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The Fragile Crescent Project (FCP): Analysis of Settlement Landscapes Using Satellite Imagery

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Abstract

The Fragile Crescent Project (FCP) is analyzing the rise and decline of Bronze Age urban settlements and associated political and economic structures in the ancient Near East between ca. 3500 and 1200 BC. The Near East is a key area for urban development; but for too long the settlement record from Southern Mesopotamia has been taken as the paradigm for the entire region, and has provided the key data for the reconstruction of the processes of urbanism and state development. Evidence from surveys in northern Mesopotamia and the Levant suggest not only that developments there were very different from those of southern Mesopotamia, but there was marked diversity between different sub-regions. Recent overviews highlight the need for a comprehensive review of the settlement record, and the FCP is an attempt to rectify this lacuna.

In order to tackle the diversity of Early Bronze Age urbanization the FCP is harnessing data on trends in settlement drived from as large an area as possible, and, in turn, is relating these data to the regional environment. This requires the creation of a large-scale and coherent set of high quality settlement data to tackle specific questions fundamental to the economic and social dimension of the rise of early states and civilizations. The Fragile Crescent Project is enhancing the value of a series of earlier and ongoing regional surveys by analyzing the data within a single geographical and environmental framework, specifically by taking advantage of recent advances in the use of satellite imagery and digital terrain models. Consequently this is a project that has only recently become possible through the convergence of a range of digital technologies. The core methodology of the project is to re-analyze "sample" surveys, the data from which is readily available, and to re-calibrate these within a GIS framework. Remote sensing is used to identify, confirm and provide a landscape context for sites previously recorded in the field (i.e. within existing survey areas) and also provides data on areas that were not surveyed. The FCP therefore is able to extend existing surveys to encompass larger geographical areas that appear more meaningful for the analysis of questions of urban development. The paper demonstrates the value of landscale analysis of high spatial resolution optical imagery and digital terrain models derived from modern and declassified satellite data.

***Key words**: Remote sensing, Settlement analysis, Fertile Crescent, CORONA, Levant*

1 INTRODUCTION

Existing models of early state development in the Near East over simplify a much more complex reality. Archaeological surveys over the past 30 years have demonstrated that settlement patterns, that form the framework for early states, varied significantly from place to place, but that this variability tends to be lost in surveys of single areas. By analyzing multiple survey regions throughout Upper Mesopotamia and the northern Levant the Fragile Crescent Project hopes to demonstrate that this area can be understood, not simply as an area of "secondary state formation," subordinate to a dominant Mesopotamia, but on its own merits. The primary objective of the Fragile Crescent Project is to chart the rise and fall of Bronze Age urban centres within the Fertile Crescent and to analyze their spatial variability using the best available satellite imagery together with field surveys from across the region within a GIS framework. Such large agendas require the use of a wide range of computer-aided technologies that are essential to organize and analyze the large bodies of data that are generated over the large areas involved[1].

Geographical scale is fundamental to an understanding of long-term trends in settlement because the overall dimensions of the Fertile Crescent are so large, namely 750 km E-W by 300 km N-S (some 225,000 sq km), whereas individual survey areas are rather small, usually covering only some 400 to 1,000 sq km. Because of the spatial and temporal variations, it is not possible simply to "scale up" the results from a single area and apply them to the entire region. Rather the approach of the FCP is to take a series of nine surveys extending from near the Tigris in the east to almost the Mediterranean in the west. These areas were surveyed between 1975 and the present day are being enhanced and extended by means of satellite imagery. Remote sensing helps to identify, confirm and contextualize sites already recorded within existing survey areas but also will plug gaps in the settlement record for areas that were not surveyed. Medium-resolution satellite imagery provides the geographical cover for the whole of upper Mesopotamia that helps to provide a context for the more detailed coverage obtained from detailed surveys and high-resolution satellite imagery.

Many surveys conducted over the past 30 years have been confined to arbitrary "salvage" areas delineated according to the agendas of public agencies. The FCP gives us the opportunity to extend existing survey universes to encompass geographical areas that are more meaningful for the analysis of early state or urban development. For example, if major urban centres exist just beyond a survey area, remote sensing is used to extend the mapping framework to encompass the city beyond as well as an enlarged political or economic territory. The extrapolation of settlement patterns beyond existing survey areas is based upon the recognition of tell and soil mark sites on satellite imagery using a range of techniques including: topographic data, shadow effects, and soil marks.

[1] For recent review of spatial technologies and archaeology see McCoy and Ladefoged "New developments in the use of spatial technology in archaeology," *Journal of Archaeological Research* 17 (2009): 263-95.

The area under investigation consists of a mosaic of broad agricultural lowlands, in part oriented along the main valleys of the Orontes, the Euphrates and Tigris rivers (fig. 1). These are incised into a series of low plateaus formed in predominantly Tertiary period sedimentary rocks interrupted by occasional basalt sheets, and rare upstanding mountains. The latter are mainly located in the west of the region where the Ansariye, Zawiye, Akra and Amanus Mountains flank the Orontes Valley trough formed by the Dead Sea transform fault. These rise to some 1800 m above sea level in the Amanus Mountains of southern Turkey.

Bronze and Iron Age settlements tend to be concentrated in the broad agricultural lowlands, and so the main archaeological surveys have also focused upon those areas. However, when surveys have also included the uplands and mountains, as was the case in the Oriental Institute's Amuq Valley Regional Project, there is an apparent dearth of Bronze and Iron Age settlement in the uplands, whereas post-Hellenistic settlement can be remarkably abundant[2,3]. However, such patterns are spatially variable. This is particularly the case in the Homs area along the southern Orontes where very different patterns of human use of the land are evident between the southern Marl area and the northern basalts[4]. Moreover, in the Khabur basin of eastern Syria, where similar basalt plateaus are also present, the pattern of human use of the landscape is markedly different from that of the basalt landscapes near Homs. As some lowlands fall beyond the limit of reliable rainfed agriculture, it is especially important to consider the role of mobile pastoralists that have evidently had a significant precense in he landscape since at least the Amorites of the third millennium BC.

