ARCHAEOLOGY IN THE ELECTRONICS AGE

Electronic "dowsers" prove their mettle in locating the remains of ancient Peruvian cultures

By Robert A. Feldman and Alan Louis Kolata

LAST SUMMER saw the Field Museum's Programa Riego Antiguo (Ancient Irrigation Project) begin a new phase of archaeological research in South America: the determination of subsurface features without excavation. This feat is accomplished neither with dowsing rods nor by means of clairvoyance, but with highly sophisticated electronic tools—products of Soiltest, Inc., of Evanston, Ill., which has lent them to Field Museum for this project.

Now in its third year, the Programa Riego Antiguo (PRA) is a multidisciplinary project designed to study the prehistoric irrigation system in the Moche Valley of Peru, located along that country's northwest coast. By supplementing basic archaeological data of the region with information on its geology, hydrology, and palynology (the study of pollen), we are seeking to understand the physical and political nature of the water and land management practices of the people who inhabited the valley centuries ago. The project focuses on the area around Trujillo, modern Peru's fourth largest city but in centuries past the capital of the Moche (*ca.* 100 B.C. to 700 A.D.) and Chimu (*ca.* 800 to 1470 A.D.) empires.

Two instruments are being used in our subsurface survey program: a seismograph and a device for measuring electrical resistance in the earth. The portable seismograph,

Robert Feldman

Auger, used to check the accuracy of the earth resistivity meter and seismograph, illustrates the depth of soil build-up along the Wiscansao Canal. Without the electronic instruments, it would have been necessary to dig a test pit by hand.

Robert A. Feldman is a research archaeologist, P.R.A. Alan Louis Kolata is archaeological consultant, P.R.A.-Soiltest Program and Tiwanaku-Soiltest Program.

basically a highly sophisticated stopwatch which measures time in ten-thousandths of a second, is used to time shock waves traveling through the earth. This speed varies with different soils: for example, shock waves travel at about 1,500 feet per second through "normal" soil and at more than 10,000 feet per second through rock.

The earth resistivity meter measures variations in the soil's electrical resistivity according to its composition, density, and water content. Loose, dry sand offers very high resistance to an electrical current while wetter agricultural soil has a low resistance.

Through a series of calculations, these instruments' measurements of seismic velocity or electrical resistance can be converted to measurements of the thicknesses of the various layers of soil producing the different readings. By testing an area with both devices we can measure two distinct properties of the earth's layers and arrive at two calculations of the depths to which they go. One instrument provides a check on the other.

The rivers that come down from the high Andes to the Pacific carry water that makes agriculture possible on the harsh desert coast. They also carry a load of suspended silt which, carried by the water, enters the irrigation canals, where it can settle out. Unless the canal is cleaned periodically, it would eventually fill in with this deposited silt. From these observations, we had hypothesized that silt deposited from the irrigation waters would tend to reinforce the placement of a canal. Silt thrown out of canals during periodic cleanings would build up the banks. The growing canal banks, in turn, would trap erosion materials, building up the ground surface of the fields near the canals. As a result, new canals should follow the built-up path of older ones.

The subsurface survey, using the two instruments, tested this hypothesis by measuring the amount of soil build-up around the major canals. The instruments proved themselves to be useful, and the results we obtained with them confirmed our hypothesis. What surprised us, though, was how great this build-up had been: in places it was over 6 meters (almost 20 feet). To dig a test pit to that depth with pick and shovel would not only require a great amount of time and money, but would also be extremely hazardous to the diggers. However, by using the seismograph and resistivity meter, it was possible to do two complete sets of tests and map the test site in an easy day's work. Since we were uncertain how well the instruments would work for our purposes, we also had a small test hole bored with a hand auger to check their results. We were pleased to find that the auger confirmed the instrument readings.

We began our instrument survey in the middle sections of the Moche Valley along a modern canal called the Wiscansao. We knew that the Wiscansao had also been a major irrigation channel in ancient times. Like other prehistoric

The seismograph's small size and easy portability make it ideal for rapid survey. The shock waves it records are generated by pounding the ground with a sledgehammer.

