EARLY CRETAN SEALS.
NEW EVIDENCE FOR THE USE OF BONE, IVORY AND BOAR'S TUSK

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Recent work on the use of hippopotamus ivory in the Aegean Bronze Age, coupled with earlier studies on the role of bone and boar's tusk in seal manufacture, enables us to modify the definitions of certain shape classes proposed by Paul Yule in Early Cretan Seals [1]. Besides providing more precise terms of reference for assessing individual seals, the modifications suggested in this paper may help to illuminate some of the chronological questions raised in Yule's study.

Yule's definitions of shape classes are of undoubted benefit for seal studies. Regrettably, however, the identifications of "ivory" seals on which Yule based many of his definitions are demonstrably incorrect. While admitting that bone and ivory could easily be confused, Yule generally accepted without demur the identifications published in the CMS [2]. This, and an incomplete understanding of the natural features of the raw materials, has led to misleading definitions of many of the commoner shape classes. Since bone and ivory account for some 20% of the early Cretan seals which Yule classifies, the need for a re-assessment of his "ivory" shape classes is beyond question.

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* In addition to the standard abbreviations, the following are used:

CM	A. Xenaki-Sakellariou, "Les cachets minoens de la collection Giamalakis", Etudes cretoises 10 (Paris, 1958).
ECS	P. Yule, Early Cretan Seals: a Study of Chronology (Mainz, 1981).
HM	Herakleion Museum inventory number.
K	catalogue number in V.E.G. Kenna, Cretan Seals (Oxford, 1960).
VTM	S. Xanthoudides, Vaulted Tombs of Mesara (London, 1924).

Yule's shape classes are referred to in the following manner: arch-incised (2).

Illustrations on Fig. 2 provided from negatives in the CMS archives.

[1] ECS 24–117; O.H. Krzyszkowska, "Wealth and prosperity in prepalatial Crete", in: Minoan Society (ed. O. Krzyszkowska and L. Nixon) (Bristol, 1983) 163–169; idem, "Ivory from hippopotamus tusk in the Aegean Bronze Age", Antiquity 58 (1984) 123–125; idem, "Hippopotamus and elephant ivory in the Aegean Bronze Age", BSA 83 (in preparation).

[2] ECS 195–196. The seals from Lenda are published in CMS II 1 as "Bein", which does not necessarily indicate "bone", but is a generic word covering both bone and ivory (pers. comm. Ingo Pini; contra ECS 196). The nearest equivalent in English would be the designation "bone/ivory", commendably adopted by John Betts for CMS X in cases of doubt. The remainder of the "ivory" seals in Herakleion are published in CMS II 1 as "Elfenbein".

The vast majority of "ivory" seals have been published in CMS II 1 and these provide the focus for the present article [3]. Of some three hundred seals published as "ivory" in that volume, perhaps as many as half should now be re-classified as bone or boar's tusk [4]. Certain shape classes are closely associated with bone. A few are found in boar's tusk, while still others occur almost exclusively in ivory. In these cases, the seal shapes are usually derived from the natural morphological features of the raw material and "substitution" of one material for another is rare. Few shapes occur equally in all three materials. Some of the small-sized seals are morphologically feasible not only in ivory but also in bone or in boar's tusk, which offer smaller amounts of solid material for carving. In these cases my re-definitions must be more tentative. Finally, a number of seals, sometimes considered to be "ivory" or bone, are found to be made from altogether different materials. These too belong to particular shape classes which can be re-defined accordingly.

MATERIALS

Ivory, bone and boar's tusk each have certain diagnostic features by which they can be differentiated whether worked or fresh. It is also possible to distinguish hippopotamus from elephant ivory and even to identify which kind of tusk supplied it, lower canines or incisors. The diagnostic features may be considered conveniently under three broad headings: morphological characteristics, surface features and structure. A detailed discussion of these criteria and their application in practical identifications is to be published elsewhere [5]. Here we may consider those features which are most commonly encountered in pre-palatial seals and on which the re-identifications presented below are based.

Bone

Cattle metatarsals and metacarpals (bones of the hind and fore feet) are the most suitable for seal manufacture, since they have straight shafts and thick walls. Metatarsals have a longitudinal depression running down the shaft in the dorsal aspect corresponding to the septum within the marrow cavity [6] *(Fig. 1a)*. In mid-shaft they have a roughly circular section. Metacarpals are

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[3] The bone and ivory seals from Lenda were examined in 1979 with the generous permission of the excavator, Professor St. Alexiou and Dr. Y. Tzedakis, Acting Ephor of Herakleion. I am also most grateful to Professor I. Sakellarakis for kindly permitting me to study a selected group of seals in the Herakleion Museum in 1987. This work was greatly facilitated by the use of the CMS microscope and benefitted from collaboration with Drs. I. Pini and W. Müller. Valuable experience was also gained during study of the Mitsotakis Collection with Drs. Pini and Müller in 1986. I am grateful to the German Academy of Sciences and the British Academy for financial assistance in these projects. The bone and ivory seals in the Ashmolean Museum were examined on several occasions. I should like to thank Mrs. H. Hughes-Brock for arranging this work and for many fruitful discussions on seals. I am also most indebted to her for her valuable advice and perceptive comments on this paper.

[4] Earlier studies suggested that some 10% of pre-palatial seals made from bone and boar's tusk: Krzyszkowska [1983] 164 and n. 1 (op. cit. n. 1). The new estimates are based on recent examination of seals in the Herakleion Museum and a detailed study of the CMS photographs. They accord with observations made by Dr. Pini.

[5] O.H. Krzyszkowska, Ivory and related materials: an illustrated guide, ICS Handbook 3 (in preparation).

[6] In the ruminants, the metatarsal consists of a single "cannon-bone" formed by the fusion of metatarsals III and IV and reflected in the septum and depression. The metacarpal is similar.

characterised by a half-moon shaped section *(Fig. 1b)*. It is possible that other long bones were used (e.g. tibiae for epomia) although this requires confirmation. Long bones of sheep/goat and pig may have been used for smaller seals: perhaps for the small, rather crude rings from Lenda (e.g. CMS II 1 No. 171). It is rarely possible to identify the precise bone and species except by handling the seal. Among those which I have handled myself are CMS II 1 No. 179 (large ring) *(Fig. 2a)*, CMS II 1 No. 210 (hammerheaded), and CMS V No. 21 (hollow cylinder), all made from cattle metatarsals.

