PHOTOGRAPHY IN ARCHAEOLOGY AND CONSERVATION

SECOND EDITION

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BASIC PRINCIPLES AND PRACTICE

A book of this nature must assume a certain knowledge of the basic principles of photography. There are many reliable books that can be consulted (Langford (1986) is one of the most comprehensive), and all that is attempted in this chapter is a resumé of the terms and concepts most often used, and a brief explanation of how the principles are applied in archaeological photography.

Forming an image

Visible light, the section of the electromagnetic spectrum from about 400 to 700 nanometres (1 nanometre, nm, = 10^{-9} metres, or one-millionth of a millimetre) that is reflected from an object or scene, can be focussed through a lens by 'bending' or refraction of the light rays to form a sharp image behind the lens. Sections of the total spectrum of wavelengths shorter or longer than visible light can also be recorded photographically by the special techniques of ultra-violet and infra-red photography.

Light reflected from a very distant object – more or less at infinity – will reach the lens as parallel beams, and the distance between the lens and the point at which such light is focussed constitutes the *focal length* of the lens. This is always expressed in millimetres. Since the focal length of a lens determines the size of the image, i.e. for an object the same distance away from the lens a long focal length lens will give a larger image than one of short focal length, it also determines the *angle of view*, the amount of the scene in front of the camera taken in by the lens.[1] For each format of camera (i.e. the size of film for which the camera is designed) one particular focal length of lens is taken as 'standard'. By convention, the *standard lens* is of a focal length about the same as the diagonal of the film format, but, more important, the angle of view accepted by the standard lens is approximately the same – about 45° – as that taken in by the relaxed human eye, disregarding the area of peripheral vision. Thus, if the whole of a negative taken with a standard lens were enlarged, or if a transparency were thrown on a screen, the observers would see much the same amount of the scene or object, and objects at different distances within the picture would be in roughly the same propor-

[1] This is not completely true, since the angle taken in by a lens focussed to infinity is not the same as that taken in when it is focussed on a closer object, but the difference is small enough to be unimportant in this context.

tions, as if they were looking at the scene themselves.[2] For a 35 mm format, the standard lens is of focal length 50 or 55 mm, for 6 × 6 or 6 × 4.5 cm format, 75 or 80 mm, for 6 × 9 cm, 100 mm, and for 5 × 4 in, 150 mm.

A term similar to angle of view, though not identical, is *covering power* or coverage. The covering power of a lens is the maximum area at the film plane over which the lens will give a sharp and evenly illuminated image. This varies with the lens construction and the format for which the lens was designed. Ideally, for a 35 mm format lens, of whatever length, the covering power should be just enough to cover the diagonal of the format at all magnifications and no more, so that there is no surplus light projected through the lens and not falling on the film. Within the body of a small-format camera, which for reasons of compactness is always as small as possible, any surplus light is likely to reflect in some degree from the walls of the body and to reach the film as '*flare*', overall unfocussed light that degrades the image. For a large-format camera with movements (see next chapter), on the other hand, the covering power needs to be considerably greater than the size of the film, otherwise camera movements cannot be used without immediately running out of image. Since the dimensions of a large-format camera are not judged to be so important, the body can be proportionately larger, and the bellows act as a baffle to intercept and absorb surplus light. Because of differences in covering power, a lens designed for one format is not usually suitable for use in a camera of a larger format, no matter what the focal length.

Lenses are available in other focal lengths, apart from the standard one, but the range of choice is widely different between one format and another. For most makes of 35 mm camera, fifteen or more different lengths of lens are available, ranging from 'fish-eye' lenses of 6 or 8 mm focal length, giving an angle of 180° or more, to extremely long lenses with a focal length of 1200 mm and an angle of only 2°. Only a few of these would be useful in archaeology; suitable sets are suggested in Chapters 8 and 9. The range is more restricted for other formats; perhaps six or eight on average for medium-format cameras, and no more than three or four for large format. Both short (*wide-angle*) lenses and long lenses (often referred to as *telephoto* lenses, although telephoto implies a certain type of design in which the focal length is greater than the actual physical length of the lens, and not all long lenses are therefore telephoto) have certain characteristics arising from their angles of view which affect the appearance of the image.

Perspective and distortion

Perspective, taken here to mean simply the apparent difference in the relative sizes of near and far objects, is a function of the distance away of the observer

[2] This again needs to be qualified. To achieve this viewpoint, strictly speaking, the observer should be at a distance from the image of the focal length of the lens × the degree of enlargement. But except in extreme cases – looking at a wall-size enlargement from a distance of 50 cm for instance – the viewing distance is not critical.

