TECHNICAL OBSERVATIONS ON GLYPTIC*

BY PAUL YULE IN COLLABORATION WITH KAY SCHÜRMANN

Two aspects are considered here: The working of hard stones (i.e. those of the quartz family) and the bleached appearance of many Aegean seals. With regard to the working of seals in hard stone, the question arises as to the actual means of engraving and the date when "modern" rotary tools were introduced. Except for a short, authoritative discussion in *Greek Gems and Finger Rings* by John Boardman, little detailed information appears on these two topics in the literature on Aegean archaeology[1].

Three sources which tell us something about engraving are the tool marks on excellently preserved seals, ancient tools (and representations of such)[2] as well as the observation of modern seal cutting. Attention is first devoted to modern carving methods.

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* Sources of illustrations: fig. 1: photo C. Albiker – figs. 3. 5: photo author – figs. 2. 4: drawing author – fig. 6: after Boardman, GGFR 381 fig. 316 – fig. 7: author and Walberg, Kamares figs. 36ff. – fig. 8: photo K. Schürmann.

This study is extracted from research on my Ph.D. thesis, "Early Cretan Seals: A Study of Typology, Style and Chronology". Many of the points which, for reasons of economy, are only touched on here, I treated more fully in my thesis. The abbreviations cited are those of the CMS as well as the following special abbreviations:

CM	A. Xénaki-Sakellariou, Les cachets minoens de la collection Giamalakis, Études crétoises X, 1958
Fischer, Entwicklung	W. Fischer, Zur Entwicklung der Steinschleiftechnik, in: Der Aufschluß, 18. Sonderheft, Festschrift Chudoba (1968) 21ff.
HM	Inventory no. of the Museum in Herakleion
Knossos	numbers referring to the seal impressions from Knossos. cf. M.A.V. Gill, BSA 60, 1960, 58ff.
Kris, Meister	E. Kris, Meister und Meisterwerke der Steinschneidekunst in der italienischen Renaissance, 1929
Richter, Gems	G.M.A. Richter, The Engraved Gems of the Greeks, Etruscans and Romans, 1968

[1] The most important studies are, however: Boardman, GGFR esp. 373ff.; cf. also Fischer, Entwicklung 21ff.; A. Löwental, Der Kunstwanderer 8, 1926, 3ff.; R.J. Charleston, Wheel-Engraving and Cutting: Some Early Equipment, Journal of Glass Studies 6, 1967, 83ff.

[2] In 1976 I was unable to locate the tools which Dessenne mentioned having found in the Mallia Seal Workshop (CRAI [1957] 123ff.). Moreover, the carving kit from Tell Asmar in the Diyala region are not on deposit at the Oriental Institute in Chicago (cf. H. Frankfort, Oriental Institute Communications 16, 1933, 47). For carving tools from Chanhu Daro cf. E. Mackay, Journal of the Royal Asiatic Society 85, 1937, 527ff. For stone carving in rural societies cf. W.F. Foshag, Mineralogical Studies on Guatemalan Jade, Smithsonian Miscellaneous Collections 135, 1957 and Hans E. Wulff, The Traditional Crafts of Persia (1966) 35ff. I am indebted to Dr. Porada for the last reference.

In the winter of 1976, the Seal Corpus, under the direction of Dr. Ingo Pini, sponsored an excursion to Idar-Oberstein, the capital in Europe for precious stones, in order to visit Richard Hahn, a master seal carver. Hahn was asked several questions regarding the methods by means of which Aegean seals could have been produced. Upon viewing several silicon impressions stamped by Middle Bronze and Late Bronze Age Aegean seals in hard stone, he observed, not surprisingly, that the seals were cut with rotary equipment, including the solid and tubular drill as well as the cutting wheel. On examining an impression of the intaglio shown in *Fig. 1,* Hahn remarked that with modern equipment such a seal could be fashioned in as little as fifteen minutes.

Later, we revisited Hahn with the intention of making a copy of the seal shown in *Fig. 1,* in order to observe the method and procedure of carving. Hahn was provided with a seal impression as well as a drawing *(Fig. 2)* of the seal profile. The original seal is in rock crystal and shows tectonic ornament[3].

