Title
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Authors
Hildebrand, John
Wiggins, Sean
Conyers, Lawrence

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John A. Hildebrand, and Sean M. Wiggins,
Scripps Institution of Oceanography
University of California San Diego
La Jolla, CA 92093-0205
jhildebrand@ucsd.edu, swiggins@ucsd.edu

Lawrence B. Conyers
Department of Anthropology
Denver University
Denver, CO 80208
lconyers@du.edu

Prepared For:
ASM Affiliates Inc.
543 Encinitas Blvd., Suite 114
Encinitas, CA 92024

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This chapter describes geophysical investigations which were conducted at Las Flores Estancia to better define the structures associated with historic occupation of the site. Field surveys were conducted on February 24 and March 1, 2000, and March 27-28, 2001. Three geophysical techniques were employed: ground penetrating radar (GPR), electromagnetic conductivity (EM), and total magnetic field measurement (MAG).

BACKGROUND

Las Flores Estancia (CA-SDI-812/H) is listed on the National Register of Historic Places as a Mission Period adobe compound in use from the 1820s up to the 1860s, overlying a prehistoric/ ethnohistoric Native American shell midden. Currently, the Los Flores Estancia lies in ruins, with only a few wall segments visible. Its full extent, including outlying features, is uncertain, and its original configuration subject to differing depictions. Adobe wall segments that are visible at the surface are enclosed within a chain-link fence, and one prominent wall segment in the southeast corner of the fenced area is covered by a protective metal shelter. The goal of this geophysical investigation is to better define the location and extent of the Estancia buildings and associated historic features using near-surface geophysical techniques.

GEOPHYSICAL TECHNIQUES

Electrical Conductivity

Electrical conductivity surveys use low frequency electromagnetic energy to detect changes in soil electrical properties. Instruments for measuring electrical conductivity have a transmitting antenna and a receiving antenna separated by a fixed horizontal distance. The antenna separation sets the optimal depth for detection. Changes in coupling between the transmitting and receiving antenna are recorded as the antenna is moved slowly along the surface of the site. Metal objects produce a particularly strong signature, since they are efficient conductors of electrical energy. It is also an effective means for detecting soil moisture content and salinity.

In the Las Flores study area, we measured electrical conductivity using a Geonics EM-38, whose transmitting and receiving antenna are separated by about 1 meter. We collected data with the sensing element held as close as possible to the ground surface (0-.2 m), yielding a maximum detection sensitivity at about 0.4 m beneath the ground surface. Data were collected at 0.4 sec intervals at walking speed along survey tracks. (See chapter 2, Figure 6, left images show the EM-38 in use at the Las Flores study area. The instrument appears as an orange rectangular shape held near the ground surface.) The data were corrected for walking speed (shifted backward along track) and then gridded for display. In the conductivity images, regions of high electrical conductivity are shown with white and red colors, whereas regions with low electrical conductivity are shown with black and blue colors.

Total Magnetic Field

Total magnetic field mapping detects changes in the magnetization of subsurface materials. A magnetic sensor is moved slowly above the ground surface as the total magnetic field intensity is recorded. Magnetized objects in the near surface produce magnetic fields that are combined with the ambient field produced within the earth. For example, fire produces a strong magnetization in clay and soils, such as the materials comprising a hearth or kiln. Metals are another class of materials that have a strong magnetic signature. There is a daily variation of ambient magnetic field strength due to the presence of the sun; at local noon an enhanced magnetic field is observed whose amplitude depends on the geomagnetic latitude and on sunspot activity. To remove the solar diurnal variation, measurements are repeated at a fixed station. The data are then corrected for solar daily variations to capture the presence of local magnetized materials.

At the Las Flores study area, magnetic field data were collected with a Geometrics 858 cesium vapor total field magnetometer which has a sensitivity of 1 nT or less. The magnetic sensor was moved in a horizontal plane at about 0.3 m above the site surface. (See chapter 2, Figure 6, left images show the Geometrics 858 in use at the Las Flores study area. The instrument appears at the end of an aluminum pole, held at waist height.) Collecting a grid of magnetic field measurements with 0.5 m line spacing allowed us to produce a two-dimensional map. After removing the average ambient field (47800 nT) and correcting for diurnal variation, the magnetic field images are shown as a color map, with white and red colors representing increased field strength, and black and blue colors representing decreased total magnetic field strength.

Ground Penetrating Radar
Ground penetrating radar transmits high frequency electromagnetic energy into the ground and measures energy reflected from buried interfaces, such as between soil and rock or wood. GPR is a means for delimiting buried site stratigraphy, and objects or structures that disrupt the natural stratigraphy. In the Las Flores Estancia study area, we used a GPR unit manufactured by GSSI (SIR-2000) with a 400 MHz antenna. The wavelength of a 400 MHz antenna in sandy soils, such as those found at this site, is about 0.34 m. The near-field zone of the 400 MHz antenna is about 1.5 times this wavelength, therefore the shallowest features separated from the out-going pulse in the Las Flores dataset should be about 50 cm deep. Imaging capabilities should extend to 100 cm or greater depths.

GPR data were collected at 16 scans/seconds as the radar antenna was moved along the ground surface at walking speeds. (See chapter 2, Figure 6, right images show the SIR-2000 in use at the Las Flores study area. The antenna appears as an orange box dragged near the ground surface, connected to a sampling computer with a long cable.) Individual lines of radar data show subsurface reflectivity in a vertical cross-section. Grids of data were collected with 0.5 m line spacing. A series of map views of radar reflectivity at depth were produced by combining the individual lines; these are called time-slices. Data were collected with a total time window of 40 (ns) nanoseconds from the surface, and were divided into 10 ns time-slices for display (e.g. 0-10 ns, 11-20 ns). The radar data were gridded with a 1 m search radius to filter out clutter, and to emphasize the largest features. All radar time-slice images were given red colors for reflective materials and blue colors for non-reflective materials.

RESULTS

The geophysical survey grids were designed to test for historic structures or objects. Each site grid was marked on the ground with corner stakes, and survey measurements were made to position the grid relative to a site datum. All geophysical data were collected at 0.5 m line spacing. Measuring tapes were placed along the ground surface and control marks were entered into the data at 5 m intervals during the data collection process.

