Photographic Documentation in Archeological Research: Increasing the Information Content

Abstract. *Improved records of observations on ancient seals were obtained by photography of the objects at two angles in polarized light; positive transparencies in registered combination with the negative both reversed intaglio to relief and increased relief, contrast, and detail of the cut surface.*

Many museum and private collections of ancient seals have been described and photographed; the importance of such data in archeological studies and other fields of scientific historical research is undoubted. Standards of excellence in the reproduction of seals were set by Fürtwangler (*1*) in 1900, and techniques of modern reproduction have rarely excelled those of his classical work. Von der Osten (*2*) has listed over 450 papers relating to ancient seals, the seals being illustrated by the standard method accepted for their documentation. This method consists of making photographic reproductions of the seal impressions at their natural size or, less frequently, at 1.2 to 1.5 : 1.

The transmission of information about seals has been limited by this method of illustration since many details of cut and style are lost (Fig. 1). Von der Osten (*3*) remarked on this loss and supplied drawings to supplement photographs of the impressions; this has been a frequent practice. It may be assumed that the reason for continued use of the method has been that it was always applied to the early cylinder seals and, since photographic techniques used for seal impressions have not changed, the method has become routine for all types. In fact, cylinder seals form the minority of published examples. Photographs of the seal itself of whatever type were usually less satisfactory, because increasing the outline contrast deepens shadow in the cut.

To increase the information content of the photographic record, combination prints of negative and positive transparencies were made. This method, which has been known for many years, was described by McKay (*4*) as having a value exceeding that of novelty; he suggested it as a means of increasing both relief and contrast in subjects of geometric outline. In spite of this it has been regarded as a manipulation without practical application. It can be shown that this view is incorrect. Modified in important respects to suit the special conditions, this photographic technique can be scientifically applied to the problem of intaglio reproduction.

Standard photomacrographic equipment with means for reflex viewing and 35-mm film were used (Leitz Aristophot). Extension rings were also suitable but less flexible. A microlamp—preferably the compact ophthalmic hammer lamp—was aligned close to the photographic lens. The seal was arranged at a slight angle (approximately 2° to 3°) to reflect the plane surface into the camera lens; polarizing filters were necessary to obviate glare and increase contrast. After the first exposure (Fig. 2*a*) the hammer lamp was moved to one side by 50° to 60° and a second exposure made; a third exposure was made with the lighting at an angle of 120° in the same plane. The camera setting and object position remained constant. After film development, contact transparencies were prepared from the second and third negatives. One positive transparency (Fig. 2*b*) was then combined in close register with the direct negative and a print was made (Fig. 2*c*). Of the two positives the one chosen was that which revealed most detail of the design; the most suitable combination can also be judged by projection before printing; both positives may be used to reveal obscure detail.

Reversal of the cut to a relief resulted and the combination increased this relief; at the same time surface details were brought into sharp contrast. Maximum information was thus

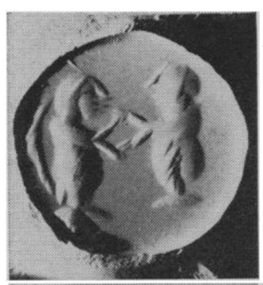
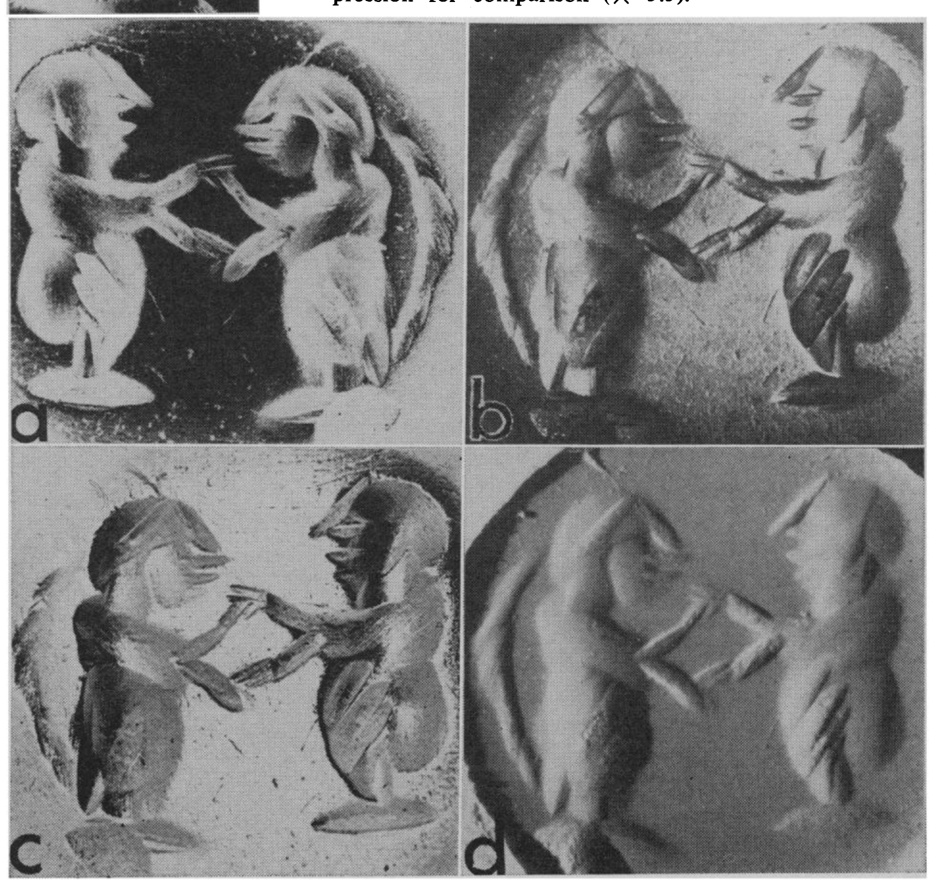


