PNAS RESEARCH ARTICLE | ANTHROPOLOGY

Pre-Hispanic ritual use of psychoactive plants at Chavín de Huántar, Peru

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Edited by Daniel Sandweiss, The University of Maine, Orono, ME; received December 1, 2024; accepted March 25, 2025

Ritual is broadly accepted as an important locus of social interaction in the pre-Hispanic Central Andes, and research into the development of durable sociopolitical inequality in the region often focuses on the social and political roles of public rituals. At the Middle-Late Formative Period (ca. 1200–400 BCE) monumental center of Chavín de Huántar, as well as at contemporary sites, ritual has long been hypothesized to include the use of psychoactive plants. However, neither psychoactive plant remains nor chemical traces of psychoactive compounds in likely ritual contexts have been identified at any of these sites. Recently excavated deposits sealed in an underground gallery at Chavín contained twenty-three artifacts of forms (especially bone tubes) associated with consumption of psychoactive plants elsewhere in the region. We here report, based on independent microbotanical and chemical analyses, two kinds of direct evidence for use of psychoactive plants in institutionalized ritual at Chavín. These results are direct evidence of psychoactive plants in archaeological bone tubes used as inhalers and the northernmost direct evidence of vilca and *Nicotiana* use in the pre-Hispanic Andes.

psychoactive plants | Chavín de Huántar | Central Andes | early sociopolitical complexity | archaeology of ritual

Significance

Ritual activity is commonly argued to have played an important role in the development of complex sociopolitical formations worldwide. In the Central Andes, where ritual apparently contributed to both social integration and political maneuvering, a variety of evidence argues that ritual activity often included inducement of altered mental states. Here, we report results of independent microbotanical and chemical analyses that demonstrate use of psychoactive plants in institutionalized ritual in the first millennium BCE, demonstrating that even in their early stages, sociopolitically complex societies incorporated psychoactive plants into ritual activity. This direct identification of contents of psychoactive paraphernalia from pre-Hispanic Peru sheds light on the content and function of ritual at Chavín de Huántar and other early monumental centers.

The 1st millennium BCE archaeological site of Chavín de Huántar, located in the north-central highlands of Perú, is a complex of monumental structures long interpreted as a major center of public ritual activity (1–4). Such ritual is argued to be a key element of the Middle-Late Formative Period (ca. 1200–400 BCE) in the Central Andes, a period characterized by the development of significant sociopolitical complexity and inequality, as well as the spread of many of the technological innovations (e.g., irrigation, terracing, and craft production) and social, political, and economic elements (e.g., hierarchy and regional interaction) that distinguished subsequent pre-Hispanic Central Andean societies. The role of ritual activity in those developments—and its increasing association with not only centers of collaborative community and supra-community activity but also increasing sociopolitical differentiation—has been a key focus of research (5–8).

Although ritual is broadly accepted as a pillar of communal activity and an important locus of social interaction in the pre-Hispanic Central Andes (9–12), the specific content, function, and effects of ritual have remained elusive. The role of psychoactive substances in ritual practice and increasing institutionalization of these practices with apparently shamanic origins (13–17) are vital subjects of research regarding the social and political functions of public rituals and their role in the development of durable sociopolitical inequality in the region (3, 18, 19).

The importance of psychoactive plants in pre-Hispanic Andean ritual practices is attested by several lines of evidence. Iconography depicts a wide botanical pharmacopeia across the Andean region dating back at least three millennia (20–23). The earliest evidence of possible snuffing trays and tubes comes from the Peruvian coast at Asia (24) as early as *ca.* 1350 BCE and in Cupisnique contexts at Huaca Prieta (25) *ca* 1200 BCE, and finds of trays, snuff tubes, spoons, spatulas, container tubes, and small mortars and pestles, along with textile and leather pouches, are known from Colombia to Chile and Argentina (22, 26–29). In recent decades, various studies have recovered direct evidence in the form of chemical residues of psychoactive plants from both these paraphernalia (28, 30, 31) and human tissue (32, 33) in southern Peru and Bolivia, northern Chile, and northwestern Argentina.

Ritual practices at Chavín and contemporary sites have long been hypothesized to include the use of psychoactive plants. Chavín art includes representations of plants themselves and humans in altered states (Fig. 1) (15, 34–37), and paraphernalia possibly

The authors declare no competing interest.

This article is a PNAS Direct Submission.

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This article contains supporting information online at https://www.pnas.org/lookup/suppl/doi:10.1073/pnas.2425125122/-/DCSupplemental.

Published May 5, 2025.

