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The Environment of Petra National Park Means of Scientific Detection in the Service of Archaeological Research

The environment of an archaeological site is of vital importance to the understanding of its occupants' way of life and their economical impact on their surroundings.

After fifteen centuries, the evidence left behind by the Nabateans consists of a city and a scatter of peripheral settlements, located to exploit the environment for subsistence and protection, over an area of about 200 square kilometres.

My aim here is to describe the techniques which are available to investigate both the environment and settlement structures lying in deposits that are less than 4 metres deep. Certain techniques are more appropriate than others, or at least offer the possibility of obtaining good results with technical improvements.

Whether aerial or terrestrial, photography is a means of recording information about the state of objects, constructions, soils, or vegetation at a given moment. It is an archive.

Remote sensing, as the term implies, is a means of gathering information about objects without touching them. The term refers to a set of techniques which are based on the same principle: the measurement of energy from the electromagnetic radiation emitted and reflected by the ground. Investigation of this vibratory and corpuscular phenomenon, propagating through space, can provide information about the source of the emission and the objects which reflect it.

Unlike the two processes just mentioned, a radar image is obtained by 'lighting' the ground with beams of between 1 and 30 centimetre wavelength which are diffused and reflected by the ground surface and received on board an aircraft equipped with a circular scanning radar.

In conjunction with an interpretation of aerial or terrestrial photography, geophysical survey based on differences of resistivity and artificial magnetotelluric should eventually provide information for archaeologists prior to excavation.

The geographers, epigraphers, prehistorians and archaeologists studying the Petra National Park require new methods that will enable them to develop their research. It is important that they should possess a means of identifying structures whose dimensions can vary from 20 metres in case of field systems to 5 metres with domestic buildings, to a metre, a half metre or even less with walls, facades, water conduits or bases of inscriptions.

What are the techniques that are currently available and what are their archaeological applications? That is the matter of my paper.

1) Photography

Images are captured and reconstituted by photographic emulsions which can be classified on the basis of their wavelength sensitivity or chromatic sensitivity:

- —orthochromatic emulsions: sensitive to blue and green light,
- —panchromatic emulsions: sensitive to blue, green, and red light,
- —infra red emulsions: sensitivity exceeding normal visibility, reaching 0.9 and even 1.2 micrometre,
- —colour emulsions: composed of 3 layers sensitive respectively to blue, green and red light. The complementary colours are yellow, magenta and cyan and are obtained on the negative film,
- —infra red colour emulsions or false colour: composed of three layers sensitive to green, red, and from ultra violet to infra red light, and giving blue, green and red colours on a paper print.

In terms of energy, photographic emulsions are a great deal more sensitive than human sight, as instantaneous images can be produced with an exposure time of less than 1/100 second. An object must appear for a minimum of 1/16 second for us to see it. Thus we obtain:

- —with panchromatic emulsions the black and white images,
- —with colour emulsions the same images in natural colour,
- —with infra red emulsions images we cannot see,
- —with infra red colour emulsions with unusual colours (vegetation is red).

The National Park was covered with two simultaneous photographies at a 1/10,000 scale, using both panchromatic and colour emulsions. This photographic survey was carried out by IGN (Institut Géographique National de France) in February 1974.

The photography on panchromatic emulsion was used for:

—topographic and archaeological completion with photo-identification of details on the field, by my mission in October–November 1974,
—a photomap in 4 sheets at a 1/10,000 scale carried out by IGN in 1977,
—photogrammetric plotting of a map at a 1/5,000 scale carried out by JNGC (Jordan National Geographic Centre) in 1983.

The photography on colour emulsion was used during the last week for work in the National Park for Pierre Gentelle, geographer, Dr Fawzy Zayadine and Jean-Marie Dentzer, archaeologists.

Is a new aerial photographic survey with infra red emulsion appropriate in this context? It is well known that such surveys are ideal for providing hydrographic information. All expanses of water appear extremely black, explaining the sharpness of:

—a drainage network, otherwise invisible under forest on panchromatic prints,
—submerged or non-submerged land surfaces,
—marshes that are difficult to detect on panchromatic prints,
—island contours, canals, ditches, represented by black lines.

The very dark hue of the water clearly distinguishes expanses of water from zones that are merely damp.

Infra red emulsion provides considerable information about vegetation and soils, and is sensitive to superimposed agrarian structures (e.g. reorganized fields). There are no coastlines, islands, submerged land surfaces, peat marshes or forests in the National Park. Present-day irrigation canals dug by the Nabateans and Romans along mountain sides and in the Siq are in ruins or have been destroyed. Given the time and energy the location, on foot, of the remaining sections of canals visible on panchromatic and colour prints is quite feasible. The obvious conclusion is that an exhaustive infra red photographic survey of the areas already photographed is unnecessary.

The information provided by colour emulsion can be assimilated by users who have little experience of either photographic emulsions or photointerpretation. A new infra red colour survey would be of equal interest to an infra red survey, but the unusual colours would discourage users.

