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CONTRIBUTIONS IN NEW WORLD ARCHAEOLOGY

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SEEING UNDERGROUND: THE FEASIBILITY OF ARCHAEOLOGICAL REMOTE SENSING IN COASTAL AND HIGHLAND PERU

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Abstract

This paper[1] reports programmatic recommendations, an advanced seminar series in archaeology, and field tests in geophysics undertaken during a consultancy with the Peruvian Institute of Culture (INC) in October 1982. The invited international program focused on the investigation of twelve historic, Inca, and pre-Inca sites throughout the coast and highlands. Funding was provided by the OAS, UNESCO, and the Andres Bello Fund. This is the first formal presentation of this effort. The Sendero Luminoso war prevented future investigations under this initiative. The collaborative international effort had three major components: 1) a three-week seminar series on applied technology in archaeology for the archaeological and preservation staff of the INC in Lima, Cusco, and Ayacucho; 2) investigations at twelve INC project sites to recommend appropriate applied technology strategies in support of excavation and stabilization efforts; and 3) resistivity and soil chemistry tests at each site to establish the utility of a variety of site-specific remote sensing strategies (e.g., resistivity, magnetics, or ground penetrating radar/GPR) to provide enhanced definition of archaeological boundaries and internal site structure. Among the underlying strategic goals of the collaborative testing program was the development of environmental indicators, or proxies, based on correlation of the levels of a number of chemical compounds, relative to recorded resistivity levels to project the utility of GPR and resistivity at different sites (the higher the resistivity the deeper the radar penetration). Once defined, future teams could use simple and inexpensive soil chemistry tests, without the need for expensive electrical equipment, to project the utility and penetration of ground penetrating radar (GPR) and electrical resistivity at a variety of coastal and highland Inca, pre-Inca, and Colonial sites.

Keywords: resistivity, ground penetrating radar (GPR), magnetometry, Inca, Colonial Peru, soil chemistry

[1] This paper was initially presented as part of the symposium: *The Legacies of Archaeologists in the Andes: Second Symposium, the Institutionalization and Internationalization of Andean Archaeology* organized by Monica Barnes and Mario Rivera at the 84th Annual Meeting of the Society for American Archaeology, April 10–14, 2019, Albuquerque, New Mexico.

Resumen

Este artículo presenta recomendaciones programáticas, una serie de seminarios avanzados en arqueología y pruebas de campo en geofísica realizadas durante una consulta con el Instituto Peruano de Cultura (INC) en octubre de 1982. El programa internacional invitado se centró en la investigación de doce estudios históricos, incas y yacimientos pre-incas a lo largo de la costa y sierra. La financiación fue proporcionada por la OEA, la UNESCO y el fondo Andrés Bello. Esta es la primera presentación formal de este esfuerzo. La guerra de Sendero Luminoso impidió futuras investigaciones bajo esta iniciativa. El esfuerzo colaborativo internacional tuvo tres componentes principales: 1) una serie de seminarios de tres semanas sobre tecnología aplicada en arqueología para el personal de arqueología y preservación del INC en Lima, Cusco y Ayacucho; 2) investigaciones en doce yacimientos del proyecto INC para recomendar estrategias de tecnología aplicada en apoyo a los esfuerzos de excavación y estabilización; y 3) pruebas de resistividad y química del suelo en cada yacimiento para establecer la utilidad de una variedad de estrategias de detección remota específicas del yacimiento (por ejemplo, resistividad, magnetismo o radar de penetración de tierra (GPR) para proporcionar una definición mejorada de los límites arqueológicos y la estructura interna del yacimiento. Entre los objetivos estratégicos subyacentes del programa de pruebas colaborativas estaba el desarrollo de indicadores ambientales, o proxy, basados en la correlación de los niveles de varios compuestos químicos, en relación con los niveles de resistividad registrados para proyectar la utilidad de GPR y resistividad en diferentes yacimientos (cuanto mayor sea la resistividad, más profunda será la penetración del radar). Una vez definidos, los equipos futuros podrían usar pruebas de química del suelo simples y económicas, sin la necesidad de equipos eléctricos costosos, para proyectar la utilidad y penetración del radar de penetración terrestre (GPR) y la resistividad en una variedad de zonas costeras y montañosas Inca, Pre-Inca y Yacimientos coloniales.

Palabras clave: resistividad, magnetismo, radar de penetración terrestre (GPR), Inca, colonial Perú

INTRODUCTION

This paper reports programmatic recommendations, an advanced seminar series in archaeology, and field tests in geophysics undertaken during a one-month consultancy with the Peruvian Institute of Culture (INC) in October 1982. The invited international program focused on the investigation of twelve historic, Inca, and pre-Inca sites throughout the coast and highlands. Funding was provided by the OAS, UNESCO, and the Andres Bello Fund (Figures 1 and 2). This is the first formal presentation of this effort. The Sendero Luminoso war prevented future investigations under this initiative. The findings of this paper are largely extracted verbatim from my original 1983 UNESCO-OAS-Andres Bello report by the same title, a factor that underscores the continued currency and relativity of the original results to modern conditions and programmatic challenges (Grossman *et al.* 1983). The findings of this early 1982 geophysical survey are still unique in the history of geophysics in Peru, and was not replicated (see Vickers and Dolphin 1975 for their initial work in the American Southwest and Olhoeft 1998 and also Bevan 2004 for more modern examples) in subsequent archaeological geophysical studies.

The utility of Ground Penetrating Radar (GPR) profiling of terrestrial subsurface structural features was initially demonstrated by the work of Rexford Morey (Morey 1972). Early experiments by NASA and the Jet Propulsion Laboratory with new Shuttle Imaging Radar (SIR-A) aboard the space shuttle Columbia in November of 1981, detected buried river channels under the desert sand while circling the earth over the Sahara (McCauley *et al.* 1982; El-Baz *et al*. 2007). Terrestrial GPR in archaeology had its roots in the early-1970s, beginning in 1974 with experiments at Chaco Canyon, New Mexico by Roger Vickers, David Johnson and Lambert T. Dolphin of the Stanford Research Institute and the National Park Service (Vickers and Dolphin 1975; Vickers *et al.* 1976). This study was pivotal and important because it compared radar echo profiles with the location and form of previously excavated cultural features. They also innovated, like the subsequent 1982 Peruvian work of the author, by using the measurement of site resistivity as a means of determining the potential utility and penetration of GPR (Vickers and Dolphin 1975). One of the first problem solving applications of Ground Penetrating Radar (GPR) in North American archaeology took place as part of a large-scale mitigation effort directed by the author as part of a federally funded rescue excavation of the buried (under three feet of shale fill) Revolutionary War-era settlement of Raritan Landing in New Jersey in 1978 (Grossman 1978, 1980). GPR in the archaeology of Andean Peru was not to see numerous case studies until nearly two decades later.

The earliest documented instance of geophysical survey in Peru, in this case, coastal Peru, took place as part of a University of Missouri summer field school studying the preceramic coastal site of Paloma in the Chilca quebrada, south of Lima, between June and July of 1977 (Benfer and Benfer 1978; Benfer and Greer 1978; see also Benfer 1982, 1984, 1986a and 1986b, 1988, 1990, 2001; Benfer and Gehlert 1980; Ravines 1988). Of relevance to this study, under the direction of Robert A. Benfer and Alice Benfer, their team deployed both resistivity equipment and a proton magnetometer to produce geophysical maps of Paloma, in a sector previously excavated by Frederic Engel (Benfer and Benfer 2004; Engel 1980). The fact that they incorporated a resistivity meter into their survey strategy was also a first. Except for John Rick's work at Chavin, no other major geophysical project in Peru is known to have intensively utilized resistivity either for actual survey or to calibrate the potential penetration of GPR – Bevan demonstrated that the penetration of GPR showed a direct positive correlation with resistivity, the higher the resistivity the deeper the penetration of radar (Bevan 2004: Figure B100).

Aside from the Benfer's early geophysical work at Paloma in 1977, and the geophysical survey of coastal and highland Peruvian sites as part of this UNESCO-OAS-Andres Bello initiative in 1982 by the lead author, - which used resistivity to study the electrical contrasts between buried Inca and historic structural features and their surrounding fill to calibrate the utility of GPR - reported on in this article (see Grossman *et al.* 1983) - there appears to have been no cases of the use of geophysical systems in Andean archaeology until John Rick's work at Chavin in 1998, some two decades after the first experiments and applications of GPR in North American archaeology, specifically in historical archaeology in the early 1970's. When published accounts of geophysical surveys in general, and GPR studies in particular, became common in Peruvian archaeology, they did so in a two-decade chronological cluster beginning in 1998. At least thirty cases of applied geophysical survey were published about work in coastal and highland Peru between 1998 and 2020. Of these, at least 13 geophysical studies were published on geophysical surveys of prehistoric and historic coastal sites (Benfer and Benfer 2004; Haley n.d.; Lasaponara *et al*. 2014, 2017; Masini *et al*. 2008, 2016; Millaire and Eastaugh 2011, 2014; Misiewicz and Makowski 2003; Rizzo *et al*. 2010; Sandweiss *et al*. 2010; Vanvalkenburgh *et al*. 2015). One study was published about the use of intensive grid based GPR at the historic colonial site of the Hospital of San Andres in Lima (Bauer *et al*. 2007). Although some unpublished initiatives may have added to the sample, and subsequent to this UNESCO-OAS-Andres Bello-funded program undertaken by the lead author and INC personnel in October 1982, at least seventeen additional geophysical studies were conducted on archaeological sites in the sierra of Peru after 1998 (Bauer and Rodriguez 2007; Best *et al*. 2009; Dayton and Janusek 2005; Henderson 2004; Klarich and Craig 2001; Masini *et al*. 2020; Williams *et al*. 2004, 2007). One study was published on the use of geophysics and GPR at pre-Inca Formative Period sites in the Altiplano of Bolivia (Dayton and Janusek 2005) and one recent study used GPR and magnetometers to map Inca period cultural features at the highland Inca site of Chachabamba in the Urubamba Valley (Masini *et al.* 2018). Four studies were presented between 2001 and 2007 on the use of GPR survey to detect subsurface cultural features at the Middle Horizon sites of Tiwanaku and Pucura in the Lake Titicaca basin (Henderson 2004; Klarich and Craig 2001; Williams *et al.* 2004, 2007). In addition, in 2015, archaeologists at the Tiahuanaco Archaeological Research Center announced the discovery of an underground pyramid and other anomalies at the site using GPR (Leafloor 2015). Finally, John Rick reported on two cases of the early use of geophysics at the highland site of Chavin de Huantar, first in 1998 and then later in 2009. The team used GPR, and later resistivity, to define, then test through excavation, two major anomalies in the Plaza Mayor of the site, both identified as "likely" ritual contexts (Rick 2017: 32-33; John Rick personal communication, 24 November 2020).

The collaborative international UNESCO-OAS-Andres Bello Fund initiative discussed in this paper had three major components: 1) a three-week seminar series on applied technology in archaeology for the archaeological and preservation staff of the INC in Lima, Cusco, and Ayacucho; 2) a visit to twelve INC project sites to recommend appropriate applied technology strategies in support of excavation and stabilization efforts; and 3) resistivity and soil chemistry tests to recommend site-specific remote sensing strategies (e.g., resistivity, magnetics, or ground penetrating radar) to enhance the definition of archaeological boundaries and internal site structure, at INC project sites. In the end, out of twelve prehistoric and historic sites examined for conductivity and soil characteristics, a total of seven sites proved to be electrolytically responsive and to be strong candidates for additional investigation and survey with advanced geophysical procedures. This paper aims to explain how that was done in six topics: 1) the background and context; 2) the workshop-seminar series; 3) resistivity calibrations; 4) survey results and site evaluations; 5) chemical soil tests and calibrations; and finally; 6) the Peruvian-developed final report.