Hahn first selected a thin square piece of heliotrop and an assistant cut the blank with a grinding wheel until it was roughly circular and beveled the edges. The blank was then firmly attached to a wooden stick (a dop) by means of molten wax. After sketching the motif on the seal with a pencil, Hahn began to rough out the intaglio using cutting wheels mounted on a lapidary lathe *(Fig. 5).* First a wheel of relatively large (c. 1,5 cm) diameter was used to cut the heaviest lines. The stone was drawn back and forth against the wheel, gradually enlarging the cuts. From time to time Hahn brought a piece of diamond-impregnated abrasive in contact with the wheel and with a feather quil put a drop of oil on the stone. He also regularly cleaned away the excess oil with his thumb and made trial impressions in terracotta, in order to get a clear idea of his progress. The fine lines were cut with a thin, small-diameter (c. 0,5 cm) wheel. Within a total of forty-five minutes the seal (without stringhole) was finished *(Fig. 3).*

The cuts made on our copy differ from those of the original in that they are finer, deeper and the floors of the heavy cuts are slightly uneven. The smaller the diameter of the cutting wheel, the greater the difficulty to make a perfectly smooth cut. Boardman's suggestion that a straight edged cutting instrument like a file served to cut certain Minoan motifs[4] is pertinent here as such a tool conceivably would leave very even cuts, similar to those on the original seal. On the other hand, according to Hahn, nowadays metal files are not used to work stones the hardness of chalcedony. In the case of the numerous Aegean intaglios formed by "straight cuts or grooves which only acquire rounded edges or curved lines from the convex surface of the stone"[5], the use of a kind of abrasive stone or abrasive impregnated metal file seems plausible, to judge from the evenness

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[3] Kenna, Seals no. 156 (= figs. 1 and 2 here). In AA 1977, 143 fig. 2 this profile drawing is misidentified as Kenna, Seals, no. 152. For the term "tectonic" cf. W. Schiering, Gnomon 50 (1978) 567.

[4] GGFR 43. 381. Fischer, Entwicklung 25ff. suggests that the file ("lima") mentioned by Pliny in Historia Naturalis XXXVII, 109 is actually an abrasive stone.

[5] Boardman, GGFR 48. At least one example of the Cut Style, presently on exhibit in the Fogg Museum (FAMC 1960. 626), is definitely engraved by means of a wheel. The devices of this four-sided prism are engraved into the flat surface, not tangent to it. Pini is sceptical of the existence of the abrasive file for the engraving of Aegean seals. He interprets the technique of the "Cut Style" to be wheel engraving (personal communication).

of the cuts. Seals of Boardman's "Cut Style" offer the clearest evidence for the use of this tool[6]. Conceivably such a technique would be rather time consuming.

The profile of the copy *(Fig. 4)* deviates considerably from that of the original. The thin edges of the faces are unmatched on Minoan discoids. This factor, as well as the unusual cutting technique give indications of the kind of mistakes even a sensitive and gifted professional might make in attempting to forge a seal. One could question, had Hahn deliberately intended to forge a seal with tectonic ornament and not experimentally make a copy, would it have been stylistically convincing? Given the tools used, this possibility seems unlikely.

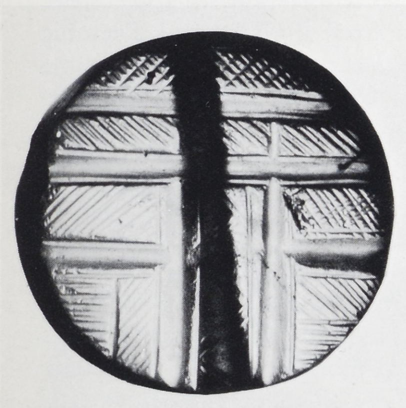

Fig. 1 Kenna, Seals K 156.

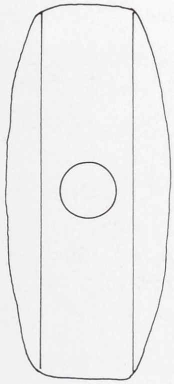

Fig. 2 Profile of seal Fig. 1.

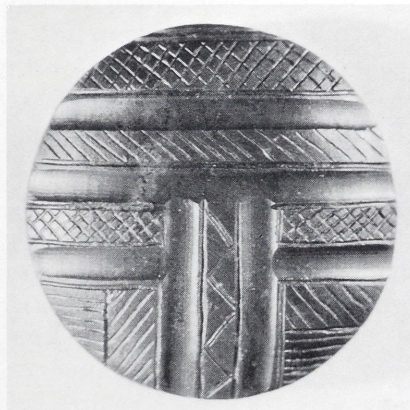

Fig. 3 Copy of seal Fig. 1.

