Geodetic field operations for cartography: an overview over the first Portuguese geodetic mission in the colonial territories (1907-1910)

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Key words: Geodesy, MGAO

SUMMARY

The independence of the American colonies put off European attention to Africa. Institutions especially devoted to African studies were created in many of those countries and expeditions were made enhancing the need of an organized and complete scientific occupation of those countries as recognized by the Conference of Berlin.

Within this context, the Portuguese Commission of Cartography was created in 19 April 1983 in view of the elaboration and publication of the cartography of all the Portuguese colonial territories as well as other geographic studies related to them.

Mozambique was the first territory being object of geodetic works for trigonometric covering with the necessary accuracy to the cartographic and cadastral needs. For that was created the Geodetic Mission of Eastern Africa, 1907-1910, usually known by Gago Coutinho´s mission, considered the pioneer mission in the area of the scientific and operational geodesy.

SUMÁRIO

Com a independência das suas colónias americanas as atenções dos países Europeus transferem-se para África. Na Conferência Internacional de Berlim, 1884, é enunciado, como modo de legitimação de um território africano, o princípio da "ocupação efectiva" que não atende a direitos históricos mas ao seu conhecimento geográfico.

Para proceder a esses estudos o governo português havia instituído, em Abril de 1883, a Comissão de Cartografia que, para o efeito, criou as Missões Geográficas.

Moçambique foi o primeiro território a ser objecto de operações geodésicas com vista à sua cobertura trigonométrica regular, com precisão apropriada para atender às necessidades cartográficas e de cadastro. Para a execução de tais operações foi criada a Missão Geodésica da África Oriental (1907-1910). que ali operou durante quatro campanhas.Conhecida por Missão de Gago Coutinho, seu chefe, é considerada a missão pioneira no domínio da geodesia operacional e científica.

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1. PREVIOUS NOTES AND HISTORICAL BACKGROUND

After the historical period of the discoveries, Portuguese cartography had a special increment in the early 18th century with the elaboration of Brazil maps and their frontiers.
The independence of the American colonies put off European attention to Africa. Institutions especially devoted to African studies were created in many of those countries and expeditions were made enhancing the need of an organized and complete scientific occupation of those countries as later officially recognized by the Conference of Berlin. Within this context, the Portuguese Commission of Cartography was created in 19 April 1983 in view of the elaboration and publication of the cartography of all the Portuguese colonial territories as well as other geographic studies related to them.
By request of Portugal, the German Chancellor Otto Bismark organized the Berlin Conference, held between the 15th of November 1885 and 26th February 1886, with the presence of 14 European countries, to discuss and sketch what would be the new map of Africa.
The decisions taken commend the possible partition of Africa between the European great powers and offer them the opportunity to divide the African territory in 50 countries disregarding any existing cultural or linguistic boundary related to the indigenous African population.

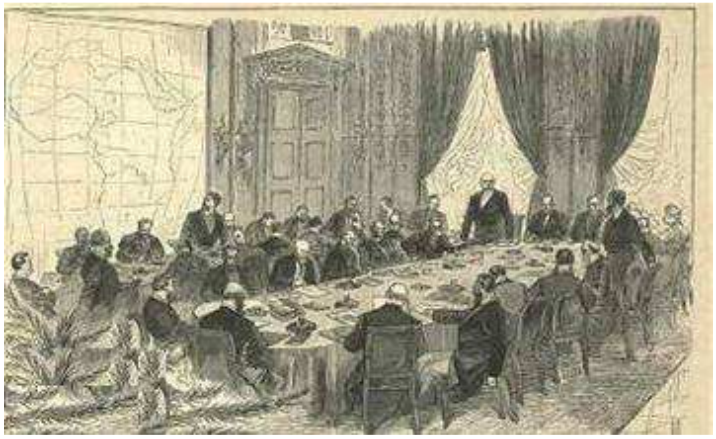


Fig.1 – Berlin Conference, 15 Nov.1884 – 26 Fev. 1885

These decisions were supported by the so called "Principle of Effectivity". Imposing an effective occupation of the African territories, the acceptance of this principle forced the Europeans to ensure they could extend their sovereignty to the local cheiftancies. In the new

colonial territories, Europeans had to be able to flew their flag, to establish and control the local administration, to set up a police force to keep order and to make use of the colony economically. And all this supposed the geographical knowledge of the territory, the existence of a reliable cartography and the definition of its boundaries A new phase will began.