ORIGINS AND ANTECEDENTS OF THE 1982 UNESCO-OAS-ANDRES BELLO INITIATIVE

The institutional context and origins of the non-university and internationally funded program are important. How it came about is relevant. The initial invitations to participate in the Peruvian geophysical and archaeological training program came about as a follow-up to a presentation I gave before an OAS sponsored conference on New World rescue archaeology held during May of 1981 in Quito, Ecuador. The initial official invitation (Figure 1) in August of 1981, highlighted the influence by one of my, at the time, recent publications, and the subject of my presentation in Quito, entitled *Defining Boundaries and Targeting Excavation with Ground Penetrating Radar: The Case of Raritan Landing* (Grossman 1980). A second official and more specific invitation (Figure 2) was solicited by Arquitecto Jorge Levano, Director of Restoration at the Church of San Francisco by the Instituto Nacional de Cultura (INC) (Levano 1982). In addition to requesting my credentials and a brief work plan, this second invitation asked specifically that I work under the auspices of the OAS to present a series of seminars to INC scientists and to evaluate ongoing archaeological work, introduce a range of applied technology strategies in historical archaeology and to train Peruvian archaeologists working on the multiyear restoration of the Church San Francisco in Lima and at other restoration sites

de Túpac Amaru y Micaela Bastidas"

INSTITUTO NACIONAL DE CULTURA

Lima, 21 AGO. 1981

OFICIO N° 666-81-DCIRBM

Señor Doctor
JOEL GROSSMAN
35 West, 19 St. New York City
New York 10011
U.S.A.

Estimado Doctor Grossman.

El Centro de Investigación y Restauración de Bienes Monumentales ha tenido conocimiento de su publicación titulada: Defining Boundaries and Targeting Excavation with Ground Penetrating Radar: The Case of Raritan Landing. También tenemos conocimiento de su importante exposición en la Conferencia sobre Rescate Arqueológico del Nuevo Mundo que se realizó en Quito-Ecuador del 11 al 15 de mayo organizada por la O.E.A. y UNESCO.

Después de haber estudiado las características de su método de investigación y la conveniencia de su uso en los sitios arqueológicos del Perú, consideramos que sería oportuno realizar algunas pruebas en nuestro país para determinar la factibilidad de su uso.

Como es de su conocimiento, la Costa Peruana actualmente un gran desierto con pequeños oasis formado por ríos que bajan de la Cordillera Occidental de los Andes. La Sierra está formada por impresionantes cordilleras y la selva caracterizada por su vegetación tropical.

En cada región hay importantes evidencias de las Culturas Pre-Incaica e Incaica y también de la ocupación Colonial Temprana. En los últimos años estamos muy interesados en desarrollar investigaciones de Arqueología Colonial de los Siglos XVI y XVII y deseamos contar con las técnicas adecuadas para las investigaciones en la Costa.

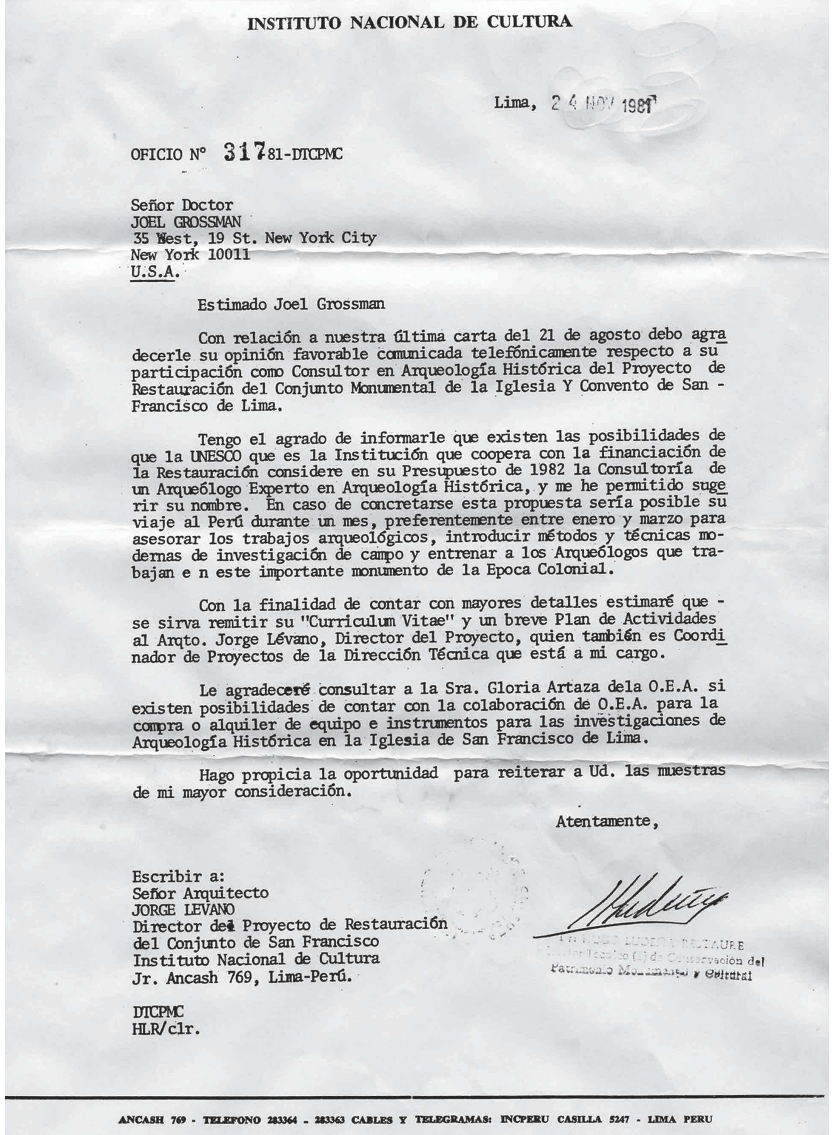
Actualmente se están efectuando excavaciones en la Iglesia de San Francisco de Lima, Casas Coloniales y otros Templos, con el objeto de restaurarlos, y consideramos que las primeras pruebas podrían realizarse en San Francisco.

Le agradeceré informarnos acerca de las posibilidades que ofrecen para ser aplicados en el Perú los métodos que usted usa, y si podríamos contar con su cooperación antes del mes de diciembre del presente año.

El Instituto Nacional de Cultura puede prestarle todas las facilidades que estén a nuestro alcance para que -

ANCASH 769 - TELEFONO 283364 - 283363 CABLES Y TELEGRAMAS: INCPERU CASILLA 5247 - LIMA PERU

Figure 1. 1981 Letter of invitation from the Peruvian Instituto Nacional del Cultura (INC) to Dr. Joel W. Grossman as part of a UNESCO-OAS-Andres Bello visiting scholars program to give a series of seminars on archaeological methods to Peruvian archaeologist working on INC projects and to conduct preliminary geophysical field tests to evaluate the viability of a range of remote sensing strategies (Ground Penetrating Radar, Resistivity and magnetometers) at twelve colonial, Inca and pre-Inca sites throughout the coast and highlands of Peru.



INSTITUTO NACIONAL DE CULTURA

Lima, 24 NOV 1981

OFICIO N° 317 81-DTCPMC

Señor Doctor
JOEL GROSSMAN
35 West, 19 St. New York City
New York 10011
U.S.A.

Estimado Joel Grossman

Con relación a nuestra última carta del 21 de agosto debo agradecerle su opinión favorable comunicada telefónicamente respecto a su participación como Consultor en Arqueología Histórica del Proyecto de Restauración del Conjunto Monumental de la Iglesia Y Convento de San - Francisco de Lima.

Tengo el agrado de informarle que existen las posibilidades de que la UNESCO que es la Institución que coopera con la financiación de la Restauración considere en su Presupuesto de 1982 la Consultoría de un Arqueólogo Experto en Arqueología Histórica, y me he permitido sugerir su nombre. En caso de concretarse esta propuesta sería posible su viaje al Perú durante un mes, preferentemente entre enero y marzo para asesorar los trabajos arqueológicos, introducir métodos y técnicas modernas de investigación de campo y entrenar a los Arqueólogos que trabajan e n este importante monumento de la Epoca Colonial.

Con la finalidad de contar con mayores detalles estimaré que - se sirva remitir su "Curriculum Vitae" y un breve Plan de Actividades al Arqto. Jorge Lévano, Director del Proyecto, quien también es Coordinador de Proyectos de la Dirección Técnica que está a mi cargo.

Le agradeceré consultar a la Sra. Gloria Artaza dela O.E.A. si existen posibilidades de contar con la colaboración de O.E.A. para la compra o alquiler de equipo e instrumentos para las investigaciones de Arqueología Histórica en la Iglesia de San Francisco de Lima.

Hago propicia la oportunidad para reiterar a Ud. las muestras de mi mayor consideración.

Atentamente,

Escribir a:
Señor Arquitecto
JORGE LEVANO
Director del Proyecto de Restauración
del Conjunto de San Francisco
Instituto Nacional de Cultura
Jr. Ancash 769, Lima-Perú.

DTCPMC
HLR/clr.

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Figure 2. Follow-up, November 24, 1981, letter of invitation from Dr. Hugo Ludeña Restaure, Director Tecnico (E) de Conservación del Patrimonio Monumental y Cultural, to present a series of seminars to INC scientists and to evaluate ongoing archaeological work, introduce a range of applied technology strategies and to train Peruvian archaeologists working on the restoration of San Francisco and elsewhere in Peru.

elsewhere in Peru. This first invited seminar series by the lead author, presented as part of the twelve year (1978-1990) UNESCO-sponsored restoration of the Church of San Francisco (Alcantara Gomez 2012: 29; Levano 1982), was followed by three additional invited seminars in historical archaeology between 1983 and 1984: by Katherine Deagan of the University of Florida in 1983, by Lorenzo Lopez y Sebastian of the University Complutense of Madrid and by Alfredo Moreno Cebrian of the High Council of Scientific Investigations of Madrid (CSIC), both in 1984 (Alcantara Gomez 2012: 41).

The inception and initial focus of the INC interest was a large scale "discovery under construction," and federal work stoppage, the Raritan Landing project, caused by the belated discovery of a buried Pre-Revolutionary War port community in New Brunswick, New Jersey, USA, in the path of a hundred-million-dollar water treatment project throughout the Raritan drainage (Grossman 1980). Here, the archaeological challenge was complicated by the fact that the buried colonial port community was finally identified under a sealed mantle of sterile shale fill, topped by sod and grass (Figure 3), which precluded its early identification by other archaeologists prior to the onset of construction.

Instead of traditional time-consuming physical test probes and blind random sampling (see Grossman and Cavallo 1982), Ground Penetrating Radar (GPR), deployed by NASA for the Lunar Lander program (which told the astronauts if they had landed on solid rock or unstable dust, was implemented on an emergency basis to "see through" the rock fill covering the lost colonial port community of Raritan Landing. Ground penetrating radar had been released as a viable technology for civilian use by DARPA, the US government Defense Advanced Research Projects Agency, in the early to mid-1970's and was commercially available before 1976 (Bevan 1983; Bevan and Kenyon 1975; Hranicky 1977; Morey 1972; Rosetta 1977; Vickers *et al.* 1976). I was introduced to the archaeological utility of GPR in the mid-1970s by the work of Bruce Bevan on Colonial historic sites being studied out of the MASCA laboratory of the University of Pennsylvania (Bevan 1975). The radar (**RA**dio **D**etection **A**nd **R**anging) equipment I deployed with Bruce Bevan and engineers from Geophysical Survey Systems of New Hampshire, in 1978 mapped the buried colonial port community of Raritan Landing, in New Jersey.