Bone may also be identified by its surface features and structure. Frequently there is a general sense of "graininess" to the material, especially on broken or damaged surfaces. Striations, which are short fine roughly parallel lines, may also be visible, either darker or lighter than the rest of the surface. Concentric cracking commonly occurs around the marrow cavity, or the remains thereof, producing an appearance akin to the lamellae of ivory. These "pseudo-lamellae" are particularly noticeable in the photograph of CMS II 1 No. 273, a cylinder (32c) from Platanos *(Fig. 2b)*.

Boar's tusk

This is the name commonly given to the lower canine teeth of wild boar *(Sus scrofa)*. They are composed of dentine, as are all teeth, covered by a layer of enamel. The term "ivory" should not be applied to this material, since it is likely to lead to confusion. Boar's tusks have a distinctive trihedral section with a tapering pulp cavity occupying the proximal or root end. No accurate statistics are available for the dimensions of boar's tusks from the Aegean Bronze Age but a good-sized tusk might measure 20–25 cms. along its outer curve. About one third of this would be entirely solid at the distal end (i.e. toward the tip). A fine black "heartline" runs through the centre of the tusk *(Fig. 1c)*. The outer surface of the tusk is covered by a distinctive, glistening enamel, slightly ridged transversely, measuring 6–7 on the Mohs scale.

Boar's tusk is most easily identified on morphological grounds. Trihedral shapes such as gables (14a) or triangular portions "missing" from sealfaces (e.g. CMS II 1 No. 11) all point to the use of this material. Occasionally traces of enamel may be preserved on the body of the seal (e.g. CMS II 1 No. 440). The layers of dentine, which present a triangular pattern, are rarely visible except under very high magnifications.

Ivory

The term "ivory" refers to the dentine found in the tusks of certain large mammals such as elephant and hippopotamus [7]. It had been assumed that elephant ivory alone was carved during the Aegean Bronze Age, but new research has demonstrated that significant amounts of hippopotamus ivory were also used as well [8]. Furthermore, the use of elephant ivory in pre-palatial

[7] Properly, the term "ivory" refers only to the dentine of elephant tusks, but it is commonly used for that found in the tusks of hippopotamus, sperm whale and walrus also. Here the word "ivory" unqualified refers to the substance dentine, that is, the raw material used for carving. Otherwise the terms "hippopotamus ivory" and "elephant ivory" are used.

[8] Krzyszkowska (in preparation) and idem [1984] (op. cit. n. 1).

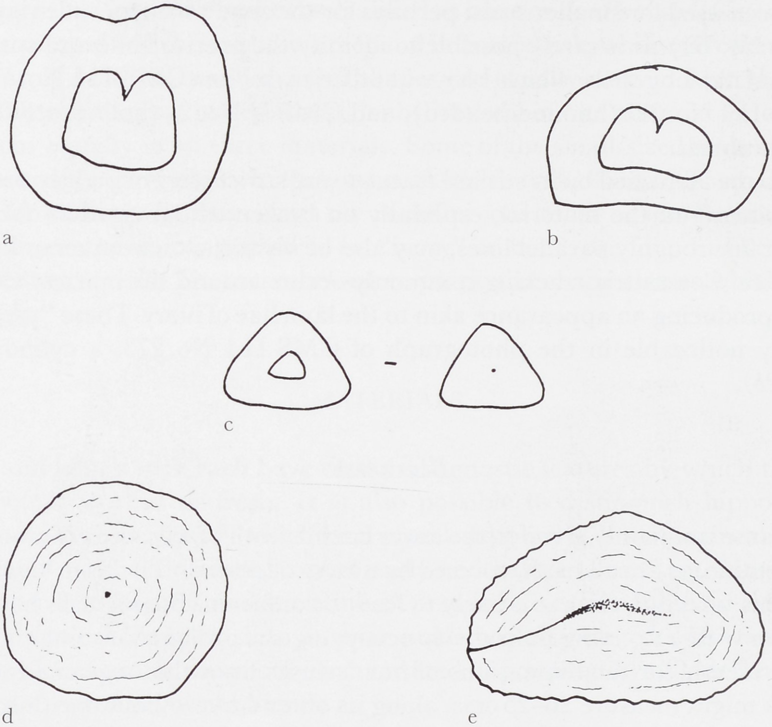

Fig. 1a–e Transverse sections of the raw materials. a) cattle metatarsal; b) cattle metacarpal; c) boar's tusk; d) hippopotamus incisor; e) hippopotamus lower canine. Scale ca. 1:2,5.

Crete is doubtful and no seals have been positively identified in that material. For large carvings, the size and shape of hippopotamus tusks may present difficulties but not for seals. Indeed, the morphological characteristics of the tusks were often exploited to good effect to produce seal shapes with the minimum of carving.

The hippopotamus possesses a series of large tusks but those most suitable for carving are the pair of large lower canines and the two pairs of lower incisors [9]. The size of these tusks varies considerably according to the age and sex of the animal [10]. The incisors are straight teeth with a sub-

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[9] For an illustration of hippopotamus dentition see: I.W. Cornwall, Bones for the Archaeologist (London, 1956) 101 Fig. 26. Photographs of a lower canine and incisor may be found in T.K. Penniman, Pictures of Ivory and other Animal Teeth, Bone and Antler (Pitt Rivers Occasional Paper, 5) (Oxford, 1952) pl. XX, 2.

[10] A mature lower canine in my collection weighs 1.5 kg and measures L. 0.58 m along the outer curve, but a smaller pair, quite suitable for seal manufacture measure L. 0.34 m and weigh only 0.35 kg each. A pair of incisors in my possession each weigh 0.28 kg and measure L. 0.20 m, W. max. 0.035 m, Th. max. 0.026 m. See also: R.M. Laws, "The Dentition and ageing of the hippopotamus", East Africa Wildlife Journal 6 (1968) 19–52; especially 38–39. I am most grateful to Dr. Laws for the large lower canine just mentioned and also to Dr. Annie Caubet of the Musée du Louvre for advice concerning hippopotamus ivory.

