Balloon Photography and Archaeological Excavation

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IT is a great help to the understanding of a piece of country, a town or a building to get to some high point in the vicinity and look down upon it, and the more nearly vertical one's point of view the more accurate is one's impression. In the 'nineties, as a boy, I used to spend hours at the top of the spire of Rouen Cathedral gazing down upon the city below, and it was only a step from this to record such a view photographically; but it was some time before I took my first truly vertical photograph.

About 1904, a friend who was engineer on the construction of the Rothesay Dock near Glasgow asked me to photograph for him the concrete foundations of a part of this dock: I could not get a proper view of these from anywhere on the ground, so I asked if I might utilize a great crane which stood nearby. It was probably against all the rules of the Clyde Trust, but I was thereupon swung high in the air over my subject, and plate 1 shows the result obtained with a no. 2 Bullseye Kodak.

During the war air-photographs became a commonplace, and it was my lot to use them a good deal, particularly in connexion with the indirect firing of machine-guns. Later on, in 1922 and 1923, when I was in the Palestine Department of Antiquities, friendly relations with the R.A.F. enabled me to examine a number of ancient sites from the air, discovering such things as the complex of buildings buried by sand-dunes inside the enceinte of the Crusaders' castle of Athlit. The air-photos obtained at that time formed the beginnings of the Department's collection, but they were chiefly what may be termed reconnaissance photos, showing the extent and character of ruins still covered by surface soil.

The excavation of Megiddo presented the opportunity of realizing an old desire—the use of air-photography as an aid to recording ruins

progressively exposed, and as a help in the often puzzling task of distinguishing excavated buildings of one stratum from those of another.

The use of aeroplanes or full-size balloons was ruled out for reasons of expense, and I cast about for other means.

Kites offered one solution of the problem, and I have to thank Major B. F. S. Baden-Powell, whose successful work with these during the South African war will be remembered, for giving me information about them. I came to the conclusion, however, that for our particular conditions and requirements a small captive balloon would be more suitable, and by renewing an old acquaintance with the Royal Aeronautical Society I succeeded in getting into touch with Mr Griffith Brewer, of whose early work I had heard. Mr Brewer replied enthusiastically to my enquiries, was good enough to show me several admirable photographs he had obtained, I believe in 1902 or 1903, by means of a camera suspended from a small balloon of gold-beaters' skin, and even offered to rout out his old apparatus for me to look at. My stay in London was too short to permit me to avail myself of this offer but Mr Brewer's verbal explanations were clear, and the apparatus itself simple. The success of the photographs since taken at Megiddo owes much to him.

On my return to Palestine it happened that one of my assistants, R. S. Lamon, was going to America, so I commissioned him to have made an electrical release, controllable from the ground, which would trip the camera-shutter. The apparatus which he procured (it was made by the Physics Department of the University of Chicago) is a beautiful little piece of mechanism : it is light and simple, and it works.

I had also asked Lamon to see if he could not find a small ready-made balloon in America, in order to save the expense of having one built specially, and he bought one of the expandable rubber kind that is used for meteorological purposes. This had the merit of being light and cheap but, as will appear, it turned out to be unsuitable.

Meanwhile O. E. Lind and E. L. De Loach had manufactured a light, fixed-focus camera of three-ply wood to take one of our lenses and a 5 by 7 inch film-holder, and when Lamon returned from America we tried the whole combination, as well as the wooden winding reels made locally to carry the light steel wire (uncovered) which we used both for holding the balloon and for passing the current to the shutter-release.

We inflated the balloon with hydrogen which I had procured in

cylinders from France : this is an expensive item, not because the gas itself is dear but because of the price of the cylinders and the shipping charges on these.[1] I can see no way of avoiding this, for all the machines for generating hydrogen on the spot, about which I have enquired, are either too large or too small.

On our first attempt we controlled the balloon by wires from two points : it went up excellently and we got two photos, one good[2] and one poor. Then came disaster. We had got the balloon back into my garage, which we were using as its shelter, and were pegging it down by means of a light fishing net thrown over it. Now whether it was that the balloon, whose skin had certainly become somewhat electrified, generated a spark through friction with the net, or that there was a flaw in the rubber, I know not ; but there was a loudish pop and the balloon, as such, ceased to exist. Perhaps it was merely because it happened to be the fifth of November—an appropriate date for more reasons than one.