This initiative with GPR was not without a litany of technological challenges. The technology was new and still partially in prototype form, with some antennas of various frequencies in pre-production wooden boxes (Plate 1). At first, we did not know how to interpret the radar data, data that came out as a series of long, sonar-like paper profiles as the radar antenna was pulled along five-foot interval grid lines in a series of NS/EW transects (Plate 1). As a solution, I decided to render the data not as absolute depth readings, but instead as a series of overlapping bands of color reflecting the relative depth of signals along each transect line. (We knew the depth off the buried settlement from initial backhoe cuts through the three to four feet of rock shale fill; what we didn't know was the extent, boundaries and internal composition of the site). Aided by US Army experts, headed by a radar specialist, Emerson Frost, from Fort Monmouth (they were mapping mosquitos for the F16 program), the results were plotted as a series of bands of different colors reflecting the relative depth of the radar echoes recorded along NS & EW survey grid lines. The resultant color-coded 3D radar map revealed the outline, location, boundaries, and relative depth of buried buildings (Figure 4). The detail provided by the polychrome radar map enabled the archaeologists and planners to engineer a joint mitigation program of redesign and data recovery for only those sectors that couldn't be avoided; instead of a 40-foot-wide pipe trench, the mitigation program reduced the excavation impact corridor to 15-foot-wide pipe trench (see Grossman 1980). The archaeological project was completed on time and on budget.

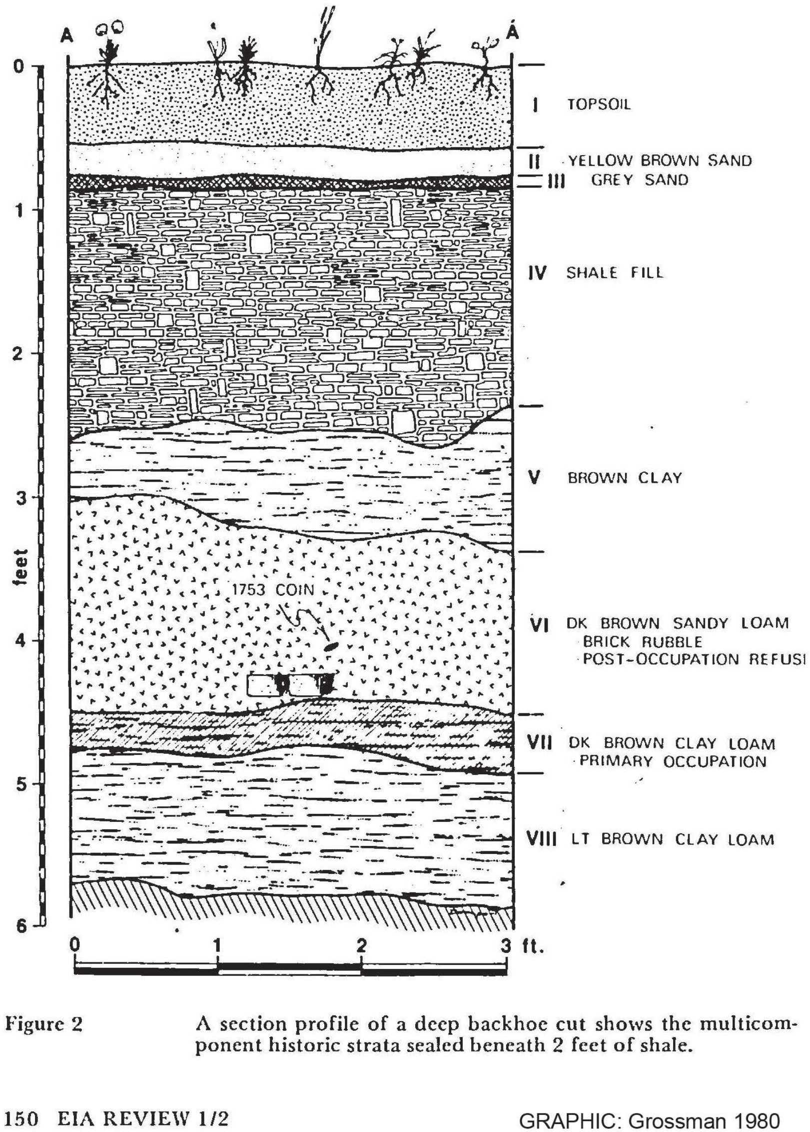

Figure 3. Profile of deep strata cut through the archaeological remains of the early 18th century port community of Raritan Landing, showing the 3-foot-thick cap of shale fill and surface sod which covered and obscured the deeply buried colonial settlement (Profile by Michael Davenport, Rutgers Archaeological Survey Office, RASO).

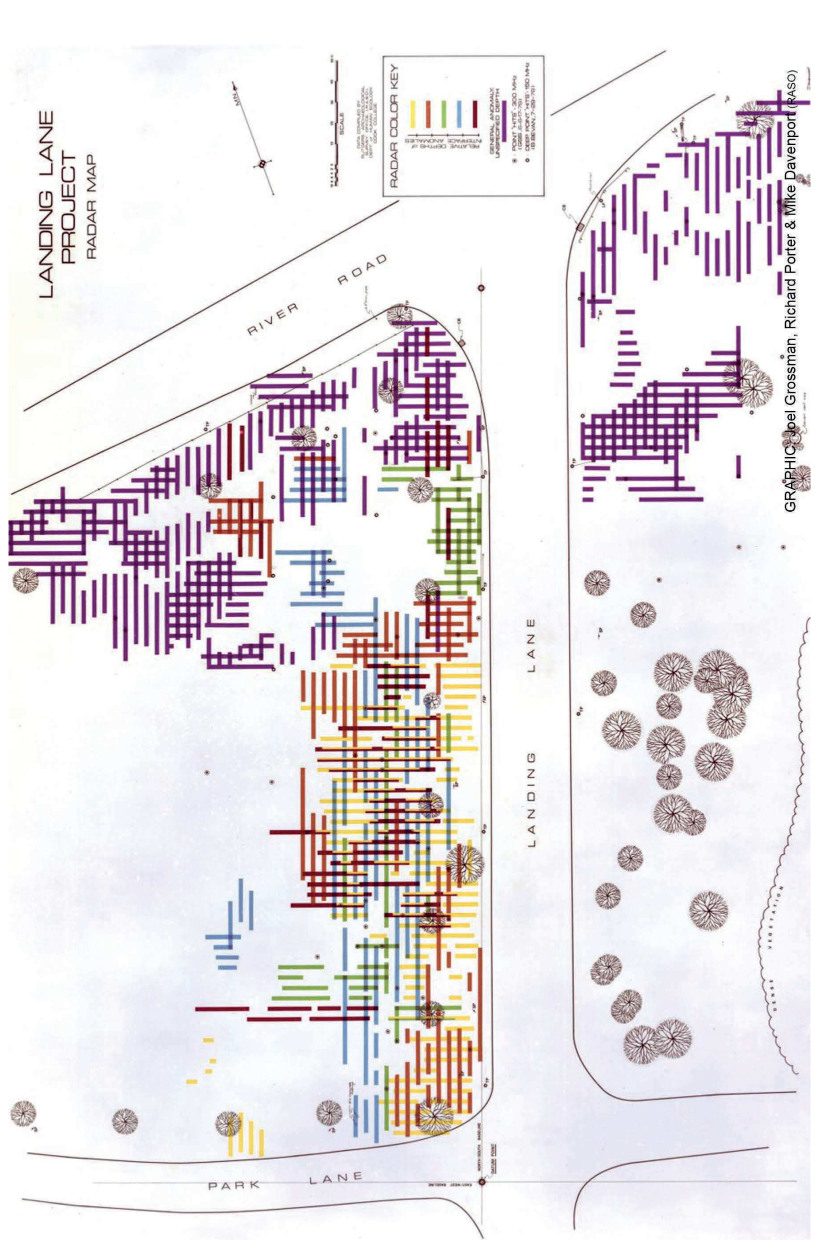

Figure 4. Developed under the direction of Dr. Joel W. Grossman of the Rutgers Archaeological Survey Office (RASO) in 1978, the 3D color-coded underground radar map showed the boundaries, extent and internal complexity of the buried Pre-Revolutionary War port settlement of Raritan Landing (Radar map graphic by Michael Davenport, RASO).

In addition to use of GPR to define the site, new recording strategies: electronic distance measurement (EDM), single-camera photogrammetry, concurrent on-site computerization of all transit readings and excavation results, concurrent on-site conservation, and the ability to work without interruption in deep winter conditions were deployed to expedite fieldwork. Instead of traditional fair-weather time schedules, heated reinforced domes and dewatering systems were built to thaw the ground, protect the scientists and artifacts, and permit all-weather excavation, even in the most severe winter conditions (Plate 2). Instead of standard hand-held measuring tapes, line levels and optical transits, the emergency rescue excavation also innovated by deploying one of the first North American uses of a computer transit, or electronic distance meter (EDM) (Plate 2) in American archaeology. This equipment had been demonstrated to be efficient in Sardis Turkey, the year before Raritan landing, by Dr. Gene Sterud of the Society of American Archaeology (SAA). Instead of tedious hand drawn field sketches of the various buried surface features, a custom-built, stereo-photogrammetric overhead "bipod" camera suspension system (Plate 2) recorded each surface as a series of stereo pairs, in 15 x 15 sq. ft. photo blocks (Plate 3). These stereo pairs were seamed together to render a metrically accurate photographic base map of the buried site (Figure 5, bottom level). I mention these capabilities because they reflect what the Peruvian delegation heard about, and was interested in, when first introduced to these examples of applied technology in the 1981 Quito-OAS sponsored conference.

Early portable computers (remember, this was in 1978) were programmed to expedite the coordinate conversion process to x, y, z points for the thousands of angle and distance measurements taken by this first generation (EDM – the first generation of laser, but it was without memory and we had to program in BASIC to convert angle and distance readings to real world, x, y, z coordinates); On-site computer terminals were linked by telephone lines to FORTRAN-based University main frame computers to produce quantified data bases recording provenience and the material and class definition of for all excavated artifacts during the fieldwork, instead of long after. The quantified and computerized results were converted into artifact density plots, or SYMAPs, for each artifact class, across each of the buried colonial surfaces (Figure 5, top three layers). On-site conservators stabilized fragile artifacts during fieldwork, instead of long after, when they had turned to cigar ash (Plate 4). These capabilities formed the core framework of the applied technologies presented by me at the UNESCO-OAS-Andres Bello sponsored seminars held in the magnificent 16th century library of the Convent of San Francisco in Lima, also the site of the Lima's underground catacombs and the focus of intensive resistivity and chemical testing during the project.