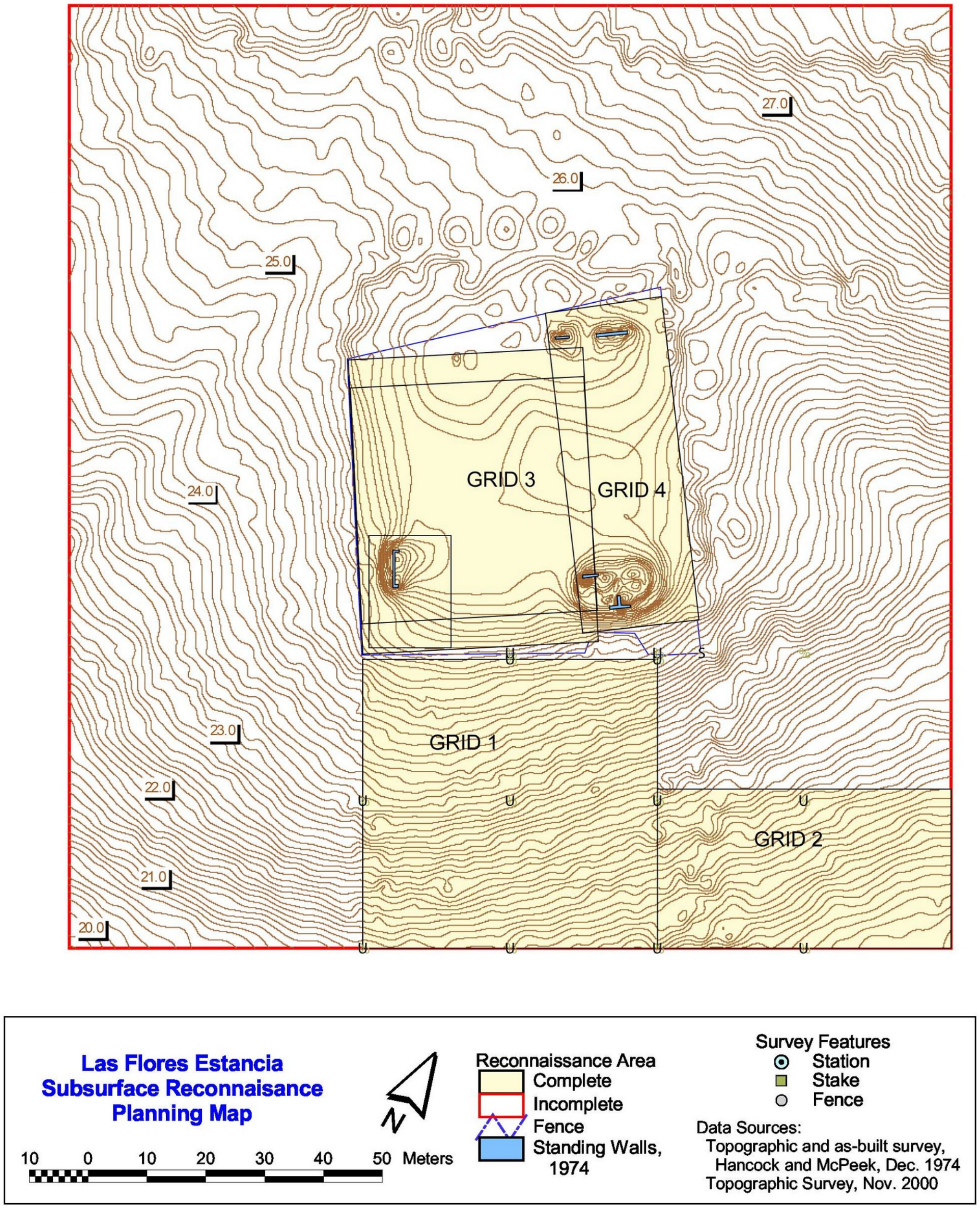

Figure 1. Location of four geophysical survey grids and associated features at Las Flores Estancia.

To date, four grids of geophysical data have been collected at the Las Flores Estancia (see Table 1). These grids are shown superimposed on existing site features in Figure 1. Grids 1 and 2 are located south of the enclosing fence and grids 3 and 4 are located within the enclosing fence. The area within the fence (grid 3 and 4) had recently been cleared of coastal chaparral vegetation. Electrical conductivity surveys were collected within all grids. Magnetic field surveys were conducted only on grids 3 and 4, and GPR data were collected on all except grid 2.

Table 1. Geophysical data grids collected at the Las Flores Estancia.

Nane	Dates	NS (m)	EW (m)	Walk	Origin	EM	MAG	GPR
GRID 1	2/24/00 3/2/00	50	50	EW	SE	X		X
GRID 2	3/2/00	27	50	EW	SE	X		
GRID 3	3/27/01 3/28/01	50	40	NS	SW	X	X	X
GRID 4	3/28/01	60	20	NS	NE	X	X	X

Electrical Conductivity

The electrical conductivity data are shown in map view in Figure 2. The EM data at Las Flores primarily may show the moisture content of the soil, and secondarily the location of metallic objects. The EM data have high conductivity values associated with the fence and metal shelter in the southeast portion of the fenced area (see white and red areas bordering grid 3 and 4 in Figure 2). Low conductivity zones are seen inside the fenced area, especially associated with locations of exposed adobe walls in the northeast and southwest corners of the fenced area. Another zone of low conductivity is observed in the northwest corner of grid 1, just to the south of the fenced area. The shape and continuity of these low conductivity areas suggest that they may be associated with adobe structures or residual abode melt from structures of the Las Flores Estancia.

Magnetometry

The Las Flores Estancia total magnetic field data are shown in map view in Figure 3. These data primarily show the location of metallic structures and objects. The magnetic field data reveal a zone of low magnetic field strength running in a broad zone parallel to the chain-link fence and beneath the metallic structure. The magnetic anomaly from these metal structures is several thousand nT strong, and obscures any magnetic signature from buried objects or structures in this zone. In the interior of the surveyed area, finer scale magnetic anomalies are observed with several hundred nT amplitudes, but they are also probably associated with metallic objects at or near the surface of the site. The character of all these anomalies suggests that the presence of metallic objects has prevented the total field magnetometer from observing features related to the buried Las Flores Estancia.