We were, however, not at all discouraged, for our experiment had in the main been successful. We had proved that we could take a good photo, and we had learned a good deal one way and another. The main things were that expandable rubber was evidently not the right material for the balloon, that thin steel wire was not good for control because it could kink easily (we later found that it also got quickly rusty), and that our rather primitive winding-reels were not good enough. Our mistake had, in short, been to spoil our ship for a ha'po'rth of tar, and I would warn other experimenters against this.

I hesitated to use gold-beaters' skin for our new balloon because I feared that it would quickly perish in the heat of Palestine, so I decided to have a rather larger balloon made of the heavier but thoroughly solid rubberized silk, and on 25 November 1929 I cabled my requirements to the firm whose name Mr Brewer had given me. They carried out the order with a speed and accuracy that are truly praiseworthy,

[1] While the balloon itself was admitted into Palestine free of duty, under the regulations governing the facilities granted by the Palestine Government to Archaeological Expeditions, I have been officially informed that 'Exemptions accorded to Archaeological Societies are not held to cover the importation of Hydrogen'. The cost is thus increased considerably, for we have been obliged to pay duty at 12% not only on the gas itself but on the cylinders, and also on the freight and insurance of each consignment.

[2] Published as fig. 10 in Oriental Institute Communication no. 9. (*Chicago : University of Chicago Press*, 1931. $1).

for the finished balloon arrived at Gaza aerodrome on 13 December, having been despatched by Imperial Airways on the 7th. It is true that the Palestine Customs held up delivery for four days, apparently expecting that I would travel 120 miles to Gaza in order to clear it there, but even though I did not do this I received it only twenty-two days after placing the order, and it has turned out to be satisfactory in every way.

Meantime Lamon had designed a better type of winding-drum, with a simple, squeeze-on friction-brake, and we had three made in Haifa. We replaced the original mooring wires by strong cords capable of holding about 80 pounds each, and also prepared a third attachment of insulated copper wire (double). This last was intended solely to carry the current for the shutter-release and to act as a height-gauge, but not to take much strain. Since the new balloon had more lift than the old one, and could carry about 12 pounds, Lind made a new camera (also of three-ply wood) to take an 8 by 10 inch film-holder.

Our whole apparatus, with its cost, is as follows :—

Balloon[3] of rubberized silk, 12 feet in diameter, 900 cubic feet capacity, made by the R.F.D. Company, 17 Stoke-road, Guildford, Surrey		£50
Camera of 3-ply wood completed with oddments, estimated cost if purchased (without lens)		£15
Electric shutter-release		$50
Battery for operating this, composed of ordinary torch batteries, with switch and connexions[4]	about	£1
150 metres insulated copper wire (double)	about	£2
300 metres stout cord (not just string)		
3 winding reels		£5
6 Hydrogen cylinders, holding 7 to 8 cubic metres each	francs	2700
Manometer for checking contents of cylinders and controlling rate of inflation of balloon	francs	175
Hooks and oddments	under	£1
Shed of wood framing and asbestos sheeting[5]	about	£70

We use a pretty fast film (Eastman Portrait super-speed) in order to get as short an exposure as possible ; this avoids muzziness if the camera happens to move a little at the critical moment.

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[3] This balloon is spherical. Mr Brewer has since suggested that a 'sausage' would work just as well, and would require a much smaller shed. I agree.

[4] Lamon is trying to get hold of a magneto to replace this : it would never run down, and would enable us to release the shutter merely by turning a handle. About 15 volts would suffice.

[5] This *must* be sparrow-proof and mouse-proof.