Within this context, during the last quarter of the 19th century, the Portuguese Commission of Cartography worked in different African territories and was involved not only on the technical and scientific work related to the cartographic coverage of these territories, but also on the necessary diplomatic workings in view of the definition of the frontiers of the African territories under Portuguese sovereignty.

In fact, to bring about the development of a country it is indispensable the previous knowledge and mapping of its resources; reason why geodetic works were needed to provide the necessary accuracy. For this purpose the Commission of Cartography created temporary geodetic Missions for specific tasks related to the production of a determined cartographic document.

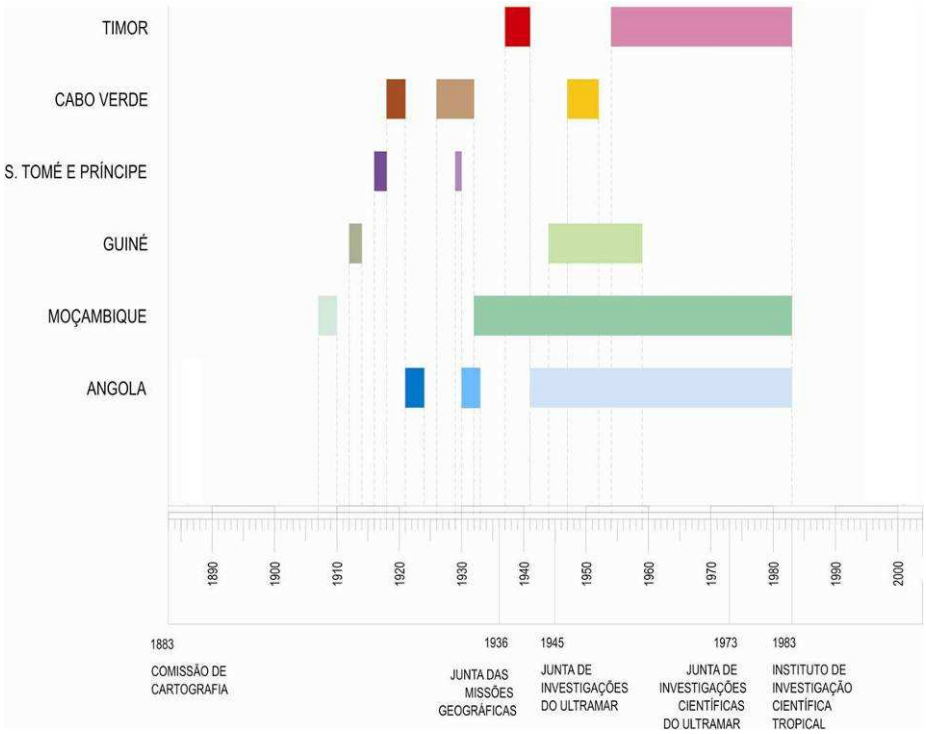


Fig.2 – Geodetic Missions between 1883 and 1983

Year after year, the missions created by the PCC, endowed by great sacrifice and efforts and sometimes taking one's own life covered geodetically the Portuguese overseas countries and contribute to an accurate cartography.

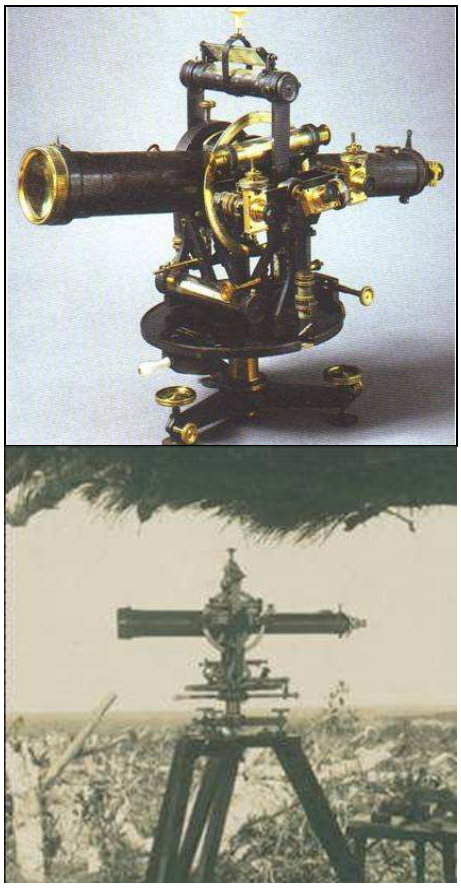
2. THE ADMIRAL CARLOS VIEGAS GAGO COUTINHO (17.2.1869 – 18.2.1959)

