consistent with, although not exclusively support, the Late Pleistocene ages of the Penghu terrestrial fauna as hypothesized in Supplementary Note 2.

Supplementary Note 4. Morphological description of Penghu 1

See Fig. 3 for illustrations.

Mandible. The transversely wide anterior symphyseal surface is strongly receding and markedly rounded in the mid-sagittal section without forming a chin. Below the small, weakly hollowed alveolar planum, the rounded posterior symphyseal surface is generally smooth with poor development of the transverse tori and fossa structures. The midsagittal cross-sectional contour assumes an elliprical shape.

The mandibular corpus is low and thick throughout, particularly in its lateral part. A strong superior transverse torus dominates the lateral surface. The torus extends posteriorly to continue into the lateral prominence below mesial M₂. This comparatively anterior location of the lateral prominence may be associated with the M₃ agenesis (see below) and shortened mandibular corpus of Penghu 1, and thus is not necessarily an expression of a primitive morphology seen in earlier *Homo*^{121,122}. A single, large mental foramen opens on the torus below P₁/P₂. The lingual surface is marked by a log-like, well-developed alveolar prominence.

The mandibular ramus is low. The gonial angle is thick and slightly everted laterally. The condyle is rounded, transversely restricted, and anteroposteriorly wide. The deepest point of the mandibular notch is posteriorly located, and the notch is “asymmetrical”¹²³, a potential primitive feature¹²⁴. The crest of the mandibular notch meets with the condyle laterally. Medially, the lingula has an independent tip and the mandibular foramen opens posteriorly. The posterior margin of the ramus shows a strong medial inflection and this contributes to the strong medial projection of the superior pterygoid tubercle. Immediately medial to the mandibular notch, the planum triangulare forms a deep depression between the crista

endocornoidea and the crista endocondyloidea. This feature is also described for Xujiayao 14 and is a rare observation among the fossil *Homo* mandibles¹²⁴.

Teeth. The preserved alveoli and tooth crowns indicate that all the teeth, particularly the anterior teeth, were large. The crowns of P₁, P₂, and M₁ are worn extensively, but M₂ remains relatively unworn. Its crown dimensions are 14.2 mm (MD) and 13.4 mm (BL).

The roots of C₁, P₁, P₂, and M₁ are generally thick and robust. The P₁ exhibits Tome’s root morphology, where the mesiobuccal and distolingual segments are fused incompletely.

The M₂ is unusual for hominins, with the markedly rounded lingual crown contour associated with a robust, conical, extra root immediately below it. This extra root is in between the lingual sides of the plate-like mesial and distal roots, which are fused extensively on their buccal sides. This supernumerary root is different from the ‘three-rooted’ lower molar occasionally found in modern humans (often on M₁), where the extra root appears immediately lingual to the distal root¹²⁵. The root of M₂ is longer than that of M₁.

Micro-CT sections of Penghu 1 indicate that right M₃ is absent inside the alveolar bone. The unworn distal face of M₂ and limited alveolar bone posterior to it rule out the possibility that M₃ was originally present and subsequently lost by some external factor such as trauma. Dozens of malformation syndromes or systemic diseases are known to cause tooth agenesis, but the remaining teeth and alveoli of Penghu 1 shows no such signs (agenesis, microdontia, abnormal positions, enamel hypoplasia, etc.)^{126,127}.

Supplementary Note 5. Penghu 1 compared to the Xujiayao 14 mandible

Among 17 fragmentary hominin fossil remains excavated from supposedly early Late Pleistocene (MIS 5 or 4) layers at Xujiayao, Hebei Province, northern China, is a right mandibular ramus (Xujiayao 14). This specimen was recently described by Wu and Trinkaus¹²⁴ who also made detailed morphological comparisons with a variety of archaic and modern *Homo* samples from Asia, Europe, and Africa. Given its chronological (and geographical) proximity with Penghu 1, morphology of this Chinese specimen is of interest.

The ramus of Xujiayao 14 is slightly broader than that of Penghu 1 (least ramus breadth: 44.5 vs. 43 mm), and is surely taller than the latter when compared with the published photograph (Fig. 1 in ref. 124). The ramus of Penghu 1 is inclined posteriorly like the single existing ramus of Javanese *H. erectus* (Sangiran 21)¹²⁸, while that of Xujiayao 14 appears to stand more vertically as seen in Zhoukoudian *H. erectus*¹²⁹.

Xujiayao 14 and Penghu 1 share many other characteristics: 1) asymmetric mandibular notch shape where its deepest point is located posteriorly, 2) the lack of mandibular foramen bridging, 3) lateral position of the meeting point between the mandibular notch crest and the condyle, 4) gonial eversion, 5) a well-developed superior medial pterygoid tubercle, and 6) a deep depression at the planum triangulare.

