Fig. 1. Troy 1894. Excavation of the fortification wall of the citadel of Troy VI by Wilhelm Dörpfeld in 1894

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In Search for the City Wall of Homers Troy – Development of High Resolution Caesium Magnetometry 1992–1994

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Since 1868 when Heinrich Schliemann came to Troy trying to verify the story of the Trojan war the site remains a focus for archaeological research. Schliemann worked very hard searching the lower city of Troy as described in the Iliad. After the excavation of numerous "wells" (today we would say deep trenches) and finding only pottery of the Roman and Greek period, but none of older types which would be expected for the remains of Troy of the Iliad – he states rather disappointed and being absolutely sure that Troy consists only of the citadel, the so-called Pergamos, but no lower city. He also says that Homer must have exagerated in this point in the Iliad.

More than 100 years later the modern excavations in the ruins of Hisarlik-Troy undertaken since 1988 by M. Korfmann (University of Tübingen for the pre-Roman periodes) and C. Rose (University of Cincinatti for the Hellenistic and Roman periods) unearthed also some settlement patterns outside of the fortification wall of the 6th "city" Troy VI of the citadel which gave evidence for a "lower settlement" but there was still the city wall missing which should surround the "lower city" of Late Bronze AgeTroy VI.

Troy became a test field for the development of high resolution caesium magnetometry and marks the enormous step from Nanotesla- to Picotesla systems 1992/1993 and 1994. First tests for magnetic prospection by Hans-Günter Jansen 1990 and 1991 using a fluxgate gradiometer Geoscan FM18 results in a very impressive picture of the Roman city Troy X but showed not the slightest sign for structures of Troy VI (Jansen, 1992). In 1992,

Fig. 2. The Trojan Horse. Figure on a Korinthian aryballos, around 560 B.C., Paris, Cabinet des Médailles

we (the author and Jörg Faßbinder) made a first test for high resolution caesium magnetometry in an area far South of the citadel, where one should expect the fortification wall of Troy VI, but which was not visible in the previous fluxgate-magnetometry. We used the Varian/Scintrex V101 caesium magnetometer which gave a sensitivity of 0.1 nT (Nanotesla) at 0.1 sec. cycle in the variometer mode at halfmeter spacial resolution. The discrete measurements at 0.5 m interval were triggered by an automised distance meter which was fixed at the box containing the readout unit for the magnetometer, an Epson handheld computer for data logging, the interface electronics and the power supply (12 V car battery) (Fig. 3).

The magnetogram of the 1992 measurement shows clearly the setup of the Roman city Ilium by straight streets and rectangular insulae measuring 106.60 to 53.30 m, which correspond to 360 to 180 Roman foot. Obviously the city planers of Troy IX combined two 180 foot squares to one insula-rectangle. A second measure may be deduced by a rectangular structure, which is rotated by 10 degrees to the west of the Roman orientation. These rectangles measure 180 to 150 Milesian yards and may be the measure of the Hellenistic city Troy VIII. But only few buildings are completely visible in the magnetogram. The superposition of several cities – here at least the three Hellentistic, Roman and

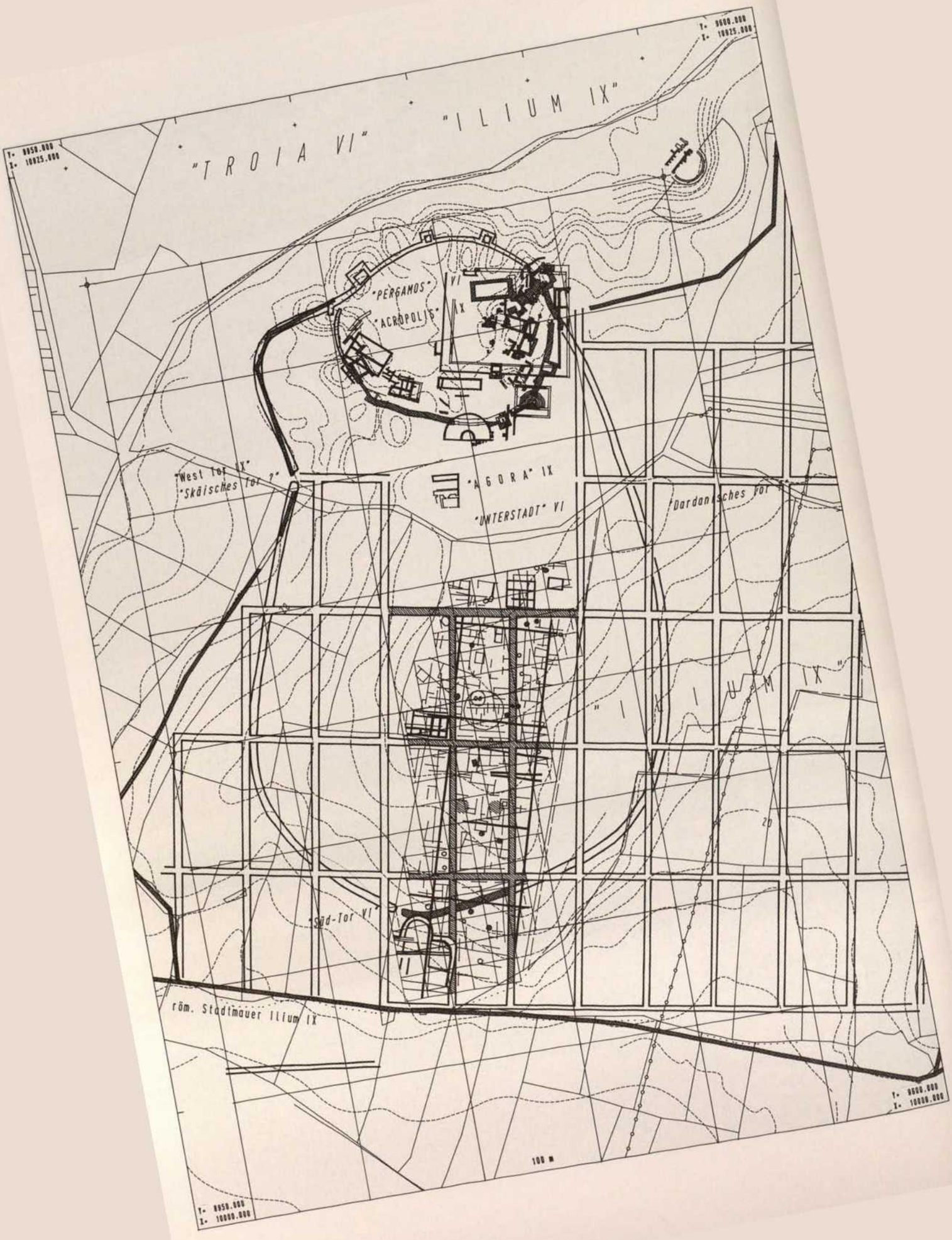
Fig. 3. Troy 1992. Magnetic prospecting in the lower city of Troy in 1992 using the caesium magnetometer Scintrex V101 in the variometer mode; the base sensor is fixed to the middle tree in the background

Byzantine city – results in a very confusing image of the archaeological structures monitored by the magnetic anomalies 30 cm above ground. Strangely enough the discovery of the searched Late Bronze Age city fortification of Troy VI caused only little problems. This positive magnetic anomaly was detected by its completely different orientation and signature in the southern part of the prospected area in 400 m distance from the citadel. First it was thought that this was the burnt wall of Troy as described in the Iliad. But the excavation in summer 1993 unearthed a ditch cut into the rock. This misinterpretation was caused by the result of a drilling program in the area of the lower city of Troy, which gave a depth of the bedrock in 2 to 3 m. We only had to turn the calculated model of the burnt wall upside down to get the filled in ditch of the fortification of Troy VI. A first reconstruction of the lower city of Late Bronze Age Troy VI on the base of the magnetic prospection revealed a minimum size of about 18 ha, which would give space for 6,000 inhabitants. Troy became a real city as described in Homer's Iliad (Fig. 4 and 5).

Unfortunately the new Picotesla magnetometer system was not ready by the summer campain 1993, so we had to rely again on the old V101 caesium magnetometer. Following the fortification ditch to the west Troy VI grows bigger and bigger covering an area of at least 22 to 25 hectare, which would be enough for 10,000 to 20,000 people. The relicts of the foundations of a huge stonebox wall of the type "Alisar" (Anatolia) could be identified in the magnetogram, but this was never verfied by the excavation. There are also two gates (interruptions of the ditch) in the south and the southwest, and one could think about the Scaeian Gate mentioned in the Iliad where Hector was killed by Achilleus.

After the news went round the world, that the burnt wall of Homers Troy was discovered, I was asked early in 1993 by Robert Pavlik from Picodas (Canada), if a high resolution caesium magnetometer with Picotesla sensitivity should be designed for archaeological prospection on the ground. In a very fruitful collaboration the hard- and software of recently developed airborne magnetometer systems were modified for the archaeological application on the ground, which resulted in the MEP720/CS2 system with MAGRAD software. The main advances of this system compared with the previous V101 was the ultra high sensitivity of 1 Picotesla, time mode – rather than distance triggered – sampling, which opens the possibilty of bandpass-filtering (1 or 2 sec) set in the hardware of the magnetometer-processor for cancelling the high frequency time variations. MAGRAD software and data logging were installed on an subnotebook computer Olivetti XX, which could be powered also by a 12 V battery. Before using this new magnetometer in Troy in August 1994, it was already tested extensivly in spring 1994 at the chalcolithic fortified settlement of Monte da Ponte in Portugal (Becker, 1995, see below).

Fig. 4. Troy 1992. Discovery of the fortification ditch of the "Homeric" city of Troy VI in the magnetogram. Caesium magnetometer Scintrex V101, sensitivity 0.1 nT, variometer mode, raster 0.5/0.5 m, dynamics –20.0/+31.2 nT in 256 grayscales (black/white), 20 m grid, North upwards ▷


"TROIA VI"
"ILIUM IX"
"PERGAMOS"
"ACROPOLIS"
VI
IX
"West Tor IX"
"Skäisches Tor"
"AGORA" IX
"UNTERSTADT" VI
"Dardanisches Tor"
"ILIUM IX"
"Süd-Tor VI"
röm. Stadtmauer Ilium IX
100 m

▽ 6b

6a △

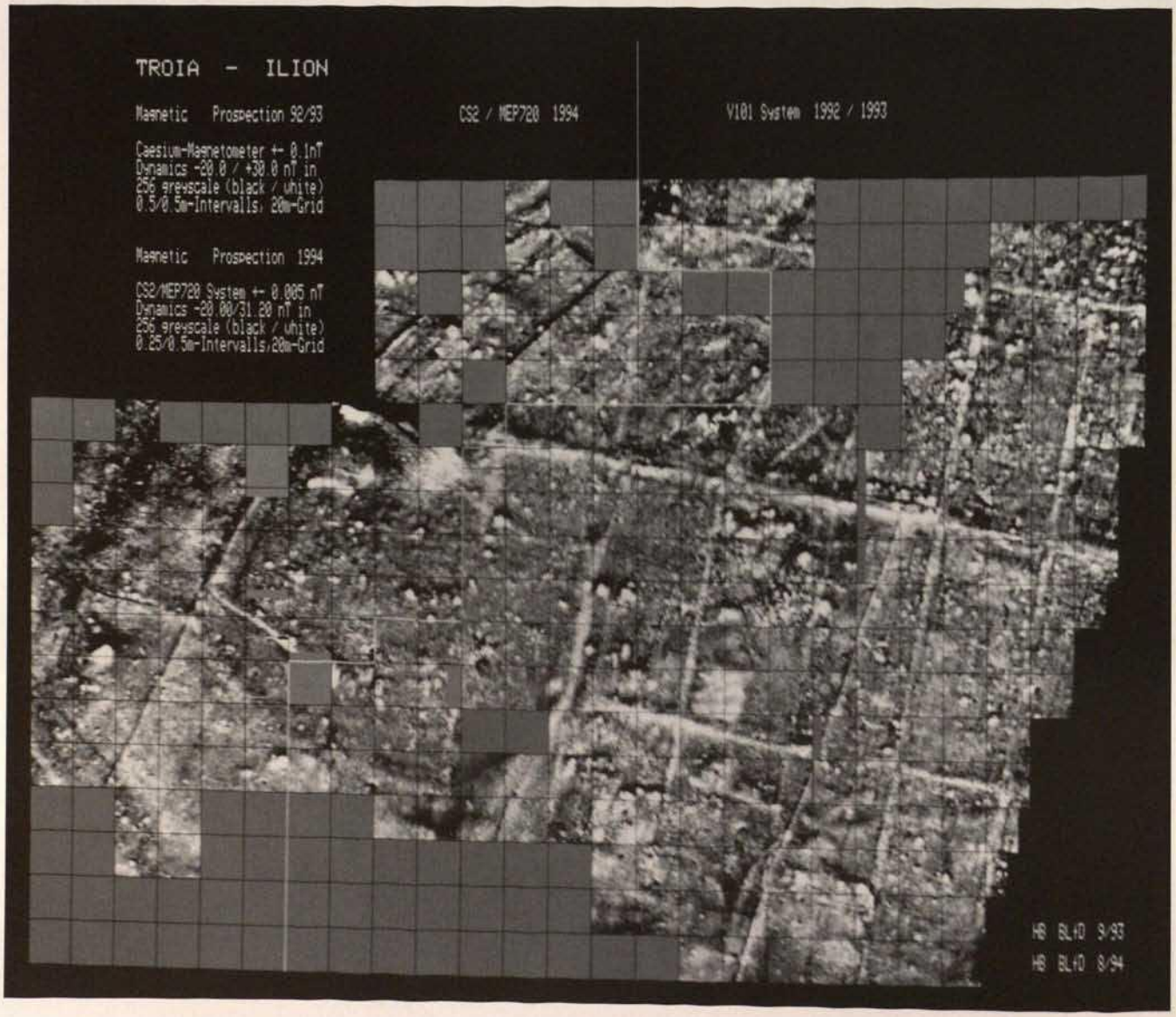
◁◁ Fig. 5. Troy 1992. Plan and reconstruction on the base of the magnetogram in Fig. 4 with the insulae of Roman Ilium (Troy IX), Hellenistic Ilion (Troy VIII) and the trace of the "Homeric" fortification of the lower city (Troy VI); the Late Bronze Age buildings of the citadel (Troy VI), the Hellenistic and Roman sanctuary (Troy VIII/IX) after the plan of Wilhelm Dörpfeld, Troja und Ilion (1902)

◁ Fig. 6. Troy 1992–1994. a) Aerial photo with the citadel of Troy and the traces of archaeological activities since H. Schliemann 1868 (Photograph H. G. Jansen, 1989). The area for magnetic prospection is adjacent to the south (downwards)
b) Magnetogram for the area south of the citadel of Troy. Clearly visible is the system of streets and insulae of the Roman Ilion Troy IX, but there can be also detected the trace of the Late Bronze Age fortification ditch of the "Homeric" Troy VI (see plan Fig. 6 for orientation); for technical details see Fig. 4

Fig. 7. Troy 1992–1994. Magnetic prospection in Troy with caesium magnetometers V101 (0.1 nT) at 0.5 by 0.5 intervals (9 ha on the right-hand side) and CS2-MEP720 system (0.005 nT) with 0.5 by 0.25 m intervals (5 ha 1994 on the left-hand side); both in variometer mode; sensor hight above ground 0.3 m; magnetogram in digital image processing technique; dynamics -10.0 to +15.5 nT in 256 greyscale (black to white); 20 m grid

In Troy the ultra high sensitivity of the CS2-MEP720 system is not needed because of the extraordinarily high content of geological magnetite in the cultural debris, but the new instrument was even faster in the field than the previous V101 system. Another 6 ha area could be prospected by the new system over ten days in 1994 at a even higher spacial resolution of 0.2 to 0.5 m with time mode sampling, which still is 1.5 times faster than the previous V101 system with 0.5 to 0.5 m spacial resolution with discrete point sampling. With the picotesla system there seems to be hardly any non-linear phase shift in the zigzag-mode sampled data. The walking speed dependent resampling procedure results in an almost sharp image, even after fast sampling in the field.

The magnetogram from 1994 adds again some important information about the urban structure of ancient Troy. Following the setup of the Roman city Troy IX we could control the extrapolation of the insula-system another 300 m to the east simply by testing the location of the crossing of the streets. The most important result was found in the outmost corner the very last 20 m grid to the West, where another ditch appeared. Its magnetic signature, size and location on the last rock bank above the Skamander plain gave enough evidence that we have found another Troy VI ditch – some 50 m outside the Hellenistic/Roman city wall. Homer's Troy might have been even bigger than the later city of Roman Ilium. The area of Troy VI would grow to at least



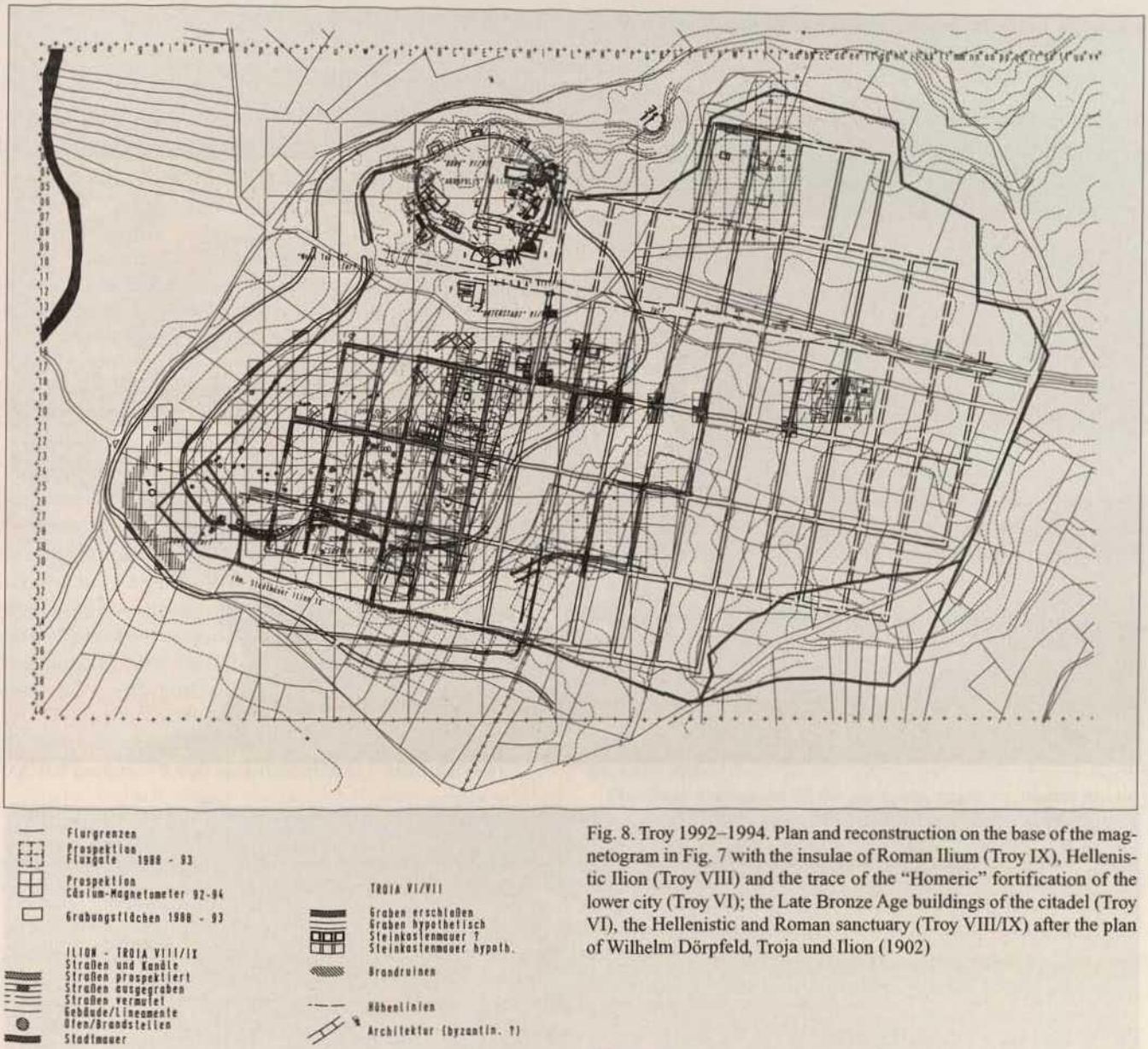


Fig. 8. Troy 1992–1994. Plan and reconstruction on the base of the magnetogram in Fig. 7 with the insulae of Roman Ilium (Troy IX), Hellenistic Ilion (Troy VIII) and the trace of the "Homeric" fortification of the lower city (Troy VI); the Late Bronze Age buildings of the citadel (Troy VI), the Hellenistic and Roman sanctuary (Troy VIII/IX) after the plan of Wilhelm Dörpfeld, Troja und Ilion (1902)

300,000 square metre (30 hectare) with a periphery of more than 2 km. Still one should keep in mind that the eastern border and fortification of Troy VI is not being prospected at all.

Therefore it would be very important continuing the most successful prospection of the cities of Troy by caesium magnetometry. Hard to believe that all further plans for finishing the magnetic prospecting of Troy were blocked by the project director. Obviously even modern archaeologists have problems accepting scientific generated data and information about areas, which could never be investigated by digging. The ready to use modern magnetometer systems with multi-sensor technic could do the job of prospecting all the remaining areas of Troy/Ilion/Ilium within 14 days. Interesting to consider how Heinrich Schliemann would have accepted these modern technologies for producing archaeological city maps in short times.

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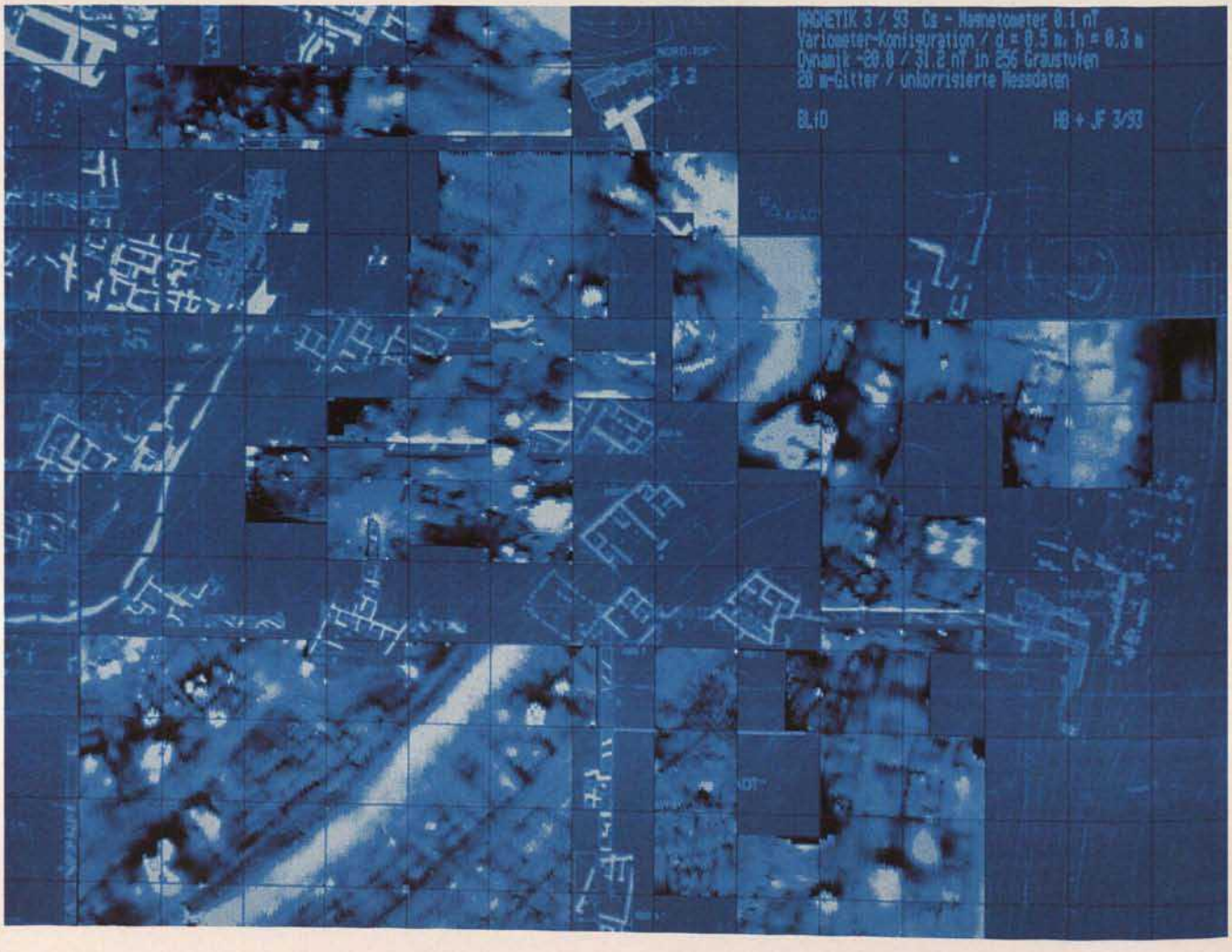
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Variometer-Konfiguration / d = 0.5 m, h = 0.3 m
Dynamik -20.0 / 31.2 nT in 256 Graustufen
20 m-Gitter / unkorrigierte Messdaten
BL10
HB + JF 3/93