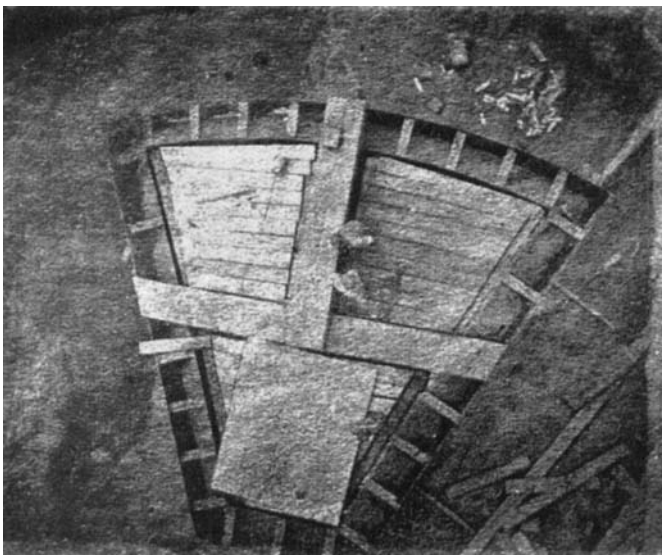
The balloon as supplied had a wide filling-tube below, and this had an open mouth which could be loosely closed by a cord. We found that, in going up and down, gas was lost, or air admitted, or both, and that the lift decreased, so we sealed it up tight with tire-repairing material, and fitted a motor-tire valve (without the inside) for inflating, and for letting out a little gas on expansion. This valve is kept closed by the ordinary type of cap.

The rigging is simple. There are 3 equidistant leading lines for walking the balloon about, and 4 lines which originally led down to a wooden hoop about 30 cms. in diameter. We found it better to replace this by a stout metal snap-hook. The camera is suspended by two spliced cords and one double electric wire, all about 50 cms. long, from a metal ring some 5 cms. in diameter : this three-point suspension facilitates adjustment for level—it is desirable that the film-holder should be absolutely horizontal. The ring is attached to the balloon snap-hook, and to the ring are attached snap-hooks at the ends of the two mooring lines. The electric wire is also attached to the ring by a snap-hook, but is insulated from it : this arrangement relieves the electric connexions with the camera of all weight and strain. For the connexions small ' wireless ' plugs are used, different colours distinguishing positive from negative. (Plate II).

We go to work in this manner. Choosing a still morning—the air *must* be still—we inflate the balloon slowly through the manometer to about the degree shown in plate III which allows for normal expansion, and we close the valve. All the apparatus is then taken to the middle of the area to be photographed ; the camera, mooring lines and electric wire are all attached ; the slide is drawn and the slit for it is blocked by a piece of cardboard cut to fit exactly so as to exclude light ; the shutter and shutter release are set, a scrap of paper is jammed behind the shutter-trigger and the plugs for the connexions are inserted. When each of these details has been checked the balloon is allowed to rise slowly and without jerks, special care being taken to prevent these at the start.

The battery-man and I remain at the middle of the area to be photographed, and the men at the mooring lines carry their reels outwards, and let out or take in line according to a simple code of hand-signals given by me. They should wear hedgers' gloves, or at least have a piece of sacking, for handling the line. The battery-man manoeuvres his reel so as to relieve the electric wire of strain. This wire is marked at 50-metre intervals, and when 100 metres are out,