– or of the camera – and nothing else. If three cameras with short, standard and long focal-length lenses were lined up side by side, focussed on, say, a building 100 m away, each viewfinder would show a different amount of the building and its background, but the perspective effect – the apparent difference in size between the nearest and the farthest parts of the building – would be the same in each case (Plates 5, 6 and 7). If, however, the cameras were so positioned that each showed the leading corner of the building as the same size on the viewfinder, the camera with the short lens being therefore closest to the building and that with the long lens farthest away, then the perspective effect would be different in each case; steeper with the short lens and flatter with the long (Plates 8 and 9). Although there cannot be a question of 'correct' or 'incorrect' perspective as such in a photograph, undoubtedly the perspective that seems most natural is that presented by a standard lens because of the correspondence of the angle of view of this lens with the eye.

Short lenses are subject to so-called *wide-angle distortion.* This arises from the obliqueness of the rays at the edge of the field and gives a radial distortion of objects at the sides, and especially in the corners, of the photograph (Plates 10, 11, 12 and 13). This effect increases the shorter the focal length, and for the purposes of accurate record becomes unacceptable with a lens whose angle of view is wider than about 75 to 80°, i.e. 28 mm lenses on 35 mm format cameras, 40 mm on 6 × 6 cm, 80 mm on 5 × 4 in. Older wide-angle lenses suffered, as cheap ones still do, from *barrel distortion* (the convex curvature of lines towards the edge of the field) and fall-off of definition and illumination in the corners of the field. These problems have largely been overcome in modern lenses, but such faults as still occur are, again, greater the wider the angle.

Long lenses are less subject to such aberrations, since the chief cause, obliqueness of the rays entering the lens, does not apply. They do suffer very often from a slight lowering of the contrast range of the image compared with shorter lenses, and from a slight loss of resolution. This is due simply to the fact that most photographs using long lenses are taken at considerable distances, within which there may be air turbulence and scattering of blue light and ultra-violet. This can be partly overcome by using a UV barrier filter for both colour and black and white. Perspective often appears to be very much flattened in photographs taken with a long lens, distant objects appearing to be of much the same size as those in the middle distance, giving a 'stacked-up' appearance to successive planes of the photograph. This effect, and at least some of the effect of wide-angle distortion, is made more apparent because photographs, if they are of a similar size, are normally viewed from about the same distance from the eye. For someone reading a book or journal, this would be about 30 or 40 cm; but using the formula of focal length × enlargement, for a photograph taken with a 24 mm lens and enlarged five times, the distance should be 12 cm, while for one taken with a

Plate 5

Plate 6

Plate 7

Focal length and perspective. Plate 5 was taken with a 35 mm camera fitted with a 100 mm lens, Plate 6 from the same position with a 50 mm lens and Plate 7 with a 28 mm lens. The angle of view, and thus the sizes of objects in the frame, is different in each case, but the perspective effect is identical.

Plate 8

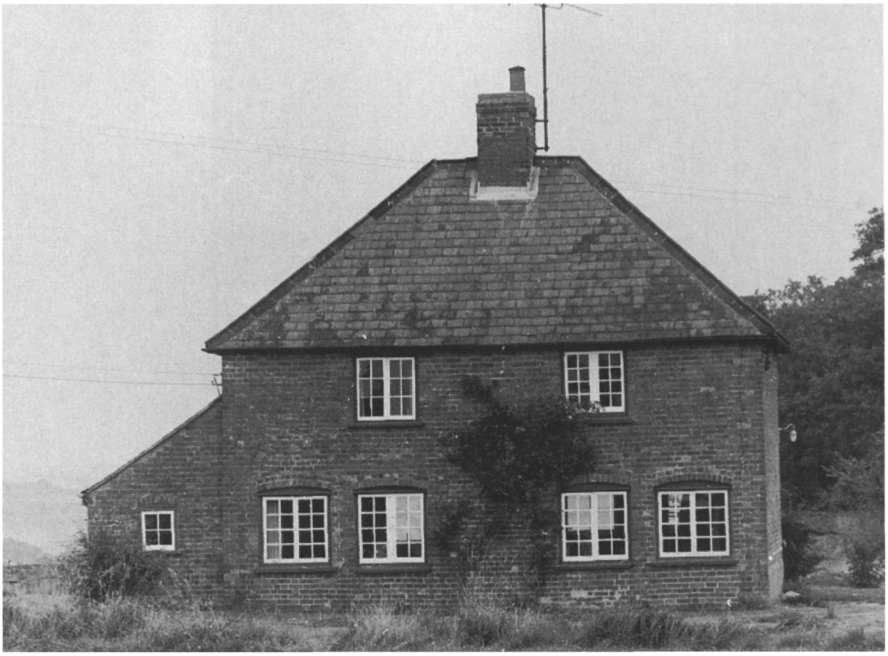

Plate 9

Focal length and perspective. Plate 8 was taken with a 35 mm camera fitted with a 28 mm lens, and Plate 9 from farther away but on approximately the same line. The perspective effect, and particularly the amount of roof revealed, is quite different.