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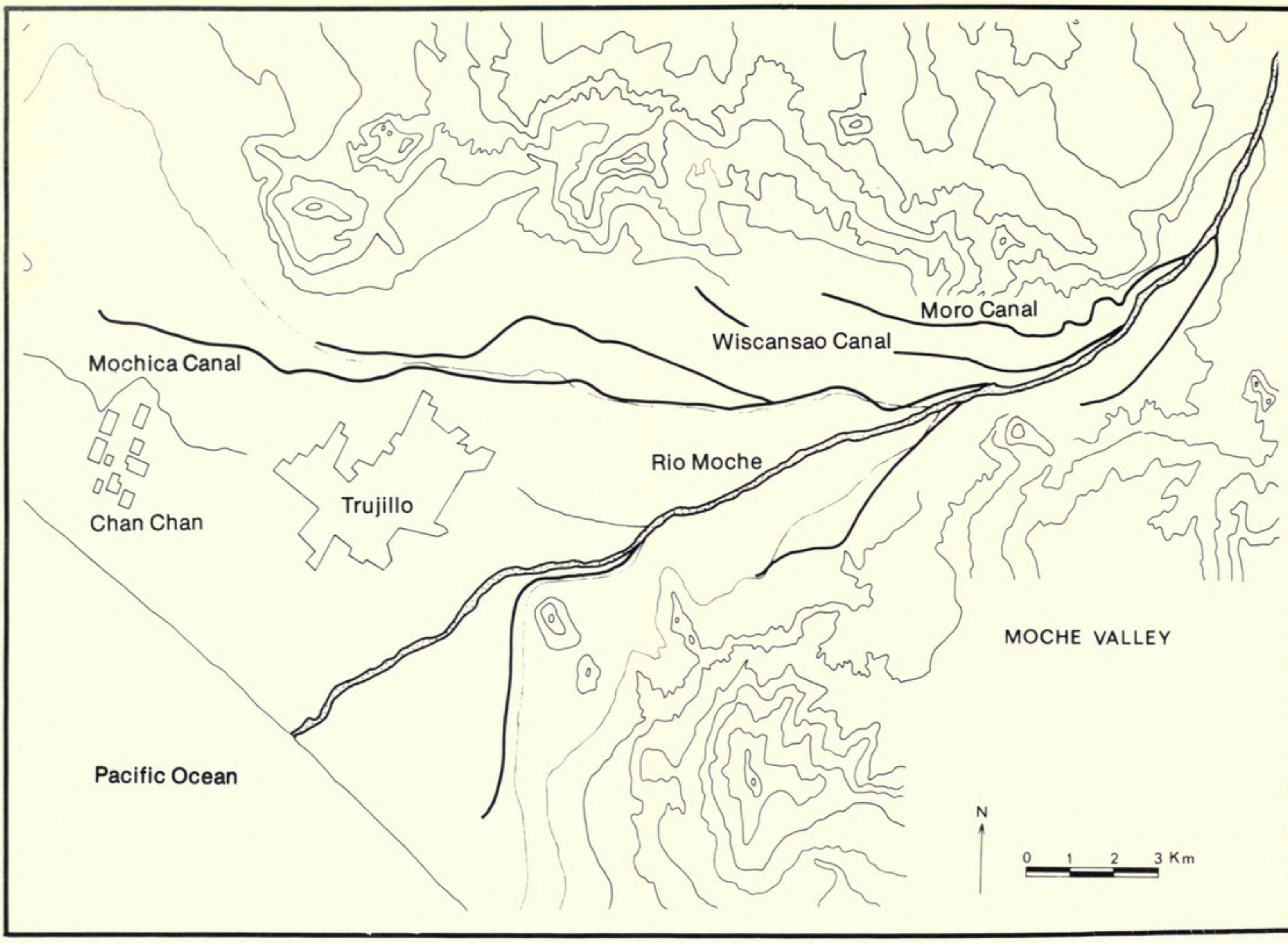

Map of the lower Moche Valley, showing the principal modern canals. These canals are shortened versions of ancient pre-Columbian canals.

canals in the valley that are still being used, the Wiscansao runs on the crest of a terrace which, in the case of this canal, is some four meters (about 13 feet) high. The purpose of our survey here was to determine whether this terrace was a natural geological feature present prior to initial construction of the old Wiscansao, or "artifically" formed by a gradual deposition of silt over centuries of use, or perhaps a combination of the two.

If the terrace were entirely natural—a *geological* pheonomenon—we would expect the "basement stratum," consisting of dry, rocky soil (with high seismic velocity and low electrical resistance) to be stepped and to occur at the same depth below the present surface on both the upper and lower sides of the canal. But if the terrace were entirely artificial—an *archeological* phenomenon—we would expect this basement stratum to remain relatively level and, therefore, be deeper below the surface on the upper side of the canal by an amount about equal to the visible elevation of the terrace.