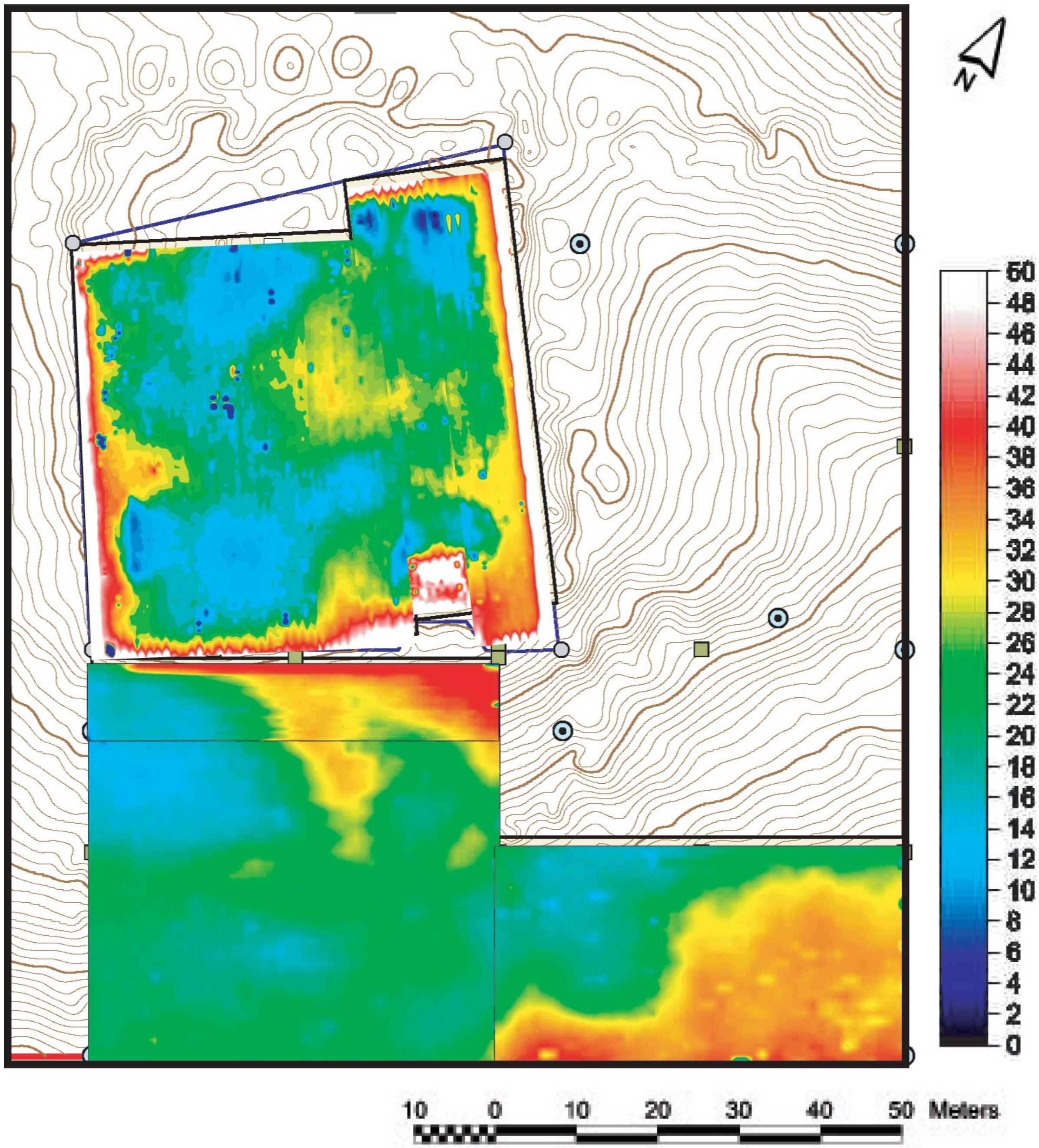

Figure 2. Electrical conductivity at the Las Flores Estancia site. The scale bar at the right shows the mapping between conductivity (mmho/m) and the image colors.