THE WORKSHOP SEMINAR

In addition to the fieldwork and site testing I will touch on below; a central element of this invited international program was the presentation of a series of workshops on applied technology in archaeology for Peruvian specialists in Inca and Colonial archaeology and site restoration. The workshop seminar was conducted in two sessions, a morning session led by me, and an afternoon series of discussions and formal seminar presentations by INC project directors from throughout Peru. Archaeologists, architectural historians, and restoration specialists from INC projects were flown to Lima to participate in, and contribute to, the seminar series. Among the topics discussed, my seminars focused on presenting issues and new directions

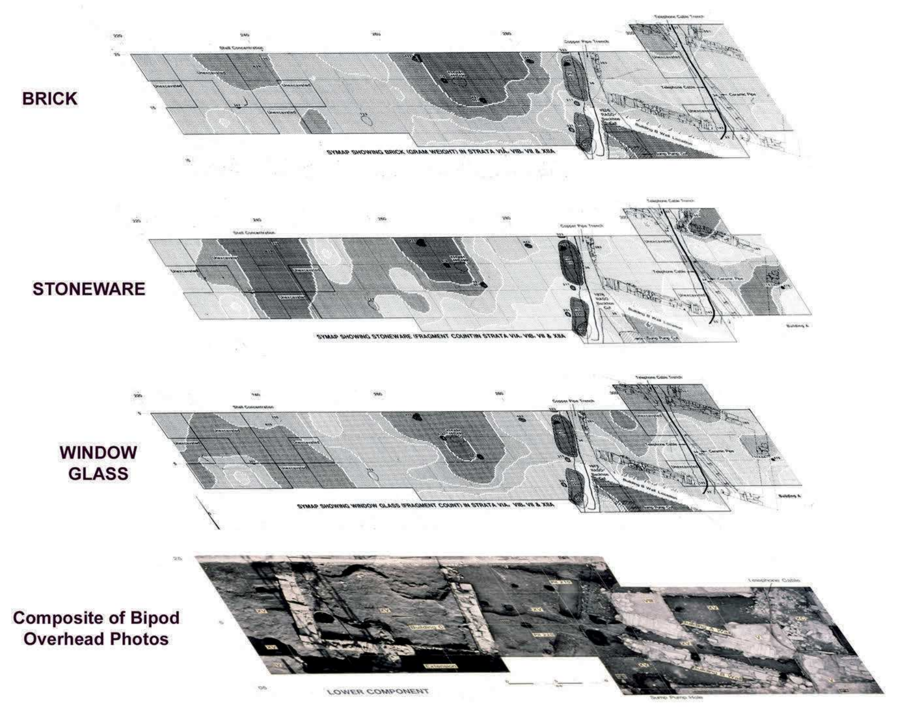

Figure 5. Stacked overlay photo-mosaic of thee SYMAP density-distribution plots (top three) of different artifact classes overlying a metrically accurate composite overhead photomosaic (bottom) of the excavated Pre-Revolutionary surface of the early 18th century settlement (Graphic by Joel W. Grossman and Michael Davenport, RASO).

for challenges of survey and excavation in urban rescue archaeology, approaches equally applicable to complex urban colonial sites, as well as multicomponent Inca and pre-Inca sites. In addition to the role of applied technology, my INC seminars focused on seven topics and areas of viable research investigation in contemporary Andean archaeology: 1) the stratigraphic record; 2) issues of ceramic chronology and analysis; 3) on-site concurrent conservation; 4) the pertinence of ethnobotanical studies; 5) paleo-environmental reconstruction; 6) logistical strategies for historic and complex multi-component urban archaeology through the presentation of case studies I directed within the US and other countries; and finally 7) an explanation of the structure and workings of current environmental compliance regulations and guidelines within US and international agencies to facilitate the efficient and effective multi-stage identification, definition and evaluation of archaeological and historical resources. In other words, how does the science dovetail with the law?[2]

[2] See Grossman 1994, 2003, 2008a, 2008b, 2011, Grossman *et al.* 2015, Grossman *et al.* 2019 for subse-

RESISTIVITY

Figure 6 shows a 1929 sketch of a crank-powered resistivity meter (Clark 1997: 1). The historic unit illustrates the use of four copper plated steel electrodes pushed into the ground in a line with equal spacing between electrodes, known as the Wenner configuration. The two outer electrodes send an electronic current into the ground, the two inner electrodes measure a voltage; when divided by current, a resistance in ohms results. Plate 5b shows Peruvian archaeologists with a more modern, battery powered, Gossen Geohm 3 resistivity unit in the catacombs of San Francisco using the same four-electrode Winner configuration as the earlier crank-powered unit. The electrode intervals varied between half and one meter, depending on the site conditions and the projected depth of buried features. Given the varied electrode spacing used, all field measurements were converted from resistance to **Effective Resistivity (ER)** (expressed in Ohmmeters, or ohm-m) to standardize the resistivity readings between different spacings of the

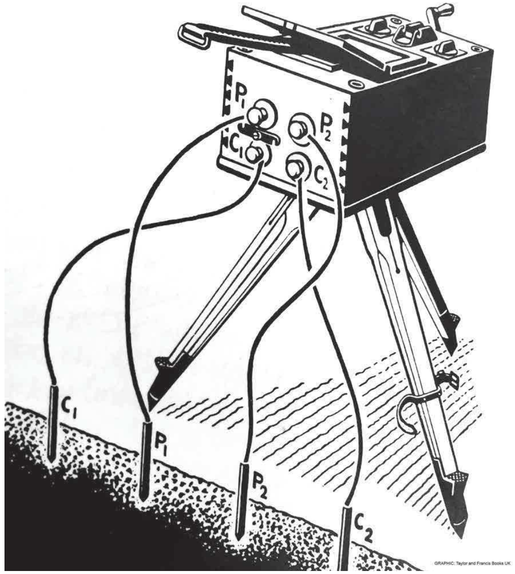

Figure 6. Close-up view of a 1929 electronic resistivity meter (Clark 1997: Figure 1) powered with a generator crank illustrating the four electrode "Wenner" configuration; the two outer electrodes provide an electronic pulse; the two inner electrodes measure the resistivity of the intervening soil matrix. Adapted from *Seeing Beneath the Soil*, by Anthony Clark, 1997, Routledge, reproduced by permission of Taylor & Francis Books UK.

quent case studies of large-scale mitigation projects and regional surveys illustrating the use of a range of applied technology, geospatial strategies, and geophysics in archaeology, in general, and on the origins of GPR in archaeology, in particular (Grossman 2018).

electrodes. Effective resistivity is calculated according to the formula: **2 π d r,** where d=spacing between adjacent electrodes, and r=recorded resistance. All resistance readings were translated by Peruvian team members into effective resistivity for all twelve site locations examined.

The potential utility of these remote sensing procedures is supported by several basic geophysical understandings and assumptions. Previous testing outside Peru has shown that the depth of penetration of ground penetrating radar, and the applicability of other remote sensing techniques can be determined by preliminary tests of subsurface soil resistivity, or its inverse conductivity, and by determining the chemical characteristics of the site's deposits. Although other factors (e.g., humidity, the amount of clay, the porosity of the soil, the relative presence of salts, the amount of organic material and soil temperature) can affect the depth of penetration of GPR, in general, the higher the effective resistivity (ohm-meters, or ohm-m) the deeper the projected penetration of GPR (Bevan 2004; Olhoeft 1998: 177-182). To quote Bevan, "higher resistivity means greater [radar] profiling depth" (Bevan 2004: Figure 100; 40). The critical cut-off appears to be around 100 ohm-m for multicomponent historic and prehistoric sites of greater than a few meters of stratified deposits. If the resistivity is greater than 100 ohm-m, many radars will be able to profile to a depth of at least 2 meters, or greater. Bevan compared the relative depth of penetration of radar profiles to measurements of effective resistivity (ohm-m) using two antennas (180 and 315 MHz) in 79 site settings. He was able to demonstrate that both antennas "saw" anomalies down to depths of ca 1-2 meters with resistivity levels of ca 100-300 ohm-m. Both antennas "saw" down to a depth of 3 to ca 7 meters at resistivity levels of 1000 to 10,000 ohm-m (Bevan 2004: Figure B100).

At each of the twelve Peruvian sites tested, the location and orientation of the resistivity readings were, whenever possible, placed to crosscut at a right angle across partially excavated buried wall and structural elements. It was possible to make measurements and transect buried walls within five of the twelve sites investigated: at Quinta de Presa in Lima; at Ollantaytambo and Sacsayhuaman in Cuzco; and at Wari and Conchopata in Ayacucho. Multiple transect readings were undertaken at most of these sites. In at least half of these sites, and as the associated line graphs and statistical plots illustrate, the resistivity testing showed good signal response and significant vertical fluctuations or spikes in subsurface effective resistivity levels across the alignment of known buried walls and exposed structural elements.

In both the coast and highlands of Peru the resistivity equipment was "seeing" buried architectural elements in both prehistoric and historic sites. The resistivity field results were graphically presented in three visual formats: 1) as a statistical histogram of the chemical results and resistivity readings at each area tested (Figure 7); 2) as a series of lineal regression line plots showing the relative correlations between resistivity and soil chemical elements recorded at each site (Figures 8 and 3) for each site tested, as a line graph showing the changes in effective resistivity across identified walls or structural elements (e.g., Figure 9).

CHEMICAL SOIL TESTS AND CORRELATIONS

In addition to the subsurface resistivity readings, each site was also tested for six chemical variables: pH (relative acidity); humidity; calcium carbonates; calcium oxides; chlorides; and sulfates. The goal of these additional tests was to determine any correlations between recorded effective resistivity and different chemical compounds for each of the twelve sites investigated. It was proposed, in the future absence of readily available resistivity equipment that positive and

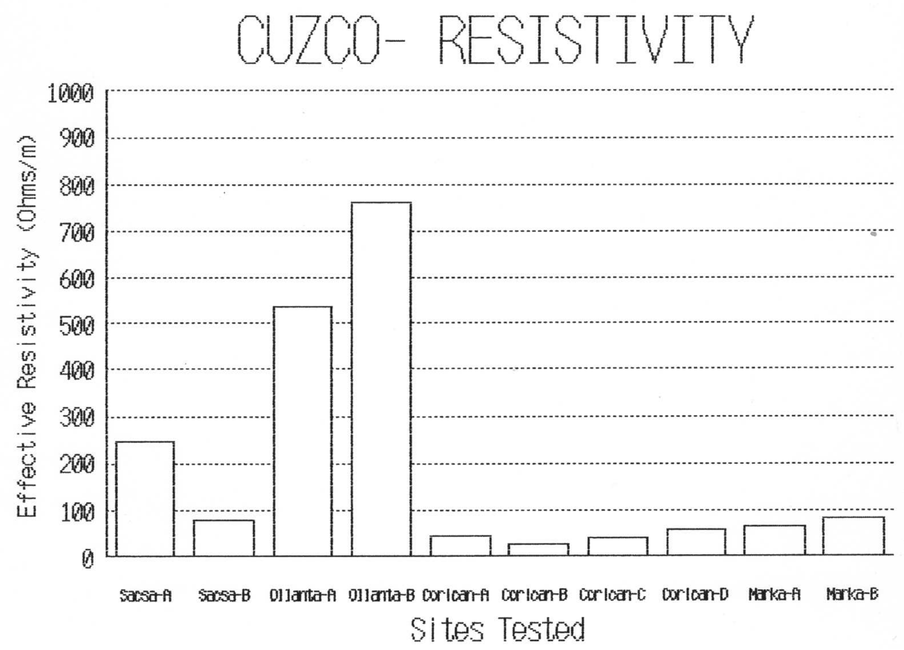

Figure 7. Histogram showing the relative effective resistivity (ER) readings in Ohms-meter (or Ohm-m), in this case, sites in Cuzco (Effective Resistivity = 2π d r, where d = electrode distance and r=recorded resistivity) (Graphic by Joel W. Grossman).

negative correlations between recorded effective resistivity (ER) and the concentrations of the tested-for chemical elements could then serve as cost-effective alternate guideposts, or proxies, for the determination of the utility of GPR and intensive resistivity geophysical survey of sites selected for additional investigation.