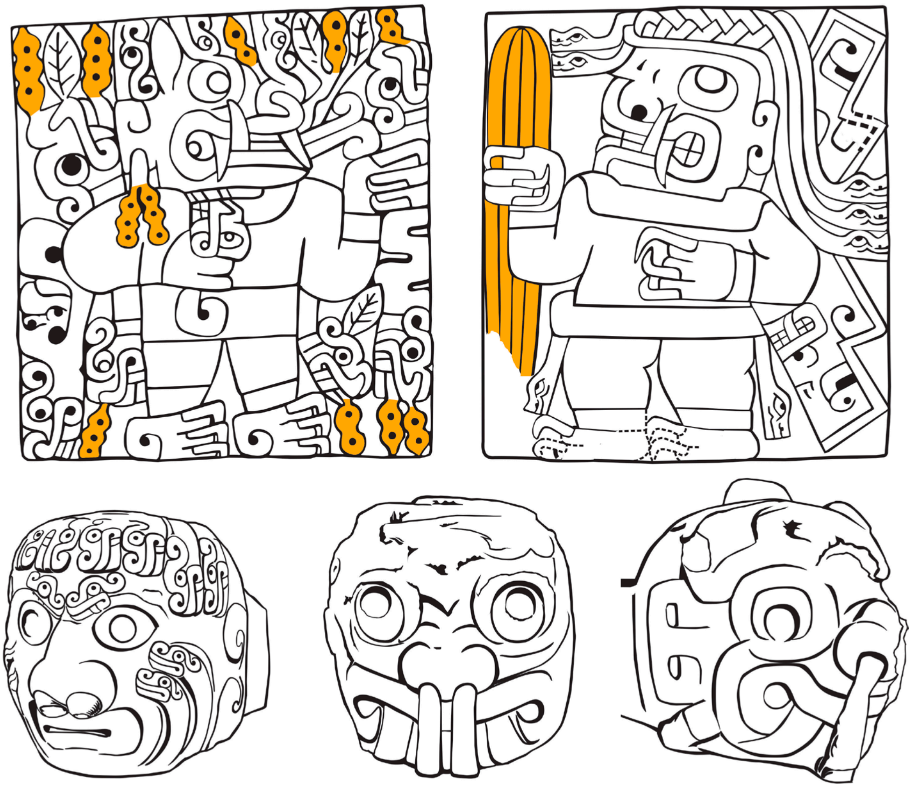

Fig. 1. Psychoactives in Chavín iconography. Vilca (*Top Left*) and *wachuma* (*Top Right*), as well as tenoned heads depicting characteristic effects of ingestion (rictus and mucal flow, *Bottom* row).

used in consumption of these plants has also been found (1, 4, 38). Prominent iconography features both the San Pedro cactus [*Trichocereus pachanoi* Britton and Rose sp. (Cactaceae), also known as *wachuma*] (15) and vilca [*Anadenanthera colubrina* var *cebil* (Fabaceae)] (15, 34). However, neither psychoactive plant remains nor chemical traces of psychoactive compounds in likely ritual contexts have so far been found at any of these sites.

Recently excavated sealed deposits in Gallery 3 in the atrium of the Circular Plaza at Chavín (Fig. 2) contained twenty-three artifacts of forms hypothetically associated with consumption of psychoactive plants elsewhere in the region (short tubes, flat tablets, and small spoons). These artifacts were sampled for microbotanical and chemical analyses. We here report, based on these two distinct analytical techniques, two kinds of direct evidence for use of psychoactive plants in institutionalized ritual at Chavín.

Results

Excavation. The monumental center of Chavín consists of an array of stone-faced structures built around open plazas (Fig. 2). Interior spaces commonly termed galleries were constructed by walling and roofing spaces within the organized stone fill; these became subterranean as the complex grew incrementally. That incremental growth included the enclosure of previously open spaces, access to which was maintained even as they became interior spaces (39).

Gallery 3 is an ~7 m long × 1.2 m wide × 1.9 m high rectangular subterranean structure that was built into the South Atrium of Chavín's Circular Plaza (Fig. 3) during the early part of the 1st millennium BCE. Walls of unmodified but semirectangular quartzite blocks in clay mortar were set in an ~2.5 m deep platform fill of angular quartzite blocks in a clay matrix that was placed in the east-facing space between Structures A, B, and C at the time of construction of the Circular Plaza. That platform contains not only Gallery 3 but also the well-known Ofrendas (40) and Caracolas (18) galleries, among others (41).

The gallery was sealed from shortly after the Chavín period, ca. 500 BCE, until excavation (41) in 2017–2018. Excavations defined a sequence of depositional events within nine strata that included 14 groups of objects interpreted as intentional deposits, i.e., artifacts either stored in the gallery and deliberately left there, or placed there during the closure process (Fig. 3). The artifacts came from both floor deposits (L7 and L5 in Fig. 3)—thin layers deposited directly above the carefully constructed compact clay-gravel floor—and from overlying deposits (L4 in Fig. 3) associated with the subsequent infill and closure of the gallery. Artifacts were found both dispersed in these layers and in concentrations with associated materials—such as fragments of ceramic vessels—that may have been offerings. These likely ritual contexts comprise four depositional episodes within the first half of the first millennium BCE. The earliest of these contexts—Layers 5 and 7 in the gallery proper, and Layer 2 in the central niche—represent on- and near-floor deposits closely associated in time with the final use of the space; the sediment is in part derived from erosion of the clay plaster covering the interior walls. The subsequent contexts consist of materials deposited in the gallery when it was no longer in active use (L4 in Fig. 3) and capping deposits of dumped stone that closed the space (L3, L2, and L1 in Fig. 3); see *SI Appendix, Supplementary Material 1* for additional detail.

Here, we analyze 22 bone artifacts and one marine mollusk shell (Fig. 4 and *SI Appendix, Supporting Information 2*). Some of these artifacts come from Features 7, 10, 13, and 15, associated with other materials like polished stamped blackware ceramics, beads, polishing stones, bone needles, and human remains,