Born in the 17th February 1869, he was a military from the Portuguese navy. He studied at the Polytechnic School in 1885-1886, before entering the Naval School. After completing his course there in 1888, he took part in 1889 of the garrison of the corvette Alfonso de Albuquerque during the military operations of Tungue. Between 1889 and 1917 he was a delegate, from Portugal, for the demarcation of the frontiers of Timor, Mozambique and Angola and starts the geodetic covering of the south of Mozambique and S. Tomé.
Between March and June of 1922 he gained international distinction when he and Commander Artur de Sacadura Freire Cabral, aboard the modest 350-horsepower hydroplane Lusitania, accomplished the aerial crossing from Lisbon to Rio de Janeiro. This was the first time that aerial navigation was accomplished by specific procedures for aerial navigation. Gago Coutinho made use of navigation tables especially adapted for this purpose and a sextant of his own invention.
In 1925 he became president of the PCC, creating and supporting geodetic missions in the field and began his studies about the history of nautical during the period of the Portuguese discoveries.
But he considered itself mostly a "colonial geographer" since he lived 20 years in the African backwoods in the open air sleeping in camping tents. During this period he crossed Africa twice and ensured the delimitation of more than 2000 km of frontiers and more than 900 Km^2 of triangulation.

1898	Delegate for the demarcation of Timor frontier
1900	Delegate for the demarcation of Zambeze frontier
1901	Delegate for the demarcation of North Angola (Noqui to Cuango) frontier
1904	Delegate for the demarcation of Tete frontier
1907	Chief of Geodetic Mission of Eastern África
1912	Delegate for the demarcation of Barotze frontier
1915	Chief of Geodetic Mission of São Tomé and Príncipe

Fig.3 – Gago Coutinho Geographical field works

A precise surveyer, with good knowledge of mathematics and physics, he used his experience from the navy in the field operations, adapted some methodologies to the difficulties of the field work in Africa and made exhaustive studies of the instruments used; one of them constructed under his own specifications to adapt it to the specific conditions in Africa. Gago Coutinho was the first Portuguese geographer measuring baselines with invar wires that he tested for several years.
He also contributed for the creation of the Geographical Engineering Course to civil persons, in Portuguese universities that would be *an interesting and well payed carreer to unembarrassed boys*.



MAKER: Filotécnica A. Salmoiraghi & C., Milan, Italy

DIMENSIONS: height 40 cm, telescope length 70 cm

HISTORY: Is one of four identical instruments made by Salmoiraghi in 1909 for Colonial Office by specifications of the Admiral Gago Coutinho, a famous Portuguese geographer. In order to provide highest accuracy was required a covered horizontal circle, graduated to 4' and read by micrometers to 2" and scales engraved in platinum to avoid oxidation, so common in tropical climates. During the first field campaign in Mozambique, Gago Coutinho noticed that the instrument was far from ideal being its principal defects the ocular thumbscrew and the circles very difficult if not impossible to engrave accurately at that time. Some improvements made it operational until 1921.

Fig.4 – Theodolite Salmoiraghi constructed under specifications of Gago Coutinho for the geodetic mission of Eastern Africa

During his work all the operations contributing to the geodetic covering of one country - recognition, measurements of azimuthal and zenithal angles, astronomical determinations and measure of baselines - were exhaustively described in several reports that, later on, served as a guide to other geographers.

3. THE GEODETIC MISSION OF EASTERN AFRICA (MGAO)

Mozambique was the first territory being object of geodetic works for trigonometric covering with the necessary accuracy to the cartographic and cadastral needs. The Geodetic Mission of Eastern Africa (1907-1910), was created for this purpose. Directed by the Admiral Gago Coutinho, it is considered the pioneer mission in the scientific and operational geodesy.

