Article

Historical Aerial Photography of Ethiopia

Recovery & Organisation of Important Documentation from the 1930s

This article gives an account of the discovery, preservation and utilization of a large archive of historical aerial photography of Ethiopia dating from the mid-1930s. The circumstances and the rather unique technology involved in the acquisition of this archive of aerial photography are described. The photography has now been converted to digital form and constitutes an invaluable record of the landscape of the region from nearly 80 years ago. As such, it has already started to be utilized for a wide variety of projects and studies.

Jan Nyssen and Gordon Petrie

Fig. 1– The aerial photos were stored in ammunition boxes belonging to the Italian army, which were left behind when it withdrew from the city of Addis Ababa in 1941. (Source:Prof. J. Nyssen)

1. Introduction & Background

The use of historical aerial photographs has become ever more common with the huge archives of coverage from World War-II becoming of ever greater interest and importance to planners, developers and scientists, especially in the countries of Western Europe. However, recently, a large archive of even older war-time aerial photography has come to light, still further afield – in Eastern Africa. It comprises the coverage of ***Northern and Central Ethiopia*** that was acquired during the Italian invasion of the country in 1935-36 and during the period of occupation that followed. This activity ceased after the defeat of the Italian army in East Africa in 1941 during World War-II.

This remarkable archive of aerial photography was discovered (or re-discovered) in the basement of the ***Ethiopian Mapping Agency (EMA)*** in Addis Ababa where it had been stored in ammunition boxes that had belonged to the Italian Army [Fig. 1]. In total, the archive comprises approximately 34,000 individual photographs, made up of 8,281 discrete assemblages, each comprising four adjacent photographs [Fig. 2]. An individual group or set of four photographs comprises a vertical (nadir-pointing) photo, flanked by two low-oblique photos and a single high-oblique photo [Fig. 3]. All four photos had been exposed simultaneously in a fan configuration in the cross-track direction (at right angles to the flight line) to ensure the widest possible angular coverage of the terrain. Each successive set of four photos overlaps on the previous set by approximately 60% in the along-track direction, thus ensuring 3D stereo-coverage of the terrain. The format size of each individual photograph in the archive is 10 x 15 cm.

Each set of four photos in the archive has been mounted as an ***unrectified print laydown***, glued on to a 50 x 20 cm hardboard tile, with each set identified by a label. [Figs. 1, 2 & 3] As a result of an agreement between Ghent University (Belgium), the Ethiopian Mapping Agency (EMA) and Mekelle University (Ethiopa), all the photos in the archive have been transformed into digital form at the EMA offices in Addis Ababa using an A3 scanner with a resolution of 600 dpi. Besides which, the scanned photos have been carefully organised into a searchable inventory.

2. Acquisition of the Original Aerial Photography

The acquisition of this systematic aerial photographic coverage began immediately after the Italian invasion of Ethiopia in October 1935. The main objective of the coverage was to provide the raw material for the rapid production of topographic maps of the area of Northern Ethiopia lying immediately adjacent to Eritrea – at that time, the Italian colony from which the main

Fig. 2 – Dr. Kiros Meles (Mekelle Universty, left), Prof. Jan Nyssen (Department of Geography of Ghent University, centre) and two staff members of the Ethiopian Mapping Agency show examples of the historical aerial photographs that had been preserved in the Agency's headquarters in Addis Ababa. (Source:Prof. J. Nyssen)