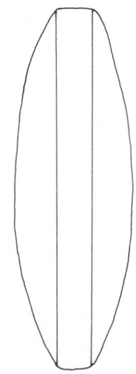

Fig. 4 Profile of copy.

Three major kinds of tools appear to have been in use in the Aegean for seal carving: the hand graver, hand-held bow drill (and gimlet) as well as the stationary lapidary lathe[7]. The hand graver is well suited to working ivory and soft stone and the hand-held bow drill is serviceable for both hard and soft materials. But for the engraving of hard stones, the stationary lathe offers a degree of precision not obtainable from a bow drill. By the word "stationary" is meant a lathe composed of a shaft which turns within a mount. The seal, affixed to a dop, is brought into contact with the cutting wheels or drill points which are mounted on the shaft. Since the nineteenth century most experts have considered wheel cutting to be an obvious feature of Late Bronze Age seal cutting[8] but the actual origin of the lapidary lathe on Crete has received little attention.

When did rotary tools come into use on Crete? Warren notes that the tubular drill

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[6] On the "Cut Style", ibid.

[7] No evidence exists for the use of the running drill, AA 1977, 146 n. 12. On this tool cf. Boardman, GGFR 388.

[8] Cf. J. Middleton, The Engraved Gems of Classical Times ... (1891) 109ff.; A. Furtwängler, Antike Gemmen (1900) 4 n. 3; H. Frankfort, Cylinder Seals (1939) 5; H. Biesantz, Kretisch-mykenische Siegelbilder (1954) 2f. 63. For an exhaustive bibliography cf. Boardman, GGFR 447–449.

was in use as early as "EM III/MM I"[9] for roughing out stone vases. Powdered quartz and later (MM III–LM I) emery were in use[10]. Unfortunately, owing to the dearth of seals from closed MM IB–II A contexts, the onset of hard stone carving (and perforce of rotary tools) at about this time is difficult to discuss and at present we must rely more on typological or stylistic and less on stratigraphic evidence[11].

Significantly, MM II is a period of dramatic technical and artistic achievement in ceramic (cf. Classical Kamares) which are directly linked to working conditions in the palaces[12]. What of glyptic development? Two stylistically definable groups of seals provide a fixed point for discussing the onset of cutting in hard stone. Both of these groups are stylistically homogeneous and in addition, well documented in palatial contexts. The first may be called the Hieroglyphic Deposit Group and the second the Classical Tectonic Group (a Common Tectonic Group also exists)[13]. Evidence from the Classical Tectonic Group for the use of rotary tools is weak because the abrasive file may have been responsible for the work. The Hieroglyphic Deposit Group, named after the so-called Hieroglyphic Deposit in Knossos, is composed largely of prism-seals and *Petschafte* in hard stone which show such fine carving that the use of a lathe (not a hand held bow drill) is highly probable. This style-group is known from 153 seals and sealing types and dates to "MM II (–?)"[14]. The question mark indicates the possibility that the group may continue later than MM II. The Classical Tectonic Group, of which *Fig. 1* shows a typical example, is known from 92 intaglios and sealing types and dates to MM II–III[15]. While the end termini of these two groups are somewhat problematic, their onset in MM II is more secure owing to stratified examples. A comparison of the motifs of the Hieroglyphic Deposit Group with those on Kamares vessels *(Fig. 7)* provides further evidence for the dating. In the comparison, significant are the individual form elements and the syntax by which they are arranged.

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[9] P. Warren, Minoan Stone Vases (1969) 161.

[10] Ibid. 160.

[11] Contexts containing seals in hard stone which appear to be mixed (i.e. not solely Prepalatial) include A. Onouphrios, Mochlos Graves I. III and XVII. On the dating of Grave III cf. Kadmos 17, 1978, 4. On the basis of his finds in Phourni, J. Sakellarakis believes that the use of hard stones goes back as early as MM IA (cf. Archaeological Reports for 1975–76, 29). On the problem of graves as contexts cf. W.-D. Niemeier in the present volume, 96ff. The only hard stone seal which in my opinion stems from an unmixed context dating earlier than MM II is CMS II 1, 366. This rock crystal Stamp Cylinder is decorated with tubular drill ornament and came to light in an EM II–MM IB burial in Porti. I think that in this case the context dates the seal and not vice versa.