Fig. 1 (left). Impression of ancient seal by standard methods (× 1.4). Fig. 2 (below). (*a*) Negative image of direct photograph of seal with practically parallel lighting (polarizing filter; × 3.5. (*b*) Positive image (on transparency) obtained by exposure with the lighting at an angle of 60° to the plane surface of the seal (× 3.5). (*c*) Registered combination print of (*a*) and (*b*) showing relief, contrast, and detail of surface (× 3.5). (*d*) Enlargement of direct seal impression for comparison (× 3.5).



obtained from the worked surface. The example shown in Fig. 2*c*, an early Persian seal of the Sassanian Period (A.D. 200 to 600) is a shallow cut intaglio; this makes the least satisfactory impression photograph. On the combination print may be seen grinding traces which remained invisible not only on the impression but under direct inspection with a × 4 hand lens. This basically photographic technique has important applications to documentation in at least one field of archeological research.

C. A. Erskine
School of Anatomy, Trinity College, University of Dublin, Dublin, Ireland

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Clinoenstatite: High-Low Inversion

Abstract. *Clinoenstatite undergoes a metastable displacive inversion at 995°C. The new phase can be indexed (from x-ray powder pattern) on a triclinic cell with dimensions* a = *10.00 Å;* b = *8.934 Å; c = 5.170 Å; alpha = 88.27°; beta = 70.03°; gamma = 91.09°. The new phase persists from 995° to 1010°C at the composition $MgSiO_3$. For a solid solution (15 percent by weight) of diopside in clinoenstatite, the new phase persists from 995° to at least 1400°C and does not invert in periods of several hours to protoenstatite, the phase previously thought to be the stable form in this region.*

In spite of many studies, which have been reviewed elsewhere (*1*), over the past 15 years, the stability relations of the polymorphs of $MgSiO_3$ are still uncertain. To date, three principal polymorphs of $MgSiO_3$ have been described and indexed: orthoenstatite (*Pbca*), protoenstatite (*Pbcn*), and clinoenstatite ($P2_1/c$). Disordered forms of both orthoenstatite and clinoenstatite have been reported by Brown and Smith (*1*) and Byström (*2*). Boyd and Schairer (*3*) have presented the latest data on the enstatite-diopside system at atmospheric pressure. They find that phase relations on the "enstatite" side of the system are extremely difficult to determine if conventional quenching techniques are used. Because their complex and sometimes inconsistent findings may result from rapid inversion during quenching, we have attempted to determine the phase relations directly at high temperature with a Tem-Pres furnace (*4*) attached to a Norelco diffractometer. Our investigation was stimulated by Boyd and Schairer's discovery that some charges quenched from above 1385°C contained orthoenstatite, and their speculation on the presence of a new form of $MgSiO_3$ which inverted to orthoenstatite during the quenching. Their conjecture has not yet been proved or disproved by us because of the possibility of metastability, but it has led to the discovery of a new displacive-type inversion in clinoenstatite. This high form of clinoenstatite is probably the intermediate form which Foster (*5*) encountered, but unfortunately he was unable to reproduce his results which, as discussed below, are due to the narrow range of temperature in which this form exists in pure $MgSiO_3$.