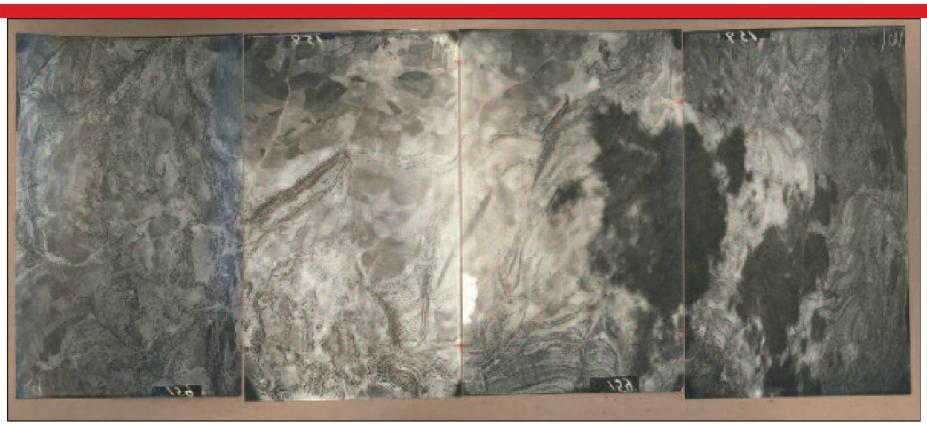


Fig. 3 – An example of a set of four photographs comprising – from left to right – low oblique; near-vertical; low oblique; and high oblique exposures in a fan configuration covering the Hauzien area in Northern Ethiopia. (Source: Ethiopian Mapping Agency)

invasion was mounted. This particular area of Northern Ethiopia had only been mapped at a very small-scale prior to the invasion through simple ground surveys conducted along the main routes in the border area by an Italian officer in civilian clothes. Thus the very large areas of rugged mountainous terrain lying between these routes were completely unmapped.

The topographic mapping that resulted from the newly flown aerial photographic coverage was produced very rapidly by a unit (called the 7th Topocartographic Section) of the ***Italian Military Geographical Institute (IGMI)***. This unit, which was equipped with extensive photographic, photo-mechanical and printing facilities, had been set up prior to the invasion in a specially-built facility located in Asmara, the capital of Eritrea. A three-engined, high-wing Caproni Ca-101 D2 transport aircraft [Fig. 4] and crew were provided by the Italian Royal Air Force (Regia Aeronautica) to undertake the flying of the aerial photographic coverage.

Because of the urgency with which the maps had to be produced from the aerial photography for use by the invading army, initially the resulting maps were mainly ***planimetric*** in terms of their content. This planimetric information was supplemented by rough ***form lines*** (not measured contours) that were used to show the relative heights and the shape and character of the land forms of the terrain. These form lines were produced by the map compilation staff undertaking the 3D stereo-viewing and interpretation of the photos using mirror stereoscopes [Fig. 5] – with the terrain form lines being drawn in to fit the drainage pattern.

These rapidly produced maps were supplemented by numerous ***rectified mosaics***. More detailed and more accurate maps at 1:50,000 and 1:100,000 scales were produced later for the same areas, once the Italian army had occupied them and the IGMI ground surveyors had access to the actual terrain to establish the required triangulation and ground control points and record the toponymy (place names). After the Italian army had occupied Northern Ethiopia, later aerial photographic flights covered the routes leading to the south towards the Ethiopian capital, Addis Ababa, along which the Italian army advanced to capture the city in May 1936.

3. Instrumentation for Photography & Mapping

The instrumentation that was used for the acquisition of the aerial photography and the subsequent mapping had been designed by the famous Italian photogrammetrist, ***Ermenegildo Santoni***, who, at that time, was employed by IGMI at its headquarters in Florence.

3.1 Aerial Cameras

Prior to the war, in 1933, Santoni had designed his ***Model II glass-plate camera***. [Fig. 6] The actual cameras were built by Officine Galileo, the well known Italian optical instrument manufacturer, whose factory was also based in Florence, not far from IGMI's headquarters. Each Model II camera comprised two separate cameras coupled together to operate as a single integrated unit, so ensuring simultaneous exposures to the left and right of the flight line – with a slight overlap between them. [Fig. 7] Thus the Model II was a twin camera unit, equipped with two lenses, with each lens having a focal length (f) of 175 mm. The twin cameras used photographic glass plates to record the resulting images in the two separate focal planes, with each negative image being 10 x 15 cm in size. Each of the two rotating cylindrical drum magazines held 200 of these glass plates.