We did three separate test runs with the instruments parallel to the canal, and on both its "upper" and "lower" sides (*i.e.*, on the crest and at the base of the terrace). Upon completing these tests, we discovered that the basement stratum on the lower side of the canal was at a depth of about 3.25 meters, while on the upper side (on the crest of the terrace), the depth to this layer was about 5.25 meters. This meant that the ancient Wiscansao was originally constructed on a natural terrace some 2 meters high. Through time, erosion materials washing down from above the canal were trapped behind its banks, gradually reaching a present depth of over 5 meters. Below the canal, without a similar "soil trap," the silt build-up was much smaller—just over 3 meters. We concluded, then, that the terrace carrying the Wiscansao was composed of *both* natural and artifical features.

Our instrument tests have given us insight into the history of soil development around canals and some understanding of the strategy of canal placement practiced by the engineers of these waterworks in ancient times. It is clear that the designers of the original Wiscansao took advantage of the elevational difference between the natural terrace and the surrounding landscape in sighting this canal.

Tests along other ancient Peruvian canals revealed

P.R.A. codirector Thomas Pozorski probes for a buried canal with the earth resistivity meter. This instrument and the seismograph shown on p. 5 were on loan from Soiltest, Inc., of Evanston, Ill.

Shelia Pozorski

that, at times, they were built on entirely natural terraces, or were themselves wholly responsible for the artificial development of a terrace through the process of gradual silt deposition. By extending our instrument survey to other canals, we will eventually be able to map the relationship between the original natural landscape and irrigation features throughout the valley.

Another test that we ran was designed to estimate the rate at which soil build-up occurred. The Wiscansao canal passes through a very old mound group called Caballo Muerto. Earlier excavations by PRA codirector Thomas Pozorski had located the base of one of these mounds more than four meters below the present ground surface. Nearby is a small mound of the Chimu period. We were able to locate the foundation of this mound at a depth of only one meter. Tests between the two mounds showed that the Chimu mound was built on soils deposited since Caballo Muerto times. Assuming that these three meters of soil had been deposited at a uniform rate over the 2,200 years between *ca.* 1000 BC and *ca.* 1200 AD, the average yearly deposit comes to about 1.3 mm (about 1/20 inch). A similar rate can be calculated using the one meter of soil build-up that has occurred in the almost 800-year span since the construction of the Chimu structure.

What did we learn from our work? Perhaps the most important point is that irrigation agriculture, even in the nonmechanized world of pre-Columbian Peru, has a tremendous impact on the environment. The Peruvian coast is a very dry desert, so there is normally little or no soil formation. By contrast, soil built up at the rate of about an inch every 15 to

The modern Wiscansao Canal runs along the top of this terrace. Three thousand years ago, the ground surface was over 5 meters lower.