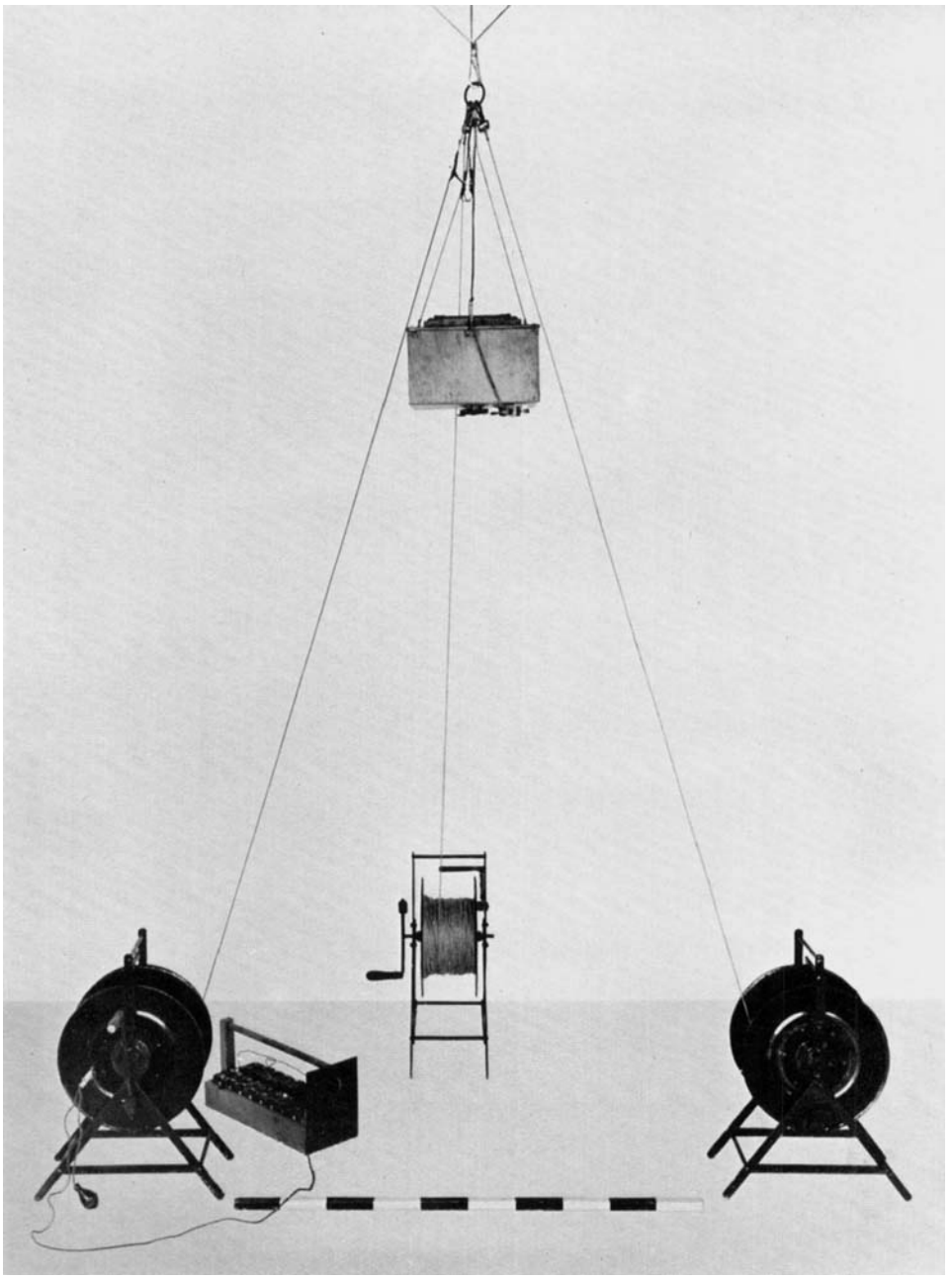
PLATE I



OVERHEAD PHOTOGRAPH OF FOUNDATIONS, ROTHESAY DOCK

facing p. 152

PLATE II



CAMERA AND WINDING REELS

The electric shutter-release can be seen to the right of the lens. The left-hand reel carries the electric wire, and the battery box is beside it. The friction-brake can best be seen at the top of the centre reel; by squeezing the bell-crank against the carrying-bar a block of fibre is pressed against the right-hand side of the drum. Scale, 1 metre long.

PLATE III

BALLOON READY FOR USE, WITH CAMERA ATTACHED. THE OLD TYPE OF REEL IS SHOWN.

PLATE IV

EXTENSIBLE LADDER USED AT MEGIDDO FOR OBSERVATION AND PHOTOGRAPHY
Height 9.7 metres

and the balloon is over my head, I tell the battery-man to make contact. If, on doing this, the scrap of paper does not fall from behind the shutter-trigger, he moves his wires along so as to take current from more cells in his battery until the paper does fall. This, of course, indicates that the exposure has been made, and we then wind in, change the film and pass on to the next area to be photographed.

It is better to work as quickly as may be without hurrying, and to get as many photos as possible in the same morning, for the weather may change and the balloon does lose lift in time. Up to a point it may be topped up by the admission of more hydrogen, but after a while the effects of osmosis become pronounced and then it must be completely deflated and refilled. This indicates that if one has very much photography to do one must have a reserve of full gas cylinders. Cylinders, by the way, need checking by manometer to see that they are really full—we once received a consignment which had evidently been tampered with *en route*, and it took the contents of all six to fill the balloon to the degree normally reached by three. As a general rule we find that in a single morning we can take as many photos as the progress of excavation requires.

In order to be able to make exposures in quick succession the ground must naturally be prepared beforehand—any weeds that have grown up in odd corners must be removed, and the whole area must be properly cleaned up and examined before the balloon is inflated. The area one's particular lens will cover at the height it is decided to use must be known, and the points to be the centres of the different photos, at which one will take one's stand for control purposes, must be fixed in advance.