For the purposes of "colonial mapping" in Libya and East Africa, where a much wider angular coverage of large areas of terrain in a single set of exposures was required for the purposes of small-scale mapping, Santoni devised a ***four-coupled version*** of the Model II camera. This comprised two of the twin camera units coupled together, along with his special ***solar periscope***. [Fig. 8] The latter was an auxiliary camera pointing vertically upwards from the top of the aircraft. This additional camera exposed images of

Fig. 4 – A three-engined high-wing Caproni Ca-101 D2 aircraft flying over the rugged terrain of Northern Ethiopia during the Italian invasion. (Source: Wikipedia; Original Source: www.finn.it/regia/immagini/caproni/caproni_ca101.jpg)

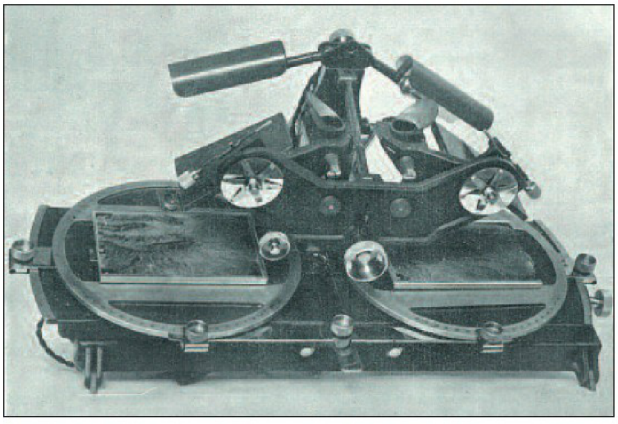


Fig. 5 – A table-mounted mirror stereoscope used by IGMI personnel to create and interpret the visual 3D stereo-models formed from the overlapping aerial photos. (Source: IGMI.)

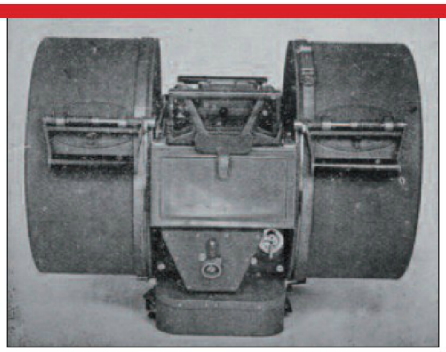


Fig. 6 – A Santoni Model II camera with the two rotating drum magazines containing the photographic glass plates mounted on either side of the camera. The twin camera cones with their focal planes, lenses and shutters occupy the space between the two cylindrical drums. (Source: IGMI Museum)

the Sun on to ***photographic film*** at the same instant as the exposures were being made by the terrain-pointing glass plate cameras in the main four-coupled camera unit. The resulting solar images allowed the determination of the tilts of the set of four terrain-pointing photos at the moment of their exposure. This information was used as an aid in the provision of control points through a special form of aerial triangulation.

For the Ethiopian campaign, the solar periscope unit was mounted on a tall metal framework which was itself mounted on a metal stand that was constructed by the Mechanical Workshop of IGMI [Fig. 8 (a)]. This metal stand allowed the main four-camera unit to be ***rotated (oscillated or rocked)*** around its horizontal axis between successive sets of exposures, thus allowing the exposure of the high-oblique photographs alternately to the left and right of the flight line. [Fig. 9] Figure 8 (b) shows the installation of the four-camera unit over the hole that had been cut in the floor of the ***Caproni Ca-101 D2*** aircraft to act as the camera window. The metal stand and part of the frame that supported the solar periscope can also be seen.

When flown from a height of 4,000 m above sea level (2,000 m above average ground level), the scale of the resulting photography was approximately 1:11,500 for the central photos and 1:16,000 to 1:18,000 for the two low-oblique photos. However some flights were operated at higher altitudes – up to 4,500 m above sea level (2,500 m above average ground level) – in which case, the scale of the near-vertical photos would be approximately 1:14,000 and the oblique photos correspondingly smaller in scale. Of course, these values could vary considerably across an individual photo due to relief displacements, especially given the mountainous character of much of the terrain of Northern Ethiopia.