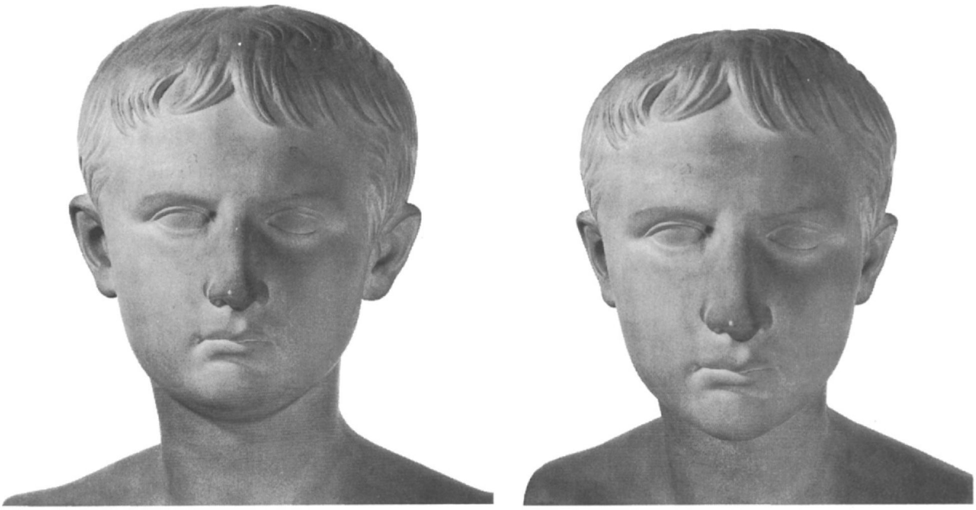

Plate 10, Plate 11 Wide-angle lens and perspective. Plate 10 was taken with a 5 × 4 in camera fitted with a 240 mm lens from a distance of about 3 m, Plate 11 with the same camera with a 90 mm lens from about 50 cm. The distorted appearance given by the wider angle lens is due to the steeper perspective.

Plate 12, Plate 13 Distortion due to viewpoint. Both were taken with a 5 × 4 in camera fitted with a 150 cm lens, Plate 12 from about 2 m and Plate 13 from about 40 cm. The difference in the proportions of the figures is due partly to the steeper perspective of the near viewpoint, and partly to the steeper angle of view. The more distant view also 'sees' farther round the pot.

500 mm lens and enlarged to the same extent, it should be 2.5 m. Some distortion is therefore inevitable.

Focussing and exposure

On nearly all lenses the amount of light passing through the lens is controlled by an *iris diaphragm*, a device of overlapping metal leaves within the lens, itself controlled by the *aperture ring* on the lens barrel. The *stops* or *f-numbers* marked on this ring are *relative apertures*, i.e. they are calculated from the ratio of the diameter of the opening and the focal length of the lens, so that the amount of light passed by a lens set to a particular f-number will be the same, in theory, as that passed by any other lens, no matter what its focal length, at the same setting. There is, as usual, a slight reservation about this, since different lenses have rather different light-passing qualities, depending on the density of the glass, the number of elements and the lens coating, but these differences are usually small enough to be ignored. The rather arcane series of numbers shown on the aperture ring, a series which all manufacturers now follow (f2, f2.8, f4, f5.6, f8, f11, f16, f22, f32) is related to area and not diameter, so an adjustment of the aperture ring from one position to the next will halve or double the amount of light admitted through the lens. Fast lenses, i.e. lenses of large diameter in relation to their focal length, often have maximum apertures larger than f2, e.g. f1.8, 1.4, or 1.2; f1.4 is roughly twice the area of f2, and f1.8 is intermediate between the two.

Apart from its importance in determining the exposure (the total dosage of light reaching the film, calculated from aperture × shutter speed), the aperture is one of the factors affecting the *depth of field* and *depth of focus*.