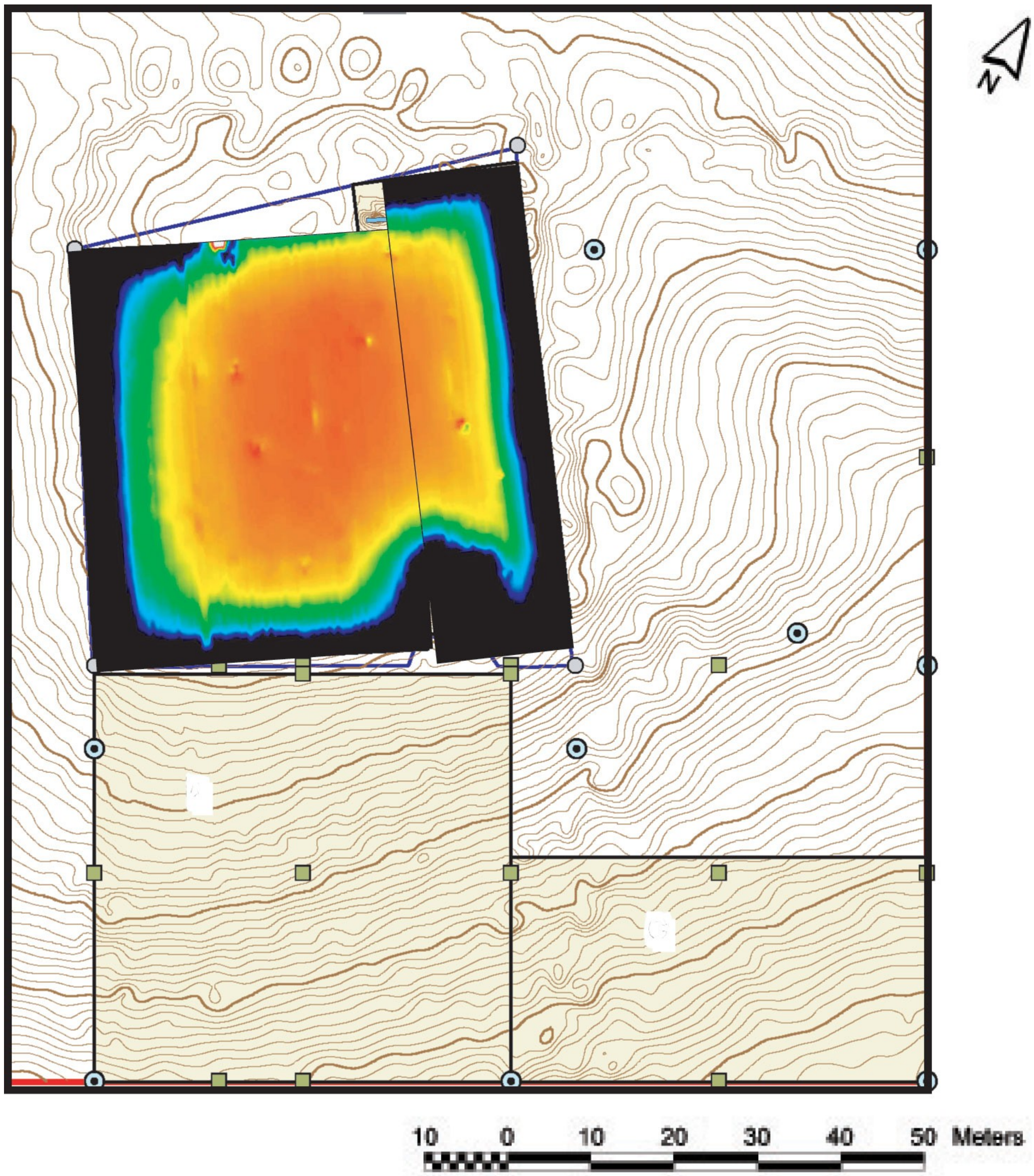

Figure 3. Total magnetic field intensity at the Las Flores Estancia site. An ambient field of 47800 nT and diurnal variations have been subtracted from the data. A clipping level of -200 nT (black) is set to moderate the influence of the metal fence. A maximum of 100 nT (red) is observed in the interior of the grid.

Ground Penetrating Radar

The GPR data were collected and initially processed as a series of vertical profiles. Examples of these vertical slices for grids 3 and 4 are presented in Figures 4 and 5 (respectively). These GPR lines run from north to south within the fenced area (see Figure 6 for their locations), with example lines presented at 5 m increments throughout the survey grids 3 and 4. The horizontal axis of each line (in meters) is referenced to the grid origin (SW corner for grid 3 and NE corner for grid 4).

The vertical profiles reveal both buried site stratigraphy (denoted by yellow marking in Figure 4 and 5) and potential architectural features (denoted by blue marking). In all profiles a prominent reflection at 0.5 – 1.5 m depth suggests a major stratigraphic boundary, perhaps the interface between the pre-estancia surface and the estancia living surface and later materials. Figure 7 is a contouring of the depth to this prominent reflector. Deep reflector areas (> 1.4 m depths are colored blue) are seen in the southern and eastern portion of the fenced area, and are particularly associated with known wall segments. Likewise a shallow reflector area (< 0.5 m depth are colored yellow and red) are seen in the center and northern portion of the fenced area.

The shallow depth (0-0.5 m) time-sliced GPR data for the Las Flores Estancia are presented in Figure 8. This time-slice is an attempt to map the reflectors with potential architectural associations (denoted by blue marks in Figure 4 and 5). Linear alignments off these features are seen in grids 3 and 4, particularly near the exterior edges of both grids.