Some of these are widely observed in other archaic *Homo* mandibles (No. 1), or relatively common

among both archaic and modern specimens except for Neanderthals (Nos. 2, 3, 4)¹²⁴, and thus are not diagnostic. Wu and Trinkaus described that Xujiayao 14 looks similar to Neanderthal exhibiting the character No. 5. In our observation, the strong superior medial pterygoid tubercle in Penghu 1 is largely affected by the strong medial excursion of the posterior ramus border (Supplementary Note 5). Interestingly, such strong curvature of the posterior border is not present in Xujiayao 14 but is clearly observed in the remaining upper part of the border in Sangiran 21, in which the portion of the tubercle is unfortunately damaged. The character No. 6 was described as rare among Pleistocene *Homo*¹²⁴, and Penghu 1 is the second example of such morphology among archaic mandibles after Xujiayao 14.

In summary, although the rami of Penghu 1 and Xujiayao 14 are similar to each other in some aspects, there are few features that support taxonomic affinities between them. They share the deep pits on the planum triangulare, but taxonomic significance of such surface morphological character is unclear in the presently available small sample.

Moreover, the two specimens seem to be different in one important aspect: Although the corpus of Xujiayao 14 is missing, its comparatively narrow extramolar sulcus (Fig. 1 in ref. 124) suggests that Xujiayao 14 did not have an extremely thick corpus, a peculiar characteristic of the Penghu 1 mandible.

Supplementary Note 6. Penghu 1 compared to a molar of “Denisovan”

In light of recent claim that “Denisovan” genome was once widely distributed from southern Siberia to insular Southeast Asia during the Late Pleistocene¹³⁰, possible relationships between the Penghu and Denisova hominins are of interest. Currently, dentognathic elements of Denisovans are represented by a single left maxillary molar (M^2 or M^3)⁸⁷, which cannot be directly compared to Penghu. Nevertheless, two Asian fossil assemblages with similar M_2 crown diameters to

Penghu 1, Hexian and older Sangiran, include three M^2 s (PA837, Sangiran 4, Sangiran 27) of comparable crown length and breadth to the Denisovan molar. Therefore, the currently available indirect evidence does not preclude the possibility that the Denisova and Penghu hominins had similarly large molars. However, their morphological affinities remain elusive until more fossil materials become available for direct comparison.

Supplementary Note 7. Third molar agenesis

External observation and micro-CT scan indicate that Penghu 1 originally lacked the right M_3 (Supplementary Note 5). M_3 agenesis is a relatively common, normal variant in modern humans including Upper Palaeolithic people¹³¹, but is rare in premodern hominins.

The earliest example of M_3 agenesis in the existing hominin fossil record is an early *Homo* (*H. habilis*) mandible from Ethiopia, Omo 75-14,

dated to 2 Ma (unilateral M_3 agenesis)^{132,133}. The second oldest is the D2735 mandible from Dmanisi (unilateral M_3 agenesis)⁶³, followed by Lantian (bilateral M_3 agenesis in the PA 102 mandible)¹³⁴. LB1, the type specimen of *H. floresiensis*, also exhibits agenesis of right M^3 as well as right P_2 ^{135,136} (contra. ref. 137). M_3 agenesis is also seen in the middle Upper Paleolithic of Europe, and becomes increasingly common through modern human samples^{138,139}.

Supplementary Note 8. Molar teeth from Hexian

Xing and his colleagues recently published detailed morphological description and comparative analyses of 10 isolated hominin teeth from Hexian¹⁴⁰. These authors identified the seven Hexian molar teeth as follows (wear-corrected MD and BL diameters by Y.K., in mm):

PA838 = M ₂	MD: 13.9, BL: 14.1 [cast]
PA839 = M ₂	MD: 14.5, BL: 13.5
PA834-1 = M ₂	MD: (12.8), BL: 13.0
PA834-2 = M ₃	MD: 13.7, BL: 13.6
PA836 = M ¹	MD: 12.5, BL: 14.1
PA833 = M ²	MD: 12.0, BL: 14.0
PA837 = M ²	MD: 12.8, BL: 15.6

Y.K. and R.T.K. had an opportunity to observe the original specimens of the above teeth in 2011 at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing. We agree with the molar number assignments by Xing and colleagues for PA839 (M₂) and PA837 (M²), and only these teeth are plotted in our Figs. 5 and 7. We also agree that PA836 is M¹. However, in our view, PA838 is probably M₁, and the two associated

molars, PA834-1 and -2 are M₁ and M₂, respectively. Also, PA833 may be M¹ rather than M².

If Xing and colleagues identifications are correct, the Hexian assemblages include two more M₂ and one more M² specimens, that are slightly to moderately smaller than the Hexian M₂s plotted in Figs. 5 (PA839) and 7 (PA837). If our identification is correct, the Hexian M₂ assemblage includes another tooth (PA834-2) that is only slightly smaller than the specimen plotted in Fig. 5 (PA839).