[12] G. Walberg, Kamares 126.

[13] The specific characteristics, dating and iconology of these two style-groups are treated in detail in my Ph.D. thesis.

[14] Cf. CMS II 2, 3. 227. 249. 256. 282–284. 286. 296. 316. 321 etc. On the dating of the Hieroglyphic Deposit cf. Kadmos 17, 1978, 1ff. Examples stratified in MM II contexts: CMS II 5, 204. 299. 300. 311 and evidently Kenna, Seals no. 117. CMS II 5, 204 is not wholly typical of this style-group but its attribution becomes certain when it is compared with CM 160, a foliate back in hard stone; foliate backs are characteristic of this group. Sealings from a MM II context in Mallia will be published shortly by J.C. Poursat which are impressed by seals of this style-group.

[15] Cf. CMS II 2, 1. 4. 8. 11. 18. 45. 56. 75. 81 etc. MM II context: HM 396 = Kenna, Seals p. 37 fig. 52. MM II–III context: CMS II 2, 18. MM II B context: CMS II 5, 242–244. MM III context: CMS II 2, 45. 56. MM III–LM I context: HM Precious Metal 1789 = Evans, PM IV, 511 fig. 455. MM III B context: Knossos L 10 = BSA 60, 1965, pl. 5; Knossos L 11 = Evans, PM I, 565 fig. 411 b; Knossos Vc = Evans, PM II, 420 fig. 242.

As to the actual appearance of the lathe, both foot powered and bow powered lathes are known from later periods[16]. But owing to the widespread use of the hand-held bow drill in the Bronze Age, the use of a bow powered stationary lathe in the Aegean is a likely possibility[17]. The reconstruction of a bow driven lapidary lathe from a second century A.D. grave relief may well correspond to what was used in the Bronze Age *(Fig. 6)*. Before this lathe was correctly reconstructed, some writers believed that prior to the Renaissance seals were embedded in cement and worked with the free hand[18]. In addition to rotary tools and the abrasive, it seems reasonable that hand tools, such as wooden polishers, were also used for working hard stone[19]. Thus, we have attempted here to describe seal cutting in action, the appearance of certain ancient tools and the chronology of their use.

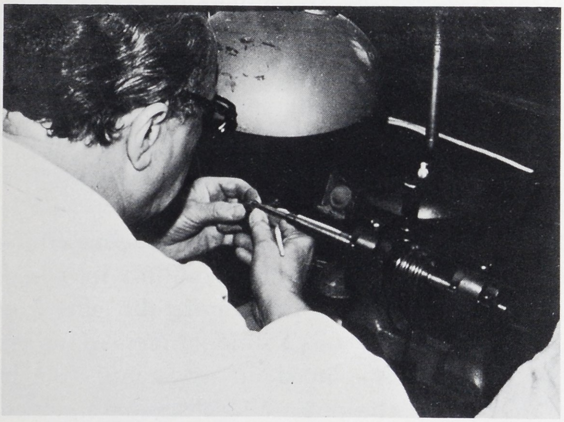

Fig. 5 Herr Hahn working with a lapidary lathe

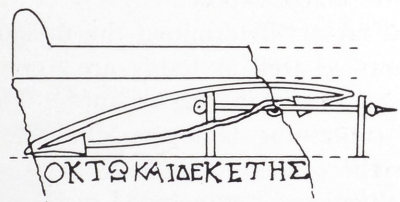

Fig. 6 Lapidary lathe, after Boardman.

For the student of glyptic it is interesting to note that the same tools evidently used in MM II are essentially those used today: the solid drill, tubular drill and wheel. These tools may be powered by a bow, pedal, footwheel or electric motor but in principle they function in the same way. A result of this observation is that the geometricizing

[16] Boardman, GGFR 379ff.

