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EDITED BY
Francesco Berna,
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Elliot H. Blair,
University of Alabama, United States

*CORRESPONDENCE
Gabriel M. Sanchez
✉ gsanche2@uoregon.edu

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Tsnungwe stewardship and archaeological geophysics at *łe:ldin*—the place where the rivers come together

Gabriel M. Sanchez* and Rose Mooney

Department of Anthropology, College of Arts and Sciences, University of Oregon, Eugene, OR, United States

Collaborative and Indigenous archaeological approaches are becoming more standard in North America, especially in California and the Far West. With the growth of this archaeological subdiscipline has come a shift in archaeological field and laboratory methodologies, specifically in the application of low-impact, remote sensing, and archaeological geophysics. Applying a medical analogy to archaeological practice, these research models work from the least invasive methodologies to more invasive field strategies such as subsurface excavations. Through collaborative studies, especially in North America, data from the least invasive stages, such as LiDAR, magnetometry, and ground penetrating radar surveys, provide initial findings that can inform research planning and Indigenous stewardship practices. In this study, we highlight a collaborative research project conducted with, for, and by the Tsnungwe Council and Tsnungwe Elders Council. Our project seeks to relocate, map, and identify subsurface features at the site of *łe:ldin,* a cultural heritage site foundational to Tsnungwe worldview and history.

KEYWORDS
California archaeology, collaborative archaeology, ground penetrating radar, Indigenous stewardship, low-impact archaeology, Tsnungwe Council

Introduction

Globally, the development and growth of Indigenous and collaborative archaeology has coincided with a rethinking of research designs and field and laboratory methodologies (Apodaca and Sigona, 2023; Apodaca et al., 2024; Atalay, 2006, 2012; Cipolla and Quinn, 2016; Cipolla et al., 2019; Dillian et al., 2025; Gonzalez, 2016; Gonzalez and Edwards, 2020; Gonzalez et al., 2006; Leondorf, 2026; Lightfoot, 2008; Lightfoot et al., 2021, 2025; Nicholas et al., 2011; Sanchez et al., 2021, 2024; Sigona et al., 2021; Supernant et al., 2020). A major component of several Indigenous and collaborative archaeology projects is the incorporation of low-impact field methodologies guided by the inclusion of archaeological geophysics (Brunson, 2024; Glencross et al., 2017; Gonzalez, 2016; Gonzalez et al., 2006; Lightfoot et al., 2025; Sanchez et al., 2021, 2024; Sanger and Barnett, 2021; Wadsworth, 2020; Wadsworth et al., 2021a,b). Applying a medical analogy to archaeological practice, low-impact research models work from the least invasive methodologies, such as surface survey units, remote sensing and archaeological geophysics, to more invasive field strategies such as auger probes, shovel test pits, opportunistic and non-opportunistic column samples, and subsurface excavations (Gonzalez, 2016; Lightfoot, 2008; Sanchez et al., 2021).

Through these strategies, collaborative researchers can work to "diagnose" surface and subsurface deposits to guide all aspects of field research, including potential places to avoid, sensitive areas such as cemeteries, areas for "targeted" excavations, and evidence that supports Tribal priorities (Conyers, 2016, 2023; Sanchez et al., 2021; Wadsworth, 2020; Wadsworth et al., 2021a). The application of geophysical techniques in archaeology has contributed to site protection and stewardship of Indigenous cultural heritage, while raising ethical considerations related to the invasive and extractive nature of remote sensing techniques, even if nondestructive (Davis and Sanger, 2021; Sanger and Barnett, 2021; Sturm and Herrmann, 2024; Wadsworth et al., 2021a).

A critical component of Indigenous and collaborative archaeology is the incorporation of Tribes and other descendant communities in all aspects of the research process. This includes but is not limited to research design, field methodologies, laboratory methodologies, destructive analyses, reporting, among other issues (Apodaca et al., 2024; Atalay and McCleary, 2022; Dillian et al., 2025; Lightfoot, 2008; Sanchez et al., 2024; Supernant et al., 2020). In geophysically oriented archaeological research, these considerations are central to meaningfully incorporating geophysical surveys within a collaborative research model. Even in archaeological research contexts that exclude subsurface excavations, such as geophysical surveys, research projects can still pose risks to cultural heritage. For example, to successfully complete ground penetrating radar surveys, vegetation removal is often required to ensure adequate ground contact for the antenna (Conyers, 2023). While these actions are critical for maximum data recovery, vegetation removal can expose features and artifacts, unintentionally drawing local attention. This attention could attract advocational archaeologists and looters. Therefore, it is essential that the risks posed by the geophysical survey be discussed in depth with Tribal collaborators, and that a research plan be developed in full with the Tribe and other descendant communities. Although low-impact survey methods provide an alternative to destructive subsurface excavation, geophysical techniques such as ground-penetrating radar still disturb ancestral sites and can produce unintended consequences.

In this paper, we highlight a collaborative geophysical research project involving the Tsnungwe Council, the Elders Council, and researchers from the University of Oregon. The Tsnungwe Council is a non-federally recognized Tribe within the state of California, but is state-recognized (Native American Heritage Commission, 2026). Within the Tsnungwe Council, The Elders Council is the governing body of the Tribe and is responsible for appointing officers of the Tribe's nonprofit, including the Chairperson, Vice Chairperson, and Secretary.

Our collaborative research was designed to document subsurface features at the ancestral village of *łe:ldin*, whose name means "the place where the rivers come together" (Ammon, 2025; Rohde, 2025; Tsnungwe Tribe, 2025), Figure 1. The focus of our work includes exploratory ground penetrating radar surveys and three ground penetrating radar grids during two field surveys in the summer of 2025. Below, we highlight the development of the collaborative research project, the cultural significance of *łe:ldin*, the history of the Tsnungwe people, and demonstrate the use of archaeological geophysics to inform site stewardship by Native Californian tribes.

Background

Collaborative research project development

In the spring of 2025, Sanchez and the Tsnungwe Elders Council held a series of meetings to discuss the possibility of applying archaeological geophysics at *łe:ldin*. Since 2020, the Tsnungwe Council has maintained a cultural access and conservation easement to a five-acre portion of *łe:ldin* (loci 1). The easement at *łe:ldin* is one of several initiatives the Tribe is taking to revitalize, renew, and continue their cultural practices. Some of these priorities include: traditional dances at the *łe:ldin*, the reintroduction of cultural burning practices, fuel reduction, and other land management practices. However, the easement at *łe:ldin* and the surrounding area, while exhibiting evidence of cultural deposits through the presence of anthropogenically modified soils and house depressions, has also been impacted by several modern and historic development projects. Therefore, before the Tribe embarks on small and large-scale management projects at the easement, the Tribe has requested assistance in evaluating the site's integrity, identification of architectural features, cemeteries, or other evidence for disturbed and intact cultural deposits.

In addition to these practical questions, the Tribe evinced interest in determining the age of cultural deposits at the site and what aspects of the "community pattern" could be discerned. Specifically, the Elders Council was interested in whether geophysical methodologies could identify houses, paving stones, and hearths. In addition, they asked if evidence of plank houses existed and if patterns for identifying social stratification could be inferred. Based on these initial conversations during the spring of 2025, Sanchez and the Elders Council agreed to conduct a single-day small-scale geophysical survey on June 10th, 2025 (Field Survey 1). Before delving further into the geophysical surveys, we provide additional information below on the Tsnungwe Council and *łe:ldin*.

Tsnungwe Council

The homelands of the Tsnungwe are located in eastern Humboldt and western Trinity Counties. Historically, the Tsnungwe were divided into four Tribal groups, including the Burnt Ranch band, the New River band, the South Fork band, and the Willow Creek Band (Rohde, 2025). The village of *łe:ldin* has served, and continues to serve, as the central component of the Tsnungwe ancestral lands (Ammon, 2025; Rohde, 2025). As noted by Ammon (2025), *łe:ldin* represents the metropolis of the Tsnungwe Tribe, which is comprised of at least three villages of the region, including *Me'iłchwin-qit*, *Ta:k'iwilts'il-qit*, and *Mituq'-q'it-ding*. Furthermore, the village of *łe:ldin* serves as a critical interface not only for the Tsnungwe people but also for neighboring tribes.

As noted by Rohde (2025), as a result of this intertribal trade and relations, Tsnungwe spoke six languages or dialects in addition to their own, including Chimariko, Wintu, Whilkut, Hupa, Wiyot, and Mawenok. These perspectives are reinforced by Ammon (2025), who highlights the role that *łe:ldin* plays in

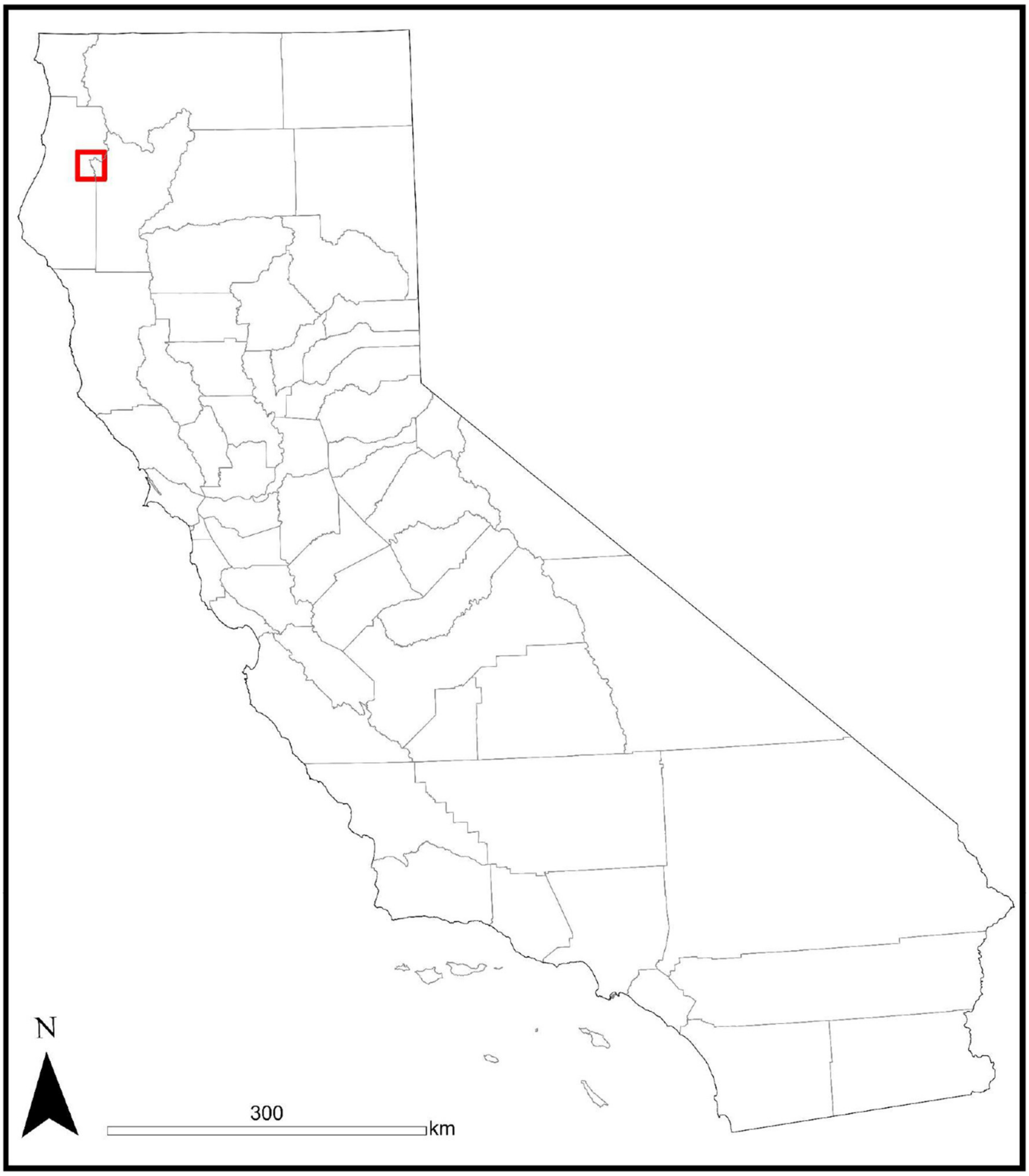

FIGURE 1
Overview of the project area with the general location of *łe:ldin*.

trade, ceremony, and in Tsnungwe worldview and lifeways. These cultural traditions continue in the present with *łe:ldin* serving a central role in communal and ceremonial life, especially for the celebration of young women through the flower dance or coming of age ceremony.

The history of *łe:ldin* is best summarized by the Tsnungwe Council and Elders Council (Tsnungwe Tribe, 2025):

> "*It is said that the Immortals lived at łe:ldin, "the place where the rivers come together" in the days before the first men. When the Immortals left to live beyond the ocean, they left łe:ldin for the first men. For thousands of years life in łe:ldin, principal village of the Tsnungwe, remained essentially the same. The climate was mild, food plentiful, and the Tsnungwe flourished. The people grew rich in number, culture, and wealth. łe:ldin became a cultural and economic center for tribes along the Klamath, Trinity, and South Fork Rivers.*"

Beginning in the 1850s, the homelands of the Tsnungwe were subjected to profound upheaval and violence (Rohde, 2025; Tsnungwe Tribe, 2025). Drawn by accounts of the gold mining success on the Trinity, Klamath, and Salmon Rivers, otherwise referred to as the "three golden rivers," French, Canadian, Chinese, and Euro-American settlers flooded the northern California coast in 1850 (de Massey and Wilbur, 1926; Madley, 2016; Tsnungwe Tribe, 2025). Over the next 15 years, these settlers would strip the Tsnungwe of their land and lives. Although there is no clear account of the number of victims, it is estimated to be beyond the thousands (Lindsay, 2012; Madley, 2016; Rohde, 2025). For example, as early as 1850, Canadian trappers carried out vigilante justice against the Tsnungwe people after some of their mules and horses were stolen, resulting in the loss of life of at least fourteen reported victims (de Massey and Wilbur, 1926, p. 231; Madley, 2016). French immigrant Ernest de Massey, reflecting on the actions of the Canadians and other events during his voyage, noted,

> "This is typical of the tales we hear around here." (de Massey and Wilbur, 1926, p. 231)

Despite settler colonialism in their homelands, the Tsnungwe retained cultural connections to their ancestral lands and, along with neighboring Tribes, actively resisted European encroachment (Rohde, 2025; Tsnungwe Tribe, 2025). Throughout the 1850s, battles between Euro-American settlers and the Tsnungwe occurred. By 1864, the military, militia members, and volunteer patrols worked to forcefully remove Tsnungwe people from their lands. By the 1860s, many Tsnungwe individuals had been killed, removed to the Hoopa Valley Indian Reservation, or had relocated to seek refuge from settler encroachment. Although the violence had ended with removal to the reservation, conditions on the reservation were deplorable (Rohde, 2025; Tsnungwe Tribe, 2025). In the mid- to late-1800s, the Tsnungwe people returned to their homelands and left the Hoopa Valley Indian Reservation. Fortunately, the Tsnungwe met no resistance. Among these families were the Campbells, Chesbros, Dartts, Footes, Kidds, Lacks, Petes, Pikes, Poles, Saxeys, Six Beans, and Wells (Rohde, 2025; Tsnungwe Tribe, 2025).

An example of Tsnungwe returning to their homeland is Saxey Kidd, who was born at *łe:ldin* before the Gold Rush and grew up at the mouth of South Fork during the years of white/Indian conflict (Merriam, 1930; Tsnungwe Tribe, 2025). Despite relocation to the Hoopa Valley Indian Reservation in the late 1850s, Kidd returned to his homeland and established Saxey Ranch, located along the South Fork, where he successfully raised a large, extended family. Kidd was an influential religious, political, and cultural leader. Anthropologist Pliny Goddard cited Kidd's religious leadership and recorded a number of stories from Saxey (Goddard, 1903, 1904). A key example of Kidd's leadership lies in his joint ownership of a Tribal fishing hole, where the Madden meets the South Fork. The examples above highlight the long-term cultural significance of *łe:ldin* to Tsnungwe people and neighboring Tribes and the foundational role that the Tsnungwe played in the development of North American and California anthropology (Baumhoff, 1958; Elsasser, 1978; Goddard, 1903, 1904; Kroeber, 1925; Merriam, 1930; Powers, 1877; Rohde, 2025; Wallace, 1978).

Anthropological data related to the Tsnungwe and *łe:ldin*

Anthropologists have long recognized the significance of *łe:ldin* (Baumhoff, 1958; Goddard, 1903; Kroeber, 1925; Merriam, 1930; Powers, 1877). From 1871 to 1900, Powers (1877) documented the importance of *łe:ldin*, highlighting its role in Tsnungwe worldview. The Tsnungwe, otherwise referred to in anthropological texts as the "South Fork Hupa," have historically been treated by anthropologists together with the Hupa Tribe. However, Baumhoff (1958) recognizes the "South Fork Hupa" as a separate "tribelet" based on linguistic evidence, and Kroeber (1925) highlights cultural differences between the Hupa and the South Fork Hupa.

To further emphasize this distinction, Baumhoff (1958) noted that the Hupa, during ethnographic interviews, separated themselves from the "Ts'a-nung-wha," as reported by Merriam (1930). So the cultural merging of the Hupa and "South Fork Hupa" appears to be a product of anthropological legacies rather than Native Californian perspectives, likely a result of both the Hupa and the Tsnungwe occupying the Hoopa Valley Indian Reservation.

Baumhoff (1958) further highlights this distinction by noting that,

> "The Ts'a-nung-wha [is an] Athapaskan tribe closely related to the Hoopah. The territory of the Ts'a-nung-wha lies directly south of…the Hoopa proper."

Therefore, while ethnographic information provides invaluable perspectives related to the Tsnungwe, these data must be disentangled from the ethnographic context of other neighboring Tribes, especially the Hoopa.

Despite these issues, Tsnungwe cultural heritage is noted in the ethnographic data, especially *łe:ldin*. For example, Kroeber (1925, p. 130) in his review of the Hupa, Chilula, and Whilkut noted *łe:ldin*, "and still farther, at South Fork, where the river branches, was the town of Tleldin–whence the "Kelta Tribe"–with subsidiary settlements about or above it." The "Kelta Tribe" was a term used by Powers (1877) to describe the Tsnungwe, or the Tribe of the South Fork of the Trinity River. The word "Kelta" is a corruption of *łe:ldin* in English.

Kroeber (1925) notes that the "South Fork Hupa," which we know represents the Tsnungwe, were a distinct group with separate cultural traditions, and that neighboring Tribes such as the Yurok recognized these distinctions. For example, in 1851, the Yurok noted the occupation of *łe:ldin* to government officials, with at least three houses present (Kroeber, 1925). Therefore, these data demonstrate the persistence of Tsnungwe people and their long legacy as stewards of *łe:ldin* and their cultural heritage. Below, we highlight examples of this stewardship.

Long-term Tsnungwe stewardship of *łe:ldin*

Despite removal to the Hoopa Valley Indian Reservation in 1864 and the genocidal actions of settlers and state and federal agents, the Tsnungwe were able to maintain their connection to *łe:ldin*, reaffirming its cultural significance. Below, we document the removal of the Tsnungwe people from their homelands and their return to *łe:ldin* in the mid- to late-1800s.

According to Tsnungwe elder James Benson (2023), native women were central in the movement to return to *łe:ldin*. Specifically, the actions taken by Tsnungwe women who married white men and settled back at the sites of former Tsnungwe villages. As early as 1860, Malinda, the widow of Squirrel Tail Tom, was living with settler James Allen Kidd. Malinda was born at New River and became a resident of *łe:ldin* when she married Squirrel Tail Tom, who was later killed during battles with settlers and miners. With the formation of the Hoopa Valley Indian Reservation, settlers living on lands that had been allocated for the reservation were required to relocate (Ammon, 2018). Upon leaving the newly designated reservation lands, James Allen Kidd and Malinda relocated, along with Malinda's children, to the Willow Creek area. In 1883, Malinda filed for a homestead, which was approved. This homestead offered a safe haven for Tsnungwe people to return to their homelands off the reservation. Malinda was the mother of Saxey Kidd (discussed above previously), Venus Foote, Amelia "Mollie" Kidd Bussell, and Nancy Kidd Douglas (Ammon, 2018).

In another case, Mary Quimby Campbell was living with settler Thomas Campbell. Mary had lived at *łe:ldin* precontact. This family returned to live at *łe:ldin*. As previously mentioned, *łe:ldin* comprises three villages *Me'iłchwin-qit*, *Ta:k'iwilts'il-qit*, and *Mituq'-q'it-ding*. The Campbells relocated to *Me'iłchwin-qit*. Thomas and Mary Quimby Campbell's farm served as a safe haven for the Tsnungwe people at the South Fork (Ammon, 2018). Thomas and Mary Quimby Campbell lived at *łe:ldin* until they sold it to Portuguese settlers who homesteaded the site by the early 1880s.

From the perspective of Tsnungwe elder James Benson (2023), the examples above and many others demonstrate a pattern of Tsnungwe reoccupying traditional territory following forced removal. The actions of Tsnungwe women, such as Malinda Kidd, Mary Quimby Campbell, and others, allowed Tribal members to safely return to their ancestral lands during the removal and reservation period. These examples demonstrate the resilience of the Tsnungwe people and their continued presence and stewardship of *łe:ldin*, despite ongoing genocidal actions.

Today, *łe:ldin* lies on lands owned by Tsnungwe Tribal members, state and federal agencies, and other private lands. The Tsnungwe Council is actively stewarding *łe:ldin* through engagement with private and agency partners. The Tribe is actively protecting the site through targeted fuels management with the goal of supporting ceremonial practices and improving visibility for research purposes, including ground penetrating radar. Current and future ground penetrating radar surveys are designed to support the Tribe in their proposal and planning efforts, while identifying subsurface features that may support archaeological research goals of the Tribe and agency partners.

Previous archaeological research

Based on previous archaeological work, the site of *łe:ldin* is recognized to include three loci that cover at least ~20 acres (Cannon, 1983). Over the course of the 1970s and 1980s, limited survey work recorded a minimum of 11 house depressions with cultural deposits at least 1 m deep (Cannon, 1983). *łe:ldin* has been impacted by infrastructure projects such as roads and utilities, as well as the construction of residential buildings and outbuildings. During these previous phases of mitigation work related to development and infrastructure projects, Tsnungwe people served as monitors. Both loci in this study have been further affected by looting activities conducted by advocational archaeologists.

While the site has not been radiocarbon dated, diagnostic artifacts suggest occupation spanning nearly 4000 to 2000 years, including the Early, Middle, and Late Periods (AD 300–1850) and the historic era (Cannon, 1983). However, due to a lack of formal subsurface excavations, time depth of the site is still unknown. Therefore, while *łe:ldin* has long been recognized by the Tribe, anthropologists, and agency partners as a culturally significant site, limited archaeological studies have occurred. Specifically, there is a need for archeological surface and subsurface surveys conducted in collaboration with the Tsnungwe people to further contextualize the site and work toward establishing a chronology for occupations through high-resolution accelerator mass spectrometry (AMS) dating.

Potential surface and subsurface features at *łe:ldin*

The study area lies within the southern Pacific Northwest Coast, which typically includes two distinct types of residential features: rectangular plank houses and circular plank houses (Ames, 1994, 1996; Kroeber, 1925; Leonhardy, 1967; Wallace, 1978). At *łe:ldin* we primarily expect the presence of plank houses (*xontah*). Goddard (1903) states that the *xontah* was typically 6 m × 6 m and would often be nearly square rather than rectangular. According to Wallace (1978), substantial rectangular plank houses were built along the Trinity River from cedar planks. These semisubterranean homes would include a central hearth bordered by stones. These homes often housed a single family, including women, single daughters, and children (Tushingham, 2020).

Separate from the family houses, every village also included a sweat house (*taikyuw*), which housed men and post-pubescent boys (Goddard, 1903). Different from the *xontah,* the *taikyuw* were rectangular, measuring roughly 5 m x 4 m (Goddard, 1903). Sweat houses were used for daily sweating and also as workshops and sleeping quarters (Wallace, 1978). According to Goddard (1903), the sweat houses were typically constructed so that the majority of the structure was subterranean. As Goddard states,

> "It [*taikyuw*] is a lower structure than the *xonta*, consisting of a rectangular pit, the roof only of which is above ground." (Goddard, 1903, pp. 15–16)

Apart from the plank house and sweat house, we also expect to potentially encounter round plank house architectural structures that have been identified and discussed in the region. These would be expected to have a circular shape and would reach a maximum diameter of 4–6 m (Kroeber, 1925; Leonhardy, 1967). These homes would also be expected to contain a central hearth feature. Circular house structures are also well documented in northern California (Leonhardy, 1967). For example, at the Iron Gate site on the Klamath River in Siskiyou County, Leonhardy (1967) documented circular houses that differed from the rectangular plank houses documented ethnographically. Leonhardy (1967) states,

> "The houses at the Iron Gate site differ from those used in the area during the ethnographic period. Shasta houses were basically rectangular plank structures, whereas the Iron Gate houses were circular, bark-covered structures."

The Iron Gate site was occupied between cal AD 1400 and 1600.

In our study area, Powers (1877) suggests that circular or conical houses were constructed. Powers (1877) states,

> "Another style of lodge, very seldom seen, was as follows: A circular cellar three or four feet deep and twelve feet wide was dug, and the side walled with stone. Around this cellar at a distance of a few feet from the edge of it was erected a stone wall on the surface of the earth. On this wall they leaned up poles, puncheons, and broad sheets of redwood bark, covering the cellar with a conical shaped inclosure."

Therefore, based on ethnographic, ethnohistorical, and archaeological data, we expect to encounter three primary types of residential structures: square plank houses, rectangular sweat houses, and circular plank houses. Sweat houses are expected to be constructed deeper than the plank houses that house women and children, thereby allowing the two structures to be differentiated. Circular plank houses would provide the most distinctive archaeological signature among the three.

Methods and materials

As part of our survey strategy at *łe:ldin*, we employed an exploratory ground penetrating radar survey (Sanchez et al., 2021). We ran transects at depths ranging from 1 to 3 m based on dielectric constant estimates; see below. During all phases of research, our ground penetrating radar collection parameters included 512 samples per scan and 50 scans per meter. The survey strategy applied a broad coverage survey of "off-site" and "on-site" locations to establish baseline data for the study area. Our survey at *łe:ldin* involved two separate field visits occurring in June and September of 2025, hereafter referred to as Field Survey 1 and 2.

Field Survey 1 was conducted on June 10th, 2025, as a single-day visit designed to provide baseline data for follow-up research at the *łe:ldin* loci 1. During the survey, a Geophysical Survey Systems, Inc. (GSSI) SIR 4000 with a dual frequency 300/800 MHz digital antenna was used with a tripod-mounted Emlid RS2+ Multi-Band RTK GNSS Receiver. We recorded GNSS data for the start and end locations of all transect files. Given the presence of dry sandy soils, we used a dielectric constant of 4. Data was collected at 100 scans/s and within a total time window of 40 nanoseconds (ns) from the surface. This initial visit resulted in the collection of 20 transects at 3 m depth (300 MHz) and 1.5 m depth (800 MHz), as shown in Table 1.

TABLE 1 Summary of ground penetrating radar surveys at *łe:ldin* loci 1 and 2.

Loci	Survey date	Transects	Distance (*m*)	*m*^{2}
1	Field survey 1	20	288.8	
1	Field survey 2	32	315	
1	Field survey 2	Grid 1 (2 x 5 m)		10
1	Field survey 2	Grid 2 (3.5 x 10 m)		35
1	Field survey 2	Grid 3 (8 x 7 m)		56
2	Field survey 2	49	491.1	
Total		101	1,094.9	101

Based on these preliminary findings, Field Survey 2 was conducted during the week of August 25th, 2025. Prior to the commencement of survey work, the Tsnungwe Council worked to conduct large-scale vegetation removal of shrubs and trees at *łe:ldin* loci 1. This included the removal of most surface vegetation across half the site, which provided new locations for geophysical surveys that had been inaccessible during Field Survey 1. This field visit expanded upon the work of Field Survey 1 at *łe:ldin* loci 1 and introduced a new exploratory survey at loci 2 (Figures 2, 3). As part of the survey, we initially conducted a secondary, broad-scale survey at loci 1 at depths of 1.5 m, 2 m, and 3 m, resulting in 32 transect files. Data was collected at 100 scans/s. Based upon the findings of exploratory transects, three survey grids were conducted at 3 m depth (300 MHz) and 1 m depth (800 MHz), named Grid 1, Grid 2, and Grid 3, Table 1.

Grids were collected with 0.3 m line spacing on the x and y axes, except for Grid 1, which was solely collected on the y-axis. All grid transects were conducted unidirectionally to avoid issues related to the "zippered effect" of zig-zag or bidirectional collection patterns (Leach, 2021, pp. 42–43). Grid 1 was collected along the y-axis, with the origin (0, 0) of the grid at the southeast corner of the unit (Figure 2). Grid 2 was collected in the x and y axes, with the grid starting (0, 0) at the southeast corner of the unit, Figure 2. Grid 3 was collected in the x and y axes, with the grid starting (0, 0) at the northwest corner of the unit, Figure 2.

Individual transects were post-processed in Radan 7 and GPR Viewer Version 1.8.5, including the use of a background filter to remove ambient regional interference. Amplitude slice maps for 300 MHz and 800 MHz antenna data were post-processed in Radan 7 and GPR Process Version 1.7.6 and visualized in Surfer Version 12 using 5 ns time slices (i.e., 0–5 ns, 5–10 ns, 10–15 ns, and 15–20 ns) or ∼0.35 m.

Results

In total, we collected 1,094.9 m of exploratory transects or 1.09 km of subsurface surveys at *łe:ldin* loci 1 and 2, resulting in 101 individual transect files, Table 1. Using our gridded surveys, we covered 101 m^2 across three grids at locus 1. During the initial

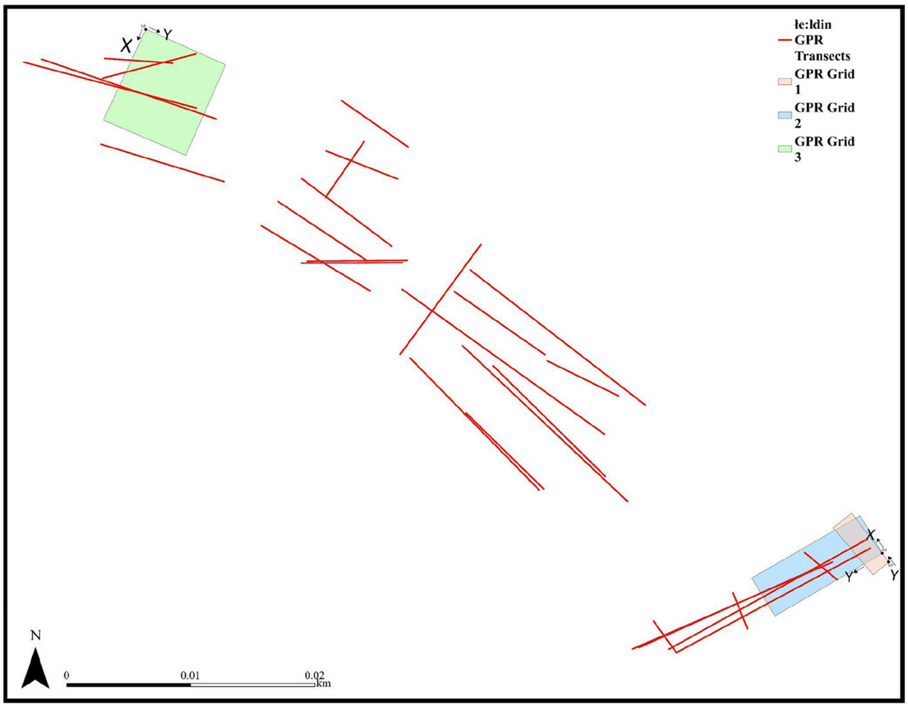

FIGURE 2
Ground penetrating radar transects and grids at *łe:ldin* loci 1.

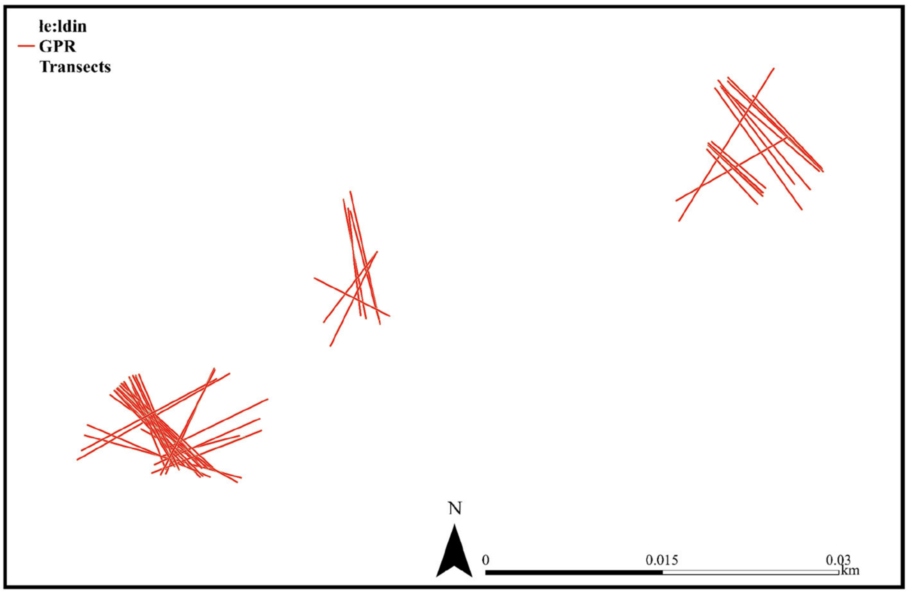

FIGURE 3
Ground penetrating radar transects and grids at *łe:ldin* loci 2.

ground penetrating radar survey in June 2025, transects 10–15 suggested the possibility of house floor features at the site based on the presence of high-amplitude planar reflections likely associated with horizontal layers of compact earth (Conyers, 2016), Figure 4. The findings from Field Survey 1 in June were confirmed during Field Survey 2 in August 2025. Therefore, two ground penetrating radar grids were placed in an area of interest at the site with a high likelihood of containing subsurface features: Grids 1 and 2, Figure 2. Grids 1 and 2 were located in an area associated with files 10–15 from Field Survey 2.

While Grid 1 identified some subsurface features, these are best captured in Grid 2, so the results from Grid 1 will not be reported further. This is likely due to the fact that the direction of the transects of Grid 2 were collected parallel to the features

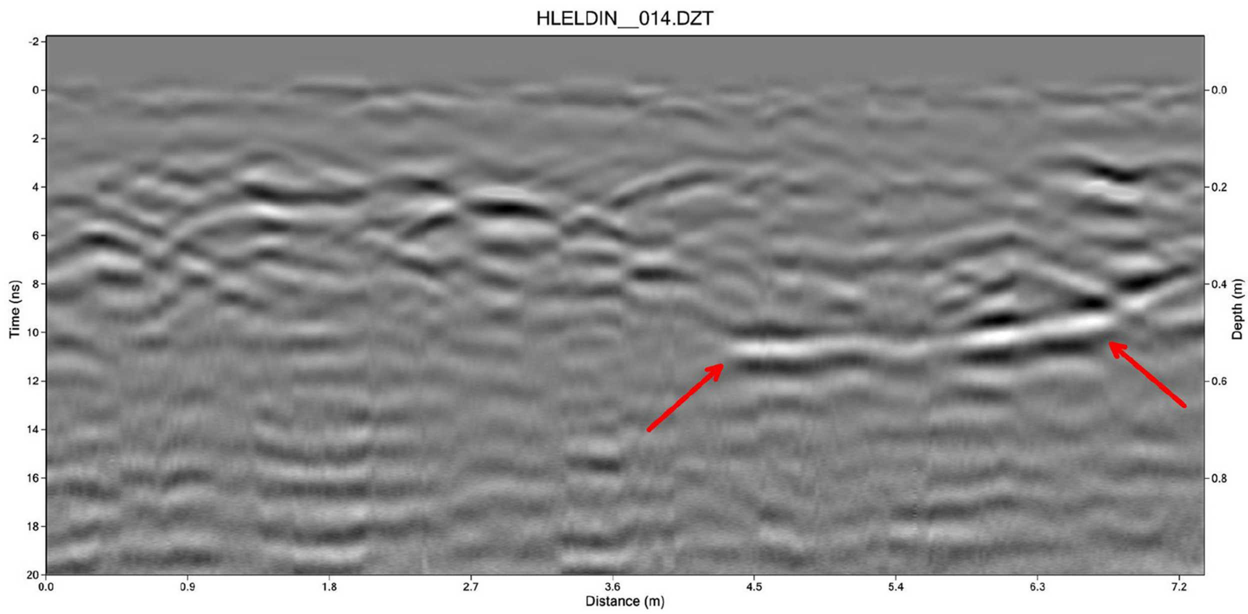

FIGURE 4
Reflection profile of a potential house floor feature from an exploratory survey. The arrows highlight the high-amplitude planar reflections likely associated with horizontal compact earth, which is consistent with house floors. The results of the exploratory transects guided the placement of Grids 1 and 2.

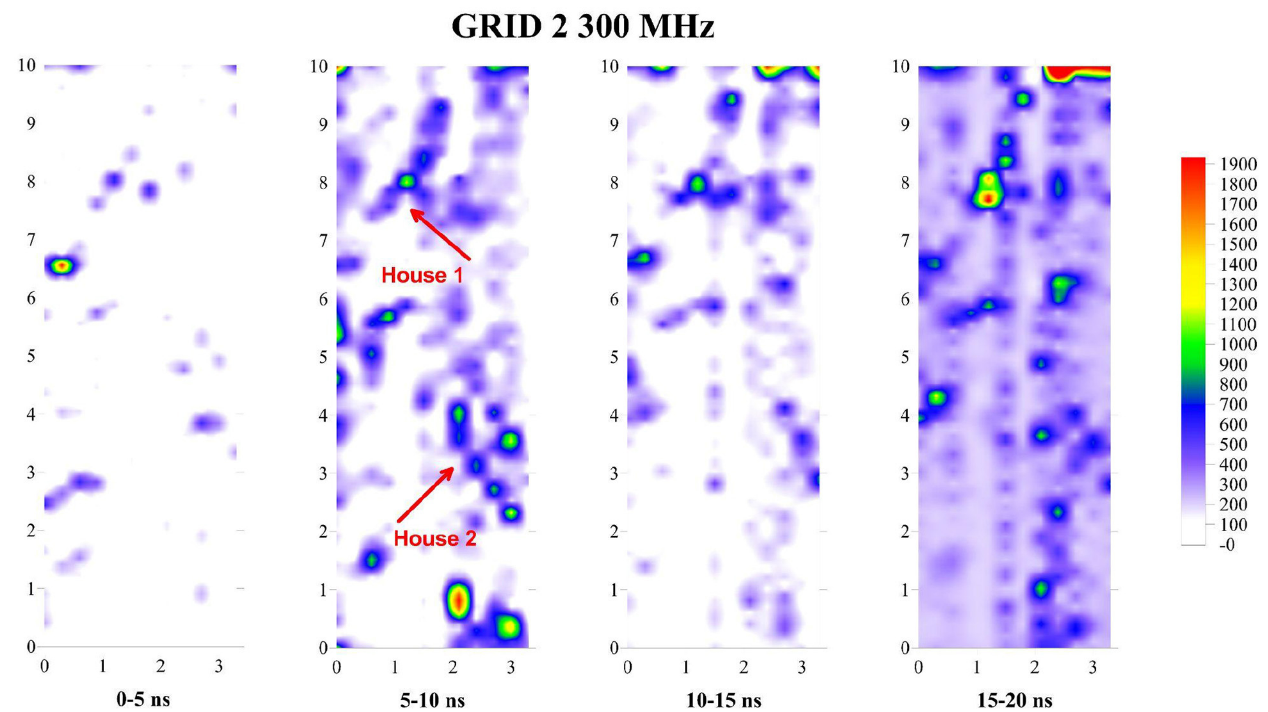

FIGURE 5
Amplitude slice maps of Grid 2 of 300 MHz antenna at 5 ns intervals.

of interest, maximizing the potential that they were captured and recorded (Conyers, 2016, 2023; Leach, 2021). Grid 3 was placed in an area where a surface depression suggested that a house feature might occur. However, the results of Grid 3 suggest that there were no architectural features present. Therefore, the results from Grid 3 will not be reported in the following.

Amplitude slice maps of the 300 MHz antenna data confirm the presence of subsurface features that were previously identified in the two-dimensional reflection profiles. These include two house floors within the 0–20 ns amplitude slice maps, Figure 5. The two features appear consistent with house floors, walls, and hearth features (Conyers, 2016, 2021). To confirm the 300 MHz data, we

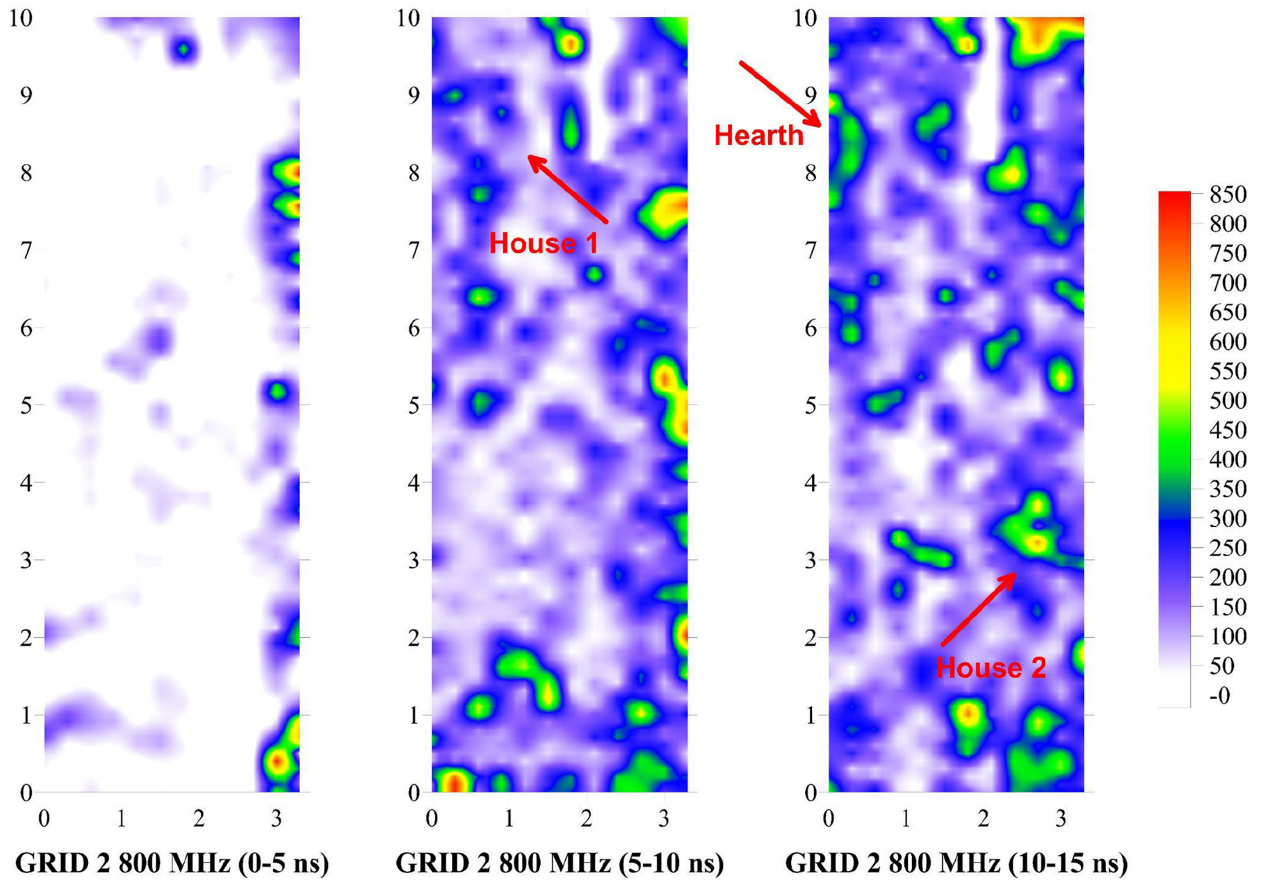

FIGURE 6
Amplitude slice maps of Grid 2 of 800 MHz antenna at 5 ns intervals.

post-processed the corresponding 800 MHz antenna data using the same parameters as those used to create the amplitude slice maps from the 300 MHz antenna, Figure 6.

The amplitude slice maps from the 800 MHz antenna confirm the findings from the 300 MHz antenna, while providing added clarity regarding a potential central hearth within the house floor of House 1 at 10–15 ns, Figure 6. The circular feature, ~2 m from the potential wall of the house structure, may be consistent with Native Californian round house types. However, these features may also represent the internal circular portion of a larger rectangular plank house (*xontah*) construction (Goddard, 1903, 1904), Figure 7.

To confirm our interpretation of house floor features within Grid 2, we analyzed the two-dimensional transect profiles in Radan 7 and GPR Viewer (Conyers, 2016, 2021). We initiated our analysis with house feature 1 and prioritized the transect at $x = 0$, where the amplitude slice maps suggested the presence of a wall feature associated with the house floor, Figures 5–7. The profile confirms these findings with the presence of a high-amplitude planar reflection with a large high-amplitude point-source reflection hyperbola occurring around 5–6.5 m. The hyperbola may be related to the presence of wall features and stone pavements typical of *xontah* construction techniques (Goddard, 1903, 1904; Kroeber, 1925; Wallace, 1978).

In Grid 2, we also identified a second house feature, which is similarly characterized by a high-amplitude planar reflection and a large hyperbola occurring around 2–4 m (Figure 8). As with house feature 1, the ground penetrating radar profile and the two-dimensional data suggest the presence of wall features and stone pavements.

Discussion

Ground penetrating radar studies of Pacific Northwest Coast plank houses demonstrate the ability of archaeological geophysics to identify, relocate, and map the boundaries of architectural features on the landscape (Conyers, 2016; Dojack, 2012; Dolan et al., 2017; Wadsworth et al., 2020, 2025). In northern California, the use of ground penetrating radar to survey and document plank house village sites is still developing. While plank houses have been documented in the southern Pacific Northwest Coast (Elsasser and Heizer, 1966; Gould, 1975, p. 19; Milburn et al., 1979; Moratto, 1972; Tushingham, 2009), the majority are associated with coastal sites rather than interior riverine settings such as *łe:ldin*. Previous studies in the region have emphasized subsurface excavations that exclude archaeological geophysics.

As part of our exploratory survey project at the ancestral village site of *łe:ldin*, our findings suggest the identification of house features with house feature 1, potentially associated with a central hearth feature. The close proximity of these

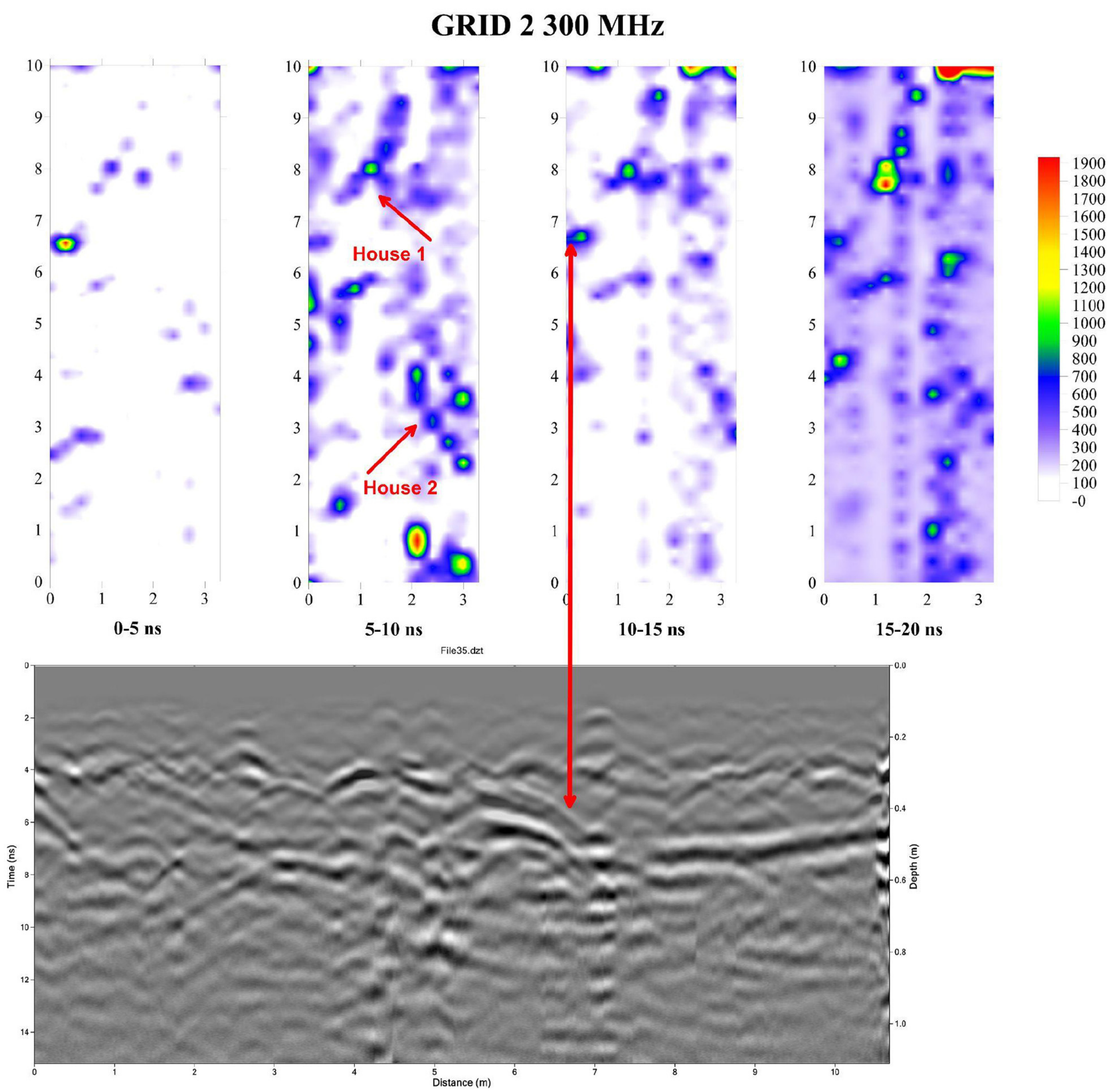

FIGURE 7
Amplitude slice maps of Grid 2 of 300 MHz antenna at 5 ns intervals with two-dimensional profile for $x = 0$.

architectural features are consistent with archaeological studies of southern Pacific Northwest plank houses and sweat houses (Tushingham, 2020). Currently, our survey of the house features has been restricted due to dense surface vegetation. However, through our survey of Grid 1 and Grid 2, our data corroborate Tsnungwe knowledge, historical documents, and ethnohistorical information related to the village of *łe:ldin*. The two-dimensional ground penetrating radar profiles (Figures 4, 7, and 8) and amplitude slice maps (Figures 5, 6) support the interpretation of subsurface features at the site. These data are critical to Tsnungwe stewardship by supporting the planning and implementation of vegetation removal and avoidance areas for subsurface disturbance. Our survey also provides initial insights into the site's extent, which portions contain subsurface features, and where intact deposits are located. These findings are highly relevant to the Tsnungwe Council and Elders Council, as they support their goals of determining the ages of deposits and identifying portions of the site with a high likelihood of yielding samples for radiocarbon dating and paleoenvironmental data that can contribute to contemporary ecological restoration and land management.

Currently, our findings suggest the presence of two house features, with house feature 1 containing a central hearth. However, our surveys have not defined the entirety of the house features, their associated features, and their boundaries. Based on the expected size of plank houses, sweat houses, and circular house features for

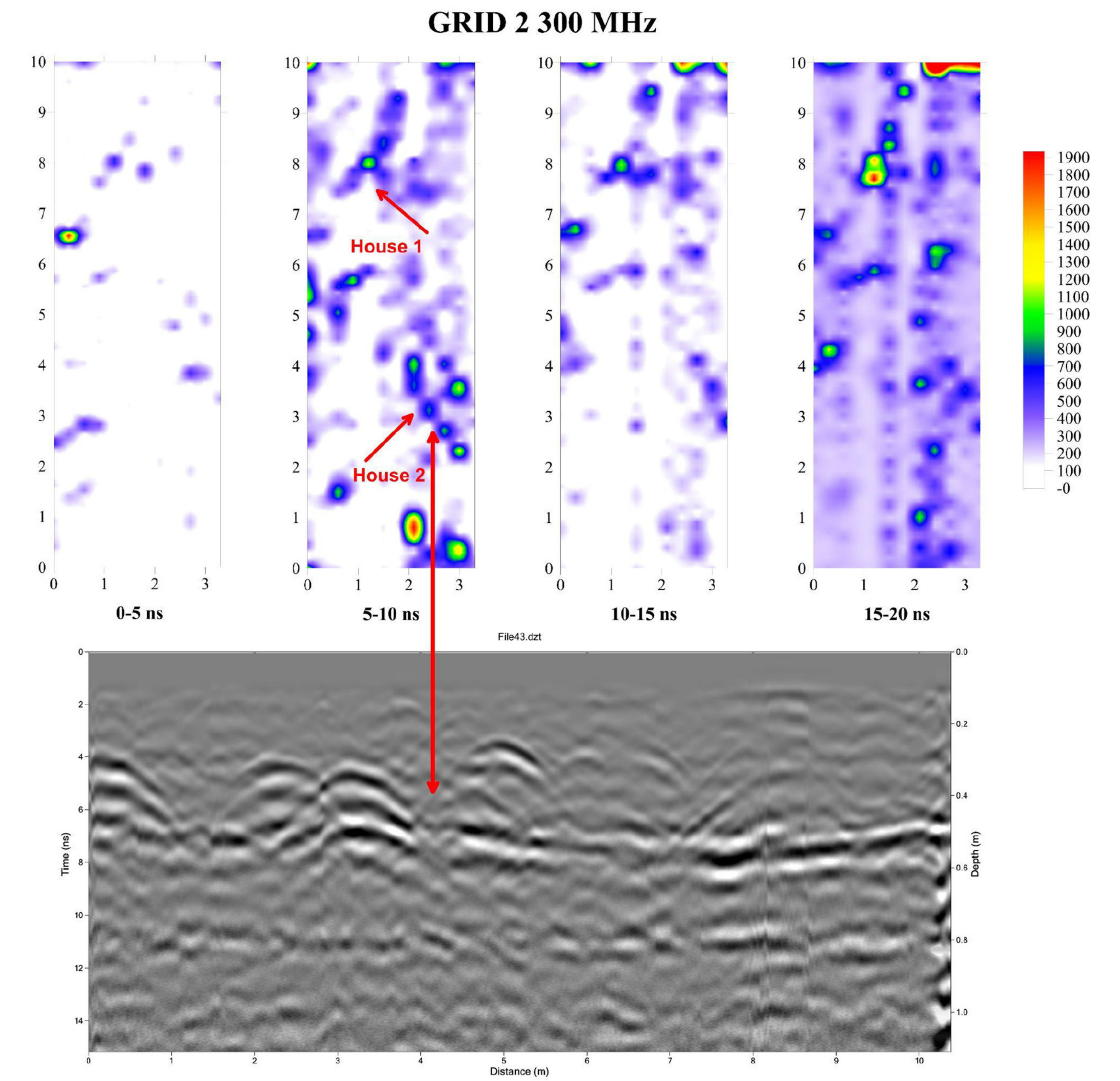

FIGURE 8
Amplitude slice maps of Grid 2 of 300 MHz antenna at 5 ns intervals with profile for $x = 2.5$.

the study area, our findings suggest the presence of plank houses at *łe:ldin*, but the possibility exists the features could be sweat houses. For example, house feature 1 ranges from 6.5 m to 10 m in the two-dimensional profile (file 35). That would place the feature at ~3.5 m in diameter, but the remaining portion of the feature is undefined. Therefore, house feature 1 is nearing the upper limits of circular house types of the region, which range at a maximum of 4–6 m in diameter based on ethnographic and archaeological data (Kroeber, 1925; Leonhardy, 1967).

Similarly, house feature 2 ranges from ~3.9 to 10 m in the two-dimensional profile (file 43). Based on the size of house feature 2, it is unlikely that the architectural feature is representative of a circular house type, given that the full extent of the house feature remains undefined. Therefore, house feature 2 appears consistent with a plank house or sweat house (Ames, 1996; Ames et al., 1992; Goddard, 1903, 1904; Kroeber, 1925; Losey, 2005; Sanchez, 2021; Tushingham, 2020; Wadsworth et al., 2020, 2025).

Conclusion

Our collaborative research project between the Tsnungwe Council, Tsnungwe Elders Council, and the Department of

Anthropology, University of Oregon, conducted geophysical surveys at the ancestral village site of *łe:ldin*. As a central component of Tsnungwe worldview and creation, *łe:ldin* features prominently in the lives of Tribal members both in the contemporary and historical times. During the summer of 2025, our research team conducted exploratory geophysical surveys to identify and locate subsurface features at the site, informed by Tribal knowledge and previous archaeological research in the study area. The broader goal of the initial geophysical studies is to support the Tsnungwe Council and Elders Council in their stewardship goals for the site, including planning and implementing vegetation removal, ethnobotanical surveys, among other goals. Based on our initial fieldwork, we identified subsurface features at loci 1. Additional geophysical surveys are planned for both loci 1 and 2 in the early summer of 2026. While house depressions are visible on the surface at loci 2, our surveys during the Field Survey 2 were impeded by dense surface vegetation.

Our case study highlights the utility of low-impact field methodologies as a critical component of collaborative archaeology (Apodaca et al., 2024; Gonzalez, 2016; Lightfoot, 2008; Lightfoot and Gonzalez, 2018; Lightfoot et al., 2025; Sanchez et al., 2021, 2024; Sigona et al., 2021; Supernant and Warrick, 2014; Wadsworth, 2020). As outlined in this article, *łe:ldin* features prominently in Tsnungwe worldview, creation, and ceremonies. It has been and continues to be a cultural landscape that has drawn Tsnungwe people and neighboring Tribes (Ammon, 2018, 2025; Rohde, 2025). As a cultural landscape and village, *łe:ldin* represents a place of Tsnungwe persistence and survivance throughout the colonial period. Therefore, as part of our collaborative research project, we have approached our work at the site with a focus on low-impact, non-invasive methodologies. Following Lightfoot's (2008) medical analogy, our work has prioritized the application of archaeological geophysics to "diagnose" the site. Based on our findings, our research team will work to conduct large-scale geophysical surveys to guide further archaeological survey during the spring of 2026, contributing to the goals outlined by the Elders Council.

While archaeological geophysics have not been a prominent feature of southern Pacific Northwest Coast archaeology in northern California, our study demonstrates the utility of ground penetrating radar surveys, including exploratory survey transects and more intensive gridded surveys, in the identification of subsurface features at ancestral village sites. These data demonstrate the utility of low-impact field methods, such as archaeological geophysics, which is a common component of collaborative research models in California (Apodaca et al., 2024; Gonzalez, 2016; Gonzalez et al., 2006; Lightfoot et al., 2025; Sanchez et al., 2021, 2024).

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

GS: Methodology, Software, Investigation, Writing – review & editing, Supervision, Funding acquisition, Writing – original draft, Conceptualization, Visualization, Formal analysis, Data curation, Project administration, Resources, Validation. RM: Writing – review & editing, Investigation, Supervision.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

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