Therefore, the exact range of size variation for the Hexian M₂ remains unclear. Still, this uncertainty does not affect the main conclusion of the present study: The Penghu M₂ is considerably larger compared to penecontemporaneous archaic Asian hominins, but the Hexian fossil assemblage includes one or more individuals who are very similar to Penghu 1.

References

- 1 Lu, Y., Li, Y. & Jin, C. Mammalian remains from the Late Pleistocene of Wurji, Nei Mongol. *Vertebr. Palasiat.* **24**, 152-162 (1986).
- 2 Archaeological Team of Provincial Museum of Liaonin and Institute of Vertebrate Paleontology and Paleoanthropology. Discovery of Plaeolithic artifacts in Gezidong Cave in Liaoning Province. *Vertebr. Palasiat.* **13**, 122-136 (1975).
- 3 Museum of Liaoning Province and Museum of Benxi City. *Miaohoushan: a site of early paleolithic in Benxi County, Liaoning* (Wenwu Press, 1986).
- 4 Pei, W. On the Carnivora from Locality 1 of Choukoutien. *Palaeontol. Sin. Ser. C* **8**, 1-216 (1934).
- 5 Kurtén, B. The status and affinities of *Hyaena sinensis* Owen and *Hyaena ultima* Matsumoto. *Am. Mus. Novit.* **1764**, 1-48 (1956).
- 6 Huang, P.-H. *et al.* ESR dating of tooth enamel: comparison with U-series, FT and TL dating at the Peking Man site. *Appl. Radiat. Isot.* **44**, 239-242 (1993).
- 7 Guo, S. L. *et al.* Fission track dating of the 4th layer of the Peking Man Site. *Acta Anthropol. Sin.* **10**, 73-77 (1991).
- 8 Pei, W. in *Multi-Disciplinary Study of the Peking Man Site at Zhoukoudian* (ed R. K. Wu) 258-260 (Science Press, Beijing, 1985).
- 9 Grün, R. *et al.* ESR analysis of teeth from the palaeoanthropological site of Zhoukoudian, China. *J. Hum. Evol.* **32**, 83-91 (1997).
- 10 Shen, G. *et al.* High-precision U-series dating of Locality 1 at Zhoukoudian, China. *J. Hum. Evol.* **41**, 679-688 (2001).
- 11 Zhou, C., Liu, Z., Wang, Y. & Huang, Q. Climatic cycles investigated by sediment analysis in Peking Man's Cave, Zhoukoudian, China. *J. Archaeol. Sci.* **27**, 101-109 (2000).
- 12 Li, Y. & Lei, C. Fossil mammals from Lishui, Jiangsu. *Vertebr. Palasiat.* **18**, 59-64 (1980).
- 13 Tseng, Z. J., Jin, C.-Z., Liu, J.-Y., Zheng, L.-T. & Sun, C.-K. Fossil Hyaenidae (Mammalia: Carnivora) from Huainan, Anhui Province, China. *Vertebr. Palasiat.* **46**, 133-146 (2008).
- 14 Wu, X. *Yunxi Man: Report of the Excavation on Huanglong Cave* (Science Press, Beijing, 2006).
- 15 Shen, G. *et al.* Mass spectrometric U-series dating of Huanglong Cave in Hubei Province, Central China: evidence for early presence of modern humans in Eastern Asia. *J. Hum. Evol.* **65**, 162-167 (2013).
- 16 Ma, A. & Tang, H. On discovery and significance of a Holocene Ailuropoda-Stegodon fauna from Jinhua, Zhejiang. *Vertebr. Palasiat.* **30**, 295-312 (1992).
- 17 Wu, M., Wang, L., Zhang, Y. & Zhang, X. Human remains and cultural relics from Tongzi, Guizhou Province. *Vertebr. Palasiat.* **13**, 14-23 (1975).
- 18 Yuan, S., Chen, T. & Gao, S. Uranium series chronological sequence of some palaeolithic sites in South China. *Acta Anthropol. Sin.* **5**, 179-190 (1986).
- 19 Shen, G. & Jin, L. U-series age of Yanhui Cave, the site of Tongzi Man. *Acta Anthropol. Sin.* **10**, 65-72 (1991).
- 20 Li, Y. & Wen, B. *Guanyindong: A lower Paleolithic Site at Qianxi County, Guizhou Province.* (Cultural Relics Publishing House, 1986).
- 21 Song, F. & Zhang, Z. in *Treatises in Commemoration of the 30th Anniversary of the Discovery of Maba Human Cranium* (ed Guangdong Museum and Qujian Museum) 23-35 (Cultural Relics Publishing House, 1988).