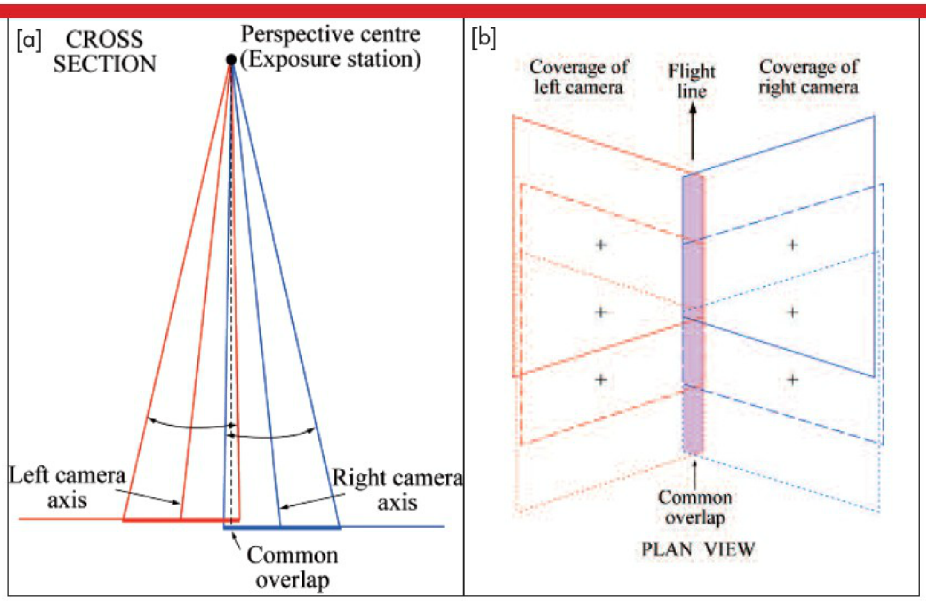


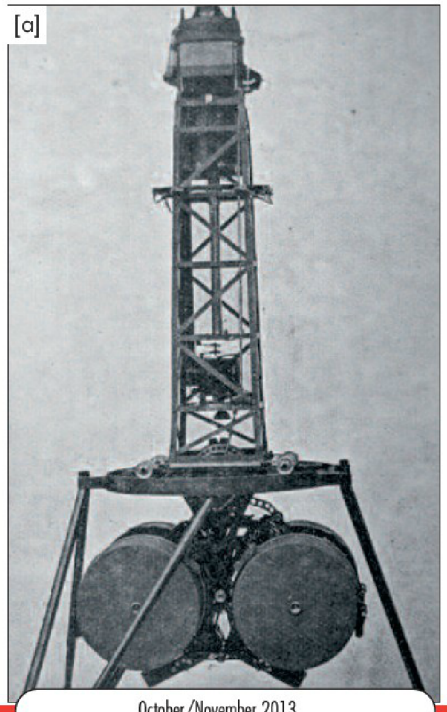
Fig. 7 – Diagrams that show (a) the angular coverage; and (b) the ground coverage of the Santoni Model II camera. (Drawn by Mike Shand)

3.2 Photogrammetric Instrumentation

Besides the four-coupled camera units, Santoni had also designed and had built a remarkable small transportable stereo-plotting instrument called the ***Stereosimplex***. [Fig. 10] This was the forerunner of the well-known series of Stereosimplex II, III, G6 and G7 instruments that came into widespread use on a world-wide basis during the later decades of the 20th Century. Unlike these later instruments, which featured a purely mechanical projection system, this original Stereosimplex was based on optical-mechanical projection.

Santoni also designed and built two ***fixed-angle optical rectifiers*** [Fig. 11] which eliminated the main angular tilt values of the low-oblique and high-oblique photographs respectively that had been acquired by the four-coupled camera. Because of the Italian army's needs for very rapid mapping, apparently the Stereosimplex instruments were not much used initially. However the rectifiers were used extensively from the start to produce rectified same-scale and enlarged prints from the low- and the high-oblique aerial photos. Much of the initial mapping was compiled from these prints by first using graphical radial triangulation methods to produce a framework of control points, within which, the planimetric maps were then compiled by tracing off the planimetric detail (roads, tracks, rivers, buildings, etc.) from the rectified photos.