Depth of field

When a camera is focussed at any distance, a point reflected from that distance should be reproduced as a point on the film, so far as the resolution of the emulsion and the aberrations of the lens allow. Points in front of and beyond that distance become successively less well-defined discs the farther they are from the focussed distance. There is a zone, however, which extends in front of and behind the focussed distance within which points will appear to be acceptably sharp in the print or transparency, since the eye has a limited resolving power. This is the depth of field, and it varies with focal length, with the distance at which the lens is focussed, with the aperture and with the size of the disc deemed acceptable (known as the *circle of confusion*). The first three of these factors are associated with the apex angle of the cone of light subtended at the lens, and thus with the diameter of the disc of light reaching the film. The geometry in this context is unimportant, but the practical considerations are considerable.

Firstly, the shorter the focal length, the greater the depth of field. This applies if two photographs are taken from the same position with lenses of different focal length. In the wider-angle photograph, each object within the viewfinder will appear smaller, and components of each object smaller down to the point level, and therefore the depth of field will take in more of them, front to back. If an object is focussed to the same size with the two lenses, however, that is if the shorter lens is closer to the object than the longer one, the depth of field will be virtually the same. There is another consideration, however; the standard lens for a 35 mm camera is 50 mm, while that for a

5×4 in format is 150 mm. Both take in roughly the same angle, but when both are set to f8, for instance, the shorter lens will give a depth of field about four times as great as that of the longer lens.

Secondly, the farther away the object, the greater the depth of field. The more distant the object, the smaller will its image be, the closer behind the lens will it be focussed, and the greater will be the depth of field. If an object in the middle distance is focussed upon, objects and spaces behind it will appear smaller than those in front of it, and thus the depth of field extends farther behind an object at this distance than it does in front. For any focal length of lens, at any aperture, it is possible to calculate a distance at which the depth of field will just extend back to infinity. This is known as the *hyperfocal distance*, and at this distance sharp focus will extend from the object back to infinity, and forward half as far as the hyperfocal distance. Thus for a photograph to show the most distant detail in sharp focus and as much as possible of the foreground sharply, it is unnecessary to focus on the distant detail; if the lens is set to the hyperfocal distance, the distance will appear sharply focussed but much more of the foreground will also be sharp. Unlike most depth of field calculations, which are rather complicated, the formula for hyperfocal distance is fairly simple:

$$\frac{\text{Focal length}^2}{\text{f-no.} \times \text{diameter of circle of confusion}} = \text{hyperfocal distance}$$

The size of the circle of confusion is discussed below, but taking it for the moment to be 0.03 mm, then for a 50 mm lens set at f8:

$$\frac{2500}{8 \times 0.03} = 10.4 \text{ m}$$

So if the lens were set at this distance, detail would be acceptably sharp from half this distance, 5.2 m, to infinity. The disparity between the two parts of the depth of field has led to the general precept 'focus one third of the way back'. This certainly holds good for distant objects, and to focus, for instance, one third back in the visible depth of a building will give the best chance of having the whole building in focus; but the difference between the two depths becomes less the closer the object, and at 'same size' the two are the same depth and the system is symmetrical. For close-up work, therefore, and for distances up to about 1 m (with a standard lens), it is better to focus one half of the way back.

The third consideration involving depth of field is that the smaller the aperture the greater the depth of field. As the lens is closed down the cone of light reflected from any point and reaching the lens is similarly narrowed, and an acceptable circle of confusion will be farther from the apex of the cone; points nearer and farther from the point of focus will therefore be rendered sharply and the depth of field will be increased. The effect is fairly straight-forward: as the aperture is decreased the depth of field increases (Plates 14, 15, 16 and 17). This applies with all focal lengths and at all distances, but the amount of increase is not constant, nor can it be plotted on a straight line. The increase, for instance, between f22 and f32 is much greater than the increase between f2 and f2.8.

Plate 14

Plate 15

Aperture and depth of field. All were taken with a 6 × 6 cm camera fitted with an 80 mm lens, at a distance of 1 m from the central figurine.

Finally, the larger the acceptable circle of confusion, the greater the depth of field. On the face of it, this means no more than saying, 'if it is acceptable for the nearest and farthest parts of the object to appear slightly out of focus, then the depth of field can be said to cover the object', a fairly meaningless provision. But there are two other considerations; one, which has already

Plate 16

Plate 17

The depth, front to back, of the group was 50 cm. In Plate 14 the aperture was f2.8, in Plate 15, f5.6, in Plate 16, f 11, and in Plate 17, f 22.