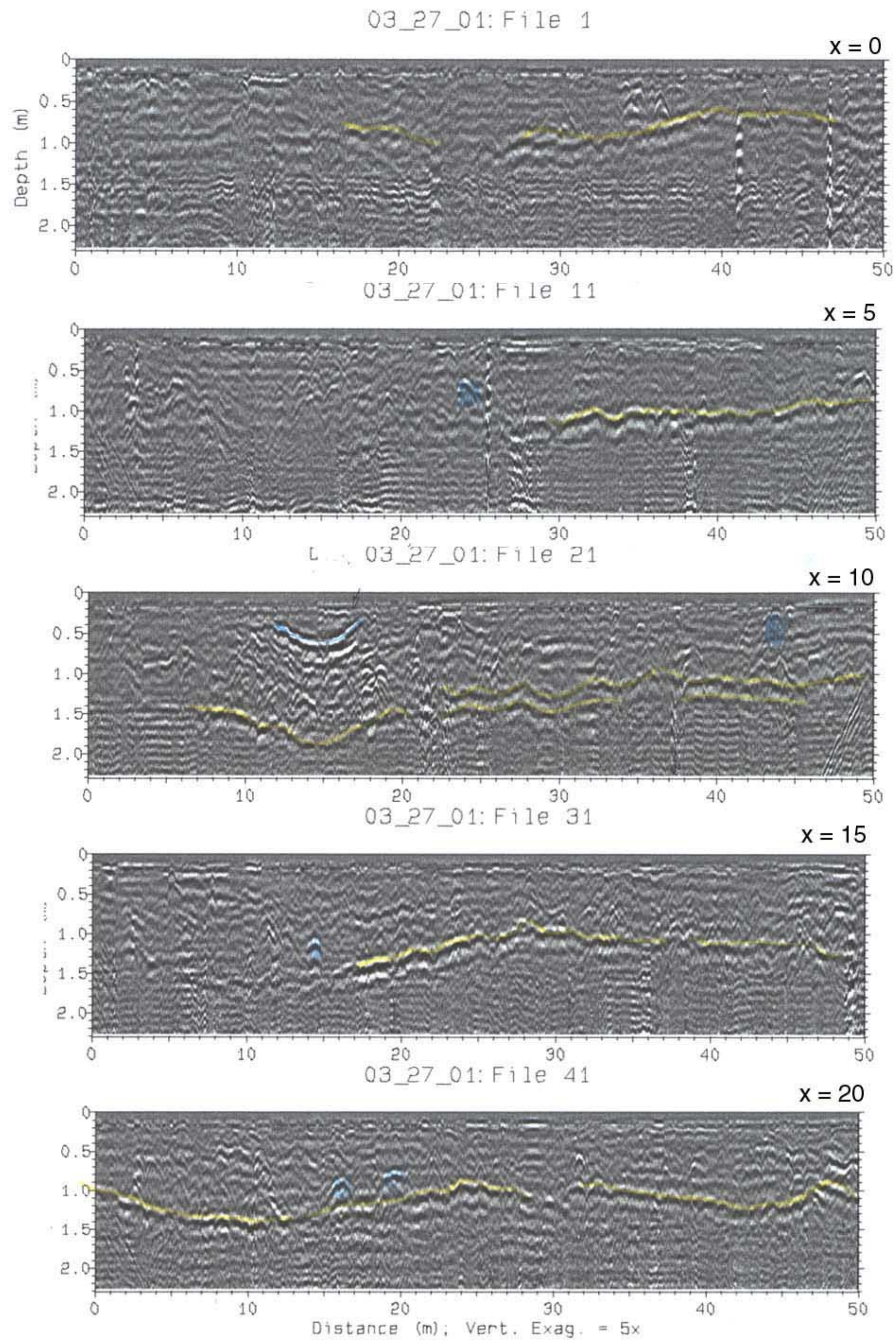

Figure 4. Selected GPR vertical profiles from Las Flores Estancia grid 3
(Figure continues on next page).

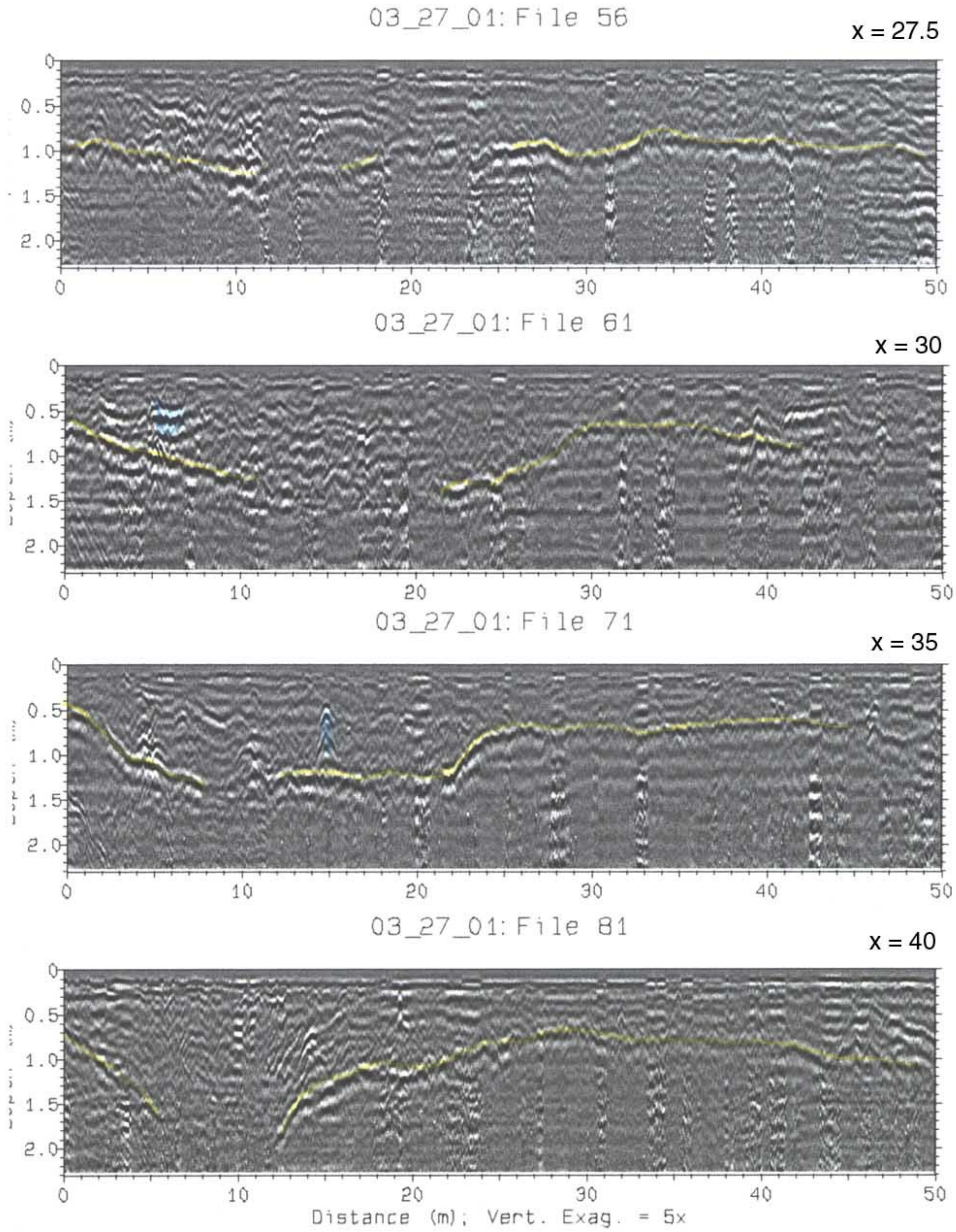

Figure 4 (continued). Selected GPR vertical profiles from grid 3. Prominent stratigraphic reflections are marked in yellow and potential architectural features are marked in blue. Vertical axis is depth in m. The profiles are taken along north-south lines (0 = south end) and the east-west location (re: the grid origin in southwest corner) is given on the right of each image. See Figure 6 for map view of profile locations.

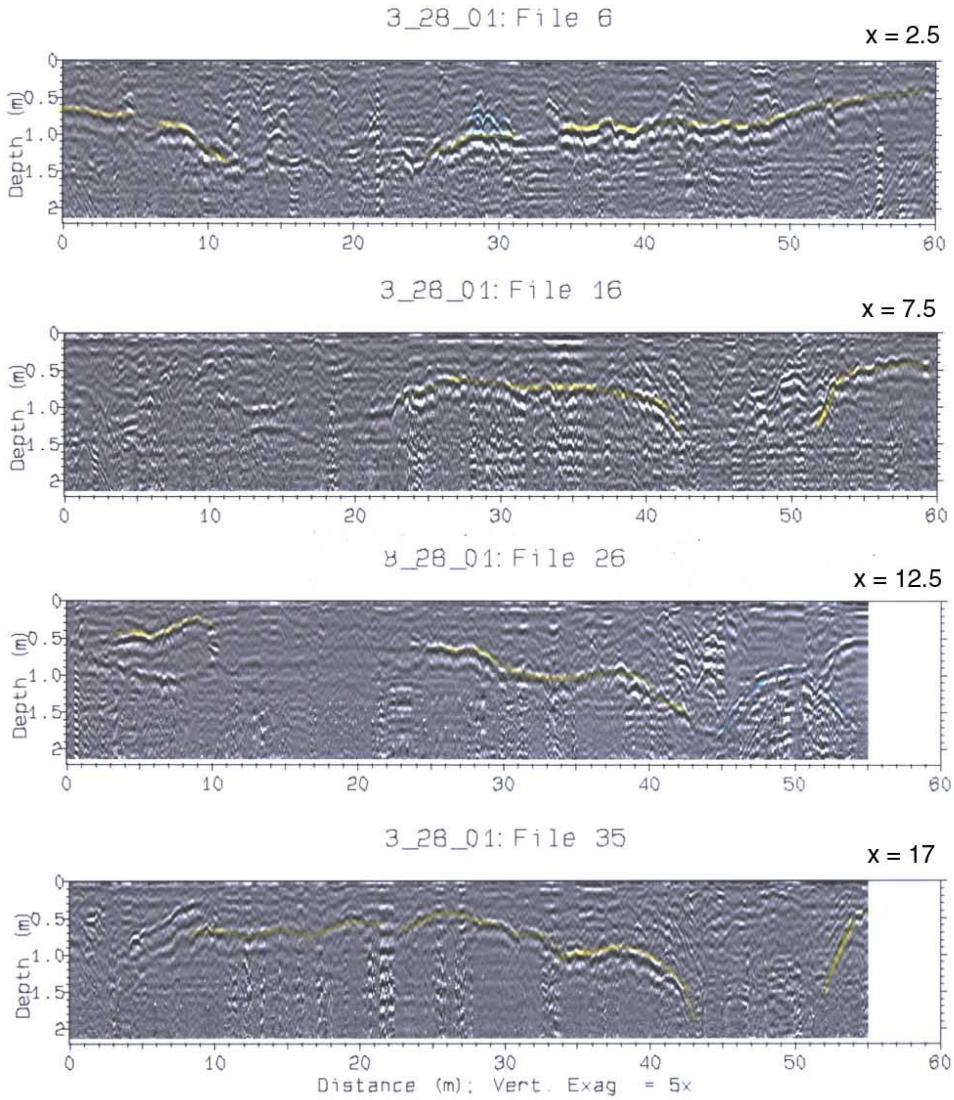

Figure 5. Selected GPR vertical profiles from grid 4 at the Las Flores Estancia. Prominent stratigraphic reflections are marked in yellow and potential architectural features are marked in blue. Vertical axis is depth in m. The profiles are taken along north-south lines (0 = north end) and the east-west location (re: the grid origin in northeast corner) is given on the right of each image. See Figure 6 for map view of profile locations.

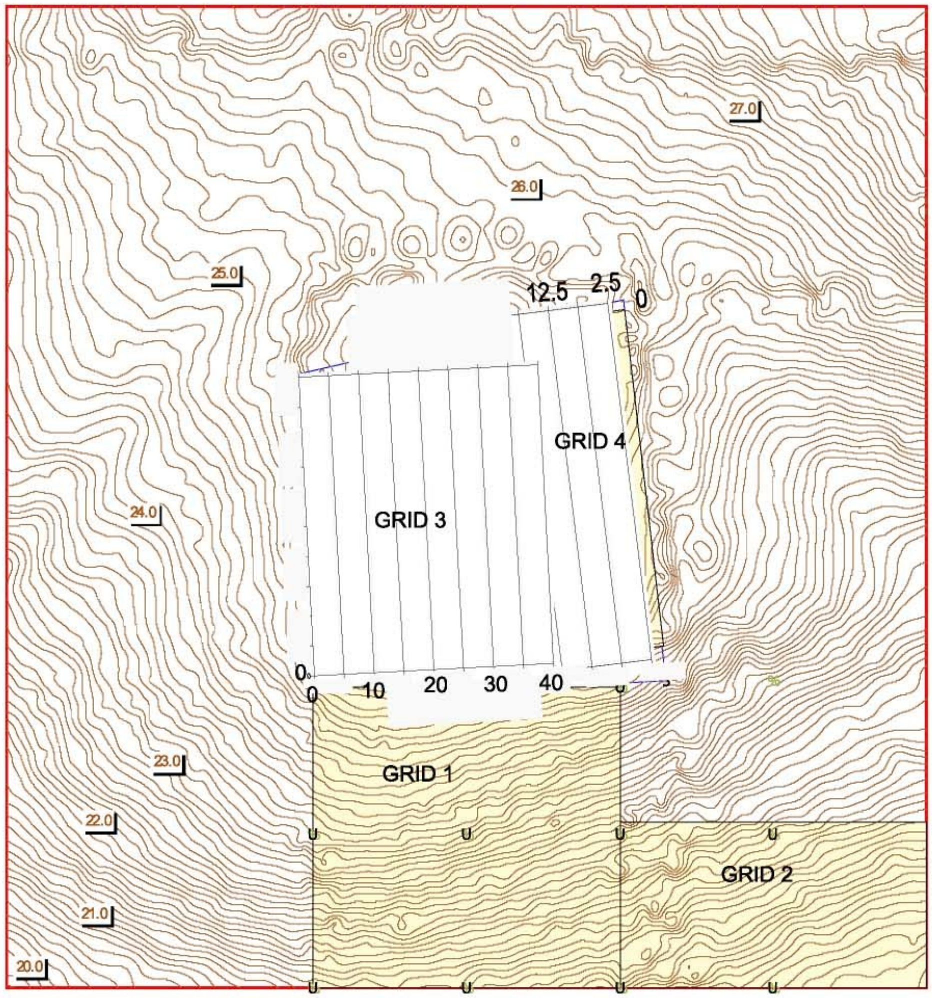

Figure 6. Location of selected GPR vertical proflies fro grid 3 and 4. The grid origins are indicated.

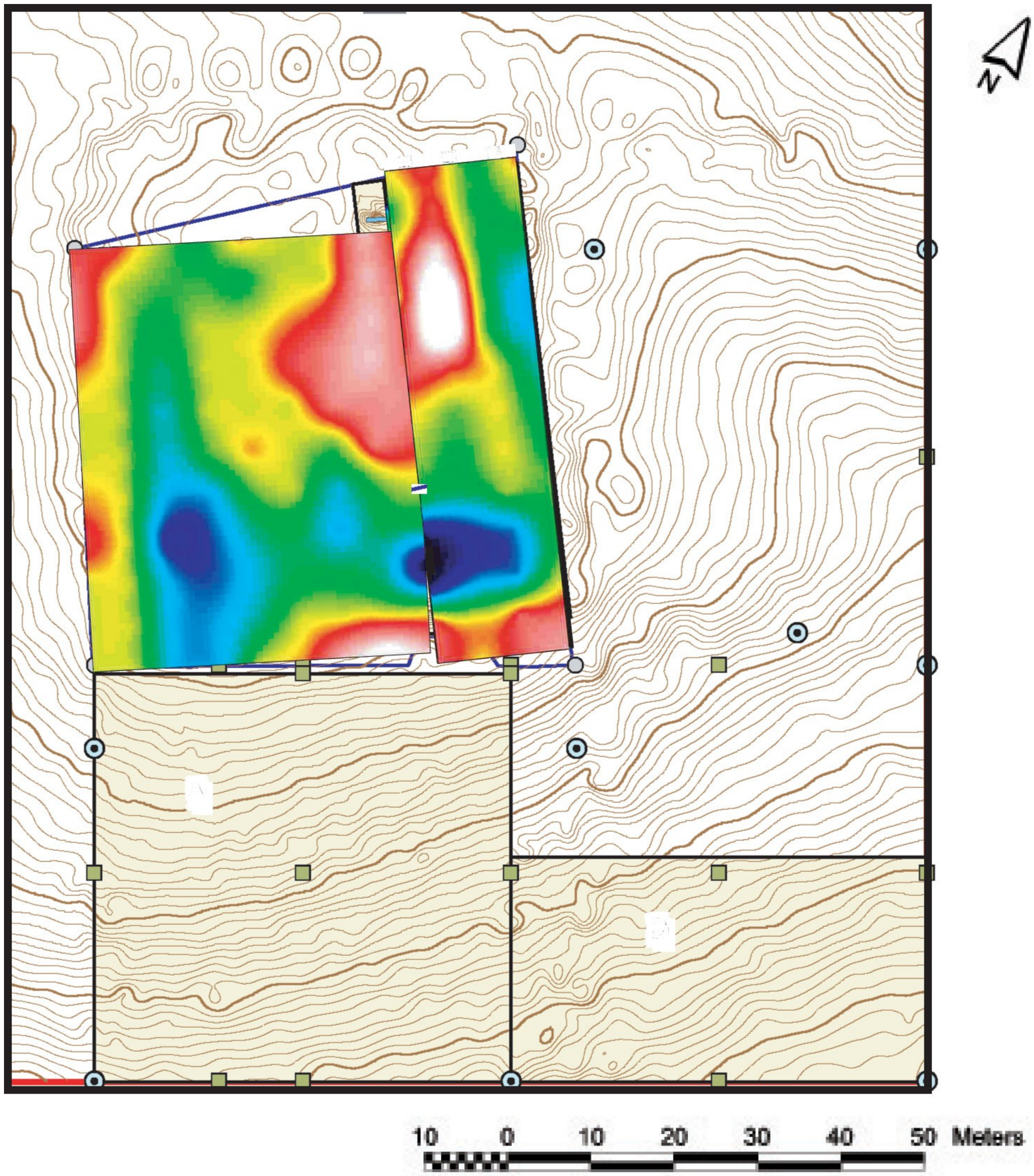

Figure 7. Depth to the prominent GPR reflector at the Las Flores Estancia site. The reflector probably represents the stratigraphic contact between the pre- and post-estancia deposit. Deep reflector regions are colored blue (1.5 m depth), and shallow regions are colored red/white (0 m).

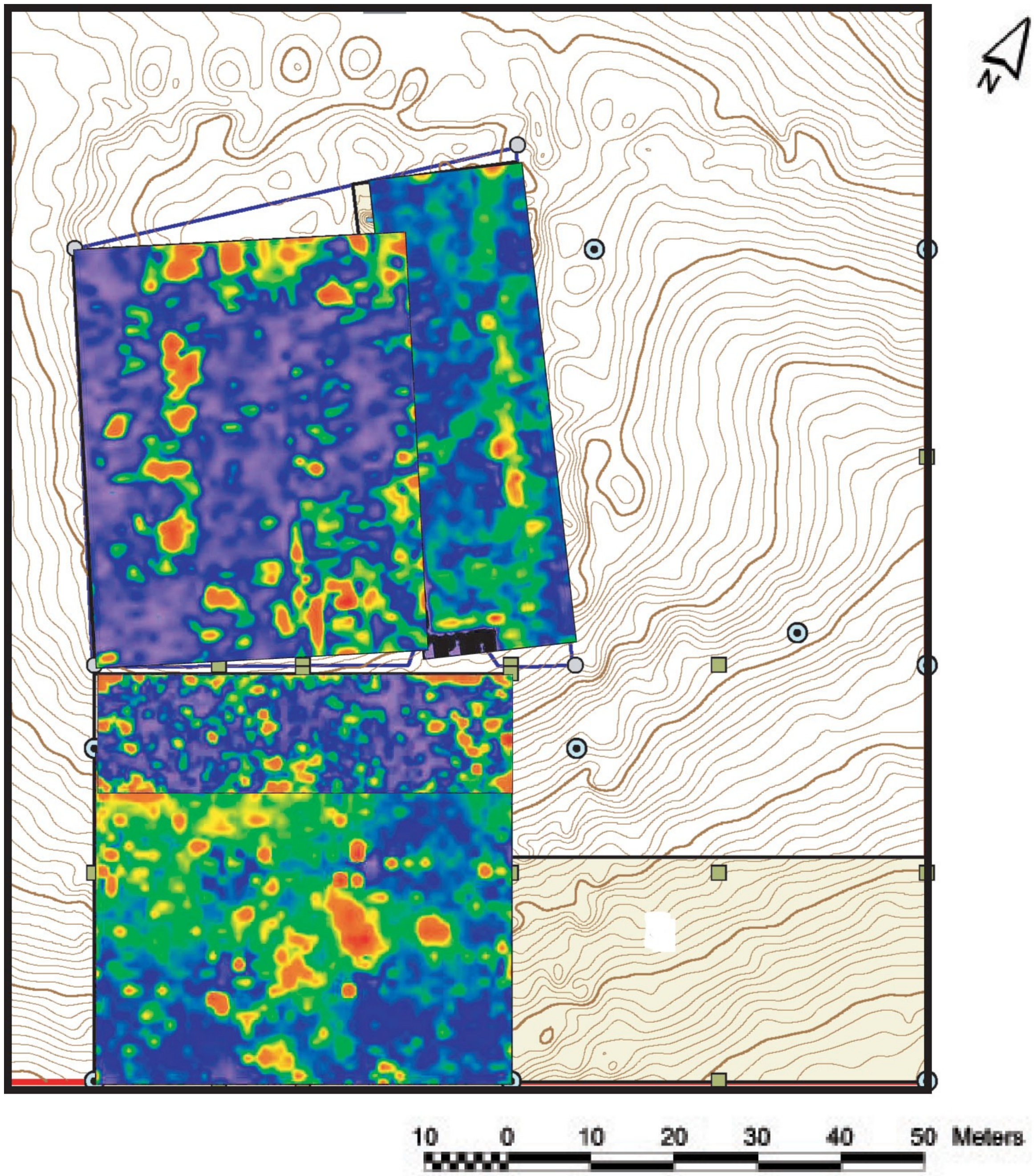

Figure 8. Ground Penetrating Radar time-slice image of the surface layer (0-10 ns; 0-50 cm) at the Las Flores Estancia site. Lineated relectors may represent architectural features such as adobe walls or wall foundations.

DISCUSSION

Both stratigraphic and architectural features appear to be imaged in the geophysical data collected at the Las Flores Estancia. The thickness of the estancia deposit (adobe walls and associated melt) appear to be the main feature contributing to both the electrical conductivity image (Figure 2) and the GPR reflector depth image (Figure 7). Comparison of these two data sets show a significant correspondence of features. The thickest portion of the deposit imaged to date appears to be along the southern and eastern portion of the fenced area. This is consistent with historic data such as the 1850 Powell sketch suggesting that the estancia may have been two stories high along some of its southeastern wing. The particularly thick deposit imaged by GPR (Figure 7) in the eastern corner of the fenced region may correspond to the two story building section in Powell's sketch. If this is the case, then the building may extend further east, outside the fence, since the two story section was located near the middle of the southeastern wall.

It should also be noted that the site topography is also correlated with the geophysical images, as expected, since the origin of the mound topography is undoubtedly the estancia materials. The mound topography also suggests that additional estancia materials may be located outside of the fenced area, particularly to the northwest and the east.

Architectural features, perhaps wall foundations and remnants, may be seen in the GPR time-slice images (Figure 8, grids 3 and 4). These features form alignments, some of which abut against the existing fence, particularly along the NW, SW and SE edges of grid 3 and the NE edge of grid 4.

Grids 1 and 2, which are located to the southeast of the fenced area, do not reveal any obvious signs of architectural features. This is the presumed location of the well shown in the 1850 Powell sketch, yet no deep reflector (GPR) or strong conductivity anomaly (EM) are seen in the geophysical data. It clearly would be beneficial to collect additional geophysical data adjacent to the fence. Data along the southwest of the fence could be used to further search for the location of the well. Along the northwest and the northeast are locations where geophysical techniques may help to define architectural features extending outside the fenced area. To collect these data it would be helpful to temporarily remove the existing fence. This would remove the high conductivity and magnetic signature of the fence so that the EM and MAG sensors could detect ground features. Temporary fence removal would also facilitate GPR data collection along regular grids, although the impact of the fence on the GPR data is minimal. Note that the non-rectangular shape of the existing fence presents difficulties in obtaining complete data coverage (see the triangular section of unsurveyed area along the northwestern side of the fenced area).

SUMMARY and RECCOMMENDATIONS

At Las Flores Estancia, we have applied three geophysical survey techniques, ground penetrating radar, electrical conductivity, and magnetometry, to delineate buried features related to historic occupation of the site. Electrical conductivity and GPR were helpful for imaging overall site statigraphy and architectural features. These techniques are less sensitive to the presence of large scale metallic objects (e.g. the enclosing chain-link fence) than magnetometry.

Buried adobe walls and melted adobe are prominently imaged along the southwestern and southeastern edges of the enclosing fence. The thickest deposit appears to be at the eastern fence corner, roughly corresponding to the location of the existing shelter and to the north of it. If this thick deposit corresponds to the two story portion of the building shown in Powell's 1850 sketch, then the estancia building may extend substantially to the east of the existing fence. Additional indications of adobe building extending outside of the fenced area are seen to the northwest.

It is recommended that the existing fence should be temporarily removed to allow additional geophysical imaging to be conducted along the east, west and north of the grids presented in this report. These data will help to define the building boundaries and other features such as the well.