Fig. 2a–d Early Cretan seals from bone and ivory. Bone: a) CMS II 1 No. 179; b) CMS II 1 No. 273.
Hippopotamus ivory: c) CMS II 1 No. 387; d) CMS II 1 No. 52.

circular section and are covered by a substance called "cementum". A tapering pulp cavity occupies the proximal end of the tusk. In transverse sections, the layers of dentine or lamellae will appear in a roughly concentric pattern. They are usually rather wavy and may seem discontinuous. In the very centre, a small dot or "heartline" may also appear [11] *(Fig. 1d)*. All of these diagnostic features may help to identify the material used for seals. They appear most clearly in the case of cylinders (32a, 32b), some of which are essentially transverse sections of incisors with slight modification. In seals such as CMS II 1 No. 336 the different diameters of the sealfaces indicate that a tapering section of tusk was employed, while traces of the "heartline" and the concentric lamellae which correspond closely to the shape of the sealface all point to the use of a hippopotamus lower incisor. Normally the "cementum" was removed during seal manufacture, although occasionally a rather furrowed and shiny seal body may suggest that this surface was retained. The tips of incisors with little additional modification could readily provide blanks for conoids such as CMS II 1 No. 387 *(Fig. 2c)* or hemispheroids.

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[11] Penniman (op. cit. n. 9) pl. VII.

The large curving lower canines have a distinctive trihedral section and wear facet at the tip rather like boar's tusks. Two surfaces are covered by extremely hard ridged enamel, registering 6–7 on the Mohs scale; the third is covered by "cementum". Two kinds of dentine are found in lower canines, but for seals, only the appearance of the outer dentine really concerns us. In a transverse section this is visible in a triangular pattern corresponding to the shape of the tusk itself[12]. As in the case of incisors, the lamellae will often be wavy and slightly discontinuous. Another diagnostic feature of great significance is the commissure, which represents the junction between the outer dentine and the inner dentine of the tusk *(Fig. 1e)*. The arched line of the commissure frequently runs through seals, sometimes appearing as a line of dots, sometimes as a slightly "resinous" substance, or sometimes as a crack. Associated with the commissure is a natural fracture line; together they often produce an angled crack across the sealface. These features of lower canines may be easily detected in photographs of the concave-sided cylinder CMS II 1 No. 52 *(Fig. 2d)*.

"White pieces"

A number of seals are described in earlier literature as "ivory", "frit", "faience", "white paste" or "white steatite" but on examination are evidently not made from these materials as we normally understand them. Such seals, which seem to form a coherent group, are provisionally termed "white pieces" [13]. Most are extremely small yet are carved with great precision, both on the seal bodies and on their faces. Many belong to or are close to Yule's Border/Leaf complex. The material from which they are carved is, for the present, a mystery. Under high magnifications, these seals may appear to have a "second layer" different from the substance beneath. Where this layer has been lost, the substance seems to contain a number of raised "bubbles" and elsewhere "craters" (as if "bubbles" had burst). These features suggest that the substance itself is man-made or that a naturally occurring material, such as steatite, was transformed in some manner during manufacture. Scientific analyses of four pieces in the Ashmolean Museum (K 85–88) are published elsewhere in this volume by Helen Hughes-Brock (pp. 87–88) and are not wholly inconsistent with an identification as talc or steatite which was somehow modified in antiquity. It is hoped that future analyses will prove more precise. Xanthoudides originally published some of these seals as "white steatite" [14], although Yule (following identifications published in CMS II 1) includes them in his definitions of shape classes occurring in ivory.

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[12] ibid., pl. VI.

[13] Although I have personally handled a number of these "white pieces", their identification properly belongs to Dr. Ingo Pini of the CMS who has generously shared his views with me. Most examples were studied by Pini in 1986 and 1987 including those in the Metaxas Collection (CMS IV). While revising this article for publication I have had the opportunity of reading Pini's paper, "Eine frühkretische Siegelwerkstatt?", presented to the 6th Cretological Congress in Chania (September 1986), to be published in the Acts of the Congress. Here Pini defines the new category of "white pieces", discusses the problems surrounding the nature of the material and offers a list of some 82 examples. Thanks to Pini's investigation I have been able to offer more positive re-definitions of certain shape classes than would otherwise have been possible.

[14] VTM 68; 118–119. It is worth paying tribute to the perception of this archaeologist. Although Pini's recent investigations show that these seals are not simply "white steatite", Xanthoudides' description is far closer to the truth than those offered by later scholars.

SHAPE CLASSES

Arch-incised (2). The examples of this shape class occur exclusively in bone and not, as Yule maintains, in ivory[15]. CMS II 1 No. 255 and No. 265 are essentially hollow cylinders with decoration, while HM 508 seems to have been provided with a central plug. CMS II 1 No. 60 is carved from a single piece of bone and might be considered a miscellaneous hemispheroid (18c).

Bottles (3a). Although the use of ivory for this shape cannot be ruled out, CMS II 1 No. 26 is certainly made from bone. In photographs the material of other examples looks similar[16].

Buttons (4a, 4c). Only one "ivory" example (CMS II 1 No. 72) is included by Yule in his list of buttons (4a) although CMS II 1 No. 71 is surely closer to this than to others in his miscellaneous category (4c)[17]. It is possible that this seal is made from bone, as is CMS II 1 No. 72, which I myself recently examined. None of the miscellaneous buttons (4c) were handled for this study but Xanthoudides' description of CMS II 1 No. 245 as "white steatite" should be noted and CMS II 1 No. 380 from Archanes is close in motif and in shape. Both should be investigated in the future[18].

Concave-convex plates (5). This shape class seems to occur principally in bone, the marrow cavity being exploited to produce the seal shape with minimum carving as can be seen in CMS II 1 No. 259 and to a lesser extent in CMS II 1 No. 128[19]. Although the shape could be made easily from the upper half of a hippopotamus lower canine, above the commissure, no certain examples have yet been identified. CMS II 1 No. 162, which is made from ivory, has a rather different shape and should perhaps be classified as a variant[20]. The pattern of lamellae shows that it was cut from the lower half of a hippopotamus lower canine.