It would be better to have a square film than an oblong, for one cannot control the exact position of the camera, which sometimes develops a slow spin, and in making calculations for area covered one can only take into account the shorter side of the film. For this purpose I usually draw circles on a squared plan of the dig, and take with me a slip on which I have noted the position of the centres of these.

The site of Megiddo is divided for survey purposes into 25-metre squares : these squares are drawn on our plans, and their corners are marked on the ground by pegs. I had placed a hollow concrete brick round each peg, for protection, and we have found that these bricks show up very clearly and distinctively on the photos. They are very helpful in preparing our finished prints.

It is more difficult than one would suppose to get the balloon at

exactly the same height for all photos, and occasionally the exposure is made at a moment when the camera has swung a little out of the horizontal, making the squares smaller at one end than at the other. In practice, however, neither of these things matters in the least, for we do not use contact prints much, but enlarge to a scale of 1 : 250, and any necessary corrections for scale and distortion are made by focussing the enlarging camera, and tilting the enlarging board, until the hollow bricks on the image coincide with the corners of squares drawn to this scale upon the board.

Apart from some 17,000 square metres which have been dug for dumping on, on the slopes round Megiddo, the whole summit of the mound, which has about the same extent (13 acres) as the Tower of London including the moat, is under excavation. We have photos, enlarged to the 1 : 250 scale, showing this area as it looked last spring, and Lind has made up two mosaics from these measuring 1.3 metres across. One has been sent to Chicago as a record; the other is a working copy, and as such it is in constant use on the dig and in the drawing office.

Megiddo is a deeply stratified site dating from about 350 B.C. to chalcolithic times, and we are excavating it, stratum by stratum, over its whole area. Most of the walls we are finding at present are of rubble and mud, and such a wall belonging to one period can look abominably like one belonging to another, especially if it happens to be connected with nothing in particular. It will be understood that a large-scale air-mosaic is a very great help in disentangling one stratum from another : for one thing it often makes it possible to see which walls belong to a particular system of alignment, and for another, it permits one to compare buildings which are perhaps a hundred or two yards apart—having spotted a similarity on the mosaic, one can walk over and verify it (or not) on the ground.

We of course do what we can to date buildings by the pottery and objects found among them, but in addition, and for making the plans, we proceed thus. Lamon (who does most of the surveying) and I go on to the site taking the mosaic with us, and compare it with the ruins on the ground. We decide which remains belong to say stratum 1, and mark them with a splash of paint, making a corresponding ink mark on the mosaic. The marked ruins are then planned and levelled in the ordinary way, and here also the mosaic is helpful for detail. When the plan is complete the marked ruins are removed ; what lies below is re-photographed, and the whole process repeated.

There is another gadget which I have found useful both for photography and for observation : it is an extensible ladder, of the type used for cleaning street lamps, which winds up to a height of 9.7 metres, and it gives a good view over a considerable area. I have had its stability increased by fitting four really stout guy-ropes, and have proved it to be safe even in a fairly strong breeze. (Plate IV).

Running through these notes I see that I must apologize for their rather scrappy nature : they lack the finish that one has come to expect in articles accepted by the Editor. But excavators who may happen to read them will perhaps excuse this when I explain that they have been jotted down at odd moments while the dig is going on.

There is one thing that worries me. We have got quantities of fine, large-scale air-photographs of Megiddo, and we shall have lots more, and shall make a mosaic of each stratum. The originals can be seen and studied by people who happen to be in Chicago, where one set will be kept, or who visit us here on the site. But I can't quite see how I am going to publish them, at their useful scale of 1 : 250, without producing a book or portfolio that only a son of Anak could handle.

At present my idea is to publish a selection of them on a reduced scale in a volume of normal archaeological format and to provide, as a kind of supplement, to be purchased optionally at a small extra cost, a set of lantern slides which those who wish can throw on a screen. Slides are all too often used only once, at a lecture, and are then put away in a box. Few people bother to get out a lantern and use the projected image for quiet study at close range : it is a method I have tried and can recommend.

But whatever means we may find for publishing our balloon-photos (we shall find one somehow) the main point about them is this —and all diggers who have seen them agree about it—they have a high and lasting archaeological value.