- 22 Xu, C. & Huang, Z. in *Treatises in Commemoration of the 30th Anniversary of the Discovery of Maba Human Cranium* (ed Guangdong Museum and Qujian Museum) 36-42 (Cultural Relics Publishing House, 1986).
- 23 Wu, X., Schepartz, L. A., Liu, W. & Trinkaus, E. Antemortem trauma and survival in the late Middle Pleistocene human cranium from Maba, South China. *Proc. Natl. Acad. Sci. USA* **108**, 19558-19562 (2011).
- 24 Bien, M. N. & Chia, L. P. Cave and rock-shelter deposits in Yunnan. *Bull. Geol. Soc. China* **18**, 325-347 (1938).
- 25 Kahlke, H. D. On the complex of the Stegodon-Ailuropoda-fauna of southern China and the chronological position of Gigantopithecus blacki v. Koenigswald. *Vertebr. Palasiat.* **1**, 83-108 (1961).
- 26 Tougaard, C. Biogeography and migration routes of large mammal faunas in South-East Asia during the late middle Pleistocene: focus on the fossil and extant faunas from Thailand. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **168**, 337-358 (2001).
- 27 Bacon, A.-M. *et al.* The Middle Pleistocene mammalian fauna from Tam Hang karstic deposit, northern Laos: New data and evolutionary hypothesis. *Quatern. Int.* **245**, 315-332 (2011).
- 28 de Vos, J. in *Encyclopedia of Quaternary Science: Vertebrate Records* (ed S. A. Ellas) 3232-3248 (Elsevier, 2007).
- 29 Bacon, A.-M. *et al.* The Late Pleistocene Duoi U'O'i cave in northern Vietnam: palaeontology, sedimentology, taphonomy and palaeoenvironments. *Quat. Sci. Rev.* **27**, 1627-1654 (2008).
- 30 Qiu, Z.-X. Die Hyaeniden aus dem Ruscium und Villafranchium Chinas. *Münchner Geowissenschaftliche Abhandlungen, A* **9**, 1-109 (1987).
- 31 Qiu, Z., Deng, T. & Wang, B. Early Pleistocene mammalian fauna from Longdan, Dongxiang, Gansu, China. *Palaeontol. Sin. New Ser. C* **27**, 1-198 (2004).
- 32 Zdansky, O. Weitere bemerkungen über fossile carnivoren aus China. *Palaeontol. Sin. Ser. C* **4**, 1-28 (1927).
- 33 Chow, M. & Xue, X. *The Quaternary mammalian assemblage in the Northeast China*. Vol. 3 (Institute of Vertebrate Paleontology and Paleoanthropology, 1959).
- 34 Kahlke, H. D. & Chow, B. A summary of stratigraphical and paleontological observations in the lower layers of Choukoutien, Locality 1, and on the chronological position of the site. *Vertebr. Palasiat.* **3**, 212-240 (1961).
- 35 Shen, G., Gao, X., Gao, B. & Granger, D. E. Age of Zhoukoudian Homo erectus determined with $^{26}\text{Al}/^{10}\text{Be}$ burial dating. *Nature* **458**, 198-200 (2009).
- 36 Hu, C. & Qi, T. Gonwangling Pleistocene mammalian fauna of Lantian, Shaanxi. *Palaeontol. Sin. New Ser. C* **155**, 1-64 (1978).
- 37 Teilhard de Chardin, P. & Piveteau, J. Les mamifères fossiles de Nihowan (Chine). *Ann. Paleontol.* **19**, 1-134 (1930).
- 38 Qiu, Z. *et al.* A human fossil tooth and fossil mammals from Nanzhao, Henan. *Acta Anthropol. Sin.* **1**, 109-117 (1982).
- 39 Wu, R. & Li, X. (eds.) *Homo erectus from Nanjing* (Jiangsu Science and Technology Publishing House, Nanjing, 2002).
- 40 Chen, Q., Wang, Y., Liu, Z. & Shen, G. U-series dating of stalagmite samples from Hulu Cave in Nanjing, Jiangsu Province, China. *Acta Anthropol. Sin.* **17**, 171-176 (1998).
- 41 Xu, C., Zhan, Y., Chen, D. & Fang, D. Human occipital bone and mammalian fossils from Chaoxian, Anhui. *Acta Anthropol. Sin.* **3**, 202-209 (1984).
- 42 Wu, X. & Poirier, F. E. *Human Evolution in China* (Oxford University Press, 1995).