[17] Bow drills: cf. Arnold Lucas (revised by J. Harris), Ancient Egyptian Materials and Industries (1962) 54; G. Goyon, JEOL 21, 1969–70, 154ff. For the textual evidence cf. Richter, Gems p. 5. The writers do not believe that the stone was held in the free hand against fixed wheels and drills in all periods; little is known of the techniques from the early Christian period until the late fourteenth century (Fischer, Entwicklung 33f.; Kris, Meister 4ff.). Moreover, the tool marks of Merovingian intaglios, for instance, bear little resemblance to earlier wheel work. Boardman's and Löwental's lathe is not the only tool possible for carving seals in hard stone; it is, however, the one for which at least some evidence exists.

[18] O.M. Dalton, Catalogue of the Engraved Gems of the Post-Classical Periods ... (1915) p. XX; Richter, Gems 5f. The frequently reproduced workshop scene from c. 1480 evidently lies at the base of this confusion. This scene is, however, probably not of seal carving but rather of bead or seal boring (Kris, Meister, vol. II, p. 7).

[19] How much of the work was done with hand polishers, "files" and other hand tools is impossible to determine.

style of the MM II (–?) Hieroglyphic Deposit Group (as opposed to the more naturalistic style of the Neopalatial seals) is related to the taste of the time and not to the use of more primitive contemporary tools[20]. The stationary lapidary lathe is the oldest kind of lathe for which firm evidence exists and it predates the earliest known representation of a stationary lathe by some 1500 years[21].

As many as seventy seals published in the CMS and in Kenna, Seals, the catalogue of the Ashmolean Museum, show a whitened and/or fractured surface. These seals are generally considered to have been burned. Boardman writes that white or grey stones of the chalcedony family (agate, carnelian, chalcedony, onyx etc.) which are not cracked, probably were not burnt but may be simply poor quality stones[22]. Owing to Pliny's mention of the artificial coloring of semiprecious stones in the classical period[23] we decided to undertake a series of laboratory tests in the hope of empirically finding indications that, with the simple technology available to them, the Minoans could have colored or bleached seals.

Most of the stones which come into question appear to be only superficially whitened, as the stringholes of a few show the original color[24]. Some examples show a matt surface-texture as well as a fracturing of the surface[25]. In a few other cases the stone is whitened, but only on sharp, exposed edges[26].

Several factors determined the designing of our experiment. Varieties of chalcedony in antiquity as well as today are sometimes stained by means of a solution in which honey is an important ingrediant[27]. Therefore, we wanted to investigate the effects of solutions containing honey on chalcedony. Although olive oil is undocumented as an agent for the coloring of semiprecious stones, it probably played an important role in Minoan chemistry; we included it as well. Stones of the chalcedony family over a period of time may be attacked by base solutions and to a lesser extent by acids. The effects of both on chalcedony also were investigated. If the Minoans had wanted to produce a base solution, they easily could have diluted finely ground limestone with water. Vinegar

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[20] In order for the Minoans to have come to the point that they could carve seals such as the superbly fashioned early foliate backs and *Petschafte*, a considerable period of experimentation must have taken place. On this aspect cf. H. Biesantz, Minoisch-mykenische Siegelbilder (1954) 62f. The same geometricizing tendencies and motifs observable in seal designs exist in the contemporary ceramic decoration (cf. Fig. 7). Their style is only secondarily a result of carving technique.

[21] The earliest known representation of a fixed lathe is datable to the third century B.C. Cf. R. Woodbury, The Origins of the Lathe, Scientific American 208, 1963, 132ff.; F.M. Feldhaus, Die Technik (1914) 210ff.; A. Rieth, Zur Technik antiker und prähistorischer Kunst: Das Holzdrechseln, Jahrb. für prähistorische und ethnographische Kunst 13, 1940, esp. 101ff.; A. Rieth and K. Langenbacher, Entwicklung der Drehbank, (c. 1950); V. Childe, in: C. Singer et al., A History of Technology, I (1956) 187ff.

[22] GGFR 376. On this topic cf. B. Allchin, The Agate and Carnelian Industry of Western India and Pakistan, in: J.E. van Lohuizen-de Leeuw (ed.), South Asian Archaeology 1975, (1979) 91ff.

[23] Hist. Nat. XXXVII, 74.

