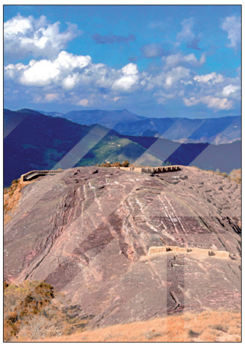

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Samaipata project – aim of the research, methodology, and methods of documentation

Projekt Samaipata – cel badań, metodologia i metody dokumentacji

Introduction

El Fuerte de Samaipata is a pre-Hispanic archaeological site in Bolivia on the eastern slopes of the Andes. It lies at an altitude of ca. 1890–1925 m in Florida Province, about 80 km (in a straight line) south-west from Santa Cruz de la Sierra.

Due to its outstanding historical and cultural values, El Fuerte de Samaipata was inscribed on the UNESCO World Heritage List in 1998. The whole site covers an area of about 40 ha and consists of two main parts:

– An administrative and ceremonial complex of ca. fifty buildings typical for provincial Incan architecture located in the southern part of the site;

– A natural rock (ca. 80 × 250 m) in the northern part of the site (Fig. 1).

The rock was the main subject of the project "Architectural examination and complex documentation of Samaipata (Fuerte de Samaipata/Bolivia) site from the World Heritage List". The rock is covered with a complex arrangement of terraces, platforms, ramps, niches, water reservoirs, and channels. Numerous zoomorphic and geometric petroglyphs are scattered between them.

El Fuerte de Samaipata owes its present form to almost 1200 years of activity of various local pre-Colombian cultures for which the rock was a sacred place (*wak'a*). The final shape of the rock, which today is one of Bolivia's most important tourist attractions, was probably carved in the 15th (2nd half?) or at the beginnings of the 16th century, when the Samaipata region was incorporated into the Inca Empire (*Tawantinsuyu*).

The earliest references to Samaipata come from 16th-century Spanish chronicles [1], but it was only in the 1st quarter of the 19th century that it became of interest for Old World science thanks to the work of Alcide Dessaline d'Orbigny [2]. Systematic scientific research only began in the 20th century [3], [4]. The establishment of the Archaeological Research Centre in Samaipata (Centro de Investigaciones Arqueológicas en Samaipata, CIAS) [5] in 1970 and the activity of German scientists associated with the University of Bonn [6]–[12] contributed to the intensification of this research.

Origin of the project

The interest of Polish researchers in the Samaipata site dates back to the years 1993–1994, when a group of students

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Fig. 1. El Fuerte de Samaipata as seen from the south (photo by J. Kościuk)

at the Institute of Archaeology of the University of Warsaw were invited by Józef Szykulski to visit the site. Szykulski was a Polish archaeologist from the University of Wrocław who at that time was a member of the German Samaipata Archeological Research Project (Proyecto de Investigación Arqueológica de Samaipata, PIAS) that was cooperating with the University of Warsaw. Later, one of the German PIAS researchers, Anja-Kathrin Meinken, participated in the work of the Polish research project known as "Condesuyos" (Arequipa, Peru) in 1999 and 2004. She compared the *kallanka* of Samaipata with similar constructions discovered by the Polish team at the Inca sites located in the Coropuna and Solimana regions. These early contacts provided Polish scholars with important and valuable information about Samaipata, and raised their interest in this emblematic site. It is also worth mentioning that in the years 2007–2014, a Polish–Italian–Bolivian team was carrying out the Tiwanaku–Kantatallita archaeological project at the site of Tiahuanaco.

In 2014, Mariusz Ziółkowski, the Polish co-director of the project at Tiahuanaco and the head of the Centre for Pre-Columbian Studies of the University of Warsaw in Cusco (CEAC), made a working visit to Samaipata at the invitation of the then-director of CIAS, Richard Alcázar de la Fuente. During this visit, the outline of a high-resolution 3D documentation project of the entire rock, together with all the engravings, was created.

The Bolivian side – CIAS and the local authorities of the Department of Santa Cruz – were aware of similar projects that had been implemented in recent years by the Polish team in the National Archaeological Park of Machu Picchu (Peru) and also of the Polish–Italian–Bolivian project at the Tiwanaku site. With this background, in November 2014, CIAS and Frank Herrera Bassta, at that time mayor of Samaipata, issued an official invitation to Mariusz Ziółkowski. He in turn invited Jacek Kościuk – the head of the Laboratory of 3D Scanning and Modeling (LabScan3D) at Wrocław University of Science and Technology, with whom the University of Warsaw had previous experience and achievements in 3D scanning monuments in Egypt, Peru, and Easter Island, among others – to work on the project.