The mixtures used in this study were supplied by F. R. Boyd (*6*). The glasses received from him were recrystallized by keeping them at 1350°C for 3 days in platinum crucibles in the absence of a catalyst and then by quenching in air. X-ray patterns of the material showed that, in accordance with the known stability relations, clinoenstatite was the only phase present at room temperature.

During a preliminary investigation of pure clinoenstatite, a marked splitting of the (310) reflection was noticed at about 1000°C, the approximate inversion temperature of clinoenstatite to protoenstatite (Fig. 1). However, further studies showed that the substitution of calcium in clinoenstatite raised the clinoenstatite-protoenstatite inversion temperature and thus permitted a full investigation of the (310) splitting. In fact, a solid solution (15 percent by weight) of diopside in clinoenstatite showed no formation of protoenstatite even at temperatures up to 1400°C, the upper limit of the apparatus. Further examination of this solid-soluiton sample showed that the (310) reflection split completely and rapidly over an interval of 10°C at approximately 1000°C, and that the splitting produced a new phase which persisted up to at least 1390°C. This phase, high clinoenstatite, apparently exists, at least for periods of 2 to 3 hours, in the temperature range formerly thought to be restricted to the protoenstatite form. A comparison of the x-ray patterns, where 2θ ranges from 26 to 32 deg, of high and low clinoenstatite of a diopside composition that is 15 percent

Table 1. X-ray diffraction data of powdered high clinoenstatite with nickel filtered copper radiation. *d*, Interplanar spacing; *I*, intensity; *hkl*, Miller indices.

d_{obs} (Å)	d_{calc} (Å)	I/I_0	*hkl*
6.43	6.38	2	110
5.19	5.08	2	101
4.47	4.46	17	020
4.12	4.11	33	210
3.94	3.98	10	120
3.76	3.76	3	$2\bar{1}1$
3.56	3.56	6	$\bar{1}\bar{1}1$
3.34	3.35	42	$0\bar{2}1$
3.22	3.23	76	021
3.06	3.05	100	221
2.98	2.98	30	$3\bar{1}0$
2.92	2.93	91	310
2.86	2.86	2	$\bar{1}30$
2.84	2.84	8	$\bar{1}\bar{2}1$
2.80	2.81	11	130
2.588	2.580	20	321
2.533	2.528	13	320
2.501	2.494	33	$0\bar{3}1$
2.456	2.459	20	212
	2.452		$1\bar{1}2$
2.296	2.299	6	$\bar{1}\bar{3}1$
2.167	2.165	30	331
	2.168		022
2.148	2.152	16	421
2.094	2.090	15	322
2.058	2.058	6	041
2.043	2.039	12	$\bar{2}40$
	2.040		$\bar{2}\bar{3}1$
2.012	2.011	6	$\bar{3}\bar{2}1$
1.975	1.972	8	241
1.943	1.943	3	511
1.815	1.818	8	430
1.806	1.808	7	$\bar{2}41$
1.782	1.784	10	$\bar{3}\bar{3}1$
1.759	1.755	12	$\bar{4}21$
1.699	1.697	3	151
	1.700		$4\bar{3}2$
1.647	1.647	27	441
	1.647		$\bar{3}12$
1.632	1.632	15	611
	1.629		342
1.611	1.612	6	$0\bar{4}2$
	1.611		$\bar{5}30$
1.5458	1.5458	10	$\bar{5}\bar{1}1$
1.5353	1.5346	4	610
1.5108	1.5108	11	$4\bar{2}3$
	1.5107		233
1.5068	1.5072	11	$\bar{5}21$
1.4931	1.4949	7	$\bar{2}\bar{5}1$
	1.4923		622
1.4328	1.4337	4	523
	1.4312		352
1.3916	1.3909	15	$\bar{2}03$
1.3777	1.3790	4	$7\bar{1}2$
1.3661	1.3665	7	$\bar{1}\bar{6}1$
	1.3655		$\bar{2}\bar{1}3$
	1.3652		343
1.3032	1.3032	3	$\bar{2}\bar{6}1$
1.2823	1.2325	7	314
	1.2821		$\bar{5}12$
1.2271	1.2267	4	$\bar{3}\bar{6}1$
	1.2273		811