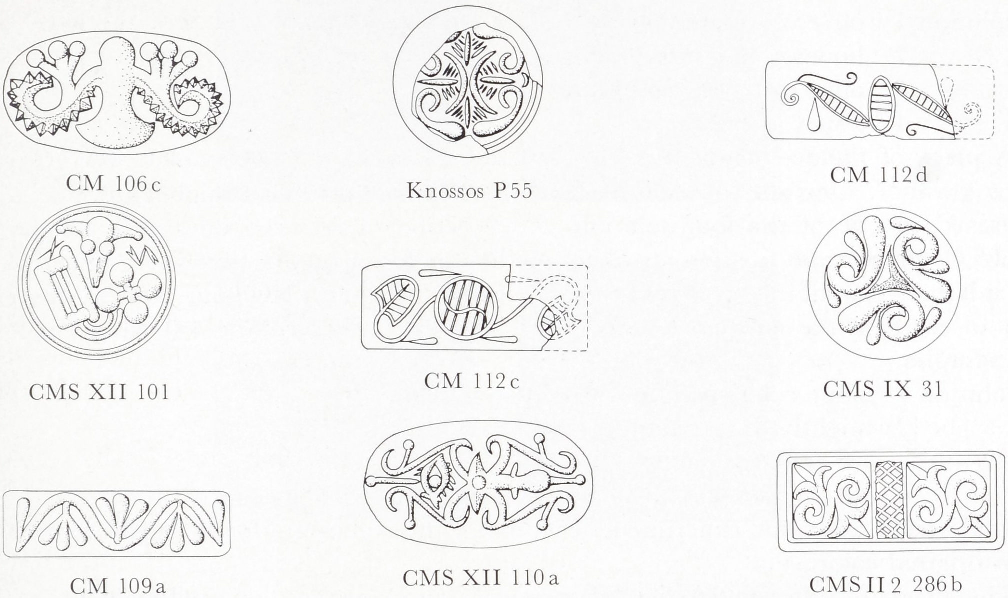
[24] Cf. Kadmos 16, 1977, 63 n. 29.

[25] Cf. CMS I 393. 408; VII 84. 120. 121; XII 107; XIII 141.

[26] Cf. CMS VIII 106; IX 50; XII 111. 144. 261. CMS VII 36 is yellow and is internally fractured. Yellow "citrine" can be produced by heating amethyst. This seal was probably also heated.

[27] Cf. C.A. Doelter, Handbuch der Mineralchemie 2 (1914) 184f.

Hieroglyphic Deposit Group MM II (-?)



Early and Classical Kamares Motifs (after G. Walberg, Kamares)

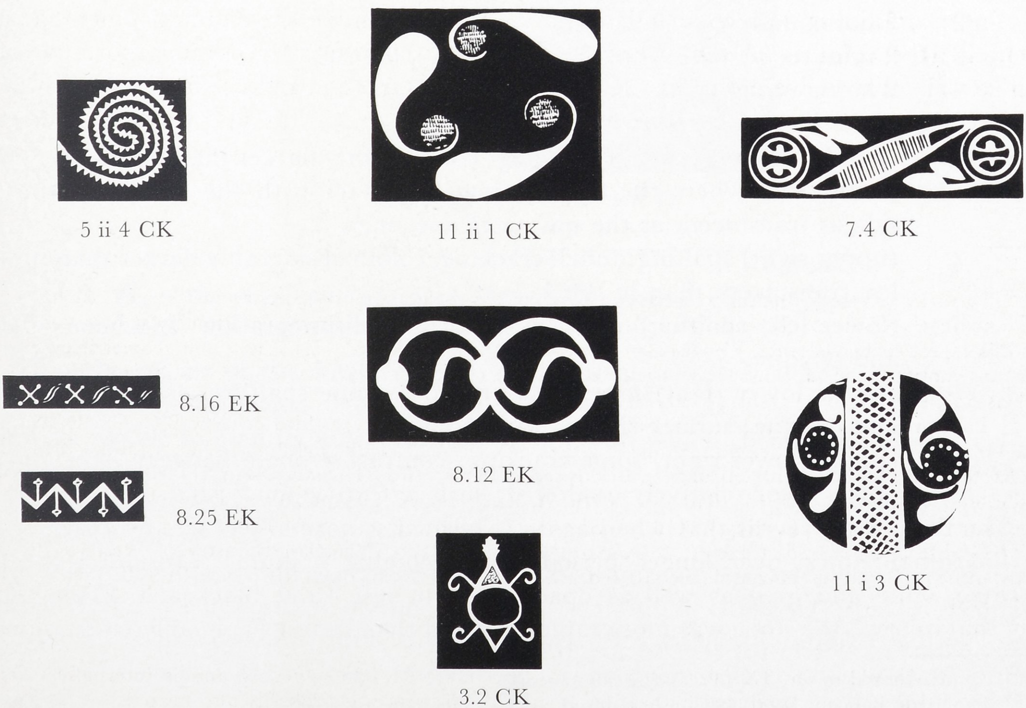


Fig. 7

is a kind of acid which is ubiquitous in all periods[28]. The effects of the following four solutions on agate were tested:

solution	1	olive oil – limestone water	pH ~ 9
	2	honey – limestone water	pH ~ 9
	3	olive oil – vinegar	pH ~ 2,5
	4	honey – vinegar	pH ~ 2,5

A piece of banded agate was cut into several cubes, each of which weighed about three grams[29]. One side of each of the cubes was polished to a high gloss. Each cube remained in one of the four solutions for a period of fourteen days at a temperature of 80° C. From time to time we checked the condition of the stones. A difficulty with the mixtures containing oil is that they separated out after a few hours and we frequently had to recreate the emulsions. After two weeks we observed the following changes in our samples:

solution 1 same color, banding slightly more contrasty
2 slightly darker than the original
3 no change noticeable
4 an obvious darkening of the stone, the banding slightly obscured.

Several weeks after our experiment terminated the stones gradually began to return to their original color.

The effects of different kinds of flames were also observed on similar cubes from the same piece of agate and on small pieces of polished jasper:

test 1: 2 minutes under a yellow flame (c. 600° C.)
2: 2 hours under a yellow flame (c. 600° C.)
3: 2 minutes under a blue flame (c. 900°–1 000° C.)
4: 2 hours under a blue flame (c. 900°–1 000° C.)

The results of the burning experiment are as follows:

test 1: (*Fig. 8,* upper left) slight cracking; color slightly darker than originally; opaque on the side where the flame came in contact with the stone; on the other side as translucent as the untreated specimen.
2: (upper right) spalting; much cracking, color considerably darker than in test 1; less translucent than in test 1.
3: (lower left) spalting; much cracking and disintegration; specimen whitened and opaque.
4a: (agate, lower right) much fine cracking, some spalting; specimen blackened and opaque; surface slightly dulled.
4b: (jasper, lower right) some cracking; contrast stronger between light and dark areas; color relatively unaltered; surface texture unaffected.

The flame tests reveal that when agate is burned it normally reacts by cracking and, as Boardman notes, over longer periods, by becoming opaque[30]. In test 3 the agate became white and grey as well as opaque but in test 4a it blackened. Owing to the fact that in test 3 the stone was more rapidly heated than in test 4a, it suffered considerably

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[28] I am indebted to Dr. Porada for this suggestion.
[29] The agate had not been previously colored.
[30] GGFR 376. The crust of the stone reacts differently than the middle.