In June 2015, the National Science Centre of Poland (NCN) granted financial support to the project, and the main beneficiary was the Wrocław University of Science and Technology.

At the beginning of August 2015, Jacek Kościuk and Mariusz Ziółkowski met with representatives of the local Samaipata administration and CIAS staff. This resulted in the signing of a tripartite cooperation agreement between the municipality of Samaipata, the University of Warsaw, and the Wrocław University of Science and Technology.

Fieldwork started in June 2016 and benefited from the logistical and institutional support of CEAC, as well as from the great help offered by the Bolivian hosts – both the local municipality and the staff of CIAS. The contribution of Bolivian archaeologists and, in particular, that of the Bolivian co-director of the project, Delfor Ulloa Vidaurre, was also extremely important.

A leading Italian specialist in South American rock art, Giuseppe Orefici, the director of the Italian Centre for Pre-Columbian Archaeological Studies and Research (Centro Italiano di Studi e Ricerche Archeologiche Precolombiane) also joined the project. In turn, German colleagues, in particular Albert Meyers, former director of PIAS, provided the project with the documentation archived in Bonn, under a cooperation agreement between the University of Warsaw and the University of Bonn.

Therefore, the results presented in the series of articles that make up this volume are the effects of international and multilateral cooperation, whose objective was to contribute to the study and conservation a valuable monument on the UNESCO World Heritage List.

Main reasons behind starting the project and its main goals

The initiative to prepare 3D documentation for the sacred rock of the El Fuerte de Samaipata site was due to the recommendations related to the study and preservation of the World Heritage Sites as stipulated in the Convention Concerning the Protection of World Cultural and Natural Heritage, which was adopted at the 17th General Conference of UNESCO in Paris on 16th November, 1972.

Article 5 of this document specifies the following:

To ensure that effective and active measures are taken for the protection, conservation and presentation of the cultural and natural heritage situated on its territory, each State Party to this Convention shall endeavour, in so far as possible, and as appropriate for each country: […].

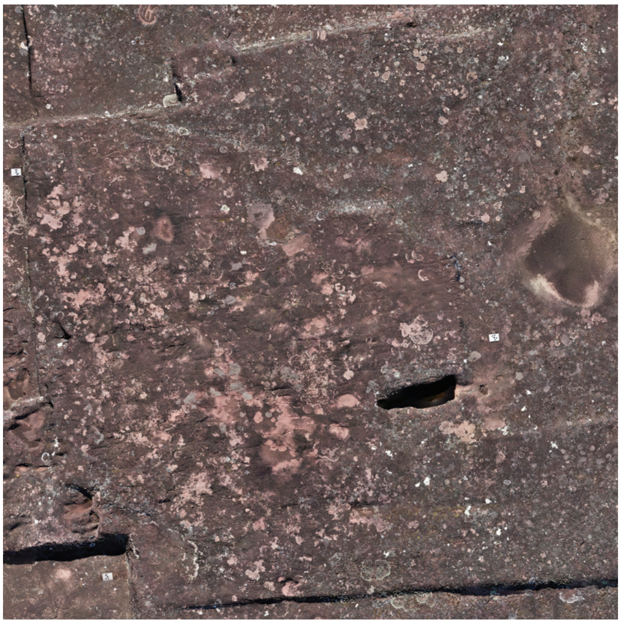

Fig. 2. The place where the petroglyph depicting an ostrich once existed (photo by J. Kościuk)

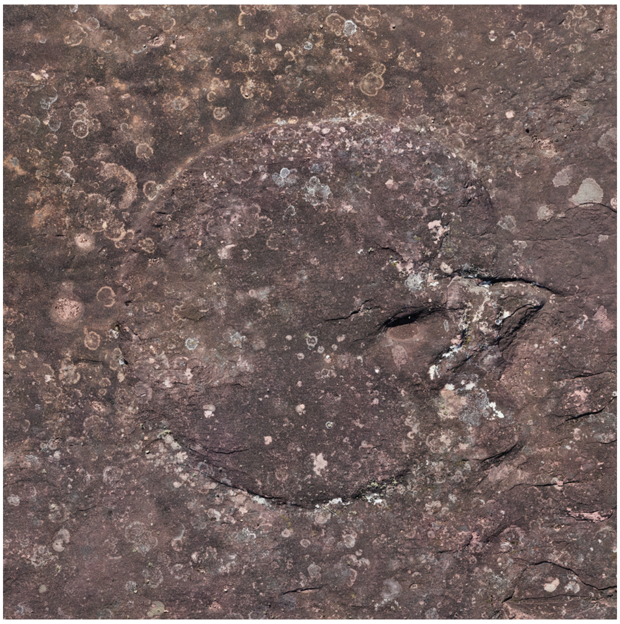

Fig. 3. Indecipherable petroglyph probably depicting a puma (photo by J. Kościuk)

3. to develop scientific and technical studies and research and to work out such operating methods as will make the State capable of counteracting the dangers that threaten its cultural or natural heritage; […].

5. to foster the establishment or development of national or regional centres for training in the protection, conservation and presentation of the cultural and natural heritage and to encourage scientific research in this field [13].

In the specific case of Samaipata and in particular of the sacred rock, all the governmental and municipal authorities, scientists, and general public of Bolivia, as well as foreign scholars, agreed that this unique monument is deteriorating due to a set of complex and interlaced environmental and anthropic factors. This deterioration mostly affects the petroglyphs carved in the rock, as the stone in which the petroglyphs have been carved is very delicate and soft and is subject to irreversible erosion. This danger was observed by the first scholars who visited and documented Samaipata [3], [4]. Comparison of photos taken in the 1960s with the current situation indisputably demonstrates that some of previously known petroglyphs (for example, the so-called "Ostrich" [14]) are now completely unrecognisable (Fig. 2).

The hard evidence that geological processes cannot be stopped must be accepted. The petroglyphs will continue to be erased. The question is whether this process will be slow or fast and how we can influence it. By applying a series of appropriate measures, we can slow its momentum to some extent, but it is impossible to stop it, let alone reverse it. Due to this, it is important to document the petroglyphs as accurately as possible using the most advanced techniques in order to provide a lasting testimony of these significant vestiges of pre-Hispanic cultures.

This task needs to be completed as soon as possible, as published studies [15], [11] show that the rapid weathering of the rock is clearly blurring the petroglyphs (Fig. 3). The reasons for this degradation are not yet fully established, but for the assessment of the current situation, the implementation of precise documentation was considered a priority.

The main goals of the 3D documentation project were the following:

– Comprehensive documentation of the entire sacred rock using 3D surveying techniques (laser scanning and photogrammetry);

– Registration and detailed documentation of all traces of anthropogenic activity visible on the rock (from pre-Hispanic petroglyphs to the inscriptions left in the 20th century by site visitors). This task also included the 3D modeling of the petroglyphs and advanced digital analysis of the traces already practically invisible to the naked eye;

– Analysis of the superposition of the petroglyphs and carvings in order to establish a relative chronology of the different phases of the transformation of the rock;

– Analysis of some environmental factors that affect the rock, in particular insolation, wind erosion, moisture (Fig. 4), and the action of lichens (Fig. 5).

The results will serve to establish a detailed account of the state of the site in the second decade of the 21st century, as the basis for future monitoring. They should also allow the areas of the monument that are most affected by deterioration to be identified. This in turn may serve as a basis for the development of practical programs of protection and preservation.

Methodology of the research and project timetable

From June 2015 to September 2019, the project was divided into four main phases:

– Literature studies and checking the archive collections of the University of Bonn, the Commission for

Fig. 4. Erosion of a petroglyph representing two pumas (photo by J. Kościuk)

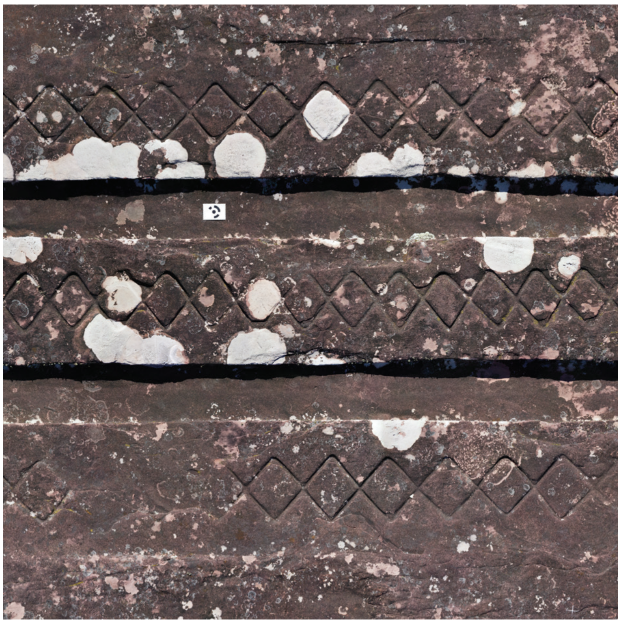

Fig. 5. Lichens on a fragment of the so-called "Big Snake" petroglyph (photo by B. Kościuk)

Archeaology of Non-European Cultures (Kommission für Archäologie Außereuropäischer Kulturen, KAAK) and CIAS (July 2015–May 2016);

– Two seasons of fieldwork (June–July 2016 and July 2017) dedicated to collecting surveying and descriptive documentation;

– Data processing in the LabScan3D computer laboratory (September 2016–June 2017, and November 2017–November 2018);

– Preparation of the final drawings, reports, and publications (January 2019–September 2019).

During this time, several conference presentations and lectures promoting partial project results were also prepared at the following places as well as others:

– South American Archaeology Seminar Institute of Archaeology, UCL, London 2017;

– III National Rock Art Conference: Heritage of the Past, Krakow 2017;

– International Conference on Structural Analysis of Historical Constructions, SAHC 2018, Cusco 2018;

– 58th Annual Meeting of the Institute of Andean Studies, Berkeley (CA) 2018;

– VI Jornadas de Astronomia Cultural Sociedad Interamericana de Astronomia en el Cultura; Simposio: El proyecto de documentación de la Roca Sagrada de Samaipata y de la interpretación de los petróglifos, Samaipata 2018.

Partial project results were also presented at the UNESCO headquarters in Paris in April 2017 during the exhibition "Against the Sands of Time. Documentation and Reconstruction of the World Heritage – the Polish Experience", which promoted Polish achievements in the field of conservation of sites from the World Heritage List, and also in July 2017 at the exhibition for the 41st Session of the UNESCO World Heritage Committee in Krakow.

Documentation, surveying, and analytical methods

Erosion is one of the most important factors affecting the conservation of archaeological sites and objects. The shapes carved by humans become progressively faded, leading to their disappearance. The sites directly exposed to climatic factors are the most affected by erosion and cause the biggest loss in historic content. In the last few decades, public awareness of erosion has increased, which has resulted in an increase in restoration projects.

Several works have demonstrated the great benefit of 3D modeling for heritage objects, especially in terms of historical analysis, documentation, preservation, and restoration [16]–[18]. Highly geometrically accurate 3D digital representation requires all details to be available. In the last few decades, terrestrial laser scanning (TLS) and close-range photogrammetry (CRP) have been found to be the best digital technology to effectively document cultural heritage. These two techniques have been used in multiple applications. For example, TLS and CRP allow degradation to be identified [19], evolution [20] and deformation to be analysed [21], and documentation to be created [22]. In comparison to traditional, expert methods to detect material degradation in historic buildings, TLS and CRP are far less time-consuming. Accurate 3D point cloud data deriving from TLS and CRP provide a very detailed and complete description of objects both in micro and macro scale. The surveys created using these two techniques (especially TLS with the addition of data derived from CRP) are used for gathering information necessary for the preservation of cultural heritage, architectural and archaeological studies and analyses [23], and historical context analysis [24]. Documentation projects with data fusion are commonly described as case studies in cultural heritage projects, especially when large or complex scenarios are documented [16], [25]–[28]. Obviously, there are some limitations of the TLS and CRP techniques, but in fact, these methods are very complementary [29], [30].

Most projects on complex sites combine different data acquisition methods. A further technique that is also very valuable is structured light scanning, which is used on smaller objects, mainly in reverse engineering and museum collections. Works dedicated to handheld structured light 3D scanners are focused on the practical assessment of the produced data [31], [32]. The data collected by such devices are considered more accurate than those from TLS and CRP.

Another technique that is becoming increasingly important in archaeological, historical, and architectural research is polynomial texture mapping (PTM), also known as reflectance transformation imaging (RTI). It allows blurred details caused by erosion and degradation to be seen clearly, and was developed by researchers from the Hewlett-Packard laboratory in 2001 [33]. This technique uses sets of photographs of an object where the camera is at a fixed point and the light source angle is changing. The results are displayed in a RTI viewer, allowing the user to interact with the scene by virtually dragging a directional light source and rendering the light changes in real time. It is also possible to use a 3D model created using CPR and TLS with the support of any 3D modeling program like Bentley MicroStation, Autodesk 3DS or Blender to emulate the behaviour of a real camera and light source.

In this particular project, hardware and software resources of LabScan3D (Wrocław University of Science and Technology) were used (Fig. 6).

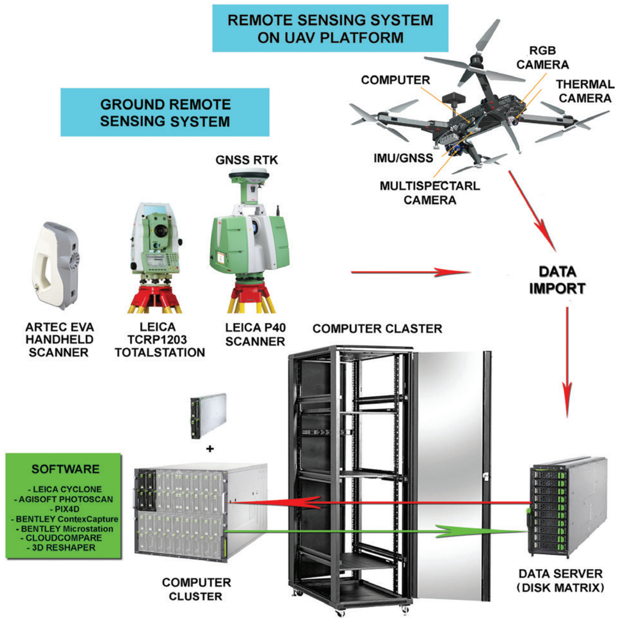

Fig. 6. Hardware and software resources of LabScan3D used during the project (elaborated by J. Kościuk)

Research team and acknowledgements

Over three years, almost twenty specialists from different countries and various research centres participated in the project:

– Jacek Kościuk (Wrocław University of Science and Technology) – director of the project, 3D laser scanning specialist, and head of LabScan3D;

– Mariusz Ziółkowski (University of Warsaw) – field director;

– Delfor Ulloa Vidaurre (Bolivian Ministry of Culture and Tourism) – project co-director;

– Giuseppe Orefici (Italian Centre for Pre-Columbian Archaeological Studies and Research) – petroglyphs consultant;

– Rosario Muñóz Risolazo (Italian Centre for Pre-Columbian Archaeological Studies and Research) – petroglyphs consultant assistant;

– Albert Meyers (University of Bonn) – consultant;

– Bartłomiej Ćmielewski (Wrocław University of Science and Technology) – drone and photogrammetry expert;

– Anna Kubicka (Wrocław University of Science and Technology) – 3D laser scanning assistant;

– Teresa Dziedzic (Wrocław University of Science and Technology) – restoration specialist;

– Izabela Wilczyńska (Wrocław University of Environmental and Life Sciences) – topographer and GIS expert;

– Ciechosław Patrzałek (Wrocław University of Environmental and Life Sciences) – drone and photogrammetry expert;

– Wojciech Bartz (University of Wrocław) – specialist in petrographic and mineralogical research;

– Janusz Kogut (Cracow University of Technology) – MES specialist;

– Małgorzata Telesińska (Wrocław University of Science and Technology) – 3D laser scanning assistant;

– Maciej Nisztuk (Wrocław University of Science and Technology) – specialist on PTM/RTI technology;

– Marta Pakowska (Wrocław University of Science and Technology) – structural light scanning assistant;

– Maria Gąsior (Academy of Art and Design in Wroclaw) – restoration expert;

– Dominika Sieczkowska (University of Warsaw) – project assistant;

– Dagmara Socha (University of Warsaw) – project assistant.

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Abstract

The Samaipata project concerns one of Bolivia's most important monuments – El Fuerte de Samaipata, a UNESCO World Heritage Site. This paper describes the origin of the project, the reasons behind starting it, and its main goals. In addition, the documentation, surveying and analytical methods used in the project are briefly described.

Key words: Bolivia, Samaipata, rock art, UNESCO World Heritage List, remote sensing

Streszczenie

Przedstawiany projekt Samaipata dotyczył jednego z najważniejszych zabytków Boliwii – El Fuerte de Samaipata, prekolumbijskiego stanowiska archeologicznego wpisanego na Listę Światowego Dziedzictwa UNESCO. W artykule opisano genezę projektu, powody podjęcia tematu oraz jego główne cele. Ponadto w skrócie opisano zastosowane w projekcie metody dokumentacyjno-pomiarowe i analityczne.

Słowa kluczowe: Boliwia, Samaipata, sztuka naskalna, Lista Światowego Dziedzictwa UNESCO, teledetekcja

Dron pilots at work
(photo by J. Kościuk)

Piloci drona przy pracy
(fot. J. Kościuk)