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The Discovery of the Royal Capital of Awsan at Hagar Yahirr, Wadi Markha, Yemen by Satellite Images, Aerial Photography, Field Walking and Magnetic Prospecting

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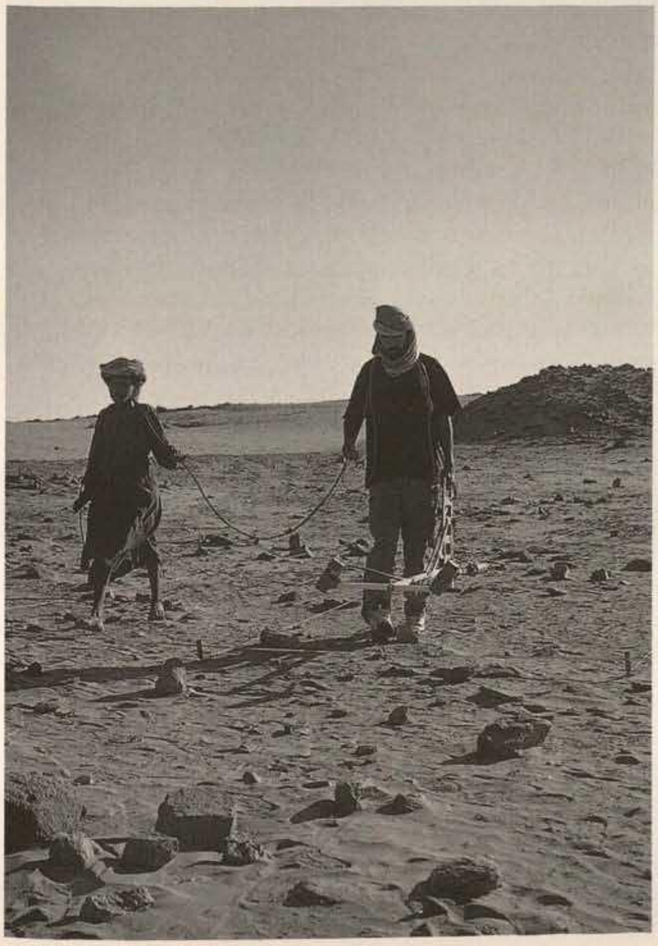
The site of Hagar Yahirr in the Wadi Markha was first investigated about 10 years ago by satellite images (taken during shuttle mission in February 1984 by MOMS, Brunner/ Haeffner, 1990). In 1991 the place had been visited by an Swiss German Yemenitic expedition (U. Brunner, W. Daum, B. Hrouda, W. Raunig, Y. Abdalla) and a first cartographic sketch was drawn, but it was completely out of scale. Early in 1994, just before the civil war, a series of vertical aerial photographs were taken by MAPSXX in 1:30,000 scale covering the whole of Wadi Markha, which is situated along the borderline of the former two Yemens (Fig. 6).

Hagar Yahirr may have been the Royal capital of the kingdom of Awsan (Pirenne 1980). The site is surrounded by a well preserved city wall. Some parts of the southern fortification and the complete western half was destroyed, presumably by activities of an enormous sail (water flood) in Wadi Markha. Ashes and burnt soil in the whole area of the ancient city seems to confirm the tradition found as an inscription in Sabwa, that the Sabaean king Karib il Watar captured in the year 695 B.C. the Royal capital of Awsan, killed 16,000 people, pressing 40,000 people to slavery, destroyed the irrigation systems and burnt down the whole city. Nowadays we see still this situation (a huge field of burnt ruins (leveled by the wind and erosion and covered with yellow sand. A radio-carbon sample of a burnt beam taken in January 1995 confirmed the date of this catastrophical conflagration in 695 B. C.

Fig. 1. Hagar Yahirr 11/1995. Caesium magnetometer CS2/MEP720 with duo-sensor configuration operated by J. Fassbinder



After a first visit to Hagar Yahirr on the ground in 1991 it became evident, that this site should be investigated by geophysical prospection in advance of any further archaeological activities. Hagar Yahirr gave the chance for remote sensing of a large archaeological site at different hights and with different methods. The range consists of satellite images from hights of 700 km (Landsat Earth Mapper, see Fig. 3), 300 km above ground (MOMS-1), followed by aerial pictures from about 4,600 m above ground and finally magnetic prospection at 30 cm hight above ground. Obviously there is still one step missing with low altitude aerial/kite/baloon photography with signaled control points on the ground for mapping archaeological or architectural structures visible above surface.

In January 1995, during the first archaeo-geographic research project in Wadi Markha, a test for magnetic prospecting was undertaken at Hagar Yahirr. Aim of the measurement was to decide whether magnetic prospecting would be a suitable method for surveying archaeological structures under the surface in preparation of planned archaeological excavations. There were already some experiences in magnetic prospecting of buried cities under similar conditions such as Assur in Iraq (Becker, 1991), Munbaqa in Syria (Becker et al. 1994) or Troy in Turkey (Becker et al. 1993). A resistivity survey, which would be rather ideal for prospecting stonewalls, may not be applicable because of contact problems of the electrodes in the dry sand. This limited test for magnetic prospection was only for the preparation of another longer campaign for surveying with fast caesium magnetometry, the whole site of Hagar Yahirr, which extends over an area of 600 x 320 m (about 16 hectare).

After an extensive field walk over the site, the southeastern part was chosen for this experiment for magnetic prospection, because the city wall vanishes here under sand. This part also includes the singular area with some fragments of well masoned square limestone and highly burnt debris of mudbricks, which could have been a major building of the city destroyed in a conflagration. A 20 m grid was orientated to magnetic north by compass and marked by wooden sticks. A fixed base station for zero point reduction and calibration was choosen in an magnetically quiet area in the centre.

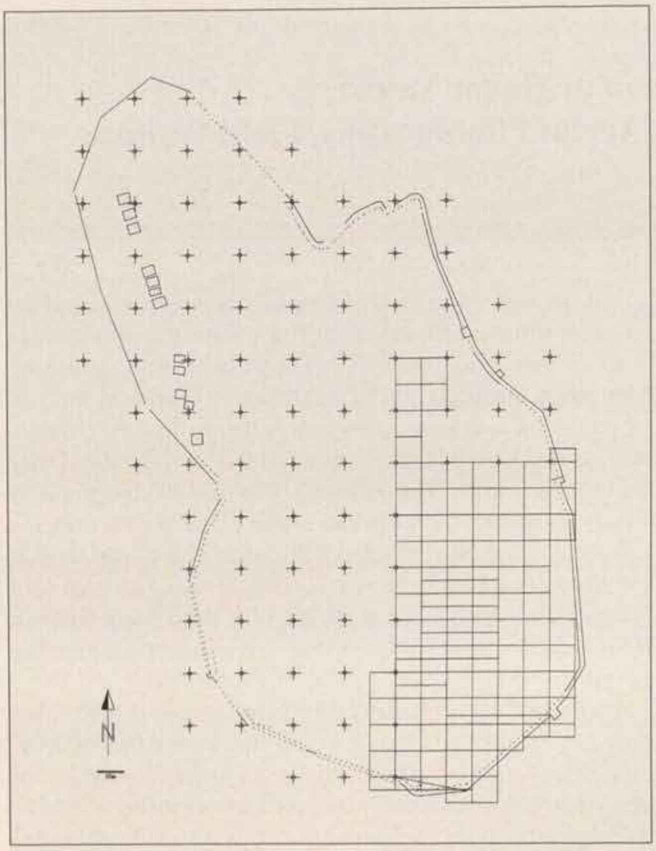


Fig. 2. Hagar Yahirr 1995. Plan of the site with 20 m grid of the magnetic survey. Plan after Breton 1994, Archäologische Berichte Jemen VIII, page 181; north orientation corrected to magnetic North 1/1995

The whole southern and eastern front of the city wall, made out of stone, is very well preserved. Gate constructions and bastions are still visible. In some parts a mud wall was detected following inside the city wall. In the southern part of the city a 120 x 200 m "Temenos" or "Akropolis" was seperated by a 2.5 m thick wall consisting of stone mantle filled in with clay. In many parts of the ancient city especially at the southwestern border complete foundation walls of stone houses are well preserved. Some huge stone structures up to 5 m hight in the eastern area of the Akropolis may have formed the base of towers. The biggest consists of two rooms and is situated outside the city wall some 150 m southeast.

In the distance of about 300 to 400 m northeast in the plain of Wadi Markha another field of ruins was detected. The pottery found on the surface seemed to be similar and contemporaneous to Hagar Yahirr. There may be some evidence that here an open trade centre or an industrial area outside of the main city was found. Until now no surface signs for an necropolis could be detected.

Magnetic prospecting with fluxgate gradiometer Geoscan FM36

The instrument used for this first test for magnetic prospecting in Yemen was a fluxgate gradiometer FM36 (Geoscan, Bradford), which is easier to transport and to handle in the field than the high sensitive caesium magnetometer CS2/MEP720 (Scintrex/Picodas, Canada), which needs at least 2 persons for operation. The fluxgate gradiometer has a sensitivity of 0.1 Nanotesla (nT) for delta Z, which is reproducable in the range of ± 0.3–0.5 nT at 10 Hz cycles. The sample trigger ST1 (Geoscan, Bradford) was used for speeding up the magnetic survey, which was carried out in a zig-zag mode. Sample interval and profile spacing was set to 0.5 m. For detailled description of FM36 see Clark (1990).

Light weight and an inbuilt data logger for 16,000 readings are the main advantages of FM36, which can be operated by one person. The help of local people and the teacher of the habitation of Hagar Yahirr today, is gratefully acknowledged.

Comparing the sensitivity of FM36 with caesium magnetometer CS2/MEP720 one should realize, that a picotesla system operates at a 1000 fold sensitivity (Becker 1995). This is a fact especially at low geomagnetic latitudes such as Yemen showing an inclination of the earth's magnetic field in the range of 10°. This means that the vertical component measured by the fluxgate gradiometer amounts only to less than a fifth of the total field value of caesium magnetometry. Another problem is given by thermal, mechanical and electronic drift of the FM36, which causes severe faults especially in plain sun. Some of these problems (e.g. tilt error) could be avoided by a field procedure in parallel mode rather than zig-zag mode, but this means a double reduction in speed, which would be never tolerable. On the other hand a duo-sensor configuraton of the caesium magnetometer CS2/MEP720 would allow the survey of 1 hectare with 0.5/0.1 m line/sample intervals (200,000 measurements) in about 5 hours.

Nevertheless an total area of 0.8 hectare (32,000 measurements) was surveyed in less than 3 days with the fluxgate gradiometer FM36.

The fluxgate gradiometer FM36 may be interfaced to any notebook computer for transformation of the field data under the GEOPLOT software package (Geoscan, Bradford). GEOPLOT also opens the possibility for advanced data processing and graphic display as dot density or shading plot with 17 grey levels. After destaggering and highpass filtering the archaeological structures show up rather clearly (Fig. 5) All data processing under GEOPLOT software can be made directly in the field. For final data processing with digital image techniques in the laboratory an ASCII-output composite file is written.

Final processing on the digital image computer in combination of aerial photographs and ground magnetics was made in the computer laboratory of the Bavarian State Conservation Office. This computer system allows the recification by a central projection, the finite transformation and scaling of oblique and vertical aerial photographs and the processing of geophysical data as a digital image with high resolution (1024x1024 pixel with 256 gray levels). The result of the data or image processing is viewed on a high resolution screen. The definition of an graphic overlay allows the interpretation of the archaeological structures directly on the image computer. The so-called vector protocol is transfered to a graphic computer and the plan of an archaeological site can be plotted in several colours representing several layers of information (Becker 1990, 1991).

Fig. 3. Satellite image from Wadi Markha at a hight of 700 km (Landsat Earth Mapper, processed by R. Blom, Passadena) ▷

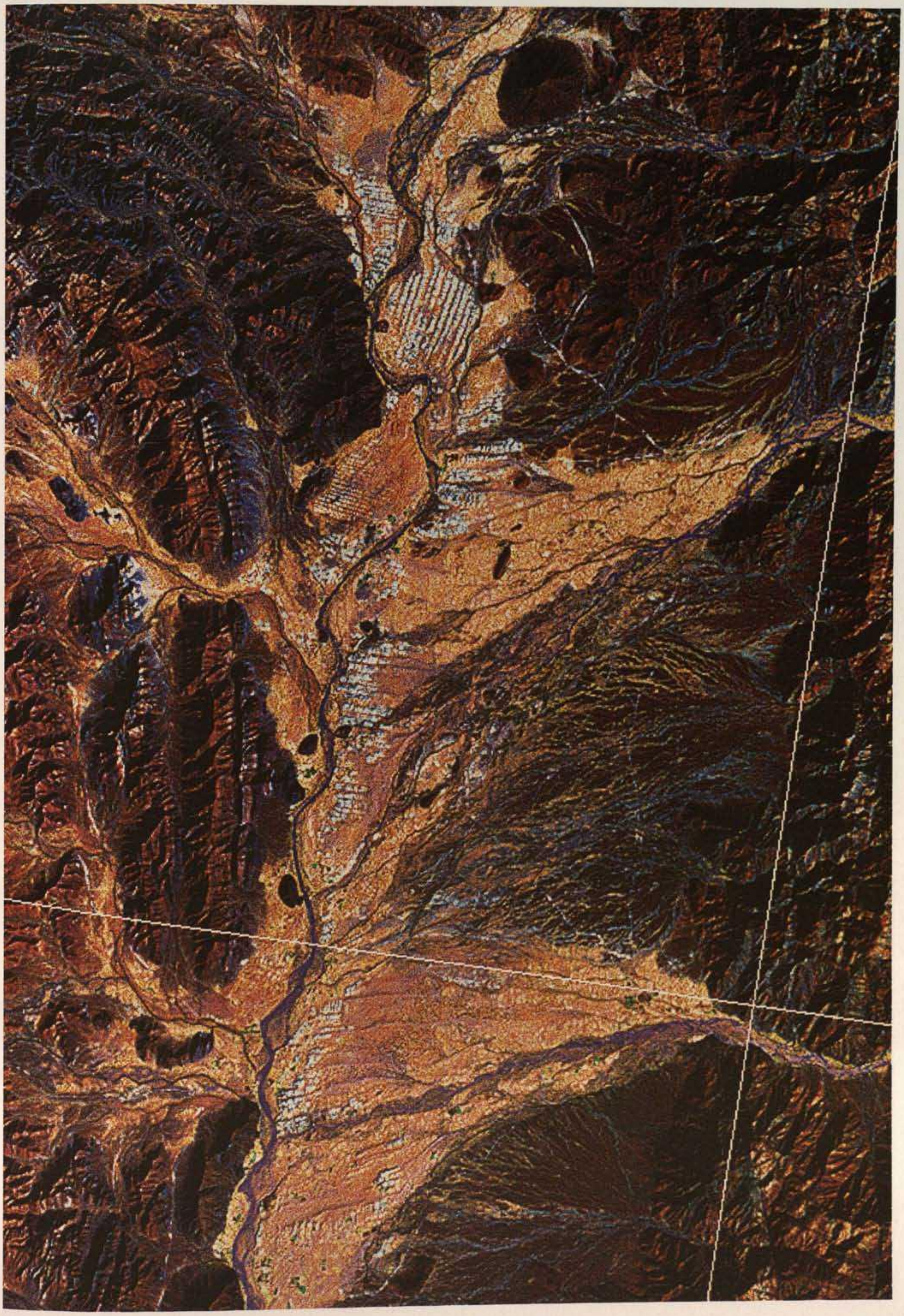


Fig. 6. Aerial photo plan of Hagar Yahirr after digital image processing (contrast enhancement), scaling on the base of Fig. 3, magnification of the aerial photo by MAPSXX 1:30,000 with makro system HR CCD-Camera (1024x1024 pixel in 256 gray levels)

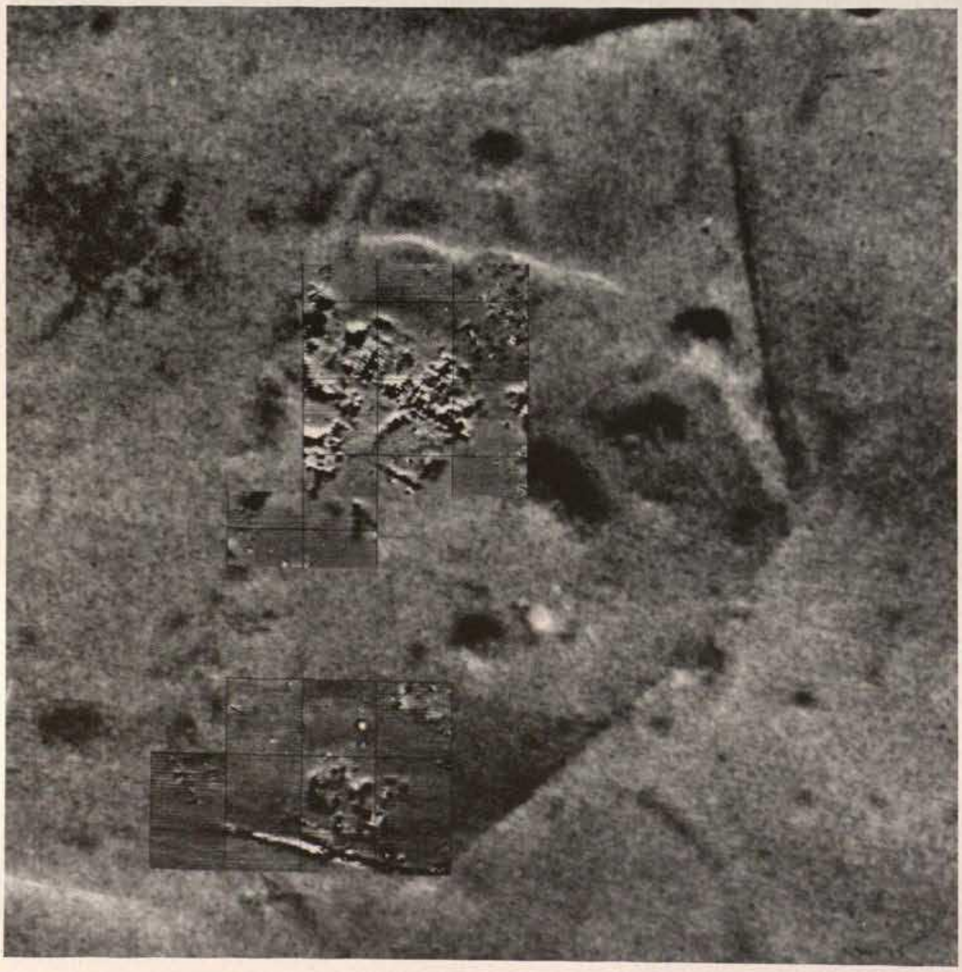
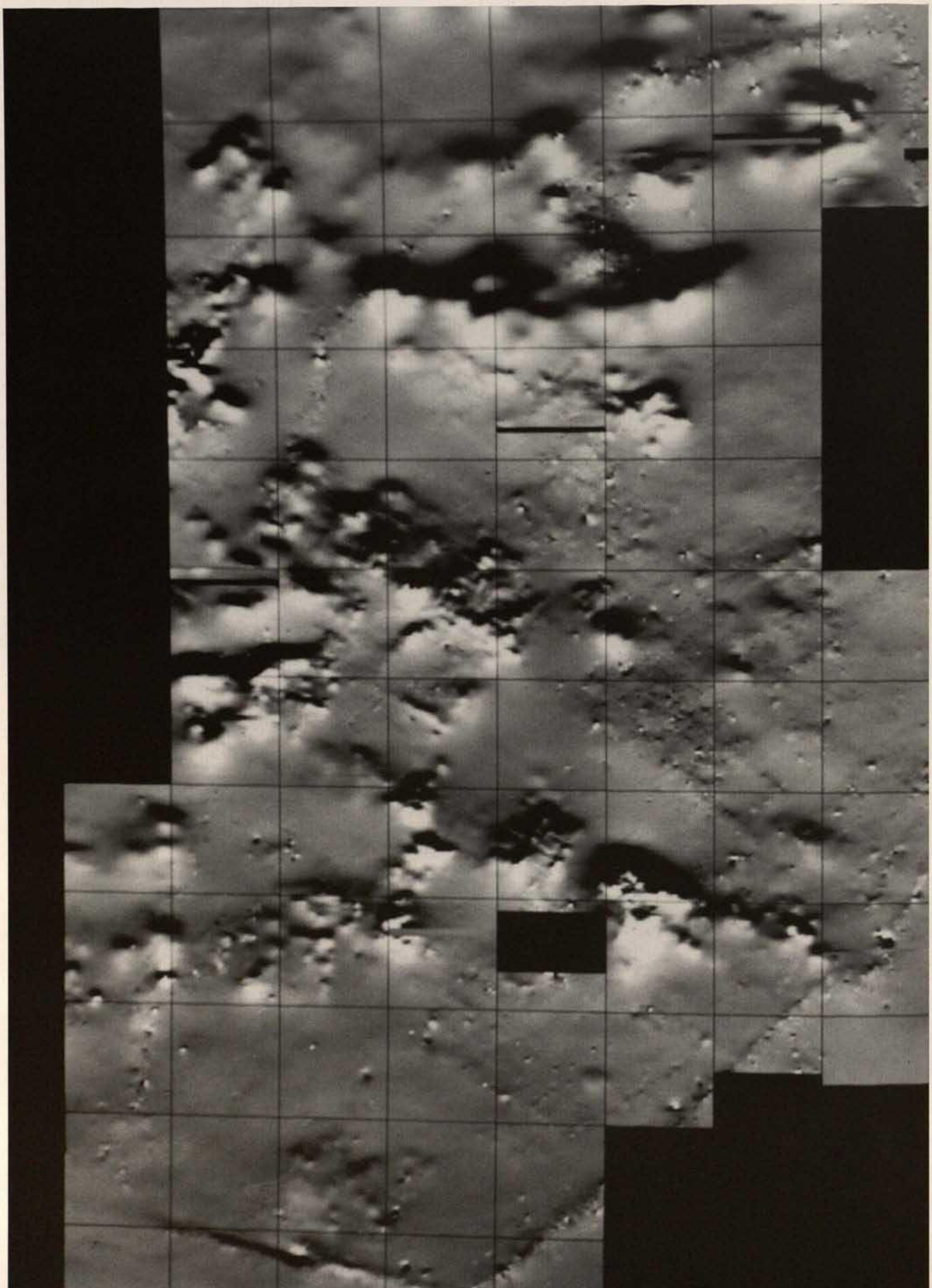
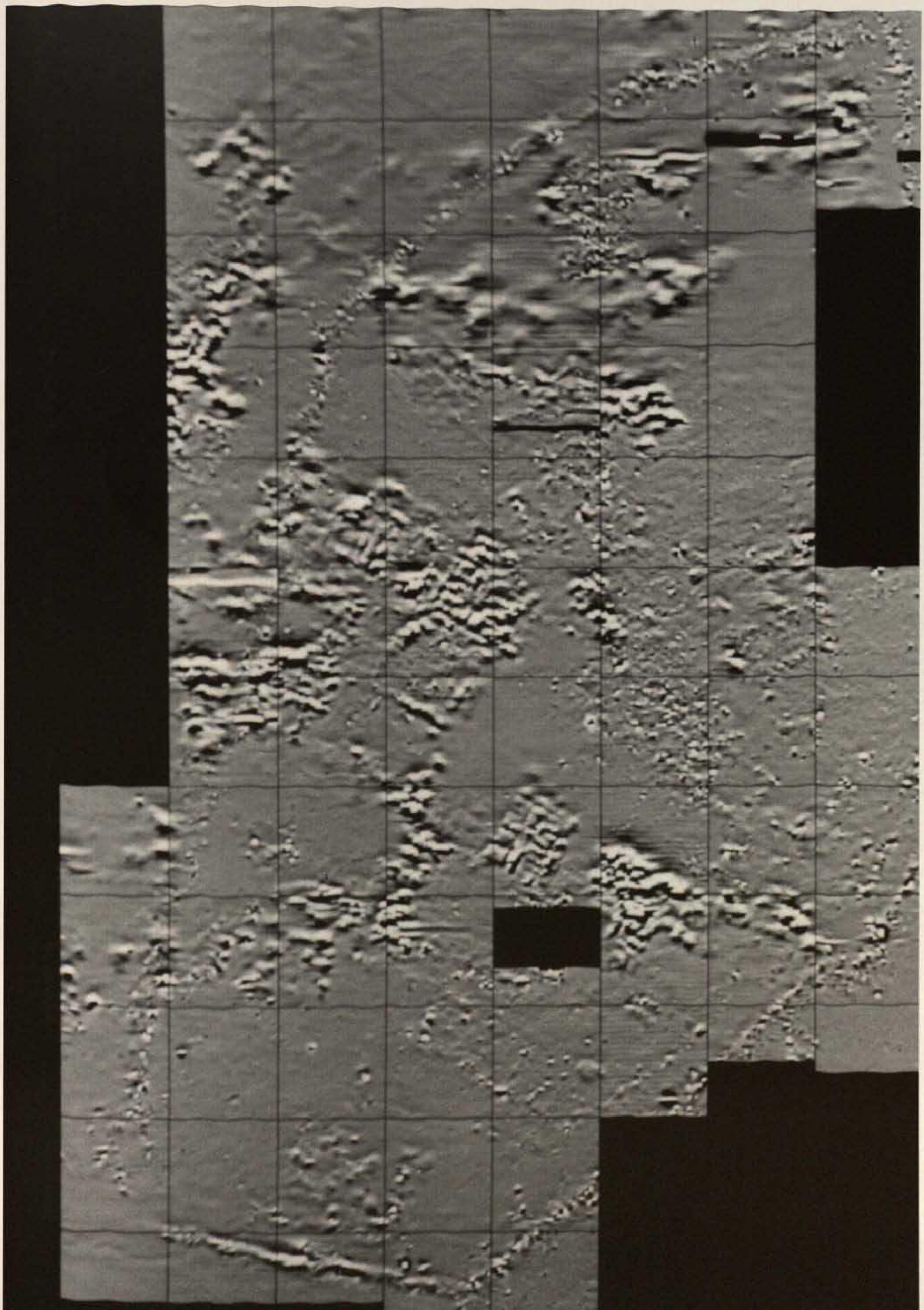


Fig. 4. Digital image (section of Fig. 6) of the Southeastern area of Hagar Yahirr, which may have been the Temenos or Akropolis of Awsan

Fig. 5. Same as Fig. 4, but compilation with the magnetogram as digital image, fluxgate gradiometer FM36, sensitivity ± 0.3 (0.5 nT delta Z), raster 0.5/0.5 m, dynamics delta Z -3.5/+3.5 nT in 256 gray levels (white/black), 20 m grid





The input image of the vertical aerial photograph series in scale 1:30,000 was an photographically magnified image of Hagar Yahirr from 1:30,000 to 1:5,000 scale. A test to see if one could identify house structures in the northwestern area, which are quite clearly visible at the surface, by digital image and contrast enhancement was not successful. But digital image processing made possible the scaling of the vertical photograph on the base of the terrestrial plan of Breton (1994). There were no problems even in finding enough control points for the compilation of the magnetic survey in the aerial photograph (Fig. 5). On the other hand there may be some possibilities of image enhancement, if one starts from the original film negatives.

The interpretaton of the magnetic prospecting is quite evident: In the southern area the city wall is clearly visible as a positive magnetic anomaly, which is caused by the high susceptibility of the stones. There may be a gate with a pronounced gateway on the southwestern wall of the Akropolis. The city wall seems to vanish completely to the west which is possibly caused by a heavy sail (water flood) in Wadi Markha. But data enhancements by zero line mean procedure, high pass filtering and destaggering show up a very faint anomaly in the continuation of the city wall buried by sand (Fig. 6). High sensitive magnetometry would be needed to clarify this question and to follow the wall at the western boundary of te city.

Just behind the wall a building was identified about 30 x 20 m wide with limestone walls (negative alignments) and burnt mud- or schist/metamorphic-walls (positive alignments). Another very big building (40 x 60 m) with many rooms, doorways and courtyards is situated in the northern part of the test area. The remains of this building were highly burnt in a conflagration. The whole area at the surface has a red colour caused by the burnt mud; there are also many burnt fragments of carved limestone found at the surface. Probably this area represents a "temple" or "palace" site inside the "Temenos/Akropolis".

The result of the test for magnetic prospecting is very evident: By means of this method it would be possible to derive the complete and detailed city plan of Hagar Yahirr. But the results would be much better by using the high sensitive caesium magnetometer, which could cover a large area in short time. Many house structures at the surface could be mapped in combination by low altitude-, balloon- or kite-borne photography with signaled control points on the ground for rectification and scaling of oblique views.

◁◁ Fig. 7a. Hagar Yahirr 11/1995. Section of the magnetogram as digital image with caesium magnetometer CS2/MEP720, sensitivity 0.001 nT, duo-sensor configuration, raster 0.5/0.25 m, dynamics -10.0/+10.0 nT in 256 graylevels (black/white), 20 m grid, North upwards

◁ Fig. 7b. Hagar Yahirr 11/1995. Same as Fig. 7a, but highpass filtering 5 x 5 pixel, dynamics -3.5/+3.5 nT

Magnetic prospecting with caesium magnetometer CS2/MEP720 with duo-sensors

In November 1995 the planned magnetic prospecting with CS2/MEP720 caesium magnetometer system was made in Hagar Yahirr with the assistance of J. Fassbinder in continuation and in the same grid of a first test with fluxgate magnetometer FM36 in January 1995 (Fig. 1). An area of 4 hectare (40,000 sqm = 320,000 measurements) was measured in the standard technique, but the sensors had to be tilted to 45°. This area covers the whole of the so-called upper city of Hagar Yahirr and some parts of the lower city (Fig. 7a, 7b). The results of magnetic prospecting are excellent and show an almost complete plan of the architecture of the city. The good results are due to the ideal magnetization process in Hagar Yahirr by the conflagration of the whole city.

Further magnetic prospection of the whole area inside the city wall of Hagar Yahirr is highly recommended before first archaeological excavation will be start. There is strong evidence, that the complete plan of the burnt city can be derived only by magnetic prospection in 1 or 2 campaigns of 10–14 days together. By field walking in the direct vicinity of Hagar Yahirr a large outer city possibly of the same age was found which was not burnt down.

Unfortunately in 1997 an archaeological excavation started at Hagar Yahirr before the next prospection campaign. It was only after the second day that this excavation was stopped by the Bedouins with guns. Any further attemps to reach Hagar Yahirr again for the continuation of the prospection in 1997 and 1998 were not successful because of the Bedouins. The last trial for reaching the site for finishing the survey in February 1998 was defeated by arms.

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