Twenty-one soil samples were tested from the twelve sites investigated. All samples were tested at the wet chemistry laboratory of the Lima office of the INC by chemist Teresa L. Quintana (Table 1; Quintana 1982a, 1982b). These compounds were selected because 1) they can be easily and inexpensively measured with existing laboratory facilities in Peru; 2) except for pH, each is electrolytically sensitive and therefore could be expected to have a strong positive, or negative, statistical correlation with levels of effective resistivity of the deposits investigated. Both humidity and pH were selected because they affect the availability of the above-mentioned compounds and are easily measurable. Humidity also affects ground penetrating radar; high humidity attenuates the radar signal and lessens its depth of penetration (Alsharahi *et al.* 2016: 574; Robinson *et al.* 2013: 22). Oxides, carbonates, and sulfates were selected because they are commonly associated with construction materials and architectural elements at both prehistoric and historic sites containing mortar and plaster. Like high humidity, in excessive concentrations, chlorides and salts can create the equivalent of an electronic shield which can negate the utility

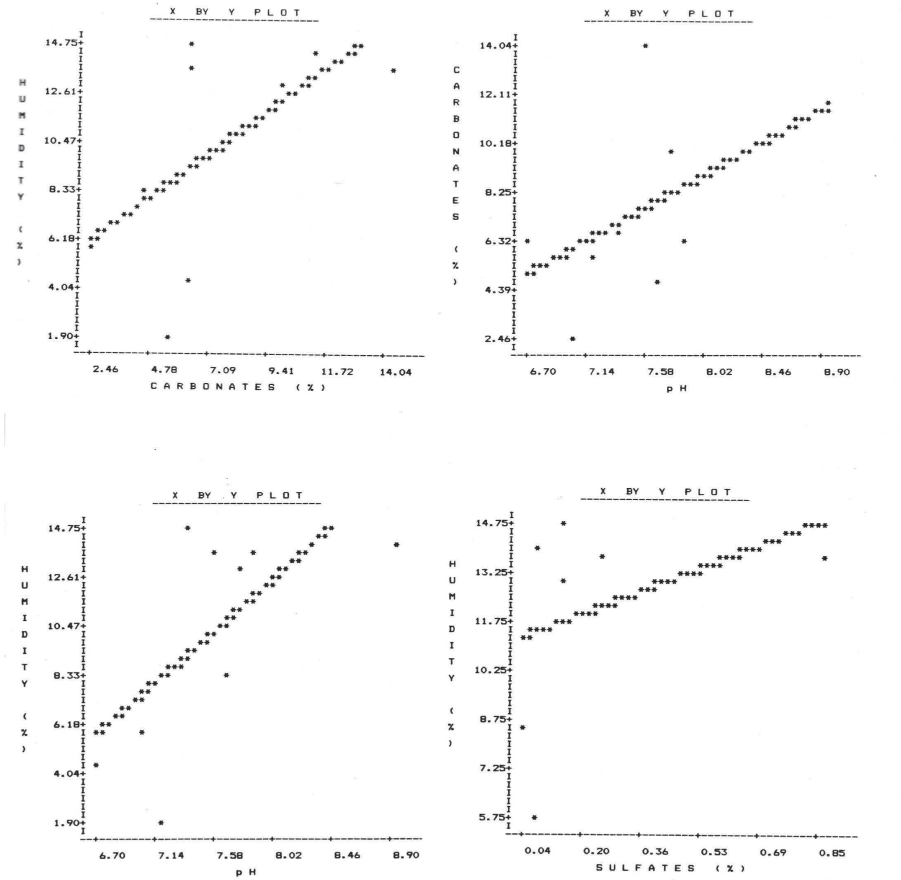

Figure 8. Plot showing the correlation coefficient of effective resistivity readings relative to percent humidity (a significant factor in radar penetration) at the site of Huari in Ayacucho (Graphic by Joel W. Grossman).

and depth of penetration of ground penetrating radar and other electrolytically sensitive remote sensing technologies (Olhoeft 1998: 177-182).

The disparities between the soil chemistry of each of the three geographic areas studied (Lima, Cuzco, and Ayacucho) indicated strongly that the chemical fingerprints were different for reach region, and as a result the recommendations for specific geophysical strategies must be tailor-made for each region investigated. This assertion is reflected in the absolute readings of elements from each region tested (Table 1). For example, at Quinta de Presa and San Francisco in Lima, humidity was consistently low (Muestra E at San Francisco, which

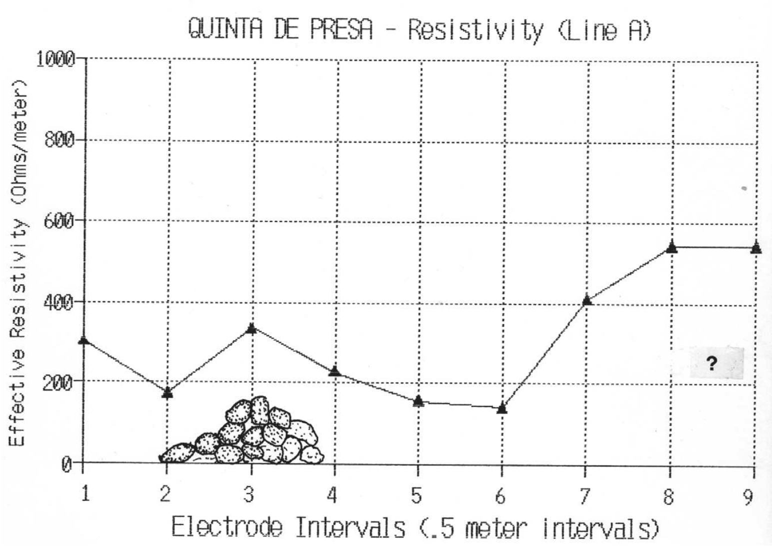

Figure 9. Line plot of recorded effective resistivity over a buried wall feature at the historic colonial site of Quinta de Presa, in Lima. The readings showed a spike in resistivity over a known wall element and drop across the adjoining soil matrix without structural features (Graphic by Joel W. Grossman).

yielded a low humidity reading of 4.85%), but was high in the highland Ayacucho sites of Wari and Conchopata with humidity readings of 14.05% at Conchopata and an upper range of 9.07 to 19.84% at Wari. Likewise, humidity was also high in the Cuzco sites of Sacsayhuaman and Coricancha with ranges between 12.78% and 14.52%. Humidity was very low at Ollantaytambo with a low range of 3.82 to 5.75%. The high humidity readings in Ayacucho were consistent with what emerged as relatively low levels of effective resistivity and as such, low expected levels of penetration by GPR.

As illustrated in Table 2, the computation of correlation coefficients between the four elements (Oxides, Carbonates, Chlorides and Sulfates) and soil conditions (pH and Humidity) showed both positive negative correlations with recorded effective resistivity, depending on the region. In Lima, the site of Quinta de Presa showed strong negative correlations between high effective resistivity and high humidity, oxides, and carbonates. In other words, at Quinta de Presa, higher levels of humidity, oxides and carbonates correlated with lower effective resistivity. In contrast, here on the coast, high levels of chlorides and pH showed positive correlations with ER, or the more basic the soils, the higher the effective resistivity. The opposite was true for Ayacucho and Cuzco; there, pH showed strong negative curves indicating that high pH would result in lower effective resistivity in these two locals.

In Ayacucho, the levels of Oxides showed positive correlation with effective resistivity, all other elements showed strong negative correlations between the tested elements and levels of effective resistivity. As stated above, both Wari and Conchopata were distinguished by relatively high levels of humidity, a strong factor which would negatively affect the potential penetration

Table 1. Chemical analysis of the soils of Huari, Conchopata and Cuzco by Teresa Quintana, Laboratorio chimica (CIRBM)

Site	Samp. Area	Humidity (%)	pH	Chlorides (%)	Carbonates (%)	Oxides (%)	Sulfaftes (%)	Provenience
Huari	Muestra"A"	13.76	7.55	0.02	3.8	3.04	0.41	Superfice del Monticulo
	Muestra"B"	9.07	7.95	0.02	9.44	3.99	0.15	"Relennade la Plaza - Erstrato 2 con cal"
	Muestra"C"	19.84	7.65	0.04	4.41	3.54	2.8	"Pizo al Oeste de la Plaza"
	Muestra"D"	17.68	8.45	0.04	8.03	3.61	0.43	"Pizo Norte de la Plaza"
	Muestra"E"	4.85	7.8	0.11	5.7	3.23	0.5	"Relleno - Estrata "B" [90 cms. debajo de la superficie]
Conchopata	Muestra :1	11.62	8.3	0.04	13.3	5.7	0.67	"Mortero del Muro"
	Muestra :2	14.05	8.95	0.02	11.15	4.24	0.07	(48 cm. debajo de la superfice)
Ollantaytambo	Muestra: 1	5.75	7.05	0.11	2.46	0.75	0.75	Estrato "B" (40 cms.)
	Muestra :2	3.82	7.1	0.12	2.95	0.93	0.06	Estrato"C" (85 cms. debajo del superficie)
Sacsayhuaman	Muestra"A"	12.78	7.75	0.09	9.72	1.49	0.15	Lado Nor-este (30 cms. deba-jo del superficie)
	Muestra"B"	13.58	7.55	0.2	14.04	1.31	0.26	Lado Sur-este (30 cms. debajo del superficie)
Coricancha	Muestra	14.52	7.39	0.14	6.4	0.75	0.15	15 cms. debajo de la superficie
Markavalle	Muestra	8.29	7.65	0.12	4.49	0.84	0.04	20 cms. debajo de la superficie

Table 2. Correlation coefficients - effective resistivity vs.chemicals

Elements	Lima-QdePresa	Lima (SF)	AYA-Huari	Cuzco
Humidity	-0.883		0.378	na
CaOxide	-0.463		-0.086	na
CaCarb	-0.228	-0.148	-0.593	-0.475
CaCl	0.306		-0.211	-0.574
pH	0.602		-0.758	-0.651
$CaSO_4$	na		na	-0.026

of GPR (Table 1). Except for calcium oxide, all other elements were inversely correlated with effective resistivity (Table 2); pH stood out from the other variables. In Ayacucho, pH was high at both Wari and Conchopata, ranging between 7.55 to 8.45% at Wari and between a high reading of 8.3 to 8.95% at Conchopata, the highest levels recorded in Peru. The correlation coefficients calculated for the combined results of Conchopata and Wari together, suggest strongly that in Ayacucho, higher levels of pH and Humidity can be taken as proxy indicators of low effective resistivity, and, by extension, a relatively low level of projected penetration for Ground Penetrating Radar. Here, the lower the levels of oxides, carbonates, chlorides, and pH, the higher the effective resistivity and projected penetration of GPR. Of these elements, carbonates stood out with strong, or steep, negative correlation coefficient of -0.593; e.g., higher carbonate levels compute to lower effective resistivity and by extension lower levels of penetration for GPR.

For Cuzco, the results were like those of Ayacucho (Table 1). The Cuzco region was represented in the sample of soil tests by Sacsayhuaman and Ollantaytambo. Both were very different in their recorded levels of humidity. Sacsayhuaman showed high levels of humidity with an average of 13.8%, while Ollantaytambo yielded a low average of 4.78% of humidity. Although Sacsayhuaman showed moderate levels of effective resistivity and clear indications that the resistivity probes were "seeing" cultural features below the surface, Ollantaytambo was distinguished by some of the highest effective resistivity readings in the multi-site survey. Histograms of the relative percentages of humidity, pH, chlorides, carbonates, oxides, and sulfides consistently showed higher levels of all compounds at Sacsayhuaman than at Ollantaytambo (Table 1). While no correlation coefficients were computed for humidity and oxides in Cuzco, all other compounds showed significant negative correlations with effective resistivity (Table 2). In Cuzco, the coefficient correlations showed that the higher the concentration of carbonates, chlorides, pH, and Sulfates, the lower the effective resistivity. Or inversely, the lower the levels of these chemicals, the higher the levels of effective resistivity. And the higher the effective resistivity, the deeper the expected penetration of GPR and the effectiveness of intensive resistivity surveying.

For all three test regions (Lima, Cuzco, and Ayacucho), only the level of carbonates was consistently inversely correlated with the effective resistivity (Table 2). Low levels of carbonates were associated with high effective resistivity, and inversely, high levels of carbonates correlated with low effective resistivity (Table 2). Consequently, high levels of carbonates translate into low effective resistivity, and therefore relatively low effective GPR penetration (Alsharahi *et al*. 2016: 574).

SURVEY RESULTS AND SITE EVALUATIONS

A total of twelve sites throughout the coast and highlands of Peru were tested for subsurface resistivity and chemical characteristics as a basis for recommending which remote sensing techniques (radar, magnetics, or conductivity) would be appropriate for each region and site. The study locals consisted of both prehistoric Inca and pre-Inca sites, as well as the investigation of historic colonial sites in each study area. In Lima, the historic sites included the Convent of San Francisco and its catacombs of buried interments and the colonial site of Quinta de Presa. In Cuzco, resistivity sampling and soil tests were conducted at two areas of Sacsayhuaman, multiple localities at Ollantaytambo, at the Inca site of Coricancha, at Markavalle and at the newly discovered multicomponent site of Wimpillay, and finally at two colonial sites, Almudeña and the Iglesia de San Bernardo (over Coricancha). In Ayacucho, geophysical studies were done at the two Wari sites of Wari and Conchopata and at the historic site of the Convent de Santa Teresa.

Of the twelve sites evaluated, half showed good electrolytic and chemical conditions for some form of additional intense future geophysical remote sensing. On the Lima coast, the catacombs of the Convent de San Francisco (Plate 6a) yielded good test results and a high promise of positive planning insights from the application of additional remote sensing techniques. Four transects were laid out along the floors of the catacombs in between the open crypts of loose human remains. Although no excavations had yet been undertaken in the underground crypts at the time of the UNESCO-OAS-Andres Bello survey, I.N.C. project personnel, Marcello Arroyo and Ernesto Nakandakari, suspected that other structures lay hidden and buried beneath the currently exposed floors of the catacombs. The resistivity results appear to have supported this hypothesis. As illustrated by the plot from a 6.5-meter resistivity transect taken at half-meter intervals across one of the vaulted chamber floors, the resultant effective resistivity readings demonstrated multiple peaks and oscillations ranging between 40 and 90 ohm-m suggesting multiple features buried beneath the floor of the vaulted catacombs (Figure 10). The fluctuations in effective resistivity also suggest that these suspected buried features would be good candidates for additional remote sensing scans with GPR and intensive resistivity. The proximity of fired brick in the crypt and domed walls of the catacombs precluded the utility of magnetometers. The floors were flat and unobstructed which is good for GPR. The fluctuations in the effective resistivity transect across the floor suggests that intensive resistivity survey at least half-meter intervals would, in most likelihood, be successful in helping to locate buried features.

Also, on the Lima coast, the multicomponent historic site of Quinta de Presa yielded good test results and a high promise of positive planning insights from the application of remote sensing techniques. Excavations by Ruben Garcia of the I.N.C. documented at least three historic building phases in a vertically series of superimposed deposits with multiple wall features down to a depth of 1.5 meters. Taking advantage of the recently completed excavations, we scanned across the modern surface over partially exposed walls and historic features with good signal response (Plate 6b). As stated, we were seeing the buried walls and foundations electrolytically. One series of readings along a 3.5-meter-long transect at half meter intervals across, first a buried double-element masonry wall, and second, a stone feature of stacked cobbles yielded extreme spikes relative to the intervening deposits. Over the foundation wall, the effective resistivity readings spiked to over 600 ohm-m, and to over 500 ohm-m over the adjacent cobble feature, with the intervening deposits without features dropping own to less than 100 ohm-m (Figure 11).

In Cuzco proper, Coricancha was evaluated, but the resistivity signal response there was very low, and the site was not a good candidate for remote sensing (Plate 7a). It also had what I understood to have been ca. 2–2.5 meters of 17th and 18th century historic fill under it. However, elsewhere in the Cuzco region, both the Inca sites of Sacsayhuaman and Ollantaytambo showed very strong indications that useful underground remote sensing geophysical maps could be generated. Both sites demonstrated strong contrasts in effective resistivity across partially excavated wall and structural elements. At Sacsayhuaman (Figures 12, 13, Plates 7b, 8a,b, 9), except for the Inti Raimi festival, the apparently empty "plaza" has been commonly perceived as devoid of architecture, or archaeologically vacant (Plate 8a). But it is interesting, it seems wherever the INC teams excavated, they were hitting Inca buildings in the great plain fronting the fortress. While I was there, I observed exposure of the foundations of two buried buildings

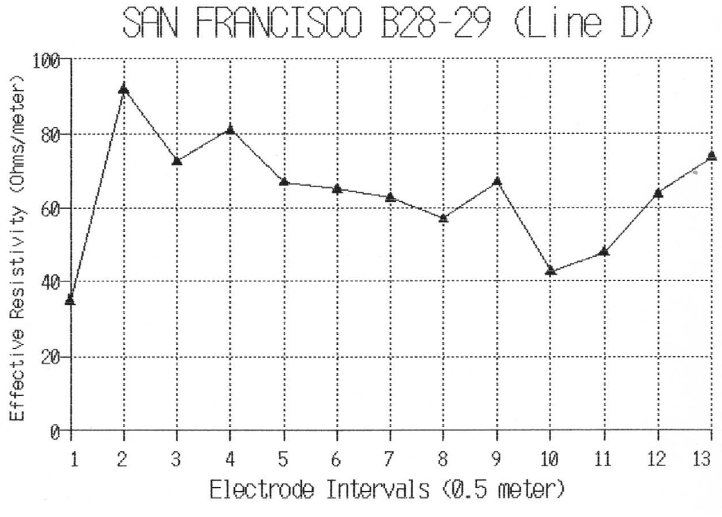

Figure 10. Computer plot of fluctuating effective resistivity across floor of the catacombs of the Convent of San Francisco showing order-of-magnitude spikes and dips in effective resistivity suggesting the potential presence of subsurface features (Graphic by Joel W. Grossman).

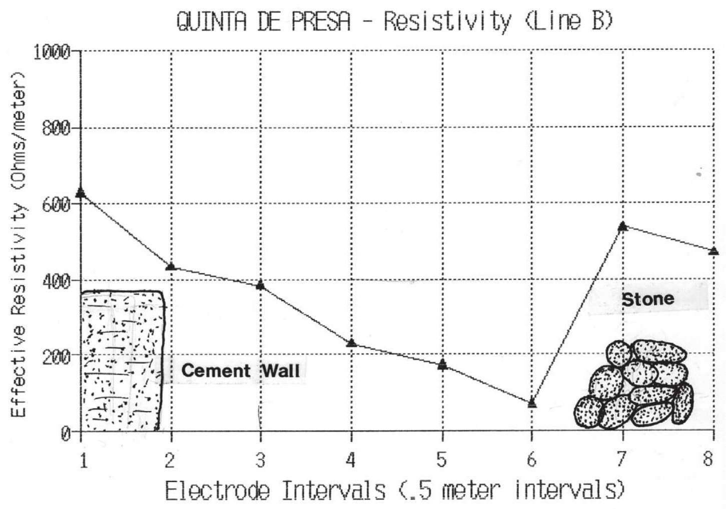

Figure 11. Computer line plot of effective resistivity readings across buried foundation wall at the site of Quinta de Presa in Lima, showing high effective resistivity over buried wall elements and lower readings across intervening deposits devoid of features (See Plate 6b) (Graphic by Joel W. Grossman).

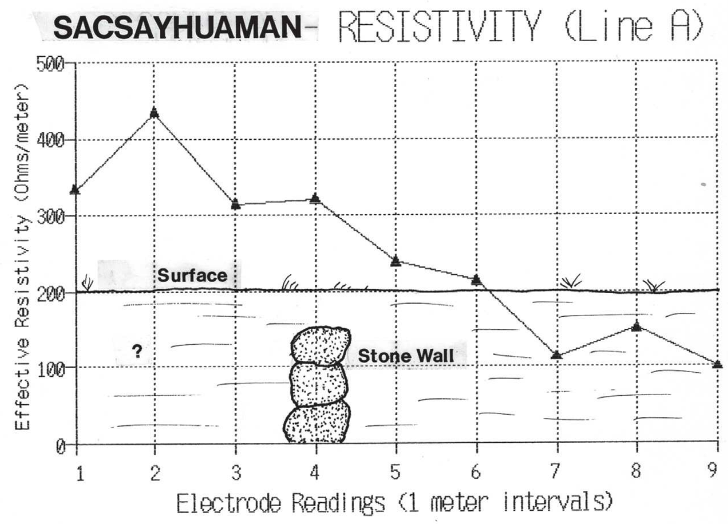

Figure 12. Profile line graph of measured effective resistivity across a buried Inca building in the Chukipampa sector of Sacsayhuaman showing increase of resistivity over the interior of the structure and lower resistivity outside of it (See Plate 9) (Graphic by Joel W. Grossman).

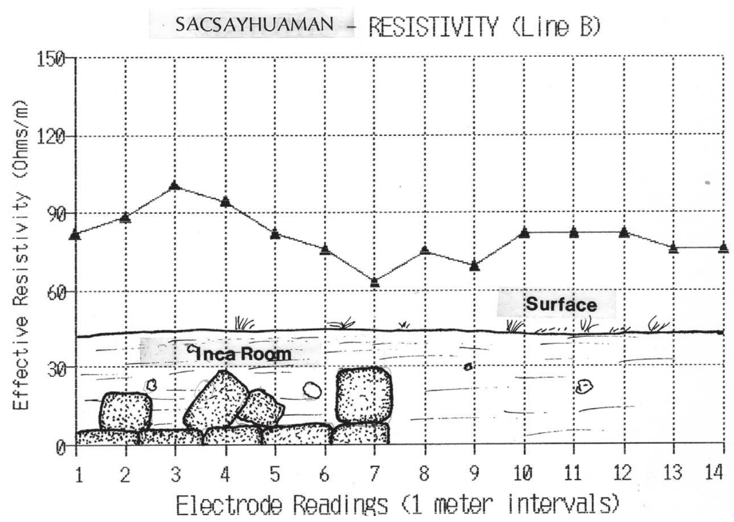

Figure 13. Profile line graph over buried foundation at Sacsayhuaman showing increase in effective resistivity over building interior (Graphic by Joel W. Grossman).

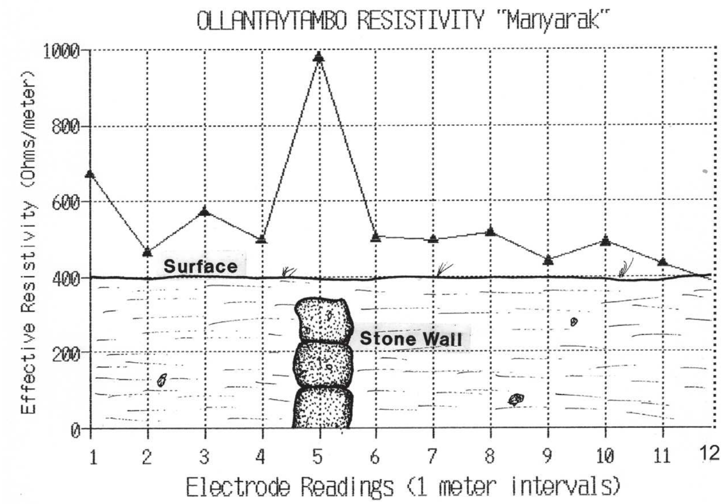

Figure 14. Line plot of recorded effective resistivity readings across a buried wall in the "Manyarak" sector of Ollantaytambo, showing a high reading of 1000 ohm-m over a partially exposed Inca wall element. The Manyarak sector was a prime candidate for additional intense geophysical remote sensing with resistivity and GPR (Graphic by Joel W. Grossman).

in the otherwise flat "plaza". They are clearly of Late Horizon Inca origin with rectilinear dimensions and cut stone construction (Plates 8b, 9). The recorded effective resistivity was higher over the building walls and interior rubble in both locals. In the first area, Chincana, the recorded effective resistivity rose to between 300 and 400 ohm-m over a buried Inca room against a background reading of 100–150 ohm-m outside the wall of the Late Horizon structure (Figure 12). At a second location at Sacsayhuaman, Chukipampa, the effective resistivity readings were less pronounced compared to the first case but showed definite spikes over the interior of the structure. Here, the effective resistivity was over ca. 100 ohm-m across the partially exposed Inca structure and dropped to less than 60 to 85 ohm-m outside the buried building (Figure 13). These two discoveries by the INC suggest the possibility that other Inca structures may indeed be present in the "barren" open space at Sacsayhuaman. At the very least, it appears not to have been an empty area in the Late Horizon. The resistivity results also strongly suggest that an advanced and intensive program of wide areas geophysical surveys using a variety of instruments (resistivity, magnetometers and GPR) is indeed warranted throughout the interior plane of Sacsayhuaman.

Although initially listed in the 1983 report as possible sites in the Cuzco region for additional geophysical survey in the Cuzco region, the results of testing at Markavalle and Wimpiyllay were disappointing. Both sites yielded low effective resistivity readings of below 100 ohm-m and thus would not be good candidates for either resistivity or GPR survey. Markavalle demonstrated an additional negative factor relative to the possibility of using a magnetometer at the site. It was bounded by multiple structures made of fired brick containing magnetically

reactive iron particles that would interfere with magnetometer readings. Finally, as originally concluded in 1983, the two historic sites of Almudena and San Bernardo both yielded very low resistivity readings and minimal probability for successful geophysical surveys.

Excellent results were recorded at Ollantaytambo outside Cuzco. In fact, the remote sensing results, and sub-surface fluctuations in resistivity at his site complex were even more pronounced than at Sacsayhuaman. At Ollantaytambo, the resistivity transects recorded strong signal response and extreme fluctuations over buried floors, interior canals within rooms, and terraces of differing depths (Plates 10 and 11). A buried wall in the Manyarak sector of the site showed a peak, or spike, of nearly 1000 ohm-m over background, and dropped by 50% to levels between 400 and 500 ohm-m on either side of it (Figure 14). At a second local at Ollantaytambo, the Incamisana sector, readings across a partially exposed terrace showed consistent spikes between 500 and 900 ohm-m which dropped off to less than 600 ohmmeters on the down-slope side of the terrace (Figure 15).

Finally, in Ayacucho, the site of Conchopata (Plate 12a) showed relatively minor, but measurable, fluctuations in effective resistivity (ER) over cultural features. ER readings over partially excavated features spiked at nearly 200 ohm-m, compared to readings of below 175 ohm-m on either side of the buried wall elements (Figure 16). Conchopata was also problematic because, like Wari, it was covered with extensive zones of debris, stones and shrubs, all impediments for GPR.

Wari was investigated over a four-day period (October 21–October 24, 1982) by Dr. Grossman and the INC team (see acknowledgements) with both resistivity transects and chemical

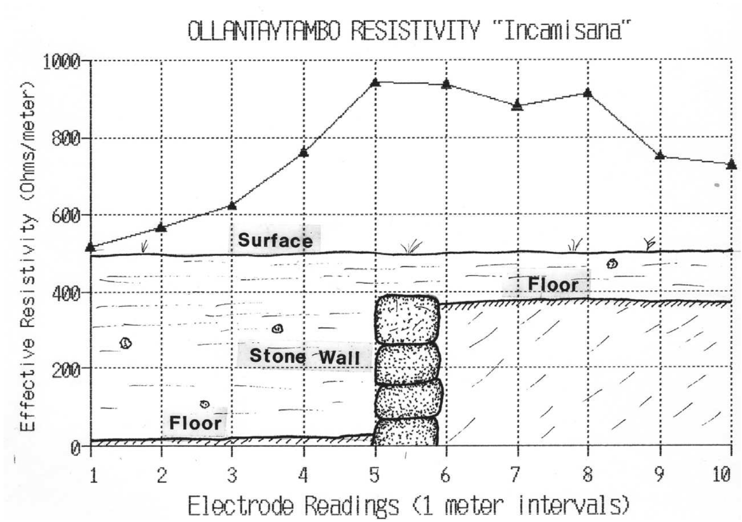

Figure 15. Line plot of effective resistivity within the "Incamisana" sector of Ollantaytambo yielded the highest readings of all the sites tested; with a mean of 760.5 ohm-m, and a spike to nearly 1000 ohms/meter over a partially exposed terrace. Like the Manyarak area, this series of resistivity readings indicated that this area too was a prime candidate for intensive geophysical investigation (Graphic by Joel W. Grossman).

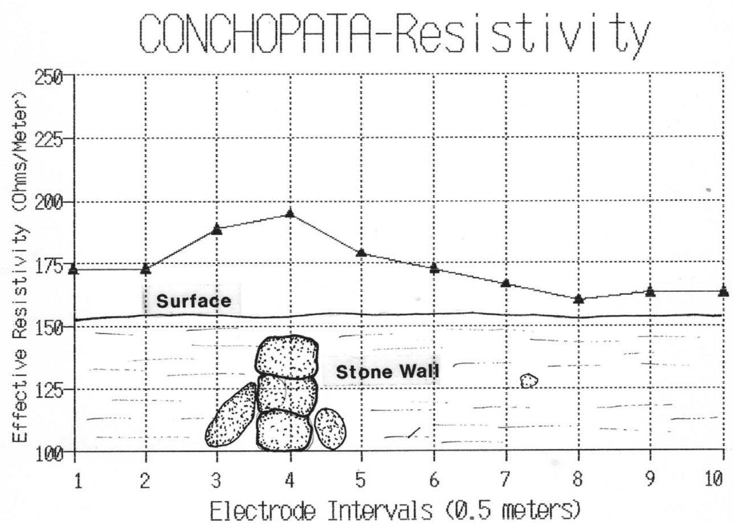

Figure 16. Profile line plot of effective resistivity readings over partially exposed wall element at Conchopata. Pronounced spikes, from ca. 175 to nearly 200 ohm-m indicate that the site would be a good candidate for additional resistivity survey. Debris and rubble across the site would render GPR difficult to deploy unless the surface was cleared prior to survey (Graphic by Joel W. Grossman).

soil tests. The INC excavation at Wari was undertaken as a large-scale wide-area exposure, versus as a series of small "telephone booths" (Flannery 1976), or small and often isolated deep stratigraphic test cuts. In contrast, the 1982-1983 INC fieldwork covered a large area, known as the Vegachayoq Moqo sector, consisting of an artificial, 8 meter-high, mound and adjacent depression over an area of 3600 square meters, at an elevation range of between 2768 and 2776 meters above sea level. Under the overall direction of Dr. Gonzalez Carre of the University of Huamanga, and the field leadership of Enrique Bragairac Davila, Director of Excavations, wide-area excavations revealed a 14-meter-diameter, D-shaped, building characteristic of many Wari sites (Plate 12b; see McEwan and Williams 2012: 72-73). The D-shaped building was found next to a series of rectilinear galleries and rooms decorated with relief impressions of Wari style motifs and painted with two and possibly three colors (see Plate 13). It was an important INC-sponsored discovery (Davila, personal communication, October 21, 1982).

Multiple resistivity transects across, and adjacent to, the Vegachayoq Moqo sector D-shaped building showed good signal response across identified structures and vertically within the fill over the site. Little signal response was recorded across the interior fill of the D-shaped building. However, transects across a cut stone chamber (Plate 14), showed identifiable shifts in recorded effective resistivity (Figure 17). Finally, despite the successes at Wari, the historic site of Convent of Santa Teresa in Ayacucho showed low diversity in the amplitude of effective resistivity and thus a low probability of success for any subsequent terrestrial near surface remote sensing investigation.

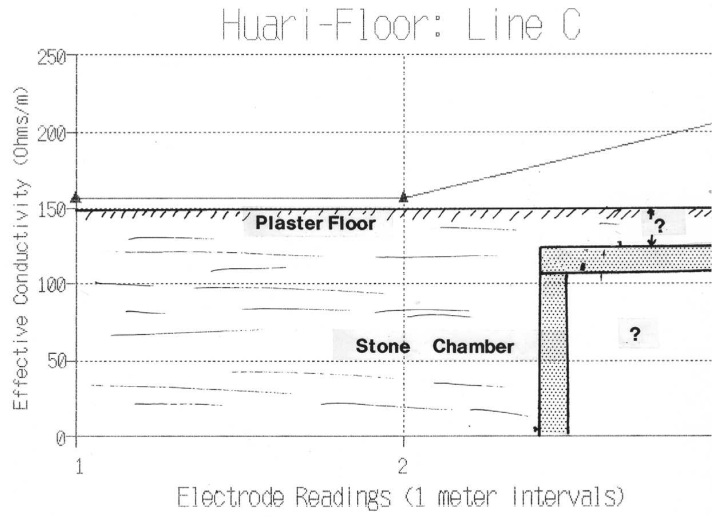

Figure 17. Profile line plot of effective resistivity readings across a section of a cut-stone multi-component basalt chamber showing a spike in readings over its roof, and lower readings outside its limits (See Plate 14) (Graphic by Joel W. Grossman).

In summary, good resistivity results and the recommendations for additional geophysical investigation were presented for six sites: San Francisco and Quinta de Presa in Lima, Ollantaytambo and Sacsayhuaman in Cuzco, and Wari and Conchopata in Ayacucho. In each of the cases with positive geophysical results, buried wall and structural elements correlated with significant fluctuations or spikes in recorded effective resistivity. As such, each of these six sites is recommended for additional geophysical remote sensing work in general, and GPR, in particular.

THE FINAL REPORT

The site-specific investigations and the seminar series at the Convent of San Francisco, were followed by a multidisciplinary, and in this case, an international UNESCO-OAS-Andres Bello sponsored technical report by me and staff of the INC in Lima, Cuzco, and Ayacucho. Archaeological and restorations specialists were flown in from Cajamarca, but no fieldwork was done there as part of the geophysical program. All field recordings, resistivity computations, and chemical tests were conducted and analyzed by Peruvian scientists and symposium participants (Grossman *et al*. 1983). I made final recommendations, but much of the report was done by the Peruvian members of the team. As documented by their project field reports (e.g., Quintana 1982a and 1982b: Table I), the INC staff both interpolated the field data and jointly produced the final site evaluations. It was truly a joint and international effort. The final 1983 report to the INC (Grossman *et al.* 1983) included specific recommendations concerning: 1) the definition of which sites would benefit from in-depth remote sensing work; 2) a listing of what remote sensing equipment would be appropriate for each individual site; and 3) a cost projection (in 1983 dollars) for each site selected. Finally, my portion of the report included an assessment of specific equipment, facilities, and training needs of then current and future INC projects and programs in general. The report also included a call for enhanced funding to support a goodly number of radiocarbon determinations to date the important finds the INC programs were uncovering (Grossman *et al*. 1983).

ACKNOWLEDGEMENTS

I want to express my special appreciation to the restauration architects Jose Correa Orbegoso, Ramiro Salas Bravo y Jorge Levano, who since 1973 organized, carried forth and executed the Restoration of the Architectural Complex of San Francisco in Lima, through the Treaties of International Cooperation International with UNESCO, the Organization of American States (OAS), y el Andres Bello Fund. As the Technical Directors of National Cultural Patrimony of the National Institute of Culture (INC), they brought about the realization of the First Seminar of Historical Archaeology in 1982 and those that followed in 1982 and 1983. Their perseverance and support made possible the participation of the International Consultants who participated in this important Interdisciplinary program. In 1988, UNESCO declared the San Francisco accord, and later in 1991 the Center of Downtown Lima was declared a World Heritage Site, as an example of "…an exceptional example of an architectural complex that illustrates a significant step in human history". At the same time, I want to express my appreciation to archaeologist, Dr. Hugo Ludeña Restaure - then the Technical Director of Restoration of Monumental Resources of the INC - currently affiliated with the Catholic University of Peru Faculty of Letters and Human Sciences, with a specialty in archaeology) who directed my participation in this geophysical initiative throughout Peru under the auspices of UNESCO, the OAS, and the Andres Bello Fund, following the 1981 Quito-OAS conference. His edits and guidance helped formulate the final version of this paper; it would not have taken place without his direction, both in the field and after. Special thanks to Arquitecto Jorge Levano, Senior Architect and Director of the Restoration Project for the San Francisco complex (Figure 2), for his hosting of the Lima symposium, his specific invitation to me to train Peruvian scholars, and for facilitating the magnificent venue for the conference of the 16th Century Library of the Convent of San Francisco (Plate 5a). My visits to each region were systematically organized and supervised by senior staff of the INC. My four-day visit to Ayacucho was undertaken within the context of severe political, military, and social tensions within the region. Throughout my visit to Ayacucho and the evaluation of three sites there, I was constantly escorted and guided by Ing. Jorge Marroquin, the INC project field engineer in charge of coordination of site stabilization activities with the archaeological field teams. My stay and access to facilities in Ayacucho were coordinated by INC Director, Dr. Walter Wong. Inspection tours and detailed overviews of ongoing research and excavation activities at each of the project sites was provided by the project field directors. The visit to Wari was facilitated by Dr. Enrique Gonzales-Carre, Principal Investigator and professor of Archaeology at the University of Huamanga, together with the Director of Excavations of the Vegachayoq Moqo D-shaped building at Wari, Enrique Braqairac Davila (see Plate 13). In terms of the institutional themes of this symposium, it is relevant to point out that, despite the ongoing Sendero Luminoso war, the entire Wari mitigation and reconstruction program was undertaken under adverse conditions as a cooperative effort between the local Ayacucho Development Corporation and the National Institute of Culture, with no external or international fiscal support. The archaeological excavation and stabilization work were conducted as an integrated multidisciplinary team effort, drawing equally on the skills of the project archaeologists, architects, and engineers to a level of integration which is only relatively recently been accepted as a standard in other countries. Field tests at the Ayacucho site of Conchopata was facilitated by the supervisory field archaeologist, Denise Pozzi-Escot together with Dr. Gonzales-Carre and Ing. Marroquin. Finally, visit to the third Ayacucho study site, the convent de Santa Teresa, were undertaken with the assistance of Dr. Gonzales-Carre and Ing. Marroquin. In addition to my overall report and recommendations (Grossman *et al*. 1983), the final report included the analysis of soil chemistry and supporting field operations by archaeologists of the INC: Marcelo Arroyo Rios, Rolando Paredes Eyzaguirre, Graciela Fattorini Murillo, Teresa L. Quintana, Carmen Thays, and Rubén Garcia.