Conoids (6e, 6g). None of the elongated conoids (6e) has been examined but all are morphologically feasible in bone, boar's tusk or ivory. The same materials are used for miscellaneous conoids (6g)[21]. Many of the small, rather crude examples such as CMS II 1 No. 441 are made from bone, sometimes preserving an unworked surface as part of the seal body. More elaborate exam-

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[15] ECS 33. Yule believed that the hollow shape was caused by the cores dropping out of the centres of tusks. HM 508 was published by N. Platon, "Mia sphragistiki idiorhythmia tis proanaktorikis minoikis periodou", Festschrift für Friedrich Matz (Mainz, 1962) 14–18, Taf. 3.2.ε; 4.3.δ. Platon regarded this as one of his seals with "removable centres". It is in fact clear that this and most other seals discussed in Platon's article are bone and owe their separate central sections to the morphological constraints of the raw material, which necessitated the use of plugs to fill the marrow cavity. See also remarks on CMS II 1 No. 273 and on hollow cylinders (below p. 121). It is curious that Yule nowhere refers to Platon's article.

[16] ECS 33–34 for list of "ivory" bottles. The splitting seen in photographs of CMS II 1 No. 473 might suggest the use of ivory for this seal, but it is morphologically feasible in bone. The enlarged photographs of certain seals in the CMS can cause confusion between true lamellae of ivory and "pseudo-lamellae" of bone. (Cf. CMS II 1 No. 50 with "pseudo-lamellae" on the sealface and above p. 113).

[17] For buttons (4a) see ECS 36–37; for miscellaneous buttons (4c); ibid. 38.

[18] Although neither CMS II 1 No. 245 or No. 380 appear in Pini's current list of "white pieces", the CMS identification of these seals as "ivory" strikes me as most improbable. For CMS II 1 No. 245 see VTM 118.

[19] ECS 38–39 for list of "ivory" concave-convex plates. Yule states that the grain of the ivory shows them to be cut from the outer section of a tusk.

[20] It also differs in motif, with a human representation (Floating Figures Group) unlike many bone examples which are decorated with cross-hatching (cf. ECS 39 n. 40).

[21] ECS 42–43 for list of "ivory" conoids.

ples, including a grooved conoid (CMS II 1 No. 40), also occur in bone[22]. The use of boar's tusk for CMS II 1 No. 440 is revealed by a trace of enamel on the seal body, while CMS II 1 No. 135 is made from an unidentified tooth. An ivory conoid from Lenda (CMS II 1 No. 187) could have been made from either a lower canine or an incisor. Although not handled for the present study, it is clear that some of the larger miscellaneous conoids (e.g. CMS II 1 No. 231 and No. 242) are made from the tips of hippopotamus incisors with little additional modification.

Cubes (7). Only one "ivory" cube (CMS II 1 No. 64) is listed by Yule[23] and this was not examined. The CMS photographs suggest that it was made from a hippopotamus incisor.

Discs (10b, 10c)[24]. Although morphologically feasible in either bone or ivory, the association of bordered discs (10b) with these materials requires confirmation. Most examples of this shape class have now been re-classified as "white pieces" by Pini including CMS II 1 No. 286 and No. 302, originally published as "white steatite" by Xanthoudides[25]. One of Yule's miscellaneous discs (10c), CMS II 1 No. 184 is made from bone, the marrow cavity providing the central hole.

Epomia (12). Epomia are regularly made from bone[26]. These seals can be made easily, by sectioning the bone (e.g. cattle metatarsal or metacarpal) transversely and then cutting it again along the longitudinal axis. The simple manufacture methods involved may be compared to the equally simple motifs (cross-hatching, herringbone) which characterise most examples.

Gables (14a)[27]. The trihedral shape of these seals immediately suggests the use of boar's tusk for some examples, confirmed in recent study of CMS II 1 No. 74 and No. 126. A lower canine might also be used for this seal shape, although it would involve rather more carving. Photographs of the variant CMS II 1 No. 289 suggest that it may be bone, while Pini has now re-classified CMS II 1 No. 97 and No. 292 as "white pieces"[28].

Hemicylinders (17a). All examples are morphologically feasible in bone as well as ivory, but examination of CMS II 1 No. 217 was inconclusive owing to its bad condition. Photographs suggest that CMS II 1 No. 450 might well be bone. The large hemicylinder in the Ashmolean Museum (1938.790), considered by many to be a forgery, has been identified as bone at the conservation laboratory in Oxford[29].

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[22] It is not clear why Yule choses to classify CMS II 1 No. 40 and No. 41 with his miscellaneous conoids (6g) and not with torsionally fluted examples (6b) under which heading he lists a similar seal CMS II 1 No. 141 (ECS 40).

[23] ECS 44.

[24] "Ivory" discs listed in ECS 49–50.

[25] VTM 118. I personally examined CMS II 1 No. 286 for the present study. Among other bordered discs published as ivory in the CMS, CMS II 2 No. 258 is also included in Pini's current list of "white pieces" (op. cit. n. 13) but CMS II 1 Nos. 268, 293 and 394 are not and should be investigated in the future. Hughes-Brock has also concluded that Yule was wrong in asserting that most bordered discs are ivory and indeed overestimated the use of ivory in his Border/Leaf seals altogether (pers. comm. Hughes Brock, June 1986 and above p. 86).

[26] ECS 54–55 for a list of "ivory" epomia. CMS II 1 No. 322 has a slightly different shape: it is morphologically feasible in bone or ivory. For an epomion in the Ashmolean Museum (1968.1844) see: Hughes-Brock (p. 83).

[27] "Ivory" gables are listed in ECS 57.

[28] Pini (op. cit. n. 13). For CMS II 1 No. 292 see VTM 118 where it is described as "white steatite". Half-ovoids (16) (ECS 58–59) are all now classified as "white pieces" by Pini (op. cit. n. 13). For K88, which Yule believed was bone, see also Hughes-Brock (p. 88).

[29] Not listed by Yule with his "ivory" hemicylinders ECS 59–60. See Hughes-Brock p. 83 and her n. 22 and n. 24 for earlier references.