- 43 Chen, T., Yuan, S., Gao, S. & Hu, Y. Uranium series dating of fossil bones from Hexian and Chaoxian fossil human sites. *Acta Anthropol. Sin.* **6**, 249-254 (1987).
- 44 Huang, W., Fang, D. & Ye, Y. Preliminary study on the fossil hominid skull and fauna of Hexian, Anhui. *Vertebr. Palasiat.* **20**, 248-256 (1982).
- 45 Grün, R. *et al.* ESR and U-series analyses of teeth from the palaeoanthropological site of Hexian, Anhui Province, China. *J. Hum. Evol.* **34**, 555-564 (1998).
- 46 Xu, Q. & You, Y. Hexian fauna: correlation with deep-sea sediments. *Acta Anthroopologica Sinica* **3**, 62-67 (1984).
- 47 Chen, T. & Yuan, S. Uranium-series dating of bones and teeth from Chinese Palaeolithic sites. *Archaeometry* **30**, 59-76 (1988).
- 48 Chia, L. Notes on the human and some other mammalian remains from Changyang, Hupei. *Vertebr. Palasiat.* **1**, 247-257 (1957).
- 49 Kurtén, B. A note on the hyaenid remains from the Lungtung Cave described by Chia. *Vertebr. Palasiat.* **2** (1958).
- 50 Colbert, E. H. & Hooijer, D. A. Pleistocene mammals from the limestone fissures of Szechwan, China. *Bull. Am. Mus. Nat. Hist.* **102**, 1-134 (1953).
- 51 Chen, S. *et al.* New discoveries from the classic Quaternary mammalian fossil area of Yanjinggou, Chongqing, and their chronological explanations. *Chin. Sci. Bull.* **58**, 3780-3787 (2013).
- 52 Zhang, Z., Song, F., Huang, Z., Liu, C. & Tang, W. in *Treatises in Commemoration of the 30th Anniversary of the Discovery of Maba Human Cranium* (ed. Guangdong Museum and Qiujian Museum) (Cultural Relics Publishing House, 1988).
- 53 van den Bergh, G., de Vos, J. & Sondaar, P. Y. The Late Quaternary palaeogeography of mammal evolution in the Indonesian Archipelago. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **171**, 385-408 (2001).
- 54 Jin, C. & Liu, J. *Paleolithic Site –The Renzidon Cave, Fanchang, Anhui Province* (Science Press, Beijing, 2009).
- 55 Li, T. *The Yunxian Man* (Hubei Science Technology Press, 2001).
- 56 Zheng, S. (ed.) *Jianshi Hominid Site* (Science Press, Beijing, 2004).
- 57 Zhang, Z., Liu, J., Zhang, H. & Yuan, C. A Pleistocene mammalian fauna from Panxian Dadong, Guizhou Province. *Acta Anthropol. Sin.* **16**, 209-220 (1997).
- 58 Rink, W. J. *et al.* Electron Spin Resonance (ESR) dating of mammalian tooth enamel at Panxian Dadong Cave, Guizhou, China. *Radiat. Measur.* **27**, 975-1025 (2003).
- 59 Pei, W. Discovery of Gigantopithecus mandible and other material in Liu-cheng district of central Kwangsi in South China. *Vertebr. Palasiat.* **1**, 65-71 (1957).
- 60 Leakey, M. G. *et al.* New fossils from Koobi Fora in northern Kenya confirm taxonomic diversity in early Homo. *Nature* **488**, 201-204 (2012).
- 61 Wood, B.A. *Koobi Fora Research Project, 4. Hominid Cranial Remains from Koobi Fora.* (Clarendon Press, 1991).
- 62 Suwa, G. *A Comparative Analysis of Hominid Dental Remains from the Sungura and Usno Formations, Omo Valley, Ethiopia.* (Ph.D. dissertation, University of California at Berkeley, 1990).
- 63 Van Arsdale, A. Mandibular variation in early *Homo* from Dmanisi, Georgia. (Ph.D. dissertation, University of Michigan, 2006).
- 64 Martínón-Torres, M. *et al.* Dental remains from Dmanisi (Republic of Georgia): Morphological analysis and comparative study. *J. Hum. Evol.* **55**, 249-273 (2008).