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Plate 1. Geophysicists including Bruce Bevan of Geosight of New Jersey and from the firm of Geophysical Survey Systems of New Hampshire, pulling a prototype 300 MHz antenna capable of "seeing" through the cap of surface deposits and shale fill covering the buried settlement of Raritan Landing. The Ground Penetrating Radar equipment required a truck for transport in 1978; modern systems now fit into a backpack (Photo by Joel W. Grossman).

Plate 2. Three-part photo composite of the 15-foot-wide excavation corridor through the buried settlement of Raritan Landing. The all-weather archaeological mitigation took place under moveable reinforced deep-winter green houses to protect the field crew and artifacts in deep winter conditions. An early version of electronic distance meter (EDM) - the precursor of modern total stations - took highly accurate angle and distance readings of datum points and feature parameters. An in-house project-designed overhead bi-pod camera system was raised to take individual metric photographs and stereo pairs of excavated colonial features (See Plate 3) (Photos by Joel W. Grossman, Victor Calderone and Robert Tucker, RASO).

Plate. 3. Overhead bi-pod photo of one of a series of stereo pairs over an underground pre-Revolutionary war drain system at Raritan Landing (See Plate 2) (Photo by Victor Calderone and Robert Tucker, RASO).

Plate 4. Field view of project conservator, Melba Myers, treating delicate organic remains during the excavation instead of long after (Photo by Joel W. Grossman).

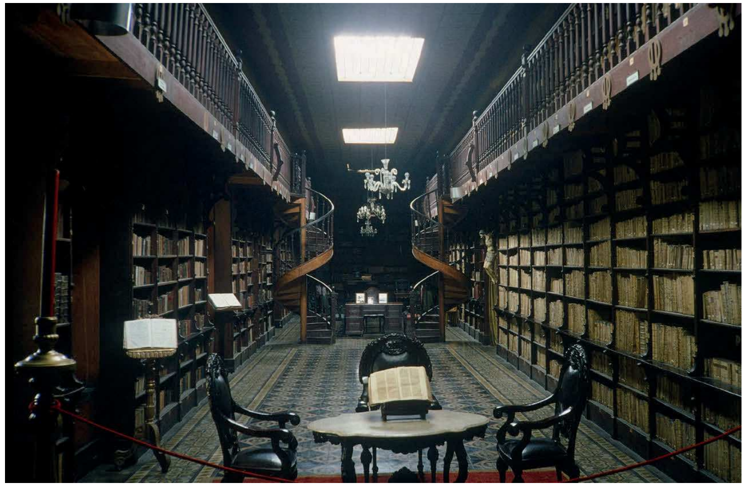

Plate 5a. Interior view of the 16th century library of the Convent of San Francisco in Lima which served as the venue for the seminars on archaeology and geophysics given by Dr. Grossman to archaeologists and restoration specialists of the INC who were flown to Lima to participate in the UNESCO-OAS-Andres Bello program (Photo by Joel W. Grossman).

Plate 5b. Peruvian INC archaeologists, Rolando Paredes, Graciela Fattorini and Marcelo Arroyo using modern battery powered Gossen Geohm 3 resistivity meter across one of the underground floors of the multi-chambered 16th century catacombs of the Convent of San Francisco (Photo by Joel W. Grossman).

Plate 6a. The Catacombs of the Convent of San Francisco showing the arched ceiling of the underground complex with rectangular brick crypts containing disarticulated human bones bordering either side of the chamber (Photo by Joel W. Grossman).

Plate 6b. Peruvian INC archaeologists, Rolando Paredes, "El Gato" in the center and behind him, Graciela Fattorini, Marcello Arroyo and Ruben Garcia, recording resistivity transect across a buried double-element plastered foundation wall at the colonial site of Quinta de Presa in Lima (See Figure 11) (Photo by Joel W. Grossman).

Plate 7a. The Spanish Church of Santo Domingo built atop the curved finely cut stone wall of the Late Horizon Inca temple of Coricancha in Cuzco (Photo by Joel W. Grossman).

Plate 7b. The main gate at the Inca site of Sacsayhuaman with Dr. Grossman standing for scale against a monolithic corner stone of the terraced Inca fortress (Photo by Ing. Jorge Marroquin).

Plate 8a. Panoramic view of the flat "plane" of Sacsayhuaman were the annual festival of Inti Raimi is held. Though thought previously to be a flat "dead" space devoid of structures, recent (1982-83) excavations by archaeologists of the INC revealed buried Inca buildings within the plane of Sacsayhuaman (See Plates 8b and 9). Preliminary resistivity transects across these partially exposed structures suggest strongly that the resistivity equipment was clearly "seeing" the Inca building's foundations. They also suggested strongly that intensive geophysical survey, in general, and with resistivity and GPR in particular, of the "Inti Raimi" plane would help define what may have been a contiguous and dense zone of Late Horizon Inca structures (Photo by Joel W. Grossman).

Plate 8b. Partially exposed Inca foundation discovered by INC archaeologists in the "Chincana" sector of Sacsayhuaman. Here, INC scientists transect a partially exposed 60 cm wide and 20-30 cm deep, foundation wall with tape-measured resistivity transect.

Plate 9. Exposed Late Horizon rectangular 8-meter wide Inca building discovered by INC archaeologist in the "Chukipampa" sector within the plane or plaza of Sacsayhuaman. The finely cut foundation stones and rectilinear plan indicate classic Late Horizon Inca architecture. The exposed wall elements measured 80 cm in width and ranged in depth between 30 and 100 cm below modern grade (Grossman *et al.* 1983: 50) (See Figure 12) (Photo by Joel W. Grossman).

Plate 10. Recently (1981) excavated "Inca-Misana" sector at the Inca site of Ollantaytambo situated between Cuzco and Machu Pichu on both sides of the Patacancha river tributary. Excavations by archaeologists of the INC under the direction of Arminda Gibaja Valencia resulted in the discovery of previously unknown urban sectors of the site, Baño de la Ñusta and the Tercer Adoratorio, with well-preserved rooms and courts with intricate channels and piping to bring running water to interior fountains and baths (See Plate 11) (Photo by Joel W. Grossman).

Plate 11. Inca fountain to spring-fed baths in the Baño de la Ñusta sector at the site of Ollantaytambo on the Patacancha tributary outside Cuzco (Photo by Joel W. Grossman).

Plate 12a. Partially reconstructed wall and room elements of the Huari site of Conchopata, located along both sides of the modern airport road to Ayacucho (See Figure 16) (Photo by Joel W. Grossman).

Plate 12b. Recently (1982-1983) discovered D-shaped Middle Horizon Huari building of Vegachayoq Moqo, found painted with Huari motifs over plastered walls, in two, and possibly three, colors. Of different areas tested within, and adjacent to, the site with resistivity equipment, only one transect showed effective resistivity readings above 110 ohm-m indicating very low signal response. Neither resistivity nor GPR would be effective remote sensing approaches for this sector of Huari. The utility of magnetometer survey was undetermined (Photo by Joel W. Grossman).

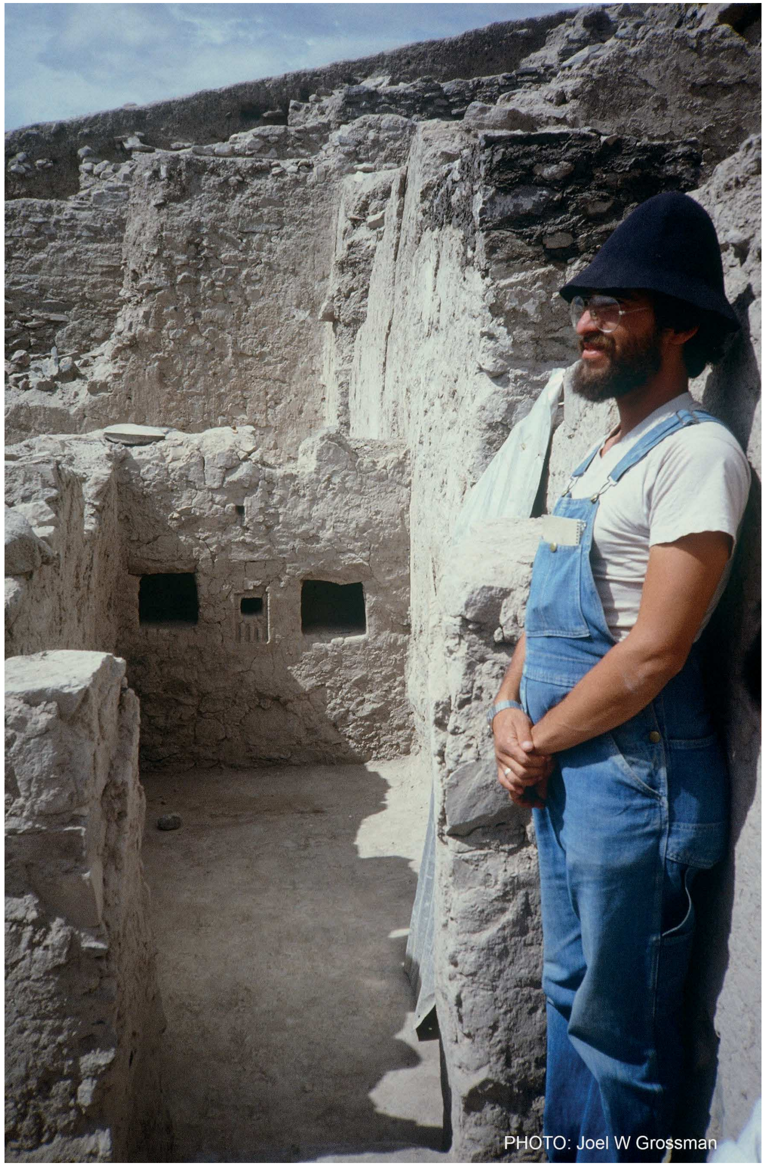

Plate 13. Field photograph of Enrique Bragairac Davila, Director of Excavations of the D-shaped Huari building of the Vegachayoq Moqo sector, standing beside a small gallery with inset portals and reliefs of Huari motifs in the walls (See Plate 12b) (Photo by Joel W. Grossman).

Plate 14. Field view of partially exposed multi-component cut stone basalt burial chamber at Huari (See Figure 17) (Photo by Joel W. Grossman).