2) **Remote sensing**

Before discussing remote sensing, it is worth remembering that, thanks to our eye's crystalline surface, an object's image forms on the retina at the back of the eye-ball. The retina is sensitive to visible light—the part of the electromagnetic spectrum with a wavelength between 0.4 and 0.7 micrometre. It is also capable of distinguishing narrower bands corresponding to the three basic colours:

—blue: 0.4 to 0.5 micrometre
—green: 0.5 to 0.6 micrometre
—red: 0.6 to 0.7 micrometre

and of providing information about light intensity. All this information is transmitted through the optic nerve to the brain which produces the colour image. The brain constructs relief and analyzes movements by comparing successive images. Our sight, which employs electromagnetic radiation, is thus an extremely refined remote sensing system.

The sun's radiation, the natural source of light, constitutes a spectral band broader than the visible band from 0.1 to 10 micrometres. The propagation of radiation in the atmosphere depends on wavelengths, and clouds do not hinder it. The captors used in remote sensing are the photographic emulsions mentioned above, radiometers and radars. The physical properties of these passive detectors are modified by electromagnetic radiation. They show differences in electric potential proportional to the energy received, which when amplified and quantified, enable visible near infra red and thermal infra red radiation to be measured. The sun's energy reflected by 10 metre and 1 kilometre squares on the ground can be measured at distances of 900 and 36,000 kilometres.

These three kinds of captors can be used on the ground or carried by vectors (e.g. balloons, helicopters, aircraft, satellites).

There are three kinds of artificial earth satellite in use:

—geostationary satellites (for meteorological purposes), with a circular orbit at an altitude of 36,000 km.,
—heliosynchronous meteorological satellites with a circular orbit at an altitude of 1,000 km.,
—earth resources satellites with a similar orbit to the heliosynchronous ones.

The spatial resolution of these satellites is very variable. In visible light the base points are squares whose sides are:

—1 to 2.5 km. for the first kind,
—1 km. for the second kind,
—30 to 80 metres for the third kind.

The French SPOT (Système Probatoire d'Observation de la Terre) satellite will soon provide a spatial resolution of 20 metres in multispectral mode on three spectral bands and 10 metres in panchromatic mode on a relatively wide band of 0.51 to 0.73 micrometre. While the latter resolution is satisfactory for compiling 1/50,000 maps, it would have to be lowered by 1 or 2 metres to be of some use for the 1/5,000 archaeological map of the National Park and for photointerpretation of its environment. How long will it take for this resolution to be obtained? The 1/5,000 map will certainly be completed beforehand.

3) **Radar**

Radar is an active sensor using microwaves not disturbed by clouds, day or night. The images produced by vertical circular scanning radar have a poor ground definition. This results from the small size of the antenna, resolution being in direct proportion to the antenna's diameter. Lateral radar images of geometric patterns are very different from photographic images. Displacement of the aircraft can make a short antenna function like a long one. As this artificial antenna is directly proportional to distance, the two effects compensate one another and we have a synthetic aperture lateral radar. This kind of radar with three wavelengths was used on Apollo 17 to survey the moon's surface from an altitude of 100 km. Accuracy was 10 metres, corresponding to the shortest wavelength.

In 1977, 1978 and 1980, R. E. W. Adams (University of Cambridge, Massachusetts), T. P. Culbert (University of Arizona) and W. E. Brown Jr. (Cal Tech's Jet Propulsion Laboratory, Passadena, California) recorded 70,000 km.^{2} of marshy forest in Guatemala and Belize from an altitude of 7,300 metres. A criss-cross pattern resembling a canal system appeared under the tropical forest. Field work carried out by R. E. W. Adams and a team of archaeologists confirmed the existence of canals, 1 to 3 metres wide and 0.5 metre deep, constructed by the Mayas to drain the marshes between 250 BC and 900 AD. Unfortunately, ground conditions in the National Park are unsuitable for this type of survey.

4) **Geophysical prospection**

Artificial magnetotelluric is a technique which consists of measuring the effects of electromagnetic waves in the ground. Their penetration is a function of their wavelength and the differences of resistivity provide information on the structures. The recording equipment is drowned in a rubber carpet which is dragged on the soil surface at a pedestrian speed. A data processing gives immediately a 'profile' of underground structures of some size.

In conclusion, I would like to make two suggestions:

—the first is that an artificial magnetotelluric survey should be carried out on a sample of probable sites revealed by panchromatic and colour photography (IGN February 1974), before the Third International Conference on Archaeology of Jordan,

—the second is that a Jordanian or foreign team, using one or more Hasselblad-type cameras and a small aircraft or a helicopter, should carry out oblique and vertical photography of certain areas of the Western and Southern part of the National Park.

The final point I would like to stress is that the information provided by photography, geophysical prospection or accidental discovery will only be of value if it is recorded on thematic archaeological maps available to the next generation of researchers.