Hemispheroids (18a, 18b) [30]. Yule's definition of hemispheroids (18a) is correct, since there seems to be a very close correlation between the use of ivory and this shape class. The large example from Platanos (CMS II 1 No. 313) is made from a hippopotamus incisor: the tips of such tusks provide ideal blanks. A seal from Lenda (CMS II 1 No. 173), classed by Yule as a cylinder (32a), is better seen as a fragmentary hemispheroid (18a). A hemispheroid (18b) from A. Triada (CMS II 1 No. 70) is made from bone, but the other two "ivory" examples in this sub-class (CMS II 1 No. 96 and No. 403) have now been identified as "white pieces" by Pini [31].

Plano-convex buttons (20). Although these are small enough to be made from bone or ivory, there is now evidence to suggest that they did not occur in either. Apart CMS II 1 No. 356 and CMS IV No. 117, all examples of this shape class listed by Yule have now been re-classified by Pini as "white pieces" [32].

Pyramids (23). Of the three "ivory" pyramids listed by Yule [33] CMS II 1 No. 401 was handled and identified as bone. CMS II 1 No. 56 could easily be bone too. The elaborate example from Archanes (CMS II 1 No. 381) should be examined in the future.

Pyramidoids (24c). Study of the CMS photographs suggests that most, if not all, of the "ivory" examples in Yule [34] are indeed made of ivory. CMS II 1 No. 54 proved on examination to be made from a hippopotamus lower canine. The seal shape is easily produced by removing the enamel, cutting the tusk transversely and then again lengthwise.

Rectangular plates (26a). Morphologically feasible in both bone and ivory, these are too heterogeneous to permit a general re-definition [35]. CMS II 1 No. 230 from Marathokephalo is made from a piece of hippopotamus lower canine cut below the commissure.

Reels (27a, 27b). The reel (27a) from Lenda CMS II 1 No. 189 is published as "aschfarbener Steatit". One wonders why Yule lists it as "ivory" [36]. The bordered reel (27b) from Platanos (CMS II 1 No. 333) is another of Xanthoudides' "white steatite" seals and has been included by Pini in his list of "white pieces" [37].

Rings (28a, 28b, 28c). The simple rings (28a) are invariably bone and not, as stated by Yule, ivory [38]. They are easily made from transverse sections of long bones with little additional modification. The unusually large example from Lenda (CMS II 1 No. 179) preserves the septum of the marrow cavity within its hoop. The short depression running across the top of the hoop is not

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30 ECS 61.

31 Pini (op. cit. n. 13). CM 155 described as "pierre blonde" might profitably be examined in the future.

32 ECS 64–65 for a list of the "ivory" plano-convex buttons. CMS II 1 No. 355 which I examined for the present study was published by Xanthoudides as "white steatite" (VTM 68). See now list in Pini (op. cit. n. 13).

33 ECS 69.

34 ECS 71.

35 ECS 72. Both CMS II 1 No. 278 and No. 299 look like bone in the CMS photographs: the latter might be a broken epomion.

36 ECS 74.

37 VTM 118–119; Pini (op. cit. n. 13).

38 CMS II 1 No. 69 is badly decayed but might be ivory. Its shape, however, seems closer to the massive rings (28b). Yule's identifications of the materials used for simple (28a), massive (28b) and miscellaneous (28c) rings seem particularly idiosyncratic (ECS 75–77). With one exception (CMS II 1 No. 188) all of the Lenda rings are published as "Bein" which he usually takes to mean "bone" (above n. 2). Here he seems to translate it as "ivory" since he defines the entire sub-class (28a) as occurring in that material. The identification of bone for all the Lenda rings (28a) was conclusively established in 1979 (above n. 3). Conversely for rings (28b) and (28c) he takes "Bein" mean "bone" whereas in these subclasses the Lenda examples are all ivory (CMS II 1 Nos. 182, 185 and 191).

carved but a natural feature of the bone (above p. 113 and *Fig. 2a*). The simple cross-hatching found on rings (28a) accords well with the rudimentary skills required for their manufacture. Massive rings (28b) are normally made from ivory. An example from Porti (CMS II 1 No. 351), recently examined, proved to be made from a hippopotamus incisor although the repair to its seal face (visible but not described in the CMS) is in bone. The hole on the top of its hoop represents the remains of the pulp cavity: it is not a "core" of ivory which has dropped out through splitting along the lamellae. Two fragmentary seals (HM 1916 and 1940) from Lenda, also ivory, should likewise be added to the list of massive rings. Yet another ring from Lenda (CMS II 1 No. 191), classed by Yule as a miscellaneous ring (28c), is also made from ivory. This, too, seems to be a fragment of a massive ring, its rather narrow section probably caused by splitting along the lamellae. One of the massive rings from Viannos (CMS II 1 No. 443) was observed on display and seems to be made from bone with a "plug" inserted into the marrow cavity to produce the massive ring shape and then pierced transversely through the seal body.

Scarabs (29). Of the scarabs made from soft materials listed by Yule[39] only two examples are published as "ivory" (CMS II 1 No. 1 and No. 332). Hughes-Brock has noted that there is a sense of an extra layer in photographs of the scarab from Aspri Petra (CMS II 1 No. 1), while Xanthoudides published it as "white steatite"[40]. This description, along with "white paste", "frit" and "faience", accounts for many of the scarabs or scaraboids published in the CMS and may indicate that they should be re-classified as "white pieces" in the future.

Signets (31a, 31b, 31c, 31f). There is some variation in the stump signets (31a) as defined by Yule[41]. Two examples (CMS II 1 No. 50 and No. 174) are very similar and have both been re-identified as bone. Two more are somewhat larger and photographs clearly reveal the lamellae of ivory. That from Kalathiana (CMS II 1 No. 125) is made from a hippopotamus incisor, while the fragmentary example from Platanos (CMS II 1 No. 325) seems to be made from a lower canine. Another large example, CMS II 1 No. 181 from Lenda, might be bone. This is suggested by the rather grainy seal body and the central hole[42]. So far, no certain examples of ivory hammerheaded signets (31b) have been identified, although on morphological grounds the use of ivory cannot be ruled out[43]. Some examples, including CMS II 1 No. 210 and No. 445, are made

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[39] ECS 78. Yule's criteria for excluding certain scarabs and scaraboids from his lists are not explained. While some are certainly Egyptian, others, not included by Yule, might be Cretan. For other pre-palatial examples see lists in CMS II 1 p. xxii.