4. Use of the Historical Aerial



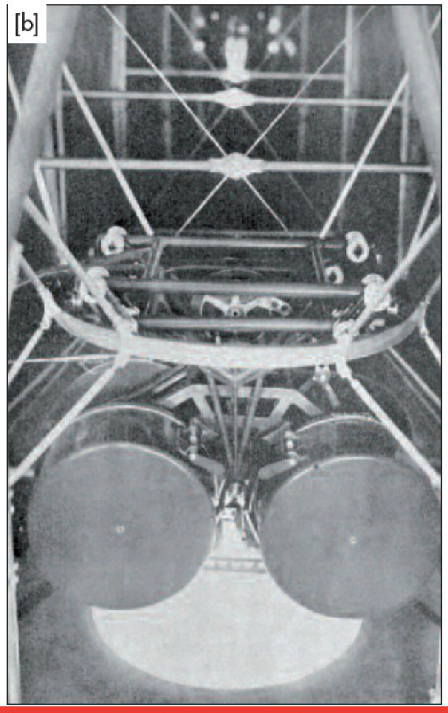


Fig. 8 (a) – The four-coupled version of the Santoni Model II camera, complete with its solar periscope. (Source: IGMI Museum) (b) – The installation of the four-coupled version of the Santoni Model II camera over the hole (which acts as the camera window) in the floor of the Caproni Ca-101 D2 photographic aircraft. (Source: IGMI)

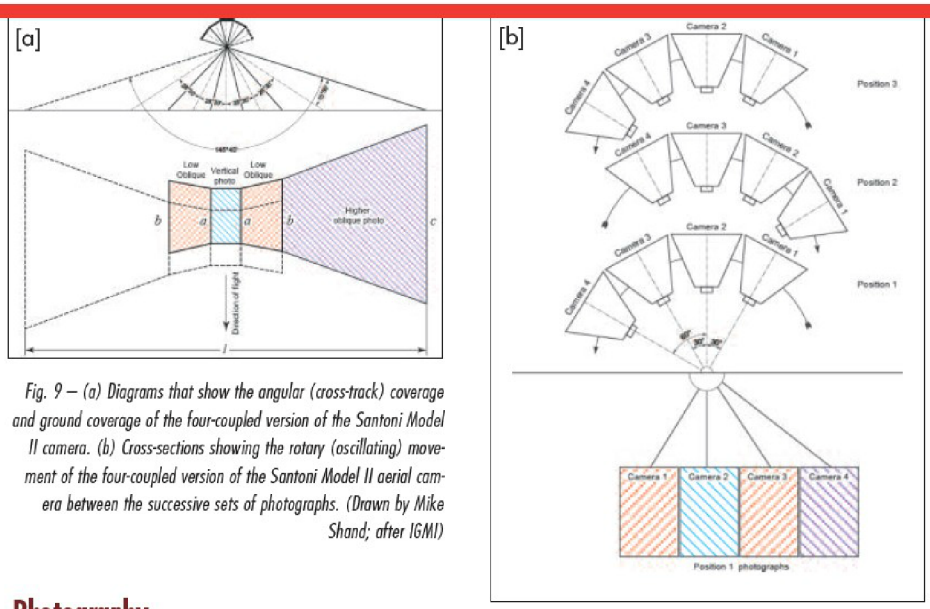


Fig. 9 – (a) Diagrams that show the angular (cross-track) coverage and ground coverage of the four-coupled version of the Santoni Model II camera. (b) Cross-sections showing the rotary (oscillating) movement of the four-coupled version of the Santoni Model II aerial camera between the successive sets of photographs. (Drawn by Mike Shand; after IGMI)

Photography

These historical aerial photographs of Northern and Central Ethiopia show the existence (or absence) of features such as buildings, structures, communication routes, etc. and the state of the land forms, land cover, land use and drainage pattern at the particular point in time when they were taken. Needless to say, nowadays this information is invaluable to those concerned with the ***planning, conservation and development*** of this particular area – which has suffered greatly from wars, droughts, crop failures, famine and physical degradation in the 77 years that have elapsed since the aerial photography was acquired.

A few representative examples of the use to which these historical aerial photos have already been put by the Department of Geography of Ghent University include their analysis to detect the changes in the ***land cover, land use and physical geography*** (including the hydrology and geomorphology) of the area by comparison with imagery from the GeoEye-1 satellite taken in 2005. [Fig. 12] In the aerial photograph of the area near Nebelet (Tigray), Dr. Amaury Frankl has shown that there were fewer terraces in 1935 (left) on the fields **(1)**, but that their edges were better covered **(2)**. The channels **(3, 4)** which are visible in 2005 (right) were only covered depressions in 1935. The temporary river **(5)** was narrower in 1935. Circles indicate two large trees which have passed the test of surviving more than 70 years of substantial changes in the landscape.