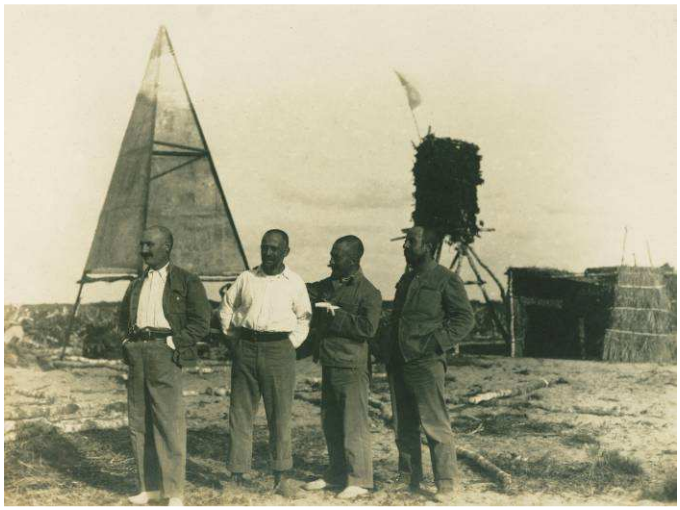


Fig.5 – Field Team in Banzú: Filipe Vieira da Rocha, Gago Coutinho, Sacadura Cabral, Filipe Dias de Carvalho (from left to right)

3.1 Geodetic operations

The geodetic covering of a territory to support cartography consists in some operations: recognition, measurements of azimutal and zenital angles, astronomy, measurements of bases, and after 1950 levelling and gravimetry. In the first years the cartographic survey was made simultaneously with the geodetic and the map designed in the field with an alidad and a plane-table.

3.1.1 Recognition

Using a compass and a podometer, the field team walked, by foot, with a local guide, throughout the area to be mapped in order to choose the appropriate local to build the benchmarks. These benchmarks, usually placed on the top of the mounts, define the triangulation chain. In plane ground that work was much more difficult. Sometimes it was necessary to pave the way cutting some kilometers of forest vegetation. Gago Coutinho said: *it was necessary to use techiques similar to navigation like to set a course with the compass,… , recognize land and make observations with the sextant at the top of the trees, to sound, …, to find the most highest and suitable point, …*

Fig.6 – Checking inter-visibilities from the top of a tree.
Measuring with the sextant (from left to right)

3.1.2 Measuring azimuthal and zenithal angles of the triangulation network

The triangulation network consists in a sequence of triangles carefully choosed to decrease the influence of the observations errors and to allow checking the results. The vertices of the triangles are materialized by benchmarks signalized with wood, metal or bright signs like heliums (day) or projectors (night) to guarantee the visibility. The distance between them depends of the topography and accuracy standards, but usually is 30 km. Azimuthal and zenithal angles of the triangles are measured with a theodolite.

In 4 campaigns including 26 months of fieldwork Gago Coutinho and his team established a benchmarks covering Mozambique coast from the south frontier to Bazaruto´s lighthouse. To measure the angles were used the theodolites Salmoiraghi (Fig.4) and the projectors were similar to those used in the triangulation works to link Italy to Sicily island. Sometimes, due to existent obstacles or the curvature of the earth, those measures were done at the top of wood towers to assure inter-visibility.

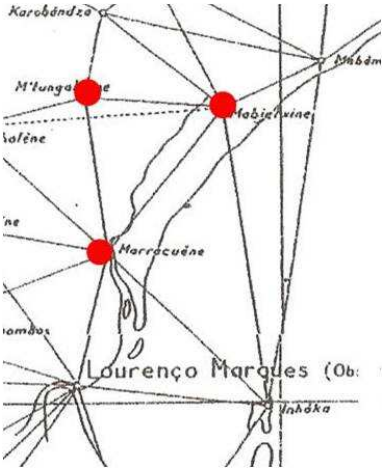


Fig.6a – part of the triangulation chain, N´Tungluane tower and projectors, *Landins* pointing heliotropes