[40] Hughes-Brock (p. 88); Xanthoudides, ADelt 4 (1918) 15, 21; fig. 7. Xanthoudides does not identify the material of the scarab from Platanos regarded by Yule as "ivory" (CMS II 1 No. 332) (VTM 118). Two others from the same tholos (CMS II 1 No. 267 and 283) are described as "white steatite" and were regarded by Xanthoudides as Minoan imitations of Egyptian scarabs (ibid. 117–118). Both are published in the CMS as "Elfenbein". Yule does not list them. See also W.A. Ward, AJA 85 (1981) 70 ff.

[41] ECS 81. Yule correctly defines them as occurring in ivory and bone: the latter presumably on the strength of the Lenda examples published as "Bein" (above n. 2 and n. 38).

[42] I originally believed (1979) that on morphological grounds it must have been made from ivory and felt that its "grainy" appearance was caused by exposure to high temperatures. On reflection I am now inclined to see it as bone, but this requires confirmation.

[43] ECS 81–82 and n. 221 (p. 81). Here Yule seems to regard the Lenda examples as "ivory" (above n. 2 and n. 38). CMS II 1 No. 183 has been badly burnt and is considerably restored. Whether it should be regarded as a hammerheaded seal is open to question. No clear diagnostic features could be seen during first-hand examination in 1979 and is perhaps best described as "ivory?".

from several components in order to plug the marrow cavity and achieve the desired shape. A smaller example from A. Triada (CMS II 1 No. 23), which resembles ivory in the CMS photographs, is carved from a single piece of bone, while a damaged example from the same site (CMS II 1 No. 48) is made from boar's tusk. The squat incised signet (31 c) also from A. Triada (CMS II 1 No. 29) proved to be bone on examination. CMS II 1 No. 45 is very similar and perhaps is also bone. No clear diagnostic features appear in the photographs of the "ivory" miscellaneous signets (31f) listed by Yule [44] but they are also small enough to be bone.

Stamp cylinders (32a, 32b, 32c). Yule's discussion of stamp cylinders glosses over the question of hollow cylinders [45], a readily identifiable shape class in its own right. Instead he lists them with the other plain cylinders (32a) and so inevitably produces a heterogeneous shape class which includes, as Yule himself remarks, "a highly diverse repertoire of motifs". These difficulties can be avoided if we define a new sub-class, which might conveniently be termed "hollow cylinders (32d)". The seals in question (CMS II 1 Nos. 6, 7, 8, 9, 10, 127, 480, 482 and CMS V No. 21), present a remarkably homogeneous appearance and all derive their shape from simple transverse sections of long bones. All possess equally simple motifs (geometrical, zigzag) on their sealfaces, mirroring the simple methods required for their manufacture and contrasting markedly with the elaborate motifs such as the Parading Lions/Spiral complex occurring on "true" stamp cylinders (32a) which are made from ivory.

The ivory plain cylinders (32a) together with their concave-sided counterparts (32b) are made from both hippopotamus incisors and lower canines *(Fig. 2d)*. The natural taper of the tusks produces the characteristic difference in the dimensions of the two sealfaces (above p. 115). Further study is needed to determine whether there are any special morphological reasons for the manufacture of concave cylinders, or whether these are simply a refinement on the basic plain cylinder shape.

It seems likely that the cylinder (32a) from Archanes (CMS II 1 No. 392) with its sealfaces pegged in position is made from bone rather than ivory. It is thus comparable to the massive ring (28b) from Viannos where an "ivory shape" is apparently copied in bone. A parallel case is one of Yule's miscellaneous cylinders (CMS II 1 No. 273), again made from bone (a central plug occupying the marrow cavity) and not ivory as published (above p. 113 and *Fig. 2b*). CMS II 1 No. 273 and No. 392, both bone, may be included in the main group of cylinders on the basis of form and motif but considered variants in respect of material. CMS II 1 No. 205 and No. 326 are more equivocal, differing from the main sequence not only in the use of bone, but also in form (they are very small) and in the case of CMS II 1 No. 326 in motif. Perhaps they should be transferred to the miscellaneous cylinders (32c) [46].

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[44] ECS 82–83 for "ivory" squat incised signets (31c); ibid. 83–84 for miscellaneous signets (31f).

[45] ECS 89. It is not clear whether Yule regarded the hollow examples of his stamp cylinders (32a) as made of ivory from which the "cores" had "fallen out" (ibid. 195 n. 43). His silence regarding Platon's theory of removable centres (above. n. 15), which pertains to many of the hollow cylinders, is decidedly strange. In any case there is no evidence that these simple bone hollow cylinders were furnished with centres. For a bone cylinder (CMS II 1 No. 273) also discussed by Platon (op. cit. [n. 15] 15 Taf. 3.1.γ), which is plugged see above p. 113 and below. Yule's identification of concave cylinders (32b) as occurring mostly in ivory is correct (ECS 90).

[46] Apart from the squat cylinder (CMS II 1 No. 273) already discussed, Yule lists five other "ivory" examples under the heading miscellaneous cylinders (32c) (ECS 91). Of these, the two larger examples (CMS II 1 No. 78 and No. 472) might be made from hippopotamus lower canines, CMS II 1 No. 423 is perhaps bone, while CMS II 1 No. 11 and No. 12 are almost certainly boar's tusk to judge from the published photographs.

Zoomorphs (33a etc)[47]. Yule rightly remarks that his sub-class "animal heads, massive" (33a) is heterogeneous in all respects[48]. This seems especially true of materials. The small, rather crude example from A. Triada (CMS II 1 No. 19) is made from bone. CMS II 1 No. 17 and No. 18 are morphologically feasible in bone also. However, the large head from the same site (CMS II 1 No. 16) is surely made from a segment of lower canine crossing the commissure, as is CMS II 1 No. 469 from Sphoungaras. The pattern of lamellae suggests that the hog's head from Platanos (CMS II 1 No. 294) was carved from a section of a hippopotamus incisor. CMS IV No. 30 is an entirely different kind of seal: its very small size, intricate carving and sealface near to the Border/Leaf Complex all suggest that it is another of the "white pieces" described above[49].