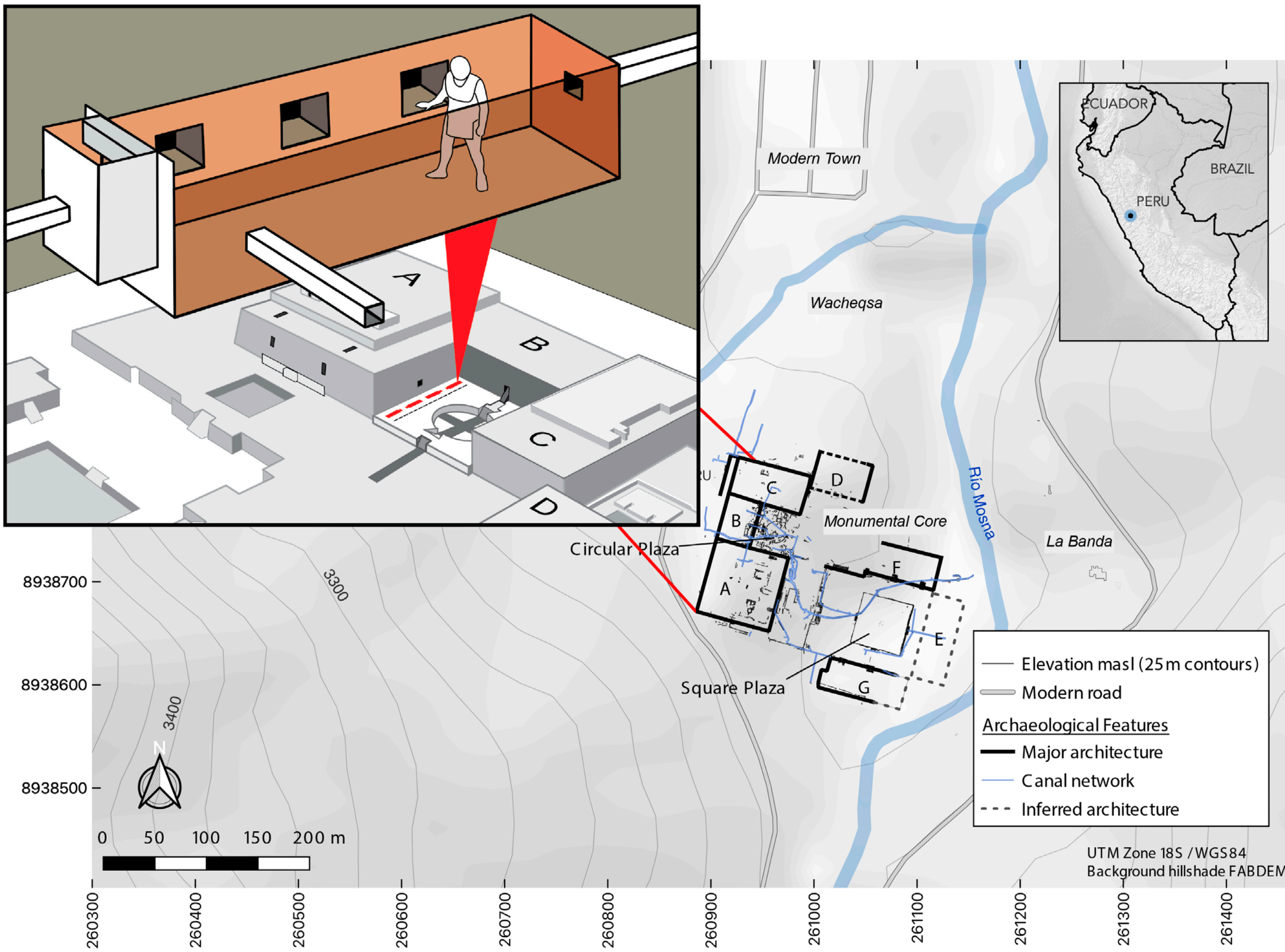

Fig. 2. Location of Gallery 3 within the monumental center of Chavín de Huántar.

while other bone artifacts were found in Layers 4, 5, and 7 (Fig. 3).

The deposits have been radiometrically dated with seven radiocarbon samples, of which four were from unidentified wood charcoal and three from human remains from the funerary contexts; three additional dates from surrounding areas constrain the period of construction (Fig. 5 and *SI Appendix, Supporting Information 3*). These dates range across late Chavín periods and into the subsequent Huaraz phase, but their clear associations within a stratigraphic sequence permit Bayesian modeling to refine the age of the dated layers. The layers directly associated with gallery use (floor sediments and supra-floor offering deposits) date within the range of approximately 800–350 BCE (*SI Appendix, Supporting Information 3*), corresponding to the latter part of Chavín's apogee [the Black and White Phase (39, 42)] and the immediately post-Chavín period.

Chemical Analyses. Twenty-three artifacts were subjected to organic chemical residue analysis. In six artifacts, these analyses revealed the presence of the alkaloids *N,N*-dimethyltryptamine (DMT), 5-hydroxy-*N,N*-dimethyltryptamine (5-OH-DMT or bufotenine), and nicotine, which are recognized diagnostic markers at the molecular level associated with the *Anadenanthera* and *Nicotiana* genera, respectively (Table 1 and Fig. 6 and *SI Appendix, Supporting Information 4*) (43, 44). These alkaloids provide consistent information on the use of these plant taxa in these archaeological materials.

Microbotanical Analyses. Eleven of the twenty-three artifacts subjected to chemical analysis were also sampled for microbotanical analysis. These tests were conducted in parallel and blind, without access to the results of the chemical analyses. Of the six artifacts that produced positive chemical results, four yielded microremains (starches, crystals, and trichomes) related to the roots of wild *Nicotiana* species and the seeds and leaves of vilca (*A. colubrina* var *cebil*) (Table 1 and Fig. 6 and *SI Appendix, Supporting Information 4*). The remaining seven artifacts had no or few nondiagnostic microremains. The control sediment had no plant remains, except for microcarbons.

Damage to the starch grains recovered from the interior of the tubes (*SI Appendix*, Table S3) indicates exposure to dry heat, indicating the drying and toasting of the vegetative organs (vilca seeds and *Nicotiana* roots) from which the starch grains came. Dry heat, as long as the humidity remains minimal, damages but does not significantly alter starch grains, avoiding the gelification and deformation of those grains and the consequent loss of diagnostic features. Drying and toasting is consistent with ethnographic accounts of the preparation of snuff in general and of vilca and tobacco snuff in particular (45–47). The latter preparation often also includes grinding, which could also be a cause of some of the observed damage.