- 65 Suwa, G. *et al.* Early Pleistocene *Homo erectus* fossils from Konso, southern Ethiopia. *Anthropol. Sci.* **115**, 133-151 (2007).
- 66 Gao, J. Australopithecine teeth associated with Gigantopithecus. *Vert. Palasiat.* **2**, 81-88 (1975).
- 67 Bermúdez de Castro, J.M. *et al.* Early Pleistocene mandible from Sima del Elefante (TE) cave site in Sierra de Atapuerca (Spain): a comparative morphological study. *J. Hum. Evol.* **61**, 23-25 (2011).
- 68 Carbonell *et al.* An Early Pleistocene hominin mandible from Atapuerca-TD6, Spain. *Proc. Natn. Acad. Sci., USA* **102**, 5674-5678 (2005).
- 69 Bermúdez de Castro, J.M., Rosas, A. & Nicolás, M.E. Dental remains from Atapuerca-TD6 (Gran Drina site, Burgos, Spain). *J. Hum. Evol.* **37**, 523-566 (1999).
- 70 Bermúdez de Castro, J.M., Martínón-Torres, M., Gómez-Robles, A., Prado, L. & Sarminto, S. Comparative analysis of the Gran Dolina-TD6 (Spain) and Tighenif (Algeria) hominin mandibles. *Bull. Mém. Soc. d'Anthropol. Paris* **19**, 149-167 (2007).
- 71 Weidenreich, F. The dentition of *Sinanthropus pekinensis*: a comparative odontography of the hominids. *Paleontol. Sin. New Ser. D* **1**, 1-180 (1937).
- 72 Wu, R. & Dong, X. Preliminary study of *Homo erectus* remains from Hexian, Anhui. *Acta Anthropol. Sin.* **1**, 2-13 (1982).
- 73 Wu, X. & Trinkaus, E. The Xujiayao 14 mandibular ramus and Pleistocene *Homo* mandibular variation. *Comp. Rend. Palevol* (in press).
- 74 Liu, W. *et al.* Huanglong Cave: A Late Pleistocene human fossil site in Hubei Province, China. *Quat. Int.* **211**, 29-41 (2010).
- 75 Rosas, A. Seventeen new mandibular specimens from the Atapuerca/Ibeas Middle Pleistocene hominids sample (1985-1992). *J. Hum. Evol.* **28**, 533-559 (1995).
- 76 Rosas, A. A gradient of size and shape for the Atapuerca sample and Middle Pleistocene hominid variability. *J. Hum. Evol.* **33**, 319-331 (1997).
- 77 Rosas, A. & Bermúdez de Castro, J. M. The ATD6-5 mandibular specimen from Gran Drina (Atapuerca, Spain). Morphological study and phylogenetic implications. *J. Hum. Evol.* **37**, 567-590 (1999).
- 78 Martínón-Torres, M. Bermúdez de Castro, J. M., Gómez-Robles, A., Prado-Simón, L., Arsuaga, J. A., Morphological description and comparison of the dental remains from Atapuerca-Sima de los Huesos site (Spain). *J. Hum. Evol.* **62**, 7-58 (2012).
- 79 Wolpoff, M. H. *Metric Trends in Hominid Dental Evolution*. Vol. 2 (Case Western Reserve University, 1971).
- 80 Tillier, A.-M. in *Le Squelette Moustérien de Kébara 2* (eds. Bar Yosef, O., Vandermeersch, B.) 97-112 (CNRS Editions, 1991).
- 81 Trinkaus, E. *The Shanidar Neandertals*. (Academic Press, 1983)
- 82 Sakura, H. in *The Amud Man and his Cave Site* (eds. H. Suzuki & F. Takai) 207-229 (Academic Press of Japan, 1970).
- 83 Liu, W. *et al.* Human remains from Zhirendong, South China, and modern human emergence in East Asia. *Proc. Natn. Acad. Sci., USA* **107**, 19201-19206 (2010).
- 84 Shang, H., Trinkaus, E., *The Early Modern Human from Tianyuan Cave*. China. (Texas A&M University Press, 2010).
- 85 Kaifu, Y., Fujita, M., Kono, R. T. & Baba, H. Late Pleistocene modern human mandibles from the Minatogawa Fissure site, Okinawa, Japan: morphological affinities and implications for modern human dispersals in East Asia. *Anthropol. Sci.* **119**, 137-157 (2011).
- 86 Brown, P. *Coobool Creek*. (Department of Prehistory, Research School of Pacific Studies, The Australian

National University, 1989).