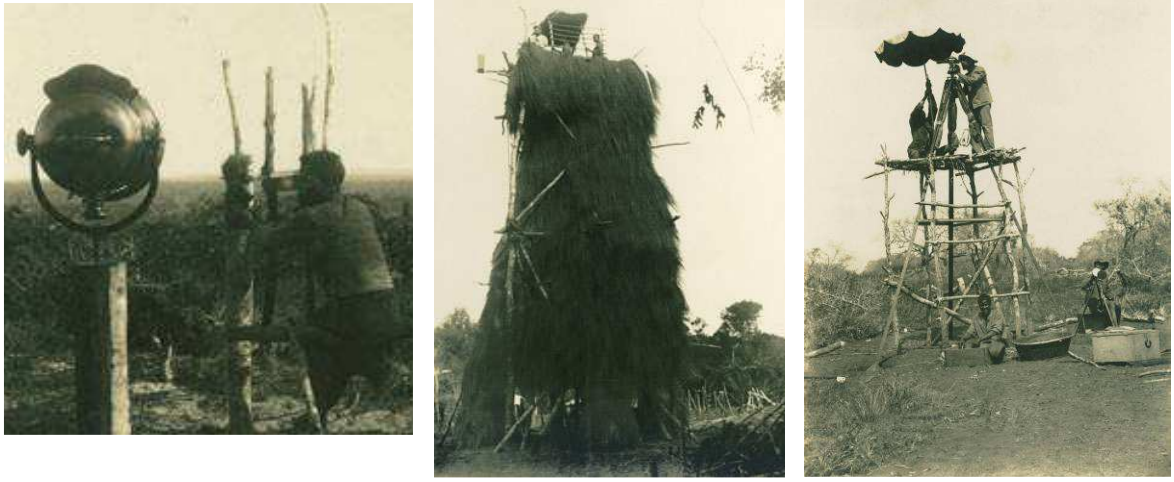


Fig.6b – projector; 10 m tower lined with straw; measuring angles (up, down, from left to right)

3.1.3 Measure of baselines

To scale the geodetic network were measured, every 200 km, lines about 10 km called baselines. During 6 decades in those measures were used invar wires. Built by Carpentier those wires were submitted to special treatments that guarantee nearly the invariableness of its length, (8, 24 the most used or 48 m) allowing a great accuracy of these measurements.
As said before Gago Coutinho was the first Portuguese surveyor using invar wires, precisely in this geodetic mission. For a long time he studied hardly this equipment concluding that after 10 years of use, the invar wires reach its final lengthening of a third of a millimeter and using the appropriate procedures it was possible to obtain a geodetic accuracy of 1/1000000.
A requisite for a baseline is to have a plane ground without obstacles. A special tripod is placed each 24m, to support the wires which tension is regulated by a 10 kg weight. In a special graduate reference - reglette - the field operator read the values to sum or deduct to the 24 meters. And so on till covering the baseline length. The MGAO measured two baselines in Mozambique, Inhambane (8km) and Manhiça (12 km).

Fig.7a – some procedures of measuring baselines: (from left to right) to make way to measure Manhiça baseline; leveling; alignement of the tripods

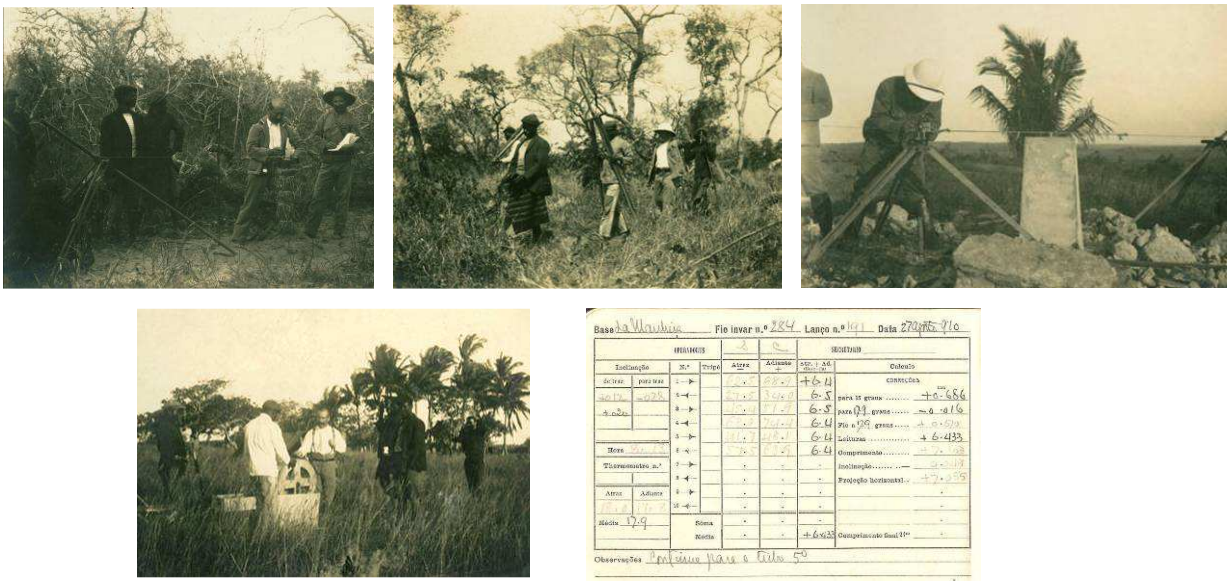


Fig.7b – (from up to down, left to right) reading the reglette and registe of the respective value in the field note book;moving the invar wires to the next front length; reading the reglette at the end of the baseline; keeping the invar wires in an appropriate box for transportation; one page of the field book