Changes in the ***towns and cities*** are more far-reaching. Thus Mekelle, the capital of the regional state or province of Tigray, has changed from being a small "medieval"

Fig. 10 – The transportable Stereosimplex stereo-plotting instrument, which was based on optical-mechanical projection, was designed by Santoni and built by Officine Galileo. (Source: IGMI Museum)

town to being a modern city with more than 200,000 inhabitants. One can easily recognize certain historic buildings on both the aerial photograph from 1935 and the Google Earth image from 2012. [Fig. 13] The river network and the pattern of the main roads have remained largely preserved. This particular historical photo was acquired by the 7th Topocartographic Section on 4th November 1935. On 8th November, the Italian army advanced and occupied the town.

5. Conclusion

The historical aerial photography will obviously be of great value to ***scientific studies*** of the area involving disciplines such as geomorphology, hydrology and biology, and the associated mapping of vegetation, land cover and land use. Indeed studies of this type are already being undertaken in order to fully understand the environmental changes that

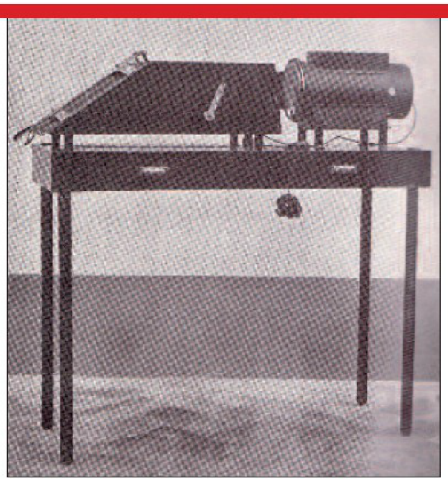


Fig. 11 - An example of one of the fixed-angle optical rectifiers that were designed by Santoni. (Source: IGMI.)

have been taking place in the region. However it is hoped that the historical aerial photography will also be of ***direct practical value*** to the local population. Thus, for example, given that food production is a matter of major concern to all of the communities of Northern Ethiopia, it is hoped that the information provided by the historical aerial photography – through the resulting comprehension of the changes that have occurred over the past 80 years – can make an important contribution to the planning and implementation of measures such as erosion control; the rehabilitation of land through terracing; improved land management; water conservation; reafforestation; crop diversification; etc. that are being undertaken to help provide the much-needed food security.

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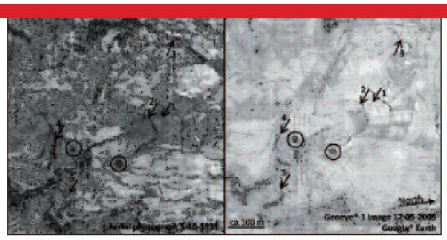

Fig. 12 - A comparison of an aerial photograph covering an area near Nebelet (Tigray, Ethiopia), that was acquired in 1935, and the corresponding GeoEye-1 satellite image acquired in 2005. (Source:Ph.D. Thesis, Dr. A. Frankl.)

Development Coordinator) of the Ethiopian Mapping Agency (EMA) and Dr. Kiros Meles and Prof. Mitiku Haile of Mekelle University – in the efforts to conserve this unique archive. The close cooperation and devoted efforts of colleagues at Ghent University – especially Dr. Amaury Frankl, Prof. Philippe De Maeyer and Ms. Valérie Seghers – have been fundamental in initiating and undertaking various projects to exploit this fantastic resource. Ms. Yetemwork Dejene and Ms. Shewaye carried out the scanning work at EMA and Mr. Martijn Debever organized the scanned aerial photographs by flight lines at Ghent University.

The authors would also acknowledge the most useful background information and material provided in the IGMI publication "Istituto Geografico Militare in Africa Orientale 1885-1937" – which has been used extensively in the preparation of this article.

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Fig. 13 - (a) A comparison of the aerial photograph covering part of the town of Mekelle (Tigray, Ethiopia), that was acquired in 1935, and the corresponding Google Earth image of the city that was acquired in 2012. (Sources: EMA and Google)
(b) An oblique aerial image of Mekelle taken in 1935 showing the Church of Enda Mariam and the Palace of Atse Yohannes (Emperor John). Both buildings can clearly be seen in the two near-vertical images that are being compared in Fig.13 (a). (Source: IGMI)