been mentioned in connection with perspective, is viewing distance. A photograph published in a book will probably be looked at from ordinary reading distance. The same photograph enlarged to cover a wall might look equally sharp if the viewing distance were similarly increased, perhaps to three or four metres, but if it were viewed from, say, one metre, the resolution would have to be much finer. In other words, the acceptable circle of confusion would be smaller. The other consideration is the degree of enlargement necessitated by the format. A 5×4 in negative would have to be enlarged about two and a half times to make an A4 print from the whole frame, while a 35 mm negative would have to be enlarged about eight and a half times to make a print of similar size. Thus the smaller the negative, the more critical must the resolution be, and the smaller the acceptable circle of confusion. If both cameras were fitted with their respective standard lenses, or with other lenses of similar angles of view, this difference would go some way to compensate for the shorter depth of field of the longer lens. Because of this need for greater resolution on small formats, good lenses for 35 mm cameras are designed to yield a circle of confusion of a maximum size of 0.03 or 0.025 mm (this, though, is the 'circle of least confusion' i.e. the maximum size of disc corresponding to a point on the plane of focus, not on the edge of the depth of field). For larger formats, an acceptable circle is often taken to be $\frac{1}{1000}$ of the focal length, i.e. 0.15 mm for a 150 mm lens on 5×4 in, or 0.1 mm for a 100 mm lens on 6×9 cm format.

So, in practice, to achieve a maximum depth of field, a short lens should be used on a small-format camera, with as small an aperture as possible, and if sharpness is needed right to the horizon, focussed to the hyperfocal distance; while for a minimum depth of field, the ideal is a long lens on a large-format camera, with a large aperture, and focussed from one half to one third of the way back in the visible depth of the object (if this gives too short an exposure to be practicable, light can be reduced with a neutral density filter without affecting the depth of field).

In general, in archaeological site photography a considerable, if not the theoretical maximum, depth of field is desirable. Almost everything in the picture is sharply focussed and all detail is clear. There are times, however, when a much shallower depth is preferable; for showing some architectural detail clearly against a jumbled background, for instance, or for selecting one artifact from among several in a museum showcase, it is effective for the detail or artifact to be sharply focussed and the background to be out of focus. The problem of depth of field in close-up photography is discussed in Chapter 10.

Depth of focus

A concept in some ways parallel with that of depth of field, and often confused with it, is depth of focus. While depth of field is concerned with how deep a zone in front of the lens can be brought into acceptable focus, depth of focus describes the distance through which the film plane can be moved, backwards and forwards, while retaining the image of an object or point in sharp focus. This adjustment, and its deliberate use, are of much less frequent concern than is the depth of field, and the factors that affect it need be discussed only briefly. It is chiefly of importance in the use of camera movements; when the back or front of the camera is swung or tilted so that the lens axis no longer meets the film plane at right angles, the edges of the image will become unsharp unless they fall within the depth of focus. (The use of camera movements is discussed in Chapter 3.)

The controlling factors are the same as those affecting depth of field, focal length, focussed distance, aperture and the acceptable size of the circle of confusion; and they are similarly based on the narrowing of cones of light from the lens, but the effects are different.

Firstly, in this case the longer the focal length, the greater the depth of focus. Thus a large-format camera with a relatively long standard lens has an inherently greater depth of focus than has a smaller format with a shorter standard lens. This is why the fullest camera movements can be achieved only with large-format cameras, and why the plane of the film in 35 mm cameras has to be so exactly positioned with pressure plate and guide rails – the shallowness of the depth of focus leaves no room for manoeuvre. Secondly, again unlike depth of field, the closer the camera is focussed, the greater the depth of focus, and this depth extends equally on both sides of the film plane. For this reason, it can be difficult to focus a large-format camera used for close-up photography; the back of the camera can be moved backwards and forwards by a centimetre or more without apparently affecting greatly the sharpness of the image. It often helps to focus with a magnifying glass in these circumstances.

Thirdly, as with the depth of field, the smaller the aperture the greater the depth of focus. For this reason, when the use of swing or tilt movements throws the edges of the image out of focus, sharpness can, within limits, be restored by stopping down the aperture. This is also the reason why a camera, or an enlarger, should always be focussed with the lens wide open, especially when the camera is being used for close-up work, or the enlarger for low magnification. The reduced depth of focus makes it easier to judge when the image is sharp. Finally, as with depth of field, obviously the lower the permissible standard of sharpness, the larger the acceptable circle of confusion, and thus the greater the depth of focus.

The practical points arising from these considerations of depth of focus can be summed up thus: the greatest correction of convergence can be achieved only with a large-format camera; any misalignment of the film in a small-format camera will result in unsharp photographs; cameras and enlargers should always be focussed with the aperture wide open; and, for close-up work with a large-format camera, the sharpness of the image should be checked with a magnifying glass.