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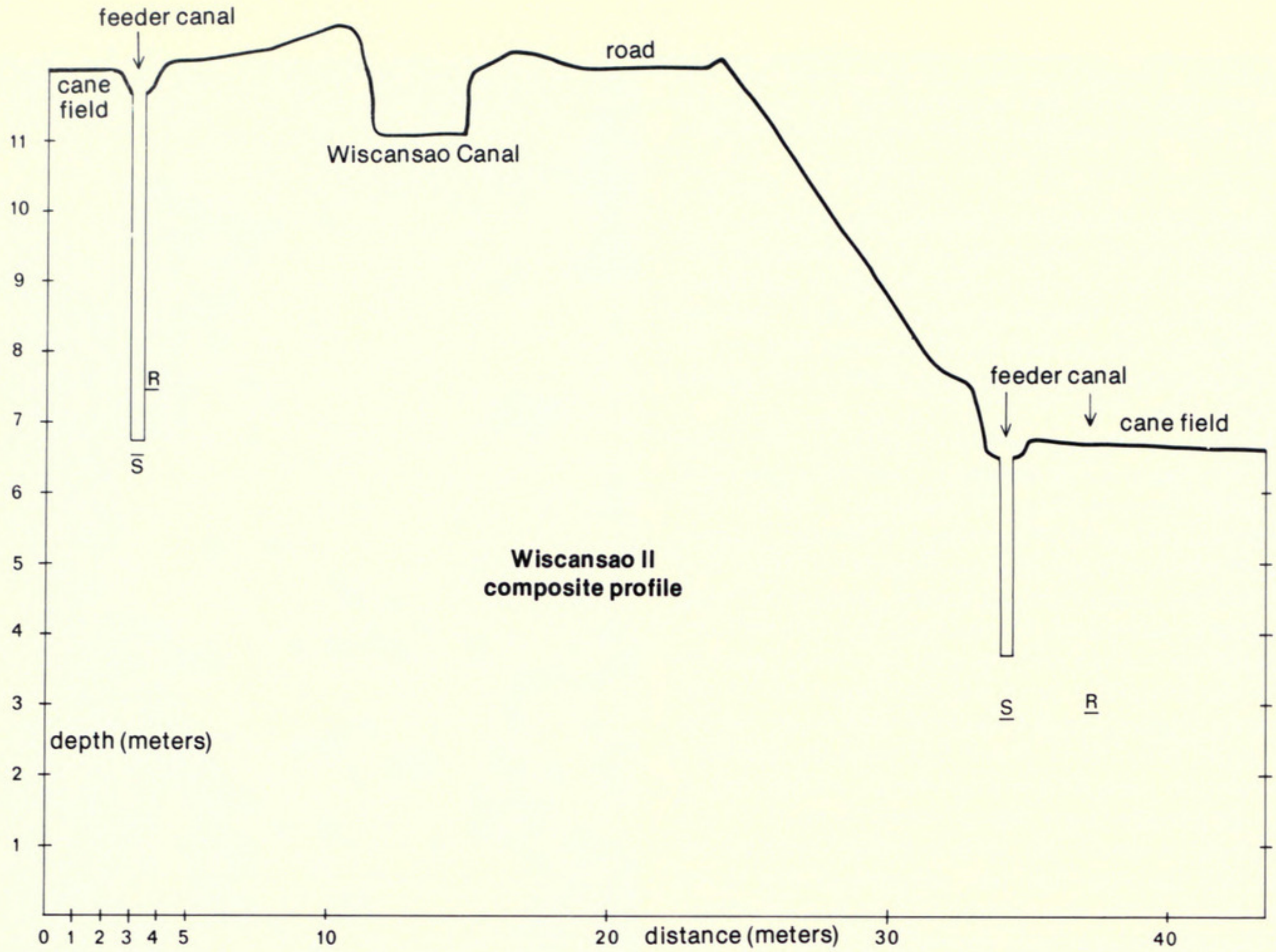

Cross-section illustrating results of seismic, resistivity, and augering tests. (Arrows mark test sites, R=resistivity depth, S=seismic depth.)

20 years in irrigated areas. The build-up was twice as great above a canal as below. This difference indicates that while some of the new soil was dropped from winds slowed by the crops, much came as silt in irrigation water from higher canals and was trapped by the raised banks of the lower canal.

Silt is not the only thing irrigation can leave behind; it can also deposit salt, ruining the land rather than renewing it. If the irrigation system is improperly designed and lacks either sufficient flow or adequate drainage to "flush" the soil clean, naturally occurring salts dissolved in the water can accumulate and precipitate out. Salinization, as this process is called, occurred in some areas of prehistoric Peru when pressure to increase farmlands led to the use of poorly drained areas; these were soon transformed into salt pans and had to be abandoned. Salinization occurs on the lower Colorado River in Arizona and in northern Mexico where too much water is being used upstream, so there is not enough left to flush the fields of the lower basin clean of salts.

Where the water comes from is often as important as where it goes. In coastal Peru canals were fed by rivers dropping precipitously from the Andes, so water that would otherwise have raced into the Pacific was diverted onto—and into—the dry land. In the Moche Valley this not only made large-scale farming possible, it also created an underground reservoir of potable water. Residents of Chan Chan, the capital of the Chimu Empire, tapped this ground water by digging huge walk-in wells and sunken gardens. Their dual use of irrigation water shows great forethought on the part of the Chimu engineers.

The natural path of water used for irrigation is something that should be considered in designing modern water projects. We can see the unfortunate results of ignoring this natural water regime in areas where irrigation systems fed by wells are lowering the water table almost as fast as deeper and deeper wells can be drilled, or in areas where the underground water supply is gradually disappearing because of unrestricted—and unwise—diversion of the great rivers that once fed aquifers (water-bearing rock, sand, or gravel).

The PRA will continue to chart the effects of irrigation on the desert landscape during the pre-Columbian past. The initial results of our research serve as a cautionary tale. In the exceptionally arid environment of coastal Peru, the architects of the ancient waterworks were supremely sensitive to the problem of utilizing their scarce and precious water resources most efficiently. Today, in the face of ever-encroaching deserts throughout the world, can we afford to be any less sensitive to this same problem? □