Zooarchaeological Analysis. The twenty-three artifacts are all animal in origin. Twenty-two were manufactured on bone; the other was manufactured on a marine mussel shell (*Choromytilus chorus*). Nineteen of the bone artifacts are made from bird long

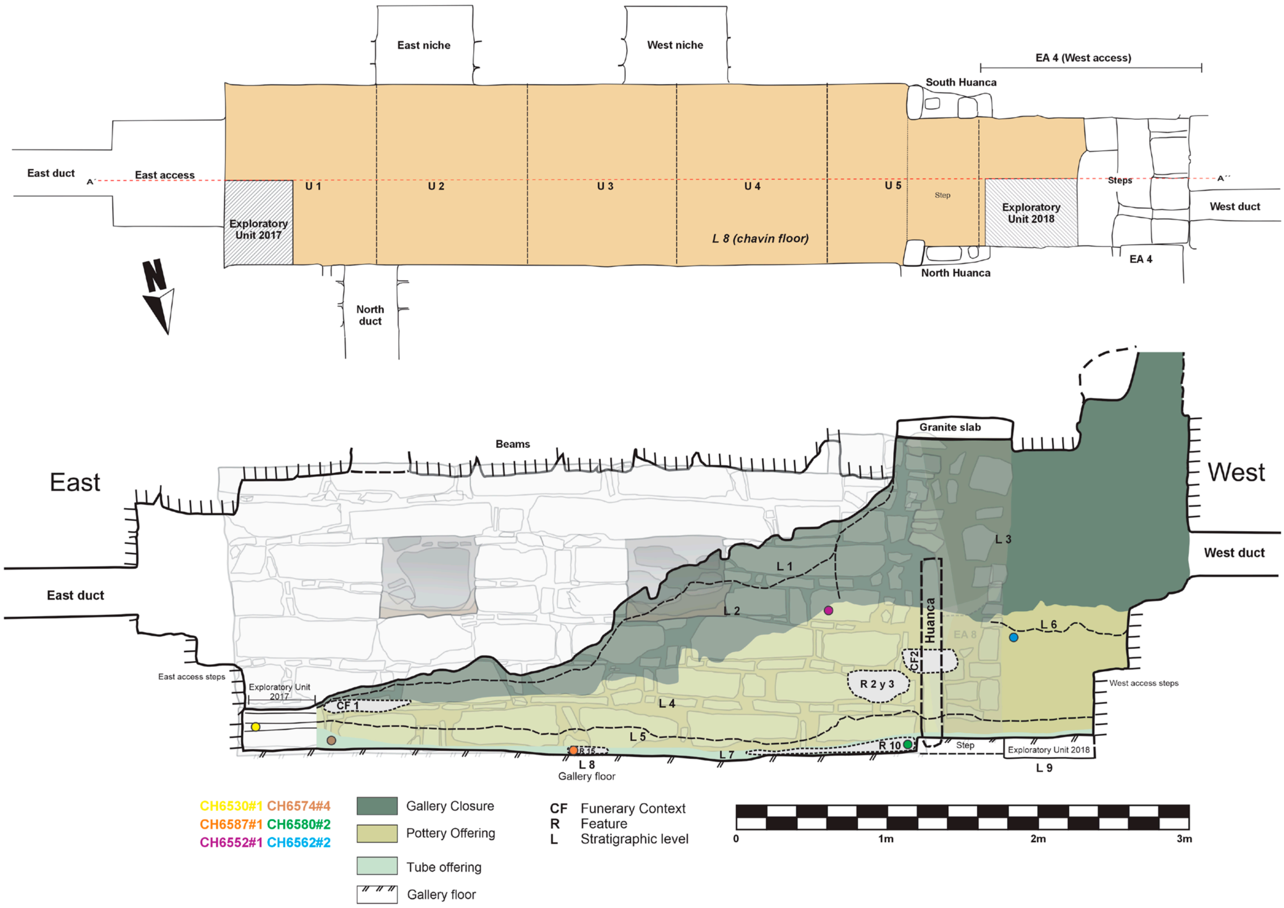

Fig. 3. Profile and plan drawings of Gallery 3, showing stratigraphy of deposits and locations of artifacts that produced positive microobotanical and/or chemical results.

bones modified to form simple tubes (Fig. 4). Another, possibly made on bird bone as well, is the bowl of a small spoon (*SI Appendix*, Fig. S5). The other two artifacts were carved on Artiodactyla bone (either camelid or cervid); these are described below.

The six artifacts with chemical and/or microbotanical traces of psychoactive plants were all made on bone. Two artifacts were made on Artiodactyla bone, one of them identified as a white-tailed deer [*Odocoileus virginianus* (Cervidae)] metacarpal. This artifact

Fig. 4. Bone artifacts from which chemical and/or microbotanical residues of vilca and/or *Nicotiana* were recovered.