- 87 Reich, D. *et al.* Genetic history of an archaic hominin group from Denisova Cave in Siberia. *Nature* **468**, 1053-1060 (2010).
- 88 Jianing, H. Preliminary study on the teeth of Jinniushan archaic *Homo sapiens*. *Acta Anthropol. Sin.* **19**, 216-225 (2000).
- 89 Xing, S., Martinon-Torres, M., Bermudez de Castro, J. M., Wu, X. & Liu, W. Hominin teeth from the early Late Pleistocene site of Xujiayao, Northern China. *Am. J. Phys. Anthropol.* (in press).
- 90 Bailey, S. E. & Liu, W. A comparative dental metrical and morphological analysis of a Middle Pleistocene hominin maxilla from Chaoxian (Chaohu), China. *Quat. Int.* **211**, 14-23 (2010).
- 91 Liu, W. *et al.* Late Middle Pleistocene hominin teeth from Panxian Dadong, South China. *J. Hum. Evol.* **64**, 337-355 (2013).
- 92 Huang, Z. & Yu, H. Morphology and geologic implications of Penghu Channel off southwest Taiwan. *Terrestrial, Atmospheric and Oceanic Sciences* **14**, 469-485 (2003).
- 93 Rohling, E. J. *et al.* Magnitudes of sea-level lowstands of the past 500,000 years. *Nature* **394**, 162-165 (1998).
- 94 Waelbroeck, C. *et al.* Sea-level and deep water temperature changes derived from benthic foraminifera isotopic records. *Quat. Sci. Rev.* **21**, 295-305 (2002).
- 95 Yokoyama, Y. & Esat, T. M. Global climate and sea level: Enduring variability and rapid fluctuations over the past 150,000 years. *Oceanography* **24**, 54-69 (2011).
- 96 Shikama, T., Otsuka, H. & Tomida, Y. Fossil Proboscidea from Taiwan. *Science Reports of the Yokohama National University, Section II* **22**, 13-62 (1975).
- 97 Gao, J.-W. Penghu fauna. *Journal of Marine Science (Geology Journal, Institute of Marine Science and Department of Marine Science, Chinese Culture University)* **27**, 123-132 (1982).
- 98 Lai, K.-Y. in *Monograph of the symposium on the Geographical Origin of the fauna of Taiwan* 27-50 (1989).
- 99 Hu, C. & Tao, X. *Animal Fossils from the Penghu Archipelago*. (Penghu Prefecture Culture Centre, 1993).
- 100 Ho, C. K., Qi, G. Q. & Chang, C. H. A preliminary study and reconstruction of late Pleistocene megafauna *Bubalus teilhardi* Young from the Penghu Channel, Taiwan. *Annual of Taiwan Museum* **39**, 1-16 (1996).
- 101 Ho, C. K., Qi, G. Q. & Chang, C. H. A preliminary study of Late Pleistocene carnivore fossils from the Penghu Channel, Taiwan. *Annual of Taiwan Museum* **40**, 1095-1224 (1997).
- 102 Ho, C. K., Qi, G. Q. & Chang, C. H. A preliminary study of late Pleistocene megafauna *Cervus* sp. from the Penghu Channel, Taiwan. *Journal of the National Taiwan Museum* **61**, 1-16 (2008).
- 103 Tseng, Z. J. & Chang, C.-H. A study of new material of *Crocota crocota ultima* (Carnivora: Hyaenidae) from the Quaternary of Taiwan. *Collection and Research* **20**, 9-19 (2007).
- 104 Tsao, K. The discovery of Holocenic "*Elaphurus davidianus*" subfossils near Shanghai and their palaeogeographical distribution in China. *Vertebr. Palasiat.* **13**, 48-57 (1975).
- 105 Ji, H. Geographical history of genus *Elaphurus*. *Vertebr. Palasiat.* **23**, 214-222 (1985).
- 106 Tedford, R. H. & Qiu, Z. Pliocene *Nyctereutes* (Carnivora: Canidae) from Yushe, Shanxi, with comments on Chinese fossil raccoon-dogs. *Vertebr. Palasiat.* **19**, 176-189 (1991).
- 107 Young, C. C. On the Artiodactyla from the *Sinanthropus* site at Choukoutien. *Paleontologia Sinica, Ser. C* **8**, 1-100 (1932).
- 108 Young, C. C. New finds of fossil *Bubalus* in China. *Bull. Geol. Soc. China* **15**, 505-516 (1936).