Two of Yule's animal finials (33b)[50] CMS II 1 No. 21 and No. 436 could well be bone, whereas the example from Lenda (CMS II 1 No. 213) was published as "Bein" and might well be ivory[51]. Of the animals with intertwined foreparts (33c) listed by Yule, the seal from Marathokephalo (CMS II 1 No. 129) shows no clear diagnostic features in the photographs. K85 and one of Yule's "birds regardant" (33e), K87, are discussed by Hughes-Brock elsewhere in this volume following analyses in Oxford (p. 87). Both should now be classified as "white pieces"[52].

None of the seated animals (33d) listed by Yule has been examined, but ivory (hippopotamus lower canine?) for the ape from Platanos (CMS II 1 No. 249) seems reasonable, to judge from photographs and morphology, although a similar seal from A. Triada (CMS II 1 No. 20) could be bone. The large perched bird (33f) from Koumasa (CMS II 1 No. 133) appears to preserve the shape of a tusk tip (hippopotamus incisor?) in the gentle arc of the bird's back. The owl (K62) is ivory (Hughes-Brock, p. 82 above) but the seal from Trapeza (CMS II 1 No. 438) may be bone. Yule correctly describes the hoof (33g) from Lenda (CMS II 1 No. 170) as bone but may not be right in calling the foot (33h) from Krasi (CMS II 1 No. 407) ivory.

Several interesting seals fall into Yule's last three groups of zoomorphs. One of the recumbant quadrupeds (33j) (CMS II 1 No. 357) was published by Xanthoudides as "white steatite". This proved to be another "white piece" on recent examination. In addition to the usual features of this category, minute traces of a greenish irridescent patch were observed under high magnifications, perhaps remains of an overall glaze. Close to this is the hybrid (K86), analysed in Oxford (Hughes-Brock, p. 88 above). Yet another "white piece" in this sub-class is CMS II 1 No. 114 from A. Onouphrios[53]. In shape and motif the reclining calf from Platanos (CMS II 1 No. 253) is entirely different. Unfortunately no clear diagnostic features appear in the photographs. It is morphologically feasible in either bone or ivory. The same applies to CMS II 1 No. 475, which Yule classes as a snail/mollusk shell (33k). Another seal in this sub-class, CMS II 1 No. 353 from Porti, is somehow related to the new category of "white pieces"[54]. CM 4, which is one of Yule's

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[47] ECS 91–100.

[48] Except for one in carnelian, Yule regards all examples of this sub-class as ivory (ECS 92).

[49] See now Pini (op. cit. n. 13).

[50] The sentence "CMS II 1 213 and 413 respectively are in shiny serpentine and bone . . ." (ECS 92) should, in fact, read: "CMS II 1 209 and 213 . . .".

[51] This was tentatively identified as ivory in 1979, but as in the case of CMS II 1 No. 181 (above n. 42) subsequent experience has cast some doubt on the earlier identification. No clear diagnostic features were visible.

[52] Pini (op. cit. n. 13).

[53] CMS II 1 No. 114, No. 357 and K86 are all included in Pini's list of "white pieces" (op. cit. n. 13). See also VTM 68 for CMS II 1 No. 357.

[54] pers. comm. Pini.

miscellaneous zoomorphs (331), has now been classified as a "white piece" by Pini[55]. The other miscellaneous zoomorphs listed by Yule need investigation, since most are morphologically feasible in bone. Examination of CMS II 1 No. 216 suggested that was made of boar's tusk.

Miscellaneous shapes (34)[56]. Only a few of these have been handled, but the material of most can be tentatively identified from the CMS photographs. The unusual multi-sided seal (34a) from Archanes (CMS II 1 No. 391) is almost certainly bone, as is the "horn" (34n) from A. Triada (CMS II 1 No. 15) and also perhaps the double cylinder (34g) from Platanos (CMS II 1 No. 254). The double plano-convex plate (CMS II 1 No. 62) might be ivory. Both tusks (34z) (CMS II 1 No. 79 and No. 143) are, of course, made from boar's tusk and should not be called "ivory". The wedge (34aa) from Kalathiana (CMS II 1 No. 139) proved to be made from a segment of hippopotamus lower canine; CMS II 1 No. 207 and No. 420 might be similar. Three more seals listed under class 34 (CMS II 1 No. 282, 98 and 354) cannot be safely ascribed from photographs alone[57].

The shape classes occurring in ivory and related materials along with those belonging to the new category of "white pieces" are summarised in *Table 1*. This, and the observations on individual shape classes made earlier, should be taken as broad guides only. Additional seals will need to be examined to test the validity of some of the new definitions. Shape classes with few examples or presenting heterogeneous forms are especially difficult to re-define without first-hand inspection. The pitfalls of relying on published descriptions or even photographs in the CMS should be apparent by now. Photographs may be trusted for many individual seals in Group I. They are less reliable for Group II, where the natural features have been largely or wholly obliterated in carving and most specimens are morphologically feasible in bone, boar's tusk or ivory.

About half of the shape classes considered are closely linked to morphological features of the raw materials (Group I). In many cases, these natural features are not merely retained in the finished seal shapes, but evidently dictated the shapes in the first place. This clear correlation between the some of the simplest shapes (hollow cylinders, rings, epomia) and the morphological features of long bones has been recognised for several years[58]. To these may now be added arch-incised and concavo-convex seals. All are based on transverse sections of bone, with secondary lengthwise cutting needed to produce epomia and concavo-convex seals. Certain hammerheaded seals require several components in order to counteract the limitations imposed by the shape of bone. The link between the morphology of boar's tusk and certain miscellaneous cylinders and "tusks" was also established in an earlier study[59]. Recent research now enables us to add certain gables to this group. However, it is the discovery that hippopotamus ivory was

[55] Pini (op. cit. n. 13).
[56] ECS 100–103.
[57] CMS II 1 No. 98 was re-studied by Pini who concluded that it was not ivory but that it was probably not a "white piece" either (pers. comm. Pini).
[58] Krzyszkowska [1983] 164–165 (op. cit. n. 1).
[59] ibid., 164.