[2] Jesse Casana and T.J.Wilkinson. "Settlement and Landscapes in the Amuq Region," pp. 25-65 & 203-280 in *The Archaeology of the Amuq Plain*, edited by K.Aslihan Yener. Oriental Institute Publications 131, Chicago, 2005.

[3] Jesse Casana "Structural transformations in settlement systems of the northern Levant." *American Journal of Archaeology* 112 (2007): 195-222.

[4] Graham Philip et al. "CORONA satellite photography: a case study from Orontes valley, Syria," *Antiquity* 76 (2002): 109-118.

Consequently there is a very real need for archaeologists to employ techniques that will enable these diverse environments and their disparate human settlements and land use to be studied over very large areas. This is where the present generation of remote sensing, digital elevations models and techniques of spatial analysis come into their own.

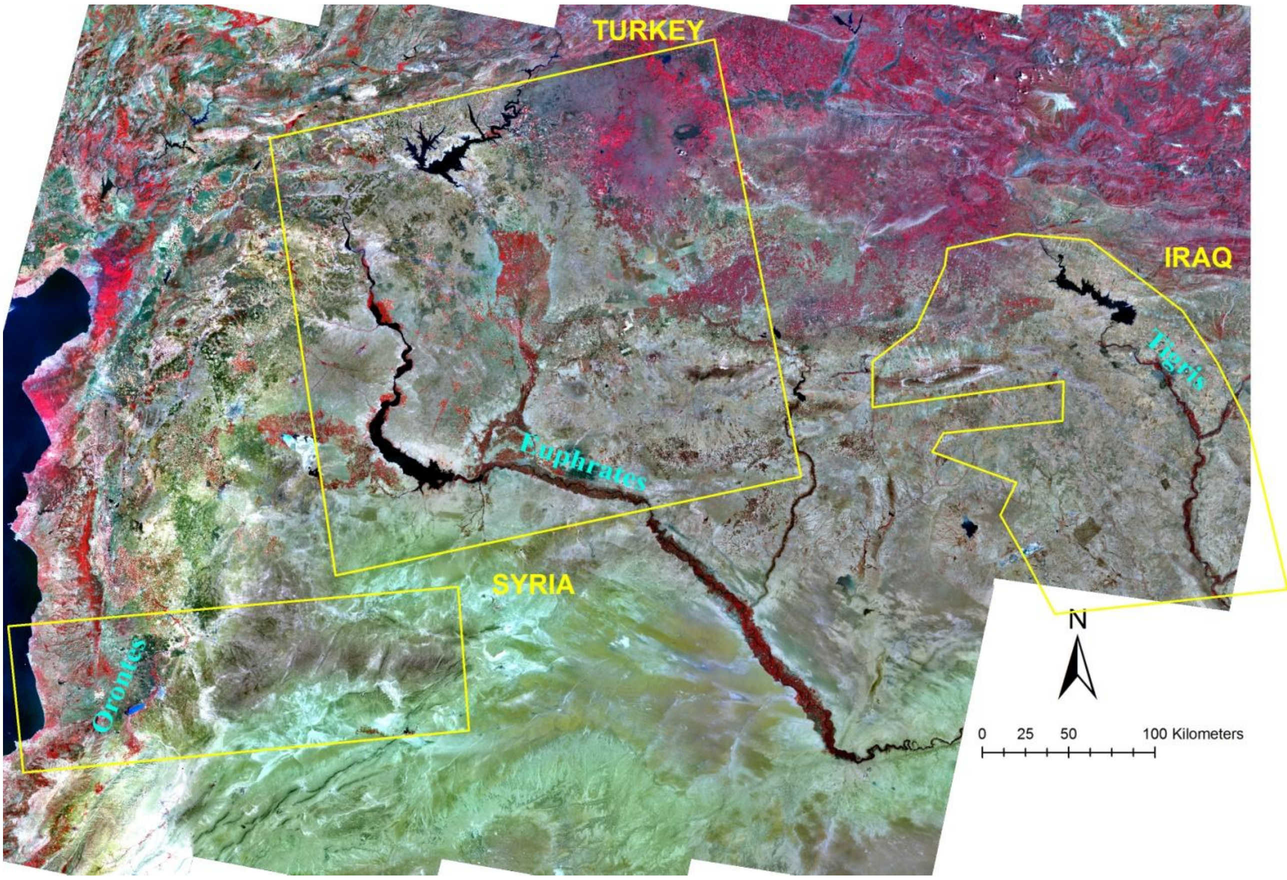

Figure 1. Footprints of the satellite data (background: Landsat 4,3,2); CORONA imagery in yellow boxes.