- 109 Chow, M. & Hsu, Y. A new species of fossil *Bubalus* from Menghsien, Honan. *Acta Paleontol. Sin.* **5**, 457-465 (1957).
- 110 Xue, X. & Li, X. Fossil *Bubalus* from Shaanxi, distribution and phylogeny of fossil *Bubalus* in China. *Vertebr. Palasiat.* **38**, 218-231 (2000).
- 111 Chang, C.-H., Takai, M. & Ogino, S. First discovery of colobine fossil from the middle Pleistocene of southern Taiwan. *J. Hum. Evol.* **63**, 439-451 (2012).
- 112 Huang, W. P. Taxonomy of the Hyaenidae (*Hyaena* and *Crocota*) of the Pleistocene in China. *Vertebr. Palasiat.* **27**, 197-204 (1989).
- 113 Xue, X. & Zhang, Y. in *The Quaternary of China* (ed Z. Zhang) (China Ocean Press, 1991).
- 114 Werdelin, L. & Solounious, N. The Hyaenidae: taxonomy, systematic and evolution. *Fossils and Strata* **30**, 1-104 (1991).
- 115 Zdansky, O. Jungtertiäre Carnivoren Chinas. *Palaeontol. Sin. Ser. C* **2**, 1-149 (1924).
- 116 Gaboardi, M., Deng, T. & Wang, Y. Middle Pleistocene climate and habitat change at Zhoukoudian, China, from the carbon and oxygen isotopic record from herbivore tooth enamel. *Quatern. Res.* **63**, 329-338 (2005).
- 117 Grün, R., Eggins, S., Kinsley, L., Moseley, H. & Sambridge, M. Laser ablation U-series analysis of fossil bones and teeth. *Palaeogeogr., Palaeoclimatol., Palaeoecol.* **416**, 150-167 (2014).
- 118 Storm, P. *et al.* U-series and radiocarbon analyses of human and faunal remains from Wajak, Indonesia. *J. Hum. Evol.* **64**, 356-365 (2013).
- 119 Hamelin, B., Bard, E., Zindler, A. & Fairbanks, R. G. U-234/U-238 mass-spectrometry of corals - How accurate is the U-Th age of the last interglacial period? *Earth Planet. Sci. Lett.* **106**, 169-180 (1991).
- 120 Sambridge, M., Grün, R. & Eggins, S. U-series dating of bone in an open system: The diffusion-adsorption-decay model. *Quat. Geochronol.* **9**, 42-53 (2012).
- 121 Rosas, A. & Bermúdez de Castro, J. M. On the Taxonomic Affinities of the Dmanisi Mandible (Georgia). *Am. J. Phys. Anthropol.* **107**, 145-162 (1998).
- 122 Kaifu, Y. *et al.* Taxonomic affinities and evolutionary history of the Early Pleistocene hominids of Java: dentognathic evidence. *Am. J. Phys. Anthropol.* **128**, 709-726 (2005).
- 123 Rak, Y., Ginzburg, A. & Geffen, E. Does *Homo neanderthalensis* play a role in modern human ancestry? The mandibular evidence. *Am. J. Phys. Anthropol.* **119**, 199-204 (2002).
- 124 Wu, X. & Trinkaus, E. The Xujiayao 14 mandibular ramus and Pleistocene *Homo* mandibular variation. *Compt. Rend. Palevol* **13**, 333-341 (2014).
- 125 Scott, G. R. & Turner, C. G. *The anthropology of modern human teeth: Dental morphology and its variation in recent human populations* (Cambridge University Press, 1997).
- 126 Vastardis, H. The genetics of human tooth agenesis: New discoveries for understanding dental anomalies. *Am. J. Orthod. Dentofacial Orthop.* **117**, 650-656 (2000).
- 127 Nieminen, P. Genetic basis of tooth agenesis. *J. Exp. Zool. B Mol. Dev. Evol.* **312B**, 320-342 (2009).
- 128 Kaifu, Y., Aziz, F. & Baba, H. Hominid mandibular remains from Sangiran: 1952-1986 collection. *Am. J. Phys. Anthropol.* **128**, 497-519 (2005).
- 129 Weidenreich, F. The mandibles of *Sinanthropus pekinensis*: a comparative study. *Paleontol. Sin. Ser. D* **7**, 1-162 (1936).
- 130 Reich, D. *et al.* Denisova admixture and the first modern human dispersals into Southeast Asia and Oceania. *Am. J. Hum. Genet.* **89**, 516-528 (2011).
- 131 Brothwell, D. R., Carbonell, V. M. & Goose, D. H. in *Dental Anthropology* (ed. D. R. Brothwell) 179-190

(Pergamon, 1963).

- 132 Wallace, J. A. Gingival eruption sequences of permanent teeth in early hominids. *Am. J. Phys. Anthropol.* **46**, 483-493 (1977).
- 133 Suwa, G., White, T. D. & Howell, F. C. Mandibular postcanine dentition from the Shungura Formation, Ethiopia: crown morphology, taxonomic allocations, and Plio-Pleistocene hominid evolution. *Am. J. Phys. Anthropol.* **101**, 247-282 (1996).
- 134 Woo, J. K. A newly discovered mandible of the Sinanthropus type - *Sinanthropus lantianensis*. *Scientia Sinica* **13**, 801-811 (1964).
- 135 Kaifu, Y. *et al.* Craniofacial morphology of *Homo floresiensis*: description, taxonomic affinities, and evolutionary implication. *J. Hum. Evol.* **61**, 644-682 (2011).
- 136 Kaifu, Y. *et al.* Brief communication: "Pathological" deformation in the skull of LB1, the type specimen of *Homo floresiensis*. *Am. J. Phys. Anthropol.* **140**, 177-185 (2009).
- 137 Brown, P. & Maeda, T. Liang Bua *Homo floresiensis* mandibles and mandibular teeth: a contribution to the comparative morphology of a new hominin species. *J. Hum. Evol.* **57**, 571-596 (2009).
- 138 Hillson, S. *Dental Anthropology* (Cambridge University Press, 1996).
- 139 Hillson, S. *Teeth*. 2 edn. (Cambridge University Press, 2005).
- 140 Xing, S. *et al.* Middle Pleistocene hominin teeth from Longtan Cave, Hexian, China. PLoS ONE (in press).