Table 1. Shape classes summarised by material

Group I. Morphological features preserved or slightly modified:		
BONE	BOAR'S TUSK	HIPPOPOTAMUS TUSK
arch-incised (2)		
concavo-convex (5)		
		some conoids (6g)
epomia (12)		
	some gables (14a)	
		pyramidoids (24c)
simple rings (28a)		massive rings (28b)
some hammerheads (31b)		
hollow cyls (32d)	misc. cyls (32c)	plain cyls (32a)
		concave cyls (32b)
		some zoomorphs (33)
		wedges (34aa)
	"tusks" (34z)	
Group II. Morphological features largely or wholly obliterated (*):		
BONE	BOAR'S TUSK	HIPPOPOTAMUS TUSK
bottles (3a)		
buttons (4a)		
conoids (6g)	conoids (6g)	conoids (6g)
hemicylinders (17)		
[hemispheroids (18b)]		
stepped pyramids (23)		
		[rectang. plates (26)]
stump signets (31a)		stump signets (31a)
hammerheaded (31b)	hammerheaded (31b)	
squat signets (31f)		
zoomorphs (33)	zoomorphs (33)	zoomorphs (33)
Group III. "White pieces" (*):		
buttons (4c)		
bordered discs (10b)		
half-ovoids (16)		
reels (17)		
[hemispheroids (18b)]		
plano-convex buttons (20)		
scarabs/scaraboids (29/30)		
certain zoomorphs (e.g. 33a, 33c etc.)		
(and other shapes)		

* Most morphologically feasible in bone, boar's tusk and ivory, but examples so far only identified in the materials indicated. [ ] indicates reservations in re-defining shape class as a whole on basis of examples handled.

used in seal manufacture which has provided the most valuable insight into the question of prepalatial seal shapes, making it possible to demonstrate that the close relationship between seal shape and the morphology of raw material already noted for bone and boar's tusk applies equally to most of the shape classes occuring in ivory. Stamp cylinders, with one seal face larger than the other, do not owe that characteristic to elaborate carving but to naturally tapering sections of incisors or canines. Hemispheroids and some of the large conoids are scarcely modified incisor tips. Other shapes are a step removed from simple transverse sections, pyramidoids and wedges requiring secondary lengthwise cutting. Further refinements are added in the case of concave cylinders or massive rings. Here some shaping or carving is involved, but even these shapes are not very far from the simple transverse tusk sections which would have served as blanks.

Group II is made up of shape classes where the natural features of the raw materials are largely or wholly obliterated. Some bottles, buttons and conoids may retain a barely modified outer surface of bone on one side of the seal. This seems less by design than by necessity. Since bone offers relatively restricted areas of solid material for carving, it is not surprising that the natural surface was sometimes preserved on the finished seal. In this respect morphological characteristics do play a part in Group II shapes, since they determine the maximum sizes of the seals. This may have particular significance for the smaller shape classes tentatively re-defined as bone. Further study can reveal whether these were ever made in ivory.

Although there are occasional cases of "substitution" where a seal is made from bone in a shape normally occurring in ivory, or vice versa, there are few cases where shape classes as a whole overlap. In Group II, stump signets (31 a) are represented in both bone and ivory, but on closer examination they prove to belong to discreet sub-types. The same may well apply to conoids (6g), and certain sub-classes of zoomorphs which are found in bone and ivory as well as in boar's tusk.

Seals which have been re-classified as "white pieces" occur in the shape classes listed under Group III. Whether these shapes are ever found in bone or ivory remains to be investigated, since the lack of morphological characteristics makes the material difficult to identify certainly, unless the seals are examined, preferably under magnification.

At this point only broad conclusions may be drawn from the new identifications of seal materials and the ensuing modifications to the shape classes defined by Yule. Bone and boar's tusk account for a much higher proportion of pre-palatial seals than was previously suspected. These, of course, are locally available raw materials. Many of the simple seal shapes in Group I made from bone and boar's tusk are characterised by extremely simple sealfaces with rudimentary motifs such as grid, lattice and zig-zag. The manufacture of such seals does not so much involve carving as cutting and incising. Some of the Group II bone seals have more elaborate shapes and motifs but they are in the minority. Most ivory seals also rely on simple manufacture methods to provide the basic seal shapes. However, they are frequently provided with finely engraved sealfaces (Parading Lions, etc.) and only occasionally use the simple grid or geometric motifs. Future studies might now profitably re-explore the relationship between the occurrence of certain motifs and the use of materials. There is scope also for further investigations of chronological questions. Here we are somewhat hampered by the lack of a large corpus of well stratified seals from the pre-palatial period. Current evidence does not permit a simple equation between the rudimentary shapes found in bone and early dating, however attractive such an hypothesis might seem[60]. Certainly ivory was available from at least EM IIA onwards, as the worked segment of hippopotamus lower canine from Knossos indicates, but the volume and reg-

[60] Geographical or economic factors might also have determined the manufacture of simple bone seals. Closer analysis of shape classes site by site may prove instructive. Lenda has an abnormally high proportion of these simple bone seals (mainly 28a rings) and indeed a higher percentage of bone seals than seems to occur at most other sites.

ularity of supplies cannot be gauged[61]. It is, however, worth noting that even the earliest stratigraphically dated ivory seals belong to "ivory shape classes" and are not simply copies of shapes pre-existing in bone. Despite Yule's progress in providing dates for the shape classes of many early Cretan seals, for those made from bone and ivory we are all too often presented with an "EM II or III–MM IA" date hardly more precise than the conventional span allotted to the pre-palatial period and covering as much as six hundred years. Perhaps eventually the new identifications of materials and the re-defined shape classes, taken in conjunction with Yule's considerations of motifs, might enable us to refine the chronology of early Cretan seals made in ivory and related materials.

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[61] For the EM IIA segment of lower canine see Krzyszkowska [1984] 124 pl. XIIIa right (op. cit. n. 1). Earlier attempts to calculate the volume of the ivory trade during the pre-palatial period were based on the incorrect assumption that elephant tusk was used: Krzyszkowska [1983] 166–168 (op. cit. n. 1). These calculations are now, of course, discredited and, as yet, no new attempts have been made to gauge the quantities of tusks represented by the extant seals.