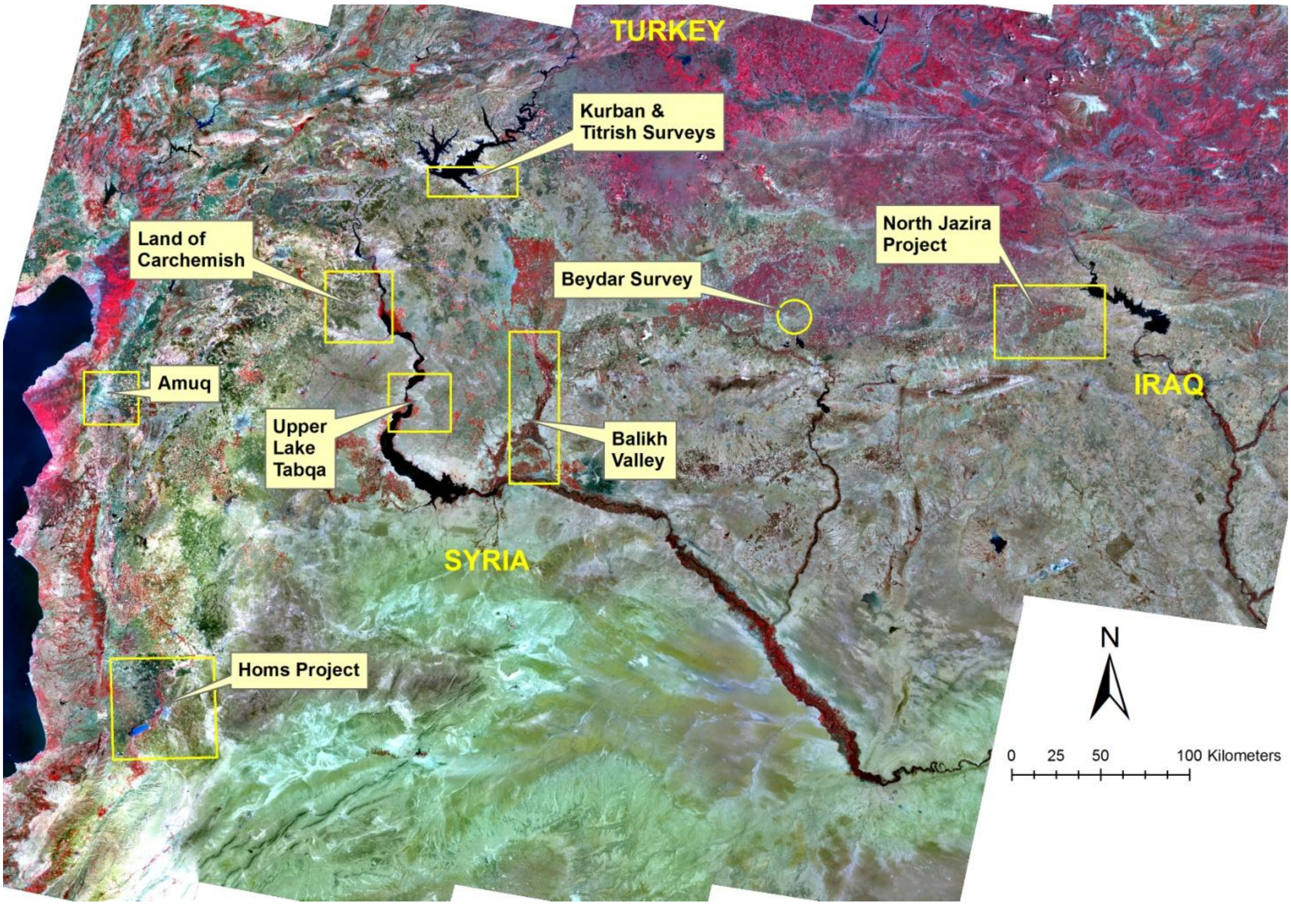

Figure 2. Sample survey areas (background: Landsat 4,3,2)

2 PROJECT IMAGE DATA

The FCP draws on three distict types of spatial information. First, medium-resolution Landsat ETM+ satellite imagery is used to provide regional coverage of the whole of upper Mespotamia; these data are used to help identify patterns of upland, steppe, plateaus, river valleys and broad agricultural plains (see fig. 1). Landsat imagery is multispectral and the different spectral bands can be processed to create thematic maps of vegetation cover and geomorphology. In the absense of large scale mapping Landsat ETM+ panchromatic data can be used as a basemap. Orthorectified Landsat[5] data were acquired from the Global Land Cover Facility (GLCF) at the University of Maryland http://www.landcover.org/.

Secondly, we use high spatial resolution satellite imagery where it is available. Such high resolution data may be obtaind from declassified space photography missions such as CORONA and GAMBIT that date from the late 1960s onwards or from more recent civilian remote sensing satellite sensors such as IKONOS-2 or Quickbird[6]. The space reconnaissance programs CORONA and

[5] C. J. Tucker, et al., "NASA's global orthorectified Landsat data set," *Photogrammetric Engineering & Remote Sensing* 70, no.3 (2004): 313-322.

[6] Nikolaos Galiatsatos, et al., "High resolution elevation data derived from stereoscopic CORONA imagery with minimal ground control: an approach using IKONOS and SRTM data," *Photogrammetric Engineering and Remote Sensing* 74, no.9 (2008): 1093-1106.

GAMBIT[7] provide high spatial resolution panchromatic photography that is readily available from the United States Geological Survey (USGS) at low cost. The CORONA missions are particularly valuable as they used a panoramic camera system to cover large geographical areas at high spatial resolution. The later CORONA missions carried stereoscopic cameras that allows us to view the ground in 3-D and can provide information about the surface features based on directional reflectance properties[8]. The Middle East has a particularly good coverage from many CORONA missions in the 1960s and 1970s. These images capture the landscape just before major phases of modern irrigation, agricultural intensification, dam construction and even urban expansion took hold. As such these data offer an valuable, and in some places the only, record of the landscape before the imprint of development obscured many archaeological features. Since its declassification in 1995, CORONA imagery has been widely used by archaeologists working in areas where aerial photography is not available or within very limited availability. Several examples of archaeological applications of CORONA imagery come from the area of Middle East[9,10,11] Fig. 2 illustrates the archaeological surveys that have been conducted since 1975 some of which are still ongoing. These are the surveys that the FCP is trying to bring together by using the satellite imagery as a source of information and a connecting link.

The GAMBIT or KH-7 was another intelligence satellite program that operated from July 1963 until June 1967 and was declassified in 2002 along with HEXAGON or KH-9. From those two programs only the imagery got declassified. The respective documentation was not declassified. The GAMBIT program focused on the acquisition of very high resolution imagery from particular areas that were initially spotted on the CORONA imagery. For this, it does not have a global coverage but it is limited to areas of interest to the intelligence community of that time. The best ground resolution was initially 1.2 m which later improved to 0.6 m.

IKONOS is spacecraft that provides commercial high-resolution imagery. It has operated since 1999 and is now one of several similar systems that provide panchromatic and multispectral imagery. The data are expensive which makes coverage of very large areas impractical but they can provide a valuable resource for survey work. The data can be orthorectified to UTM coordinates semi-automatically using camera model data; overlapping scenes can be used to gerenate 3-D data. The FCP has used these data to provide planimetric control for CORONA photogrammetry[7] and to provide accurate base maps for field survey.

Thirdly, we use topographic data to reconstruct and visualise landscape morphology and to help identify archaeological features such as upstanding monuments such as Tells, former irrigation or water management features and hollow ways. Topographic data is available from various sources at a variety of scales including the Shuttle Radar Topography Mission (SRTM), CORONA stereo images, topographic maps and, in a few very localised areas, ground-based surveys.

We downloaded the 3 Arcsecond elevation data from (ftp://e0srp01u.ecs.nasa.gov/). The SRTM DEM is valuable for parts of the world where topographic maps are not readily available. The global vertical accuracy is less than 10m with horizontal accuracy about 10m, depending on the relief of the ground[12]. The SRTM 1 arcsec product is not yet available outside the U.S. (United States). However, SRTM has a pixel size of 90m

[7] Nikolaos Galiatsatos, "Assessment of the CORONA series of satellite imagery for landscape archaeology: a case study from Orontes valley, Syria." (PhD diss., Durham University, 2004).

[8] See footnote 6; also Jesse Casana and J. Cothren, "Stereo analysis, DEM extraction and orthorectification of CORONA satellite imagery: archaeological applications from the Near East," *Antiquity* 82, no.317 (2008):732-749.

[9] D. Kennedy, "Declassified satellite photographs and archaeology in the Middle East: case studies from Turkey," *Antiquity* 72 (1998): 553-561.

[10] J.A. Ur "CORONA satellite photography and ancient road networks: A northern Mesopotamian case study," *Antiquity* 77, no. 295 (2003): 102-115.

[11] See Footnote 4.

[12] Ernesto Rodriguez et al., "A global assessment of the SRTM performance," *Photogrammetric Engineering & Remote Sensing* 72, no.3 (2006): 249-260.

which may be sufficient to detect large monumental features but is somewhat restricting for detailed analysis[13]. For larger scale, more precise topographic data we use topographic maps and stereoscopic CORONA imagery. Paper-based topographic maps at 1:100,000 scale are available for the whole region and for limited areas we have 1:25,000 and even 1:5,000 topographic maps. These can greatly assist with landscape interpretation and can also be used to provide height control for photogrammetry. The use of CORONA imagery stereopairs to create high resolution DEMs is a particular innovation that helps image interpretation and site classification. DEMs can be generated at fine-resolution using a combination of CORONA stereopairs, IKONOS data and height control from 1:100,000 scale topographic maps[14]. Table 1 presents a summary of the data of the project and fig. 1 shows the areas where we currenty have image coverage. In table 1, the Landsat imagery is described with path/row, while the CORONA imagery is described with camera design (e.g. KH-4A), mission number (e.g. 1038), and whether it is Aft (A) or Forward (F) camera.

The integrated use of imagery and topograpic data has many advantages but it brings its own problems too. The data need to be coregistered and processed using a systematic and repeatable methodology where the positional and height errors are quantified. Particular attention needs to be given to the processing of the declassified satellite data because they were originally acquired in analogue form and are not supplied with accurate positional information. For example, CORONA and GAMBIT data are scanned at 7 μm resolution by the USGS using Leica DSW700 photogrammetric scanner[15]. The higher ground resolution of GAMBIT creates larger files than the CORONA imagery. Fig. 3 illustrates a comparison between CORONA and GAMBIT imagery with respect to resolution.

Figure 3. Resolution comparison between GAMBIT (top image) and CORONA (bottom image).

The size of the film does not allow for one scan per frame, hence the frame is scanned in four overlapping parts (CORONA) or two or more overlapping parts (GAMBIT) that need to be stitched together to create a complete frame. We developed a semi-automatic method that quantifies the errors inherant in the stitching process. After all frames are stitched, we proceed to register[16] the declassified imagery using the orthorectified Landsat as a basemap. Polynomial models are used for the registration step using approximately 200

[13] B.H. Menze, et al., "Detection of ancient settlement mounds – archaeological survey based on the SRTM based model." *Photogrammetric Engineering and Remote Sensing* 72, no.3 (2006): 321-327.

[14] See footnote 7.

[15] Nikolaos Galiatsatos, "The shift from film to digital product: focus on CORONA imagery," *Photogrammetrie - Fernerkundung - Geoinformation* no.3 (2009): 247-258.

[16] M. Ehlers, "Rectification and registration," in *Integration of geographic information systems and remote sensing: Topics in remote sensing 5*, ed. J.L. Star, J.E. Estes, and K.C. McGwire (Cambridge University Press, 1997).

evenly distributed control points per frame[17]. The registration result is checked where possible with the use of GPS data collected during fieldwork.

Table 1. Summary of data with acquisition dates

Landsat 7	13/06/2001, p170r034
Landsat 7	13/06/2001, p170r035
Landsat 7	22/05/2002, p171r034
Landsat 7	19/05/2001, p171r035
Landsat 7	05/09/2000, p171r036
Landsat 7	29/05/2002, p172r034
Landsat 7	26/05/2001, p172r035
Landsat 7	11/08/2000, p172r036
Landsat 7	18/08/2000, p173r034
Landsat 7	18/08/2000, p173r035
Landsat 7	18/08/2000. p173r036
Landsat 7	22/06/2000, p174r034
Landsat 7	22/06/2000, p174r035
Landsat 7	22/06/2000, p174r036
CORONA KH-4A 1038	22/01/1967, 61-74F
CORONA KH-4B 1104	08/08/1968, 5-17A
CORONA KH-4B 1105	04/11/1968, 2-16A, 1-10F
CORONA KH-4B 1110	28/05/1970, 12-16A, 6-10F
CORONA KH-4B 1108	17/12/1969, 41-44A
CORONA KH-4A 1043	17/08/1967, 69-72F
CORONA KH-4A 1048	26/09/1968, 2-17A, 1-18F
CORONA KH-4B 1107	31/07/1969, 47-63A
GAMBIT KH7	20/02/1966 Aleppo
GAMBIT KH7	20/02/1966 Hama
GAMBIT KH7	25/04/1966 Hama
SRTM 3 arcsec	11-22/02/2002
IKONOS Geo	03/02/2002

Finally, a Geographical Information System (GIS) with its associated databases is used to integrate the imagery, topographic maps, field survey and even laboratory data. The GIS is able to store and retrieve data from different scale and formats and link these together for subsequent analysis and interpretation.

3 THE REGION AND SURVEY AREAS FROM SOUTHWEST TO NORTHEAST

Of the nine archaeological surveys chosen to provide field evidence for ancient settlement, seven have been completed and published (in part or to final report level), whereas two are ongoing. From west to east these surveys are:

- *Settlement and Landscape Development in the Homs Region* (Syria): directed by Graham Philip, Farid Jabbour and Michel al-Maqdissi since 1999.
- *The Amuq Survey*: following initial surveys by Robert Braidwood in the 1930s, resurvey commenced in 1995 under the direction of T.J. Wilkinson (Oriental Institute, Chicago). The overall director of the Amuq Valley Regional Project is Professor Aslihan Yener (Oriental Institute, Chicago and Koç University, Istanbul)[18].
- *Land of Carchemish Project* (Syria): conducted in 2006, 2008 and ongoing, under the direction of Professor T.J. Wilkinson (Durham) and Professor E. Peltenburg (Edinburgh), these build upon the Jerablus Tahtani Project directed by Professor E. Peltenburg (Edinburgh)[19].
- *Tell Sweyhat survey* (Syria): surveys were undertaken in 1974, 1991, and 1992 by T.J. Wilkinson (Oriental Institute, Chicago)[20] as part of the Tell Sweyhat Project directed by Dr. Tom Holland (Oriental Institute, Chicago).
- *Kurban Höyük Survey* (Turkey): Fieldwork by T.J. Wilkinson between 1980 and 1984 as

[17] A.J. De Leeuw, et al., "Geometric correction of remotely-sensed imagery using ground control points and orthogonal polynomials," *International journal of remote sensing* 9, nos.10-11 (1998): 1751-1759.

[18] Main publications include Braidwood, Robert J. *Mounds in the Plain of Antioch.* Chicago: Oriental Institute Publications, 1937; Yener, K.A., et al. "The Amuq Valley Regional Project 1995-1998." *American Journal of Archaeology* 104 (2000): 163-220; see also footnotes 2 & 3; F. Gerritsen et al., "Settlement and landscape transformations in the Amuq Valley, Hatay. A Long-term perspective," *Anatolica* 34 (2008): 241-314.

[19] Tony J. Wilkinson et al., "Archaeology in the land of Carchemish: landscape surveys in the area of Jerablus Tahtani, 2006." *Levant* 39 (2007): 213-247.

[20] Tony J. Wilkinson, *Settlement and Land Use at Tell Sweyhat, and in the Upper Lake Tabqa, Syria*. Chicago: Oriental Institute Publications 124, 2004.

part of the Oriental Institute (Chicago) Project at Kurban Höyük[21], director Dr. Leon Marfoe.

- *Titriş Höyük Survey* (Turkey): Fieldwork conducted by T.J. Wilkinson in 1990 and 1992[22] as part of the Titriş Höyük project directed by Professor Guillermo Algaze, Dept. of Anthropology, University of California at San Diego.
- *Balikh Valley Landscape Survey* (Syria): the landscape survey was conducted by T.J. Wilkinson between 1993 and 1995[23], with the assistance of Eleanor Wilkinson, Jerry Lyon and Fokke Gerritsen. This work complemented an earlier survey of tells conducted by Dr Hans Curvers, Amsterdam. All surveys were undertaken as part of the Sabi Abyad Project directed by Professor Peter M.M.G. Akkermans of RMO Leiden and the University of Leiden.
- *Tell Beydar Survey* (Syria): conducted in 1997 and 1998 under the direction of T.J. Wilkinson (Oriental Institute, Chicago)[24] with Dr. E. Wilkinson (Oriental Institute) and Dr. Jason Ur (Oriental Institute) as part of the Tell Beydar Project, directed by Dr Mark Lebeau and Antoine Suleiman (DGAM Damascus).
- *North Jazira Project* (Iraq): surveys were conducted between 1986 and 1990[25] under the direction of T.J. Wilkinson (British School of Archaeology in Iraq) with David Tucker and J. Wilkinson as part of the Tell al-Hawa Project, directed by Warwick Ball, British School of Archaeology in Iraq.

Of the above we have chosen two survey areas to illustrate how both archive survey data and ongoing investigations are able to be used in concert to produce a more refined data base of settlement and land use than is the case using either survey or remote sensing alone. Although satellite imagery and remote sensing have long been employed as an aid to archaeological survey, particular problems arise when they are used to enhance earlier surveys.

Whereas it is a common policy to follow a desk-based assessment, including satellite imagery, with ground survey to provide the “ground truth”, this is not possible when the surveys have been conducted before the widespread availability of high resolution satellite imagery. Therefore, when imagery is employed to complement archive surveys, previously unknown sites may be recognized on the images thereby forming what may be described as “air truth”. Such areas must be recorded, but may not be confirmable because the areas viewed are now invisible, often having been submerged beneath the waters of a number of reservoirs developed along the rivers. Owing to the variable nature of the data sources, we are not employing any single method of integrating imagery and field surveys. However, the following case studies provide just two examples of the approaches employed.

4 CASE STUDY 1: HOMS REGION

Settlement and Landscape Development in the Homs Region is a joint, Syrian-British multi-disciplinary regional project that aims to explore

[21] Tony J. Wilkinson, *Town and Country in SE Anatolia,* (Chicago: Oriental Institute Publications 109, 1990).

[22] Algaze, G. et al. “ŞanliUrfa Museum/University of California Excavations and Surveys at Titrish Hoyuk, 1991: A preliminary report,” *Anatolica* 18 (1992): 33-60.

[23] H.H. Curvers, “The Balikh Drainage in the Bronze Age”, (PhD diss. University of Amsterdam, 1991); Tony J. Wilkinson, "Water and Human Settlement in the Balikh Valley, Syria: Investigations from 1992-1995" *Journal of Field Archaeology* 25 (1998): 63-87.

[24] J.A. Ur, and Tony J. Wilkinson, “Settlement and Economic Landscapes of Tell Beydar and its Hinterland. In Tell Beydar Studies I,” *Subartu* 21, 305-27. Turnhout: Brepols, 2008; Olivier P. Nieuwenhuyse and Tony J. Wilkinson. “Late Neolithic settlement in the area of Tell Beydar (NE Syria),” in Tell Beydar Studies I, *Subartu* 21, 268-303. Turnhout: Brepols, 2008. See also Wilkinson, Tony J., J.A. Ur and Jesse Casana. “From Nucleation to Dispersal. Trends in Settlement Pattern in the Northern Fertile Crescent.” In *Side-by side survey Survey*, pp. 189-205, edited by John Cherry and S. Alcock. Oxford: Oxbow Books, 2004.

[25] Tony J. Wilkinson, and David J. Tucker. *Settlement Development in the North Jazira, Iraq. A Study of the Archaeological Landscape.* Warminster, UK: Aris and Phillips, 1995.

long-term trends in the nature, distribution and scale of human activity across a diverse landscape[26,27]. A combination of field and satellite image data was collected from an area of *ca*. 600 km^2 designed to include two contrasting landscape types, lacustrine marl and basalt, located respectively on the east and west sides of the Orontes Valley. Vital to any understanding of past human activity in this landscape is the contrasting nature of the archaeological record in what are broadly termed 'upland' and 'lowland' landscapes[28]. The marl is a classic 'lowland' landscape, characterized by mud-brick architecture and the visible settlement record is dominated by mounded tell sites. However, the lowland regions of western Syria represent prime agricultural land, much of which has remained in near-continuous use since the Bronze Age. As a result, the settlement record has suffered significant attrition, with many smaller sites now surviving only as low-visibility artefact scatters.

In contrast, evidence for human activity in the basaltic 'upland' areas consists of stone structures. However, the attention of researchers working in upland areas has usually focused upon the Graeco-Roman period, which is often characterized by substantial stone architecture (e.g. the "Dead Cities" of the Limestone massif). In these regions, evidence for both pre-and post-classical period activity has proven elusive. There are therefore sufficient incompatibilities between the datasets available for upland and lowland zones to render it difficult for scholars to provide an integrated archaeological account of settlement (and thus political and economic developments) across the upland-lowland divide.

While the identification of tell sites in the marl was straightforward, CORONA imagery played a key role in prospection for low-relief sites. These were detected through their distinctive soil marks, which were readily visible as areas of colour contrast on CORONA imagery, generally extending over one and five ha in area[29,30]. Field visits, directed by CORONA data, established that these coincided with artefact scatters, and they were interpreted as the ploughed-out remains of villages built in mud-brick, and predominantly of Graeco-Roman or Islamic date. In addition to identifying a hitherto poorly known aspect of the regional settlement record, the dating of these soil marks combined with a programme of 'off-site' sampling confirmed that Bronze and Iron Age material was largely restricted to the tell sites. We are now confident that the distribution of tells does indeed provide a reliable dataset from which to reconstruct the location, density and structure of Bronze and Iron Age settlement in the region. While many of the tell sites in the survey area were quite small (1-2 ha in area), CORONA proved invaluable in the identification of a distinctive soil mark to the west of Site 254, which upon ground inspection proved to represent a lower settlement covering some 8 ha in area[31], making this site quite different from other tells in comparable locations (see fig.4).

[26] See footnote 4.

[27] Graham Philip et al., "Settlement and landscape development in the Homs region, Syria: report on work undertaken 2001-2003", *Levant* 37 (2005): 21-42

[28] See footnote 20.

[29] See footnote 4.

[30] See footnote 19.

[31] Graham Philip, "Natural and cultural aspects of the development of the marl landscape east of Lake Qatina during the Bronze and Iron Ages". In D. Morandi Bonacossi (ed.), *Urban and Natural Landscapes of an Ancient Syrian Capital. Settlement and Environment at Tell Mishrifeh/Qatna and in Central-Western Syria*. Proceedings of the International Conference held in Udine, 9-11 December 2004, 218-226. Studi Archeologici su Qatna 1, Udine, Forum Editrice, 2008.

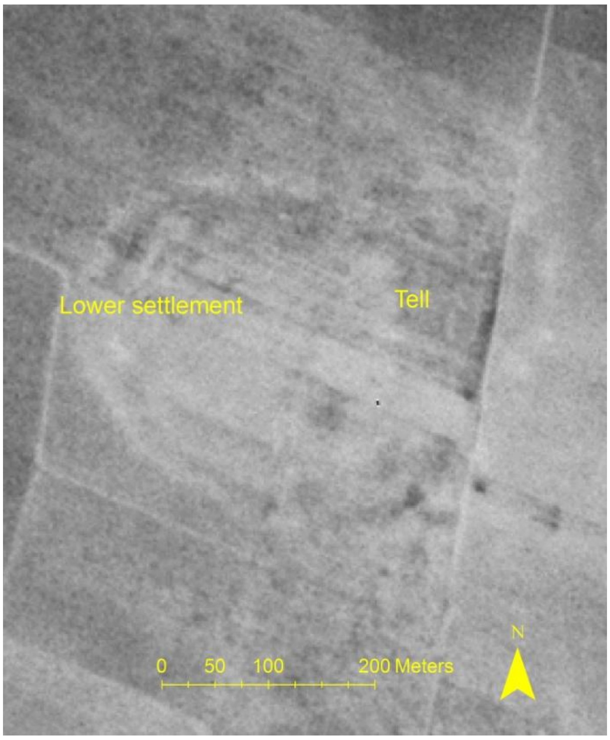

Figure 4. Site 254 small tell with lower settlement.

CORONA has also proved successful in the identification of ancient infrastructure, including a canal which appears to have exploited the natural gradient to carry water from the Orontes River some 10 kilometres to a large site of Roman date. In addition to CORONA data, the Homs project was fortunate enough to have access to high resolution IKONOS data collected in 2002, and we observed that a number of features readily visible on CORONA imagery from ca. 1970, were no longer visible on the modern imagery. This we attribute to growing landscape modification through the expansion of settlements, other forms of construction, and in particular the impact of intensive irrigated agriculture.

CORONA and GAMBIT data has made a major contribution in the basaltic landscape west of the Orontes, where the imagery has allowed the delineation of an extensive palimpsest of stone structures (see fig. 3). These include what we take to be prehistoric settlements characterised by walls and enclosures, over twenty thousand cairns - many used for burial, a number of substantial stone-built villages spanning the Roman through Medieval periods, and an extensive series of field walls, including a large-scale cadastration which we date tentatively to the Roman period[32,33]. As in the marl landscape, the basalt has undergone extensive transformation in recent years, in this case through a process of 'derocking', which involves the use of bulldozers to create large stone-free fields, a process which requires the removal of much of the archaeology.

5 CASE STUDY 2: THE KURBAN HOYUK AREA

Fieldwork along the southern banks of the Euphrates River in southern Turkey between 1980 and 1984 provided a detailed picture of settlement trends over some 8,000 years[34]. However, at the time of survey the lack of air photographs and high resolution satellite imagery meant that it was difficult to be certain that all archaeological sites had been identified and correctly defined. Specifically, many sites were of minimal elevation or were poorly defined artifact scatters, as well as because some sites were masked by a combination of sediment and developed soils.

An example of the topographic subtlety of certain features is provided by the site of Şaşkan Köcüktepe, a multi-period mound overlooking the Euphrates River. Initially discovered by the surveys of Mehmet Ozdoğan[35], this site, as its name implies, was a small site covering some 0.24 ha and 10 m in height. Subsequent surveys in 1982-1983, confirmed this, and off-site investigations indicated the presence of a small lower settlement immediately to the south as well as an extensive Iron Age settlement extended around the main site and to the south. During the same campaigns, high resolution topographic mapping revealed the presence of a semi-circular

[32] See footnote 27.

[33] Anthony R. Beck et al., "High precision satellite survey of a basalt landscape: problems and procedures." *Antiquity*, 81 (2007): 161-175.

[34] See footnote 21.

[35] M. Ozdoğan, *Lower Euphrates 1977 Survey* (Istanbul: Middle East Technical University Keban and Lower Euphrates Projects, 1977).

ring ditch extending to the south of the main mound and defining and containing the Iron Age occupation. Consequently what had been a small multi-period mound turned into an extensive Iron Age town with ramparts, which at some 15.5 ha, proved to be the largest occupation site of the Kurban Hoyuk survey region.

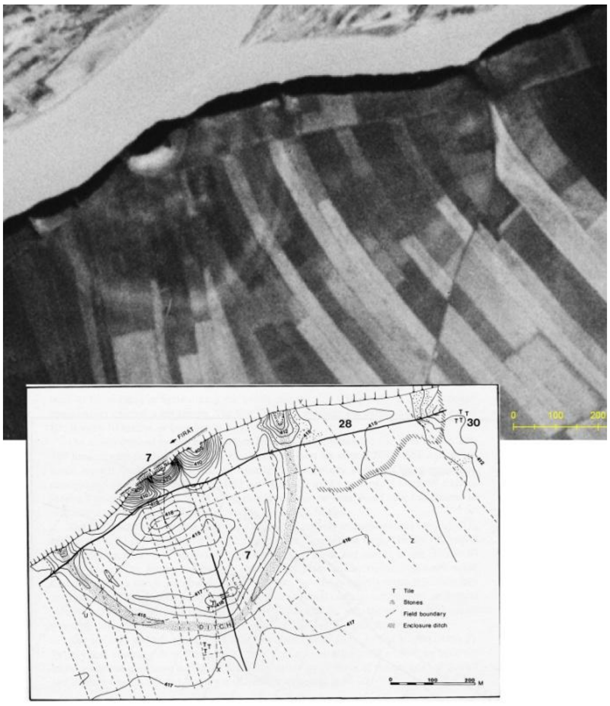

Figure 5. Top: CORONA satellite image (from 1967; USGS image, with permission) showing the site of Şaşkan Köcüktepe, with the Euphrates to the north. Below: 1 m contour map showing the semi-circular ditched enclosure visible on the CORONA image.

Confirmation of the site defined by the 1982-1983 survey came from CORONA imagery[36], and further interpretation has resulted from the combination of CORONA imagery with the initial surveys. Particularly illuminating is a pair of short but broad valleys overlooking the Euphrates immediately to the east and west of the tell (fig. 5: map). Although apparently natural valleys, when viewed in conjunction with the imagery, these appear to represent the pits that were excavated to provide mud brick for the constituent buildings of the settlement. The soft fills of these appear to have slumped and eroded out into the Euphrates to form the anomalous depressions evident on the original maps. In other words, like many sites in the Jazira region of the Fertile Crescent, the presence of pits adjacent to the long-term nucleus of settlement made it necessary for the lower town to be founded some distance beyond the initial occupation, thereby providing some geographic and perhaps social distance between any seat of long-term power and the extensive "new" town that spread around it. Thus, even though the extended lower town had been recognized by the second survey and the subsequent satellite imagery of Kennedy, the harnessing of CORONA imagery in conjuction with the original survey data have opened up new interpretational possibilities.

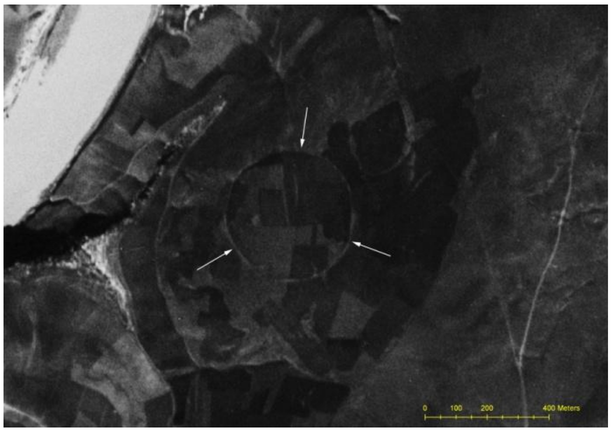

Figure 6. CORONA image showing circular feature (arrowed); possibly a Neo-Assyrian marching camp of the 9th-7th centuries BC, (USGS image, with permission).

These interpretations have been further extended by the "opportunistic" use of CORONA imagery over the greater region which have revealed a hitherto unrecognized circular enclosure downstream and to the west[37] (fig. 6). From its distinctive circular morphology and possible gateway or turret-like features around the perimeter this appears to be a circular Neo-Assyrian camp of the type that would have been used by the Assyrian kings of the 9th to 7th centuries BC during their annual military

[36] See footnote 9.

[37] See footnote 9.

campaigns in the outer empire. Satellite imagery also emphasis the pragmatic location of the putative camp overlooking a possible crossing point of the Euphrates. Because such camps were in use at roughly the same time as the site of Şaşkan Köcüktepe, together they enable us to extend our understanding of the Neo-Assyrian frontier and its associated patterns of settlement, both of local communities and Neo-Assyrians.

6 SUMMARY AND CONCLUSIONS

The FCP aims to document the patterns of Early Bronze Age urbanization over a large area of northern Mesopotamia and the Levant. Its innovation lies in the use of high resolution image and topographic data to add value to existing survey records over a vast area and to compare and contrast high quality settlement data to help reinterpret evidence for the rise of early states and civilizations. The case studes from Homs and the Kurban Hoyuk area hopefully demonstrate that new sites can be revealed and important reinterpretation of settlement pattern is possible. Although the project is still at an early stage, it is clear that our systematic use of remote sensing can identify, confirm and provide a landscape context for sites previously recorded in the field (i.e. within existing survey areas) and also provide data on areas that were not surveyed. The FCP therefore is able to extend existing surveys to encompass larger geographical areas that appear more meaningful for the analysis of questions of urban development. In time, this work will allow analysis of diversity between different sub-regions and provide us the ability to review of the settlement record over a large area but based upon a coherent set of high quality settlement data.

This is a project that has only recently become possible through the convergence of a range of digital technologies. The core methodology of the project is to re-analyze "sample" surveys, the data from which is readily available, and to re-calibrate these within a GIS framework. Two of the sample surveys, the Homs Project and the Land of Carchemish Project, are still in operation and continue to provide integrated ground control in combination with satellite imagery. This is particularly important because these projects allow us to develop our ability to interpret archaeology from imagery and help us to recognise how best to enhanced imagery for feature recognition[38]. Control for imagery does not simply derive from field work, rather the project employs a protocol based upon multiple controls. For example:

- CORONA images provide "air control" that can recognize previously un-recognized sites thereby validating the original surveys. Conversly, field surveys provide ground control for the imagery, especially because some of the surveys used a range of qualitative and quantitative definitions of soil properties.
- High resolution contour maps, some at contour intervals of 50cm, provide control for DEMs derived from CORONA stereo imagry or from the SRTM.
- Land use maps provide precise ground control for specific years[39], which therefore allow modern agricultural practices to be extrapolated over much large areas using imagery derived from those years.
- Time-sequence satellite imagery provide sequential views of the landscape that enable processes of landscape transformation to be logged and assessed.

Finally, the corpus of data that will be assembled by the Fragile Crescent Project will be archived according to guidelines set out by the Archaeological Data Service and published in their guides to good practice[40]. We recognise the problem associated with data copyright, with the sheer amount of data involved and the need to provide internet-based access to the resource for the wider research community.

[38] K.W. Wilkinson, et al. "Satellite imagery as a resource in the prospection for archaeological sites in central Syria." *Geoarchaeology* 21/7 (2006): 735-750.

[39] For example over 1982, 1983, 1984 for the Kurban Hoyuk area: Wilkinson 1990 (see footnote 20), fig. 2.7.

[40] Robert Bewley, et al. *Archiving aerial photography and remote sensing data: a guide to good practice*. Oxbow Books, 1999. http://ads.ahds.ac.uk/project/goodguides/apandrs/ (accessed June 6, 2009)

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