3.1.4 Astronomical observations

The geodetic network is positioned through a fundamental point called *datum* where astronomical observations of latitude and longitude are done and oriented by mean of astronomical azimuths. The methodology used depends of the characteristics of the territory and the technical equipment of the mission. Generally it consists in observing a group of visible stars selected in a catalogue that gives their position for the period of observation and suitable for the methodology selected.
Using a theodolite Troughton & Simms the MGAO observed 2 azimuths and latitudes by a method adapted by Gago Coutinho. As it was not possible to determinate longitude for lack of the adequate instruments these values were obtained from the Astronomical Observatory of Cape Town through the geodetic points of the frontier and the Transvaal triangulation.

3.1.5 Cartography

In those times, maps were drawn directly in the field by the geographical missions supported by technicians of the Cadastral Services.
With a plane table and an alidad the hills, valleys, courses of rivers, villages were drawn in a cartographic document. The alidad´s observations were completed by telemeters measurements of distances and barometers for heights. The toponymy was collected in the villages.

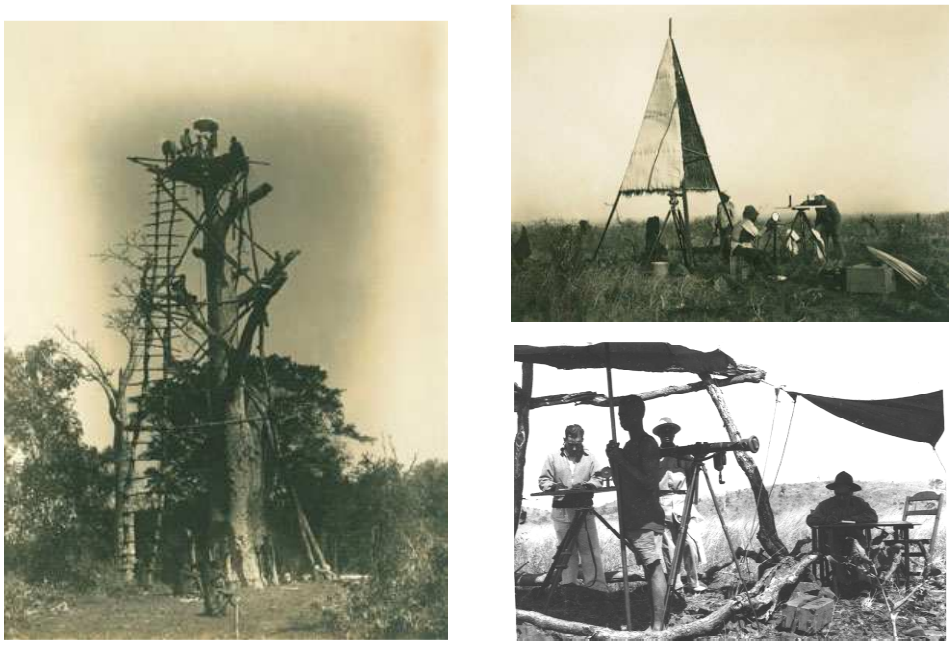


Fig.8 – Cartographic station, Boabá, 16 m (left); Plane table and alidad (up); Drawing the cartographic document (down)

4. FINAL NOTE

The work of the MGAO was continued by the Geographical Mission of Mozambique in 1932. This first work was very relevant for the progress of a scientific cartography and contributed, along with the later missions, for the setting up of a general geodetically covering of all the Portuguese overseas colonies as well for the production of a modern cartography still in use nowadays.

ACKNOWLEDGEMENTS
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BIOGRAPHICAL NOTES

Paula Santos is a researcher in geographical engineering at Tropical Research Institute. She works in the analysis of the geodetic (triangulation, leveling and gravimetric) networks established in the CPLP countries, global positioning and navigation satellite systems to reinforce and update those networks, geodetic monitorization of risk areas of natural disasters, CPLP countries frontiers, GIS and interdisciplinary projects in the scope of cartography, frontiers and geodetic mission´s history.

Ana Cristina Roque is a researcher at the Tropical Research Institute in Lisbon. Has a PhD in History of Discoveries and Expansion and works mainly in projects related to the History of Mozambique. Presently she coordinates a project on the Portuguese scientific missions of the 18^{th} - 20^{th} centuries, in the former Portuguese colonies, with a special focus on the border's process and the scientific knowledge used and produced during this process, namely in terms of cartographical representation.

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