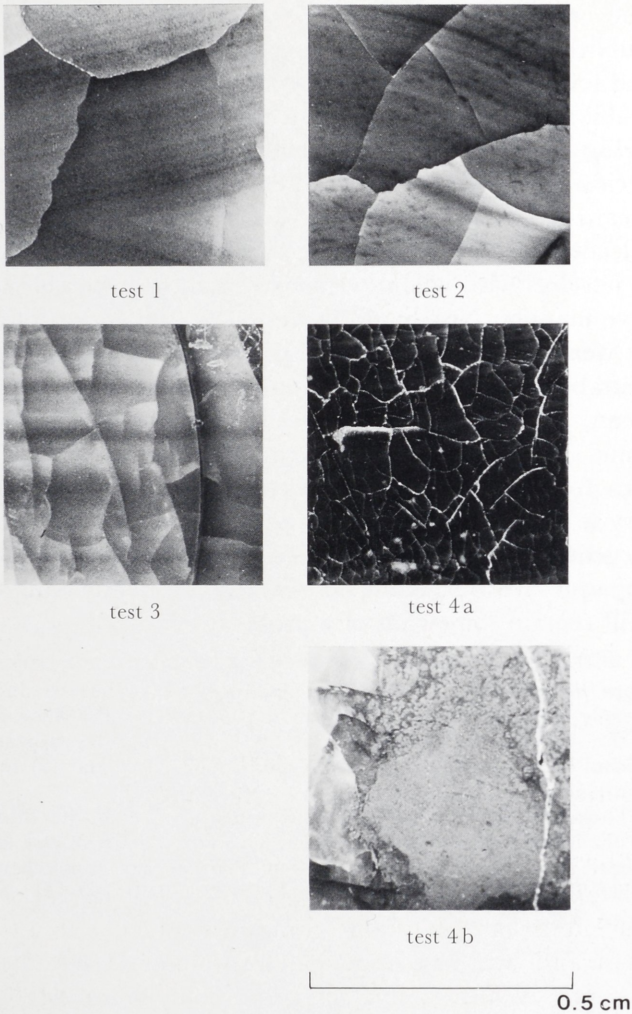

Fig. 8 The effects of different kinds of flames on agate and polished jasper.

more from the effects of the heating. In test 4b the slowly heated specimen of jasper remained relatively unaffected.

We were unable to identify any stylistic group of seals which correlates with the colors which we produced by burning or by steeping in the heated solutions and can find no evidence that semiprecious stones were intentionally colored or bleached in the Bronze Age as in later periods.

The whitening of agate specimens results from two more or less independent reactions: (1) an intensive decomposition of the aggregate condition, changing from a compact mineral to a fire-induced, microfractured mineral; (2) a color alteration resulting from a purging of absorbed or enclosed impurities[31]. The greater heat resistance of jasper

[31] This whitening is only partly the result of a kind of dehydration of the stone as chalcedony contains

than stones of the chalcedony family owes to a denser packing of its cryptocrystalline units. Of the published Aegean seals which are whitened, all appear to be varieties of chalcedony and few or none appear to be in jasper.

A further possibility which might explain the whitening of Aegean and other ancient seals is the wearing of the seal over an extended period and the resulting contact of the stone with acids contained in sweat. The writers made no attempt to control this possibility by means of a laboratory test. Instead, we asked several jewelers whether stones of the chalcedony family which were worn over a period of years tended to bleach out. None of the jewelers with whom we spoke claimed to be able to answer this question in an authoritative manner. Nearly all, however, were skeptical of the idea.

Although seals were dyed in the classical period and up to the present day, the writers were unable to establish the existence of intentional stone coloring or bleaching in the Bronze Age Aegean. If the Minoan seals were indeed bleached by the ravages of heat, how did this come about? Based on excavated pieces, it is clear that the majority of Aegean seals stem from graves and not settlement sites. Although few of the burned seals studied carry a certain provenance, most presumably came to light in tombs and, in fact, many Aegean tombs do show signs of burning[32]. Seals which show fracturing and which are opaque are burned. Those which are white and which have a normal surface texture still remain somewhat of a problem.

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a few OH groups but no molecular H_2O. X-ray investigations of burned and unburned samples show that both have the same structure (quartz-type) but the burned samples show better reflexes. This means that in addition to the cracking and powdering of the sample, a recrystallization has also taken place. The two most significant effects are thus: (1) a recrystallization effect and (2) the change of the aggregate structure already mentioned.

[32] Cf. Platanos Tholoi A and B, Koumassa Tholoi B and E et al. K. Branigan has interpreted this burning as evidence for fumigation or possibly cremation (The Tombs of the Mesara [1970] 12. 48. 86). On burned Late Bronze Age Aegean graves cf. I. Pini, Beiträge zur minoischen Gräberkunde (1968) 60; A.J.B. Wace, Chamber Tombs at Mycenae, Archaeologia 82 (1932) 140–141; M. Andronikos, Totenkult, Archaeologia Homerica (1968) 52–53.

DISKUSSION

I. Pini meint im Gegensatz zu Boardman und zum Referenten, daß es in der Bronzezeit den Gebrauch der Feile zum Siegelschneiden nicht gab, sondern daß nur Zeiger verwendet wurden.

J.G. Younger fragt, wieviel Werkzeug wandernde Siegelschneider im Gepäck mitzunehmen hatten.

I. Pini lehnt die Möglichkeit wandernder Siegelschneider ab. Seiner Meinung nach wanderten nur die Siegel.

H. van Effenterre ist der Meinung, daß sowohl Siegel als auch Siegelschneider reisten.

J.-C. Poursat weist darauf hin, daß die Siegelschneider der Altpalastzeit von Mallia eine feste Werkstatt hatten. Für die Neupalastzeit gibt es diesbezüglich allerdings keine Anhaltspunkte.