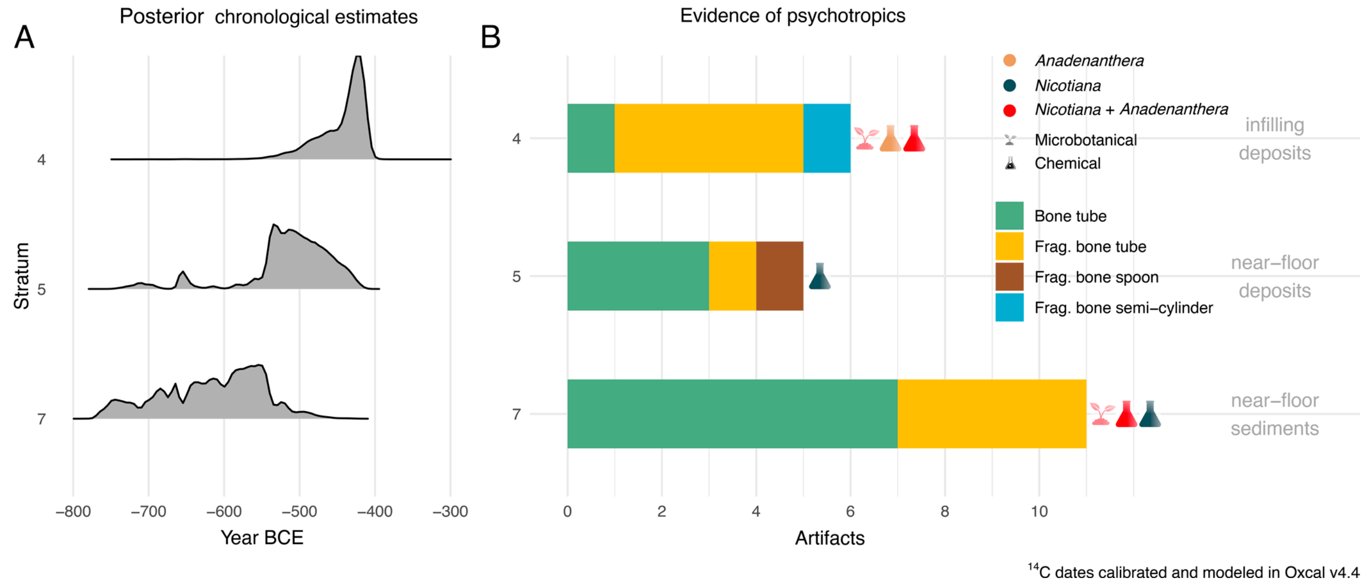

Fig. 5. Composite figure of posterior estimates from the OxCal model with artifact counts, by stratigraphic context. (*A*) Posterior chronological estimates for deposition of the stratigraphic units excavated in Gallery 3 (illustrated in Fig. 3); for Layers 4 and 5 these are derived directly from ^{14}C dates, while for Layer 7 these are estimates based on bracketing dates (*SI Appendix, Supporting Information 3*). (*B*) Artifact counts aggregated across excavated levels, with summaries of evidence for psychotropic plants. Summary classification of depositional processes at right. "Bone tube" indicates a complete or near-complete artifact. *Anadenanthera* indicates *Anadenanthera colubrina* var *cebil*.

is the widest of all, about 3 cm taken at its widest point (Table 1). It is broken on its proximal end and has four parallel grooves carved around the diaphysis (Fig. 4, CH6552-1). The condyles were cut off and two diminutive holes (3 mm) were drilled on its distal end. The second Artiodactyla artifact was made on the diaphysis of a long bone of either camelid or deer. All diagnostic features are missing, and it was found broken in six pieces. It is a semicylinder with smooth edges (Fig. 4, CH6562-1). The remaining four artifacts with positive traces are tubular in shape and were crafted on bird long bones. The tubes have had both epiphyses removed, making their precise anatomic and taxonomic identification more difficult. However, the length and shape of the diaphyses suggest they are bird wing bones: ulna (e.g., CH6580-2 based on general curvature, triangular cross-section, and the row of papillae ulnae) and radius (e.g., CH6530-1, straight diaphysis and distal tendon groove) probably from the same species (48). The length of these tubes ranges from 6 to 13 cm, and the maximum width ranges from 0.5 to 0.7 cm (Table 1). While some of the tubes have broken ends (Table 1 and Fig. 4) and neither artifact nor original bone lengths can be established, the length of preserved segments suggests a medium-sized bird [peregrine falcon ulnae, for example, are ~10 cm in length (49, 50)]. If nonlocal species are considered—a reasonable possibility, considering Chavín's known interaction with contemporary sites spread across the Central Andean coast, mountains, and tropical lowlands—the array of birds that might have provided these bones is quite large. Additional analysis with ZooMS, given sufficient baseline data, might be able to resolve this ambiguity.

The artifacts manufactured on bird bones show an even black-dark brown coloration. This could have been the result of intentional exposure to heat, perhaps to improve their hardness and durability, or the result of diagenetic forces such as manganese and iron staining from the sedimentary matrix. Although the microbotanical analysis showed the presence of microcarbons in the matrix, the chemical analysis showed no evidence of combustion in the recovered alkaloids; if thermal alteration occurred, it happened during the artifact manufacture and before their use and deposition in Gallery 3. Future bone microstructure and sediment analyses may shed light on the origin of the dark color of these bone artifacts. While only four of the 19 tubular artifacts made on bird bone had traces of psychoactive plants, all 19 artifacts are uniform in shape and manufacture.

Discussion

Both the chemical and microbotanical analyses are consistent with the identification of *Nicotiana* and vilca, two plants for which direct evidence of pre-Hispanic ritual use (Fig. 7 and *SI Appendix, Supporting Information 6*) is most extensive in the Southern Andes (22, 27, 51). Ethnographic accounts also detail the consumption by indigenous groups of *Nicotania* roots—usually wild species—as snuff and through smoking in the South-Central Andes and the Gran Chaco, respectively (45). Tobacco and vilca are commonly combined in snuffs among various indigenous groups of lowland South America (45, 47).

Recovery of *Nicotiana* macroremains in archaeological contexts in the Andes is relatively uncommon, but that scarcity may reflect both methodological and preservation biases (52). *Nicotiana* remains have been identified from archaeological contexts dated to the 2nd millennium BCE [at Cardal and Mina Perdida (53)]. However, direct association of tobacco (*Nicotiana tabacum* and *N. rustica*) and wild *Nicotiana* with psychoactive paraphernalia is comparatively uncommon. It has been detected only at the site of Niño Korin in Bolivia (54) and in northern and central Chile and northwestern Argentina in the form of seeds and leaves, pipe and snuff tray contents, and in chemical traces in human hair (27, 30, 31, 33, 44, 55) (Fig. 7).

Vilca is widely depicted in pre-Hispanic Andean iconography (47, 56), including Paracas (23, 57) and Nasca (23), Moche (21), Tiwanaku (14, 58, 59), and Wari (58, 60), and its use is ethnohistorically and archaeologically attested in the region (47, 61–63). The oldest direct evidence of vilca or *cebil* consumption comes from seeds and pipes recovered in northwestern Argentina, which date to *ca* 2000 BCE (47). Its presence has also been detected in small leather bags found in northern Chile (64) (ca. 780 CE) and southern Bolivia (28) (ca.1000 CE) as part of snuffing

Table 1. Bone artifacts that produced positive chemical/microbotanical results

Artifact ID and provenience	Zooarchaeological results				Microbotanical results	Chemical results
	Taxon	Element	Color	Dimensions (cm; length × width, diameter)		
CH6530 #1 (Level 3)	Aves	radius	dark brown	8.76 × 0.8	No identifiable microremains	Traces of nicotine
CH6552 #1 (Level 4)	*Odocoileus virginianus*	metacarpal	brown	3.28 × 2.06, 0.85	Microremains associated with *Nicotiana* and *Anadenanthera colubrina* var *cebil*	Traces of bufotenine (5-hydroxy-*N,N*-dimet hyltryptamine) and nicotine
CH6562 #2 (Level 4)	Artiodactyla	indeterminate long bone	brown	8.8 × 1.73	Microremains associated with *Anadenanthera colubrina* var *cebil*	Traces of bufotenine (5-hydroxy-*N,N*-dimet hyltryptamine) and DMT (*N,N*-dimethyltryptamine)
CH6574 #4 (Level 7)	Aves	indeterminate long bone	dark brown	6.16 × 0.9, 0.65	No identifiable microremains	Traces of nicotine
CH6580 #2 (Level 7, Feature 10)	Aves	ulna	dark brown-black	12.39 × 0.88, 0.63	Microremains associated with *Nicotiana* and *Anadenanthera colubrina* var *cebil*	Traces of bufotenine (5-hydroxy-*N,N*-dimet hyltryptamine) and nicotine
CH6587 #1 (Level 7, Feature 15)	Aves	indeterminate long bone	dark brown	11.78 × 0.5, 0.51	Microremains associated with *Nicotiana* and *Anadenanthera colubrina* var *cebil*	Traces of bufotenine (5-hydroxy-*N,N*-dimet hyltryptamine) and nicotine

paraphernalia, which usually includes tubes, wooden trays, and small spoons and spatulas, often made in Tiwanaku style (21, 22, 47). The only direct evidence of vilca in bone tubes is from the Argentinean northwest, where one bone container tube and a snuffing tube made of bone and wood have been reported (27, 65). Residues have also been detected in a stone vessel (66) and enema syringes (43, 47) in northern Chile, where seeds have also been recovered from archaeological contexts (26, 43). Macrobotanical remains were also recovered from Wari contexts in Peru (ca. 850 CE) as inclusions in *chicha de molle* (*Schinus molle* L. [Anacardiaceae]) (67). The combined presence of vilca and *Nicotiana* (leaves or roots) has been detected in pipes from northwestern Argentina as early as 2500 BCE and subsequently in snuffing trays from northern Chile (500–1500 CE) (26, 68) (Fig. 7).

Ritual activity associated with Chavín and its contemporaries—monumental centers linked through shared material culture, iconography, and architecture into what can be termed the Chavín Phenomenon (69)—is clearly linked to psychoactive paraphernalia (4, 15, 70). Stone mortars or palettes possibly used for snuff preparation include notable examples from Chavín (1, 4, 13) and Pacopampa (71), while small bone spoons argued to be for snuffing, similar to CH6544-2 from Gallery 3 (*SI Appendix*, Fig. S5), have been found at Kuntur Wasi (72), Pacopampa (73), Campanayuq Rumi (74), and Cupisnique sites on Peru's North Coast (75).

However, in many cases, especially from sites in modern-day Peru, it is not known what was inhaled using these artifacts that were apparently specialized equipment for consumption of psychoactive substances. This is the case at Chavín, where the only psychoactive plant unequivocally depicted in the iconography is the San Pedro cactus, which appears on a granite plaque found in situ in the Circular Plaza. Other lithic art that may depict psychoactive plants or their effects includes the Tello Obelisk and the tenon heads that adorned the exterior of the temple, which have been argued to depict a sequence of entheogen-induced shamanic transformation, and a relief carving of a humanoid figure that includes iconographic elements argued to represent vilca (15, 34) (Fig. 1). In consequence, San Pedro cactus, huacacachu [*Brugmansia* sp. (Solanaceae)], ayahuasca [*Banisteriopsis caapi* (Spruce ex Griseb.) Morton (Malpighiaceae), along with other ingredients], cebil or vilca (*A. colubrina* var. *cebil*), epena [*Virola theiodora* (Spruce ex Benth.) Warb. (Myristicaceae)], and tobacco [*Nicotiana tabacum* L. (Solanaceae)], among others, have been suggested as psychoactive plants that were ritually consumed at the site (15, 20, 34, 35, 37).

In this context, it is not surprising to find direct evidence that ritual activity at Chavín included consumption of vilca and *Nicotiana* snuff. Psychoactive effects were apparently a desired component of ritual experience at the monumental centers of the Middle and Late Formative periods, likely building on a deep history of shamanic activity in the region (13).

Both plants would likely have been relatively accessible from Chavín (*SI Appendix*, Fig. S7). The genus *Anadenanthera* is distributed in savannah habitats throughout much of South America, and *A. colubrina* var *cebil* is found on eastern Andean slopes up to elevations of 2,700 masl from 0 to 30° S (15, 47, 76). The *Nicotiana* genus, including wild and domesticated species, is distributed across nearly all of the environments of the Americas (45), including the Andean highlands (77).

Without finer taxonomic resolution, it is not possible to specify an area of origin for the *Nicotiana* specimens identified at Chavín,

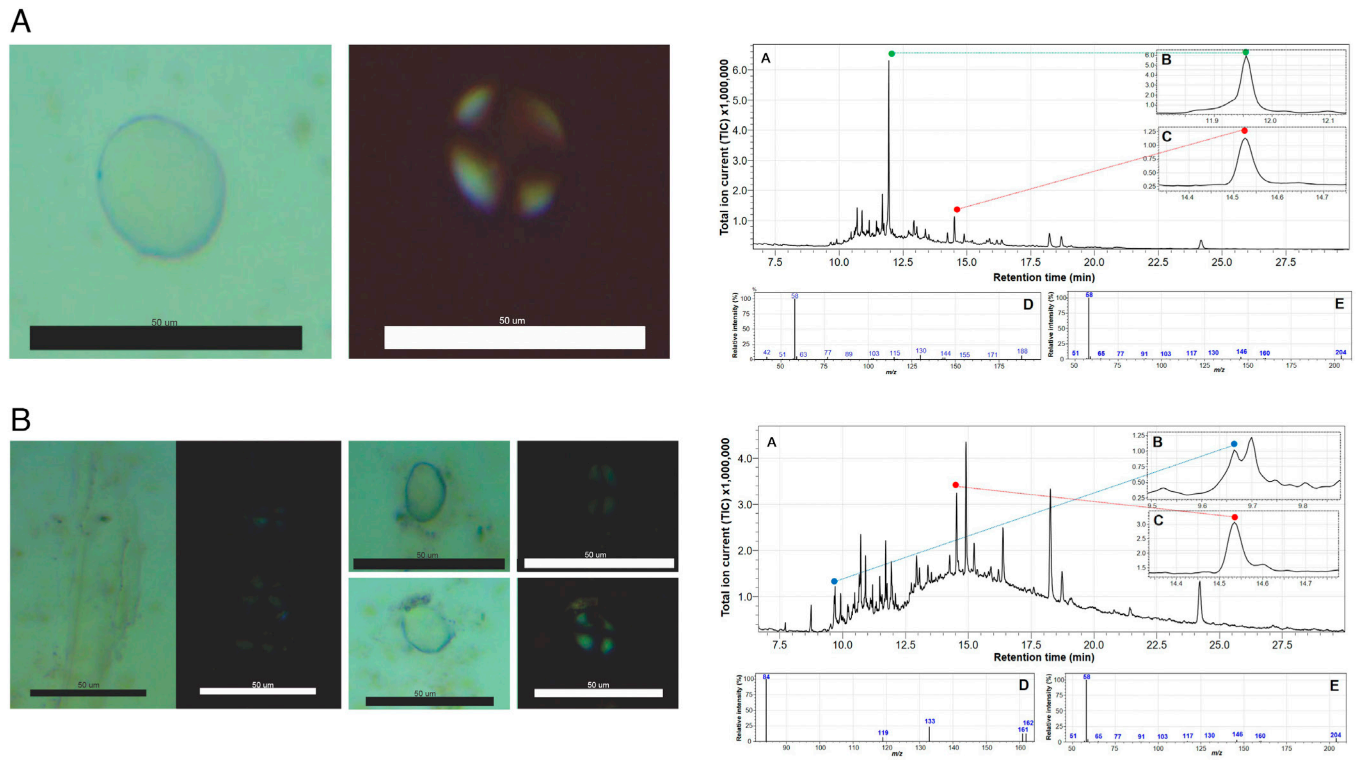

Fig. 6. (*A*) CH6562-2 residue. *Left*, archaeobotanical (*A. colubrina* var *cebil* seed starch grain), and *Right*, GC-MS analysis (*A*: Scan chromatogram; *B*: chromatographic peak identified as *N,N*-dimethyltryptamine (DMT); *C*: chromatographic peak identified as 5-hydroxy-N,N-dimethyltryptamine (bufotenine or 5-OH-DMT); *D*: mass spectrum of the chromatographic peak identified in the sample as *N,N*-dimethyltryptamine (DMT); *E*: mass spectrum of the chromatographic peak identified in the sample as 5-hydroxy-N,N-dimethyltryptamine (bufotenine or 5-OH-DMT). (*B*) CH6580-2 residue. *Left*, archaeobotanical (*A. colubrina* var *cebil* seed and *Nicotiana* root starch grains), and *Right*, GC-MS analysis (*A*: Scan chromatogram; *B*: chromatographic peak identified as nicotine; *C*: chromatographic peak identified as 5-hydroxy-N,N-dimethyltryptamine (bufotenine or 5-OH-DMT); *D*: mass spectrum of the chromatographic peak identified in the sample as nicotine; *E*: mass spectrum of the chromatographic peak identified in the sample as 5-hydroxy-N,N-dimethyltryptamine (bufotenine or 5-OH-DMT).

but the broad distribution of *Nicotiana* suggests that their presence need not imply long-distance travel or trade. Vilca, in contrast, would not have naturally occurred in the immediate vicinity of Chavín. However, while vilca could not be collected or cultivated at Chavín, descending the Mosna River only ~25 km to the east provides access to elevations below 2,700 masl. In sum, the broad ranges and adaptability of both plants suggest that they could have been obtained within approximately a day's walk of Chavín. As a result, the presence of vilca and *Nicotiana* at Chavín need not imply long-distance exchange with the Amazon Basin, although suggested links (78) based on iconography and Chavín's location on the upper eastern slope of the Cordillera Blanca remain likely.

The evidence presented here demonstrates that some bone tubes at Chavín were used—not necessarily exclusively—for consumption of vilca and *Nicotiana*. The tubes from Gallery 3 in which no botanical microremains or diagnostic molecules were detected may also indicate consumption of other substances not yet identified, though absence may also be due to poor preservation. Several of the tubes contained evidence for the use of both plants, suggesting the likely consumption of mixed vilca and *Nicotiana* powders. There does not seem to be an association between the animal used to make the tubes and the specific plant inhaled through or off of them. Previous evidence of such mixed consumption as inhaled powder has been reported only from wooden snuff trays from San Pedro de Atacama, Chile, dating between ca. 500 and 1500 CE (26). In consequence, these results from Gallery 3 at Chavín de Huántar provide the oldest evidence for inhalation of a mixed consumption of vilca and *Nicotiana* in the Americas.

The bone artifacts from Gallery 3 also shed light on consumption practices. No degradation products due to combustion of the alkaloids were detected in the analysis, which reinforces the hypothesis that these artifacts were used for inhalation rather than smoking (34, 79). The bird-bone tubes from Gallery 3 are suitable for use as inhalers [for either self-administration or collaborative use (47)]. The two small (3 mm) holes in the distal end of the tube made from a cervid metapodial suggest that this may have also been used as an inhaler. However, the relatively large (3 cm) diameter and the marks around the end suggest the possibility that some applique was attached to this end of the metapodial to make it a suitable container rather than an applicator. The open artiodactyl diaphysis, with its smoothed edges and semicylindrical shape, may have served to present snuff powder, perhaps as a sort of spoon or spatula, or a support from which to perform inhalation. The latter two are types of artifacts not previously described in relation to psychoactive paraphernalia, which, although complicating the precise definition of their function, also expands the corpus of artifacts associated with vilca and *Nicotiana* powders. The size of the spoon would make it suitable for scooping and measuring powdered material and charging it into tubes the size of the 19 reported here.

Bone tubes are not unique to Gallery 3 at Chavín. Tubes made on Artiodactyla (camelid or cervid) bone have been found in different sectors across the site, including Building C, the La Banda sector, the Ofrendas Gallery, and the Wacheqsa sector (Fig. 2). Six tubes were identified in an assemblage of 108 bone artifacts excavated from the corridor between Buildings C and D. In the La Banda sector, 152 bone artifacts were recovered from domestic units and a workshop for the manufacture of bone artifacts, of which 18 were identified as made of bird bone; 15 of those bird bone artifacts were tubes (38, 80). A few bone tubes on Artiodactyla

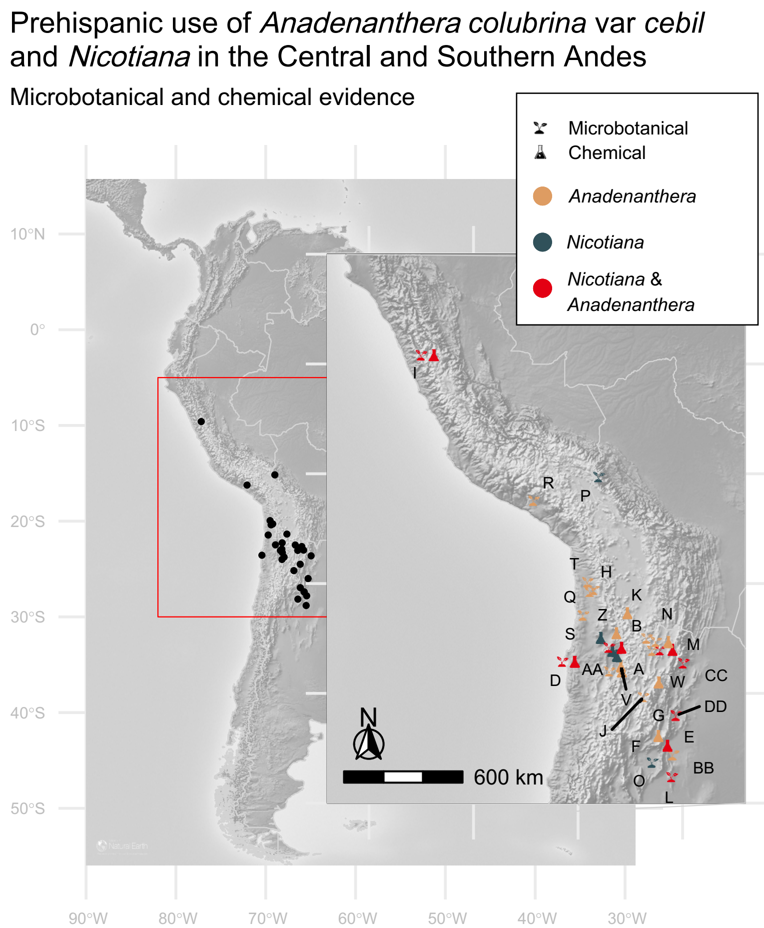

Fig. 7. Direct evidence of remains of *A. colubrina* var *cebil* ("vilca") and *Nicotiana* in pre-Hispanic contexts in the Central and Southern Andean area. In the case of *Nicotiana* only finds from artifacts are included, since the focus is on evidence of use. A—Alero Caido 1, B—Alero I La Matanza, C—Alto Loa (Alero Ampahuasi, Caspana), D—Antofagasta (La Chimba, Vertedero Municipal de Antofagasta), E—Bordo Marcial, F—Campo Colorado, G—Cardonal, H—Cerro Colorado (Cerro Colorado 7, Cerro Colorado 8), I—Chavín de Huántar, J—Cueva Inca Viejo, K—Cueva del Chileno, L—El Taco 19, M—Huachichocana III, N—Inca Cueva-7, O—La Puntilla, P—Niño Korin, Q—Planta de Ripios 2, R—Quilcapampa, S—Quillagua-89, T—San Lorenzo de Tarapacá (Caserones 1, Tarapacá-40), U—San Pedro de Atacama (Catarpe 2, Coyo Aldea, Coyo Oriente, Larache, Quitor 1, Quitor 2, Quitor 2 (Coyo Oriente), Quitor 5, Quitor 6, Quitor Conde Duque, Sequitor, Sequitