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Past - present - future

From proton- to caesium-magnetometry – my 40 years in archaeological prospection

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After military service in an artillery reconnaissance unit (1963–1965) I had a rather early start in archaeology at "Cerro de la Virgen" (Orce, Granada, Spain) doing topographical work (1965). From 1965 to 1977 I studied at the University of Munich, taking courses in physics, geosciences (mainly geophysics), altogether 19 semesters, and archaeology (prehistory and Roman archaeology), a total of 13 semesters. For my diploma and doctorate, I went to northeastern Iceland, measuring with two Askania-Gfz-torsion balance-magnetometers the vertical component on several profiles crossing a neo-volcanic zone (about 1000 km with 50 m point distance) to get a first verification of seafloor spreading on land.

In 1973–1974 I was invited to work for an archaeological project directed by Barthel Hrouda from the University of Munich at the site of Isin in Iraq. On my way back I met Manfred Korfmann at the German Archaeological Institute in Istanbul and the result was my participation in the Demircihoyük project in western Turkey, conducting a topographical survey and excavation in 1975–1976. It was my first experience in proton-magnetometry used for archaeological prospection and I was using an Askania GPR-1 instrument in variometer mode. I excavated a Middle Bronze Age ceremonial structure outside of the Early Bronze Age tell.

In 1976, I traveled to meet Irwin Scollar (Bonn), Emile Thellier, Albert Hesse and Alain Tabbagh (Garchy) and Martin Aitken (Oxford) in preparation for the Volkswagen project "Archaeo-Prospection and Archaeo-Magnetism" at the Institute of Geophysics Ludwig-Maximilians-University in Munich. At this time Irwin Scollar had a system with two proton-magnetometers and automatic data recording on punched paper-tape in a running VW-Bus and he was interested in my plans for archaeomagnetic dating. The project, run by the Institute and the Geophysical Observatory Fürstenfeldbruck, operated in 1977–1982. I still had not aquired the caesium-magnetometers, but I managed a double proton-magnetometer in conjunction with Askania GPR-1, measuring in the Landshut-Hascherkeller project in 1978. It opened my way to using, as a medi-

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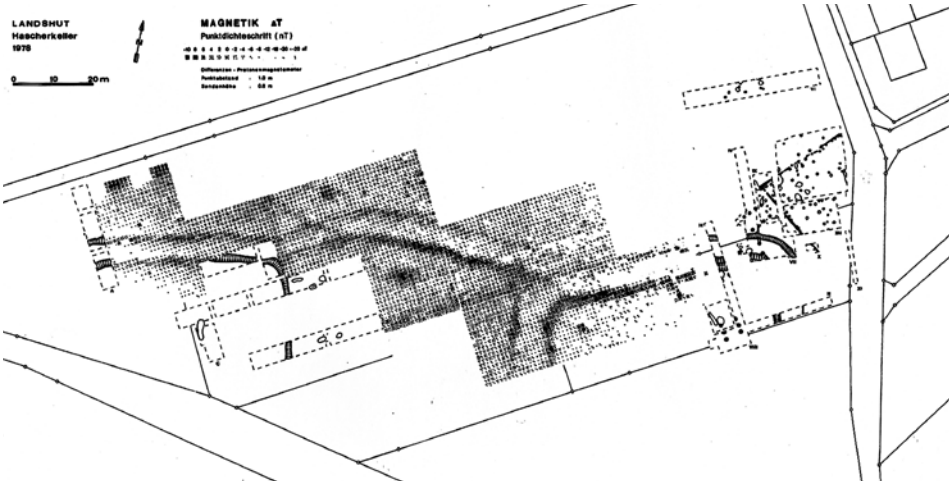

Fig. 1. Landshut-Hascherkeller (1978). Manual dot-density plot of a Hallstatt periode enclosure. Proton-magnetometry with two Askania GPR-1 in variometer mode, 20 m-grids, -10/+20 nT

eval archaeologist, ground magnetometry in combination with aerial archaeology for the Bavarian State Department for Monuments and Sites (Bayerisches Landesamt fur Denkmalpflege, BLfD).

The manual dot-density plot achieved in the Landshut-Hascherkeller project (1978) persuaded Rainer Christlein to plan a combination of ground magnetometry with aerial photography (Otto Braasch) at the Bavarian State Department for Monuments and Sites.

Starting from 1981–1982 I used a double-proton-magnetometer for measurements mainly in Greece, Bulgaria and Turkey, e.g., Tiryns, Kastanas, Kalapodi, Durankulak, Hassek-Höyük and Bogazköy (Hattusa), and managed to obtain archaeomagnetic samples at Tiryns, Bogazköy, Acem-Höyük, Masada for a reference-curve for the 15th–12th century BC. At Demircihoyük I procured a long sequence of samples for the variations of the geomagnetic field in the 3rd millennium BC.

In February 1982, at the very end of the VW project, I managed to complete my magnetic prospecting system with two caesium-magnetometers Varian V-101 and automatic data recording on a digital cassette still financed by the Volkswagen foundation. Rainer Christlein, Director of the Archaeological Department at the BLfD, gave me the chance to establish the Laboratory for Archaeological Prospection and Aerial Archaeology (ultimately comprising a staff of 12 persons, including Jörg Fassbinder, who is now the director of the unit). In 1985, I mounted two caesium Varian V-101 gradiometers on wheels and established an Epson HX20 handheld computer for data logging mainly in variometer-configuration of the sensors. This configuration became our main working tool until 1993.

In 1992, caesium magnetometry helped to uncover the Early Bronze Age fortification of Troy-VI (Heinrich Schliemann's so-called "Lower City"; Schliemann had not succeeded in finding the wall described by Homer in the *Iliad*). This was another turning point in the development of caesium magnetometry, because following the worldwide coverage that the detection of the

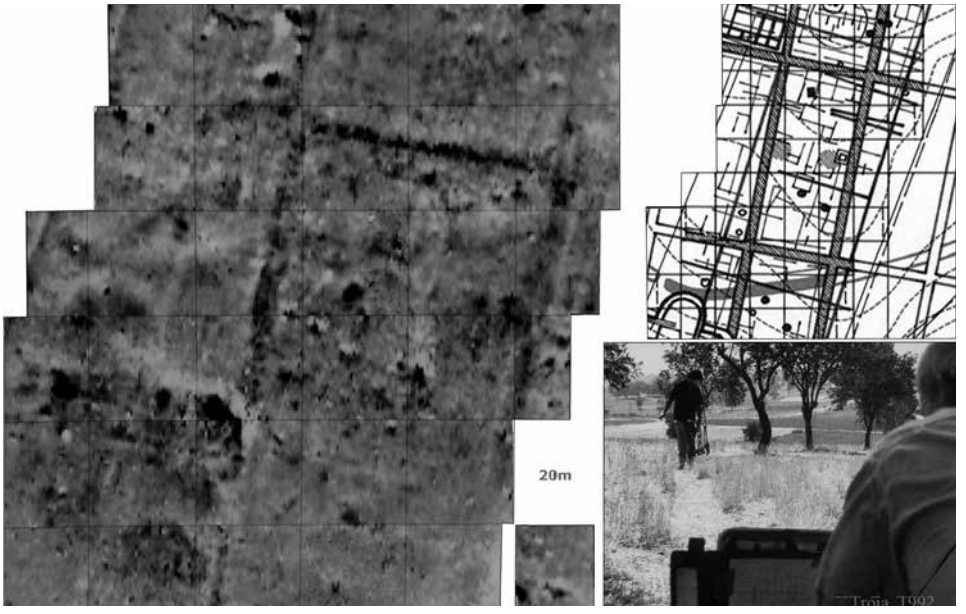

Fig. 2. Troy: magnetic map (1992–1993) measured with a Varian V-101 by H. Becker and J. Faßbinder. Caesium-magnetometry Varian V101 and CS2/MEP720; interpretation with Roman insula (Troy IX, Hellenistic Illion (Troy VIII) and the gate of the "Homeric" fortification of the Lower City (Troy VI); the plan of the citadel after W. Dörpfeld (1902); 20 m-grids, -20/+30 nT (black to white)

Lower City of Troy received, Bob Pavlik of Picodas contacted me with an offer of a caesium-magnetometer with picotesla sensitivity Scintrex CS2 /MEP720 (Picodas) and an Olivetti subnotebook for data logging.

FROM GRADIOMETER/VARIOMETER MODE TO A DUO-SENSOR CONFIGURATION

Looking at the screen of the Olivetti subnotebook showing the signal of both sensors sparked the idea of using the two sensors not only for a gradiometer/variometer mode, but also for a two-track sampling of the total magnetic field. The reductions of time variations of the magnetic field can also be done by a 40 m-line mean and full square mean without loss of linear structures that were exactly parallel to the traverses. With this very simple trick, the speed of magnetic prospection can be doubled. The hand-held duo-sensor configuration allows about 1.5–2 ha/day; the quadro-sensor on wheels ("magnetoscanner") about 3–4 ha/day (0.5 m tracks with 0.1 m samples, resampled to 0.5 m x 0.25 m) depending on the surface conditions.

In 1996, the Scintrex-Smartmag-SM4G-Special caesium-magnetometer (long cable version) 20 pT at 1/10 Hz (10 measurement per second, about 10–12 cm sampling on the line, inbuilt filter for high frequency signals) became available. It was first used at Monte da Ponte, Alentejo, Portugal, in 1996.

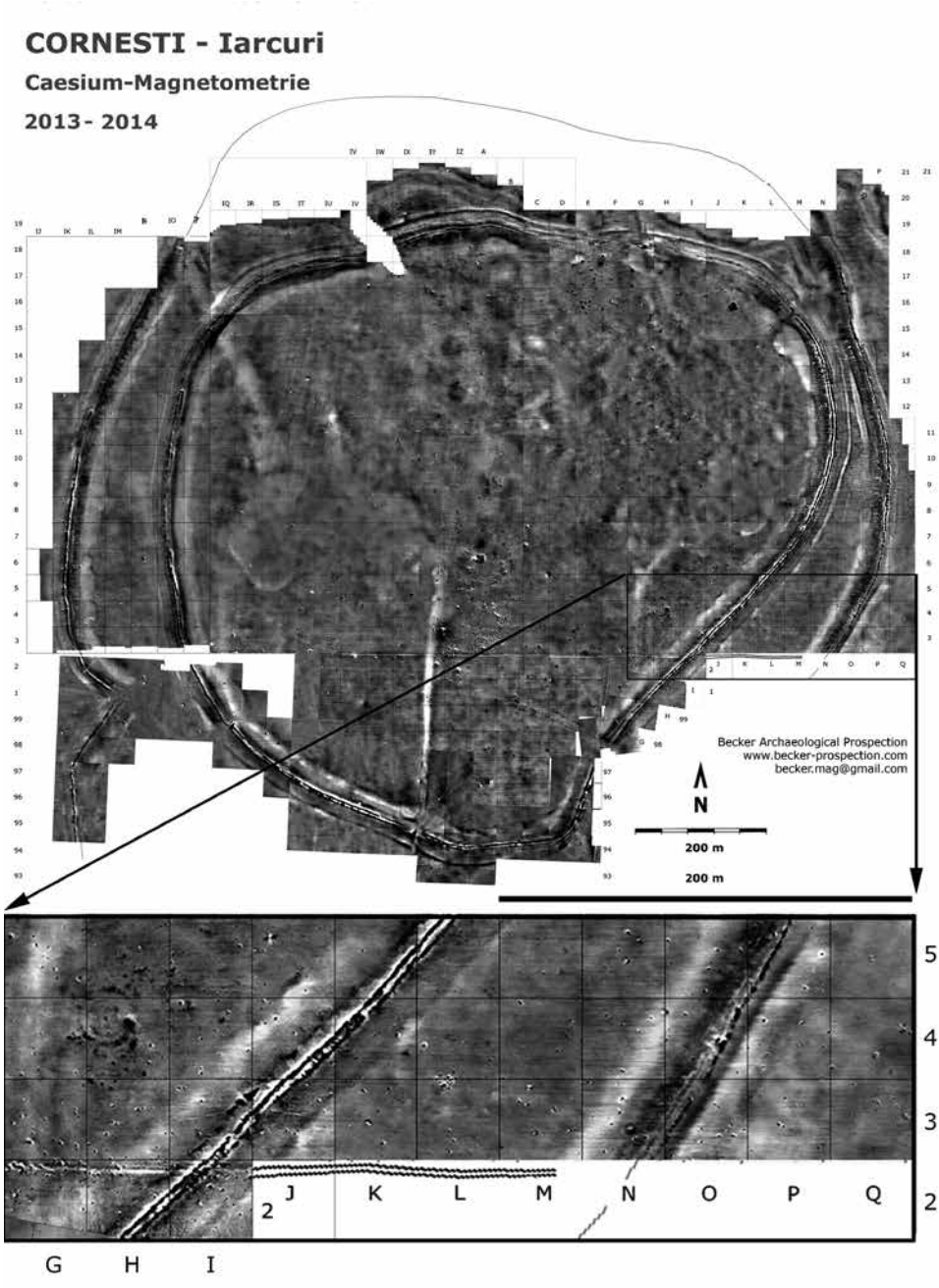

Fig. 3. Cornesti (Timis, Romania) 2008–2014, northern part of wall I and wall II, excavation in grids G-H / 4 in 2014, four Geometrics G-858G, 40 m grids, interval 0.5 x 0.25 m

Almost the entire development and adaptation of the various caesium magnetometers for archaeological prospection occurred in 1994–1996 at the Chalcolithic site of Monte da Ponte in Alentejo-Portugal.

One of the biggest projects at the BLfD was Qantir-Piramesse in Egypt, the capital of Ramesses II, with about 1.5 km2 (150 ha) measured from 1996 to 2001. Measurement was possible only using the handheld duo-sensor-configuration owing to intense agricultural activity (flooded rice fields).

Back to Bavaria. One of my last projects at the BLfD was the complete plan of the Roman castellum Ruffenhofen in Franconia with *vicus* and cemetery covering an area of about 40 ha, using four Scintrex Smartmag SM4G instruments mounted on wheels.

FOUNDATION OF "BECKER ARCHAEOLOGICAL PROSPECTION" WITH CAESIUM MAGNETOMETER GEOMETRICS G-858G

After my retirement from the BLfD in 2005, I founded, in 2007, "Becker Archaeological Prospection" which uses two Geometrics G-858G caesium magnetometers. Projects have taken me to many places in the Old World from Portugal to China, e.g., projects with the University of Ravenna (Maurizio Tosi) in Central Asia, Oman, India, etc., projects in the Celone Valley (Italy), Ras al-Hamra, Zukait, Ras al-Jinz (Oman), Lothal (India), Zazargan, Kala Kafir (Uzbekistan) and Takirbay, Murghab Delta, Togolog (Turkmenistan) — all these projects were carried out before 2008. Within the frame of the cooperation with NIA-ERA Lisbon, the following sites were surveyed in Portugal (mainly Chalcolithic enclosures), between 2009 and 2013: Perdigoes, Morreiros 2 (Chalcolithic woodhenge), Xancra (Chalcolithic moon-calendar), Monte do Olival, Monte da Contenda, Montoito ellipse.

Recent surveys, carried out between 2013 and 2015, comprise prospecting of Chalcolitic and Copper age enclosures in Romania (Cornesti, Timis) and Spain (Azutan, Province Toledo and Valencina de la Conception near Sevilla). Huge areas to be prospected there have kept me active — and will do so for some time. Many thanks to my wife Anne-Sophie Flade-Becker, who is helping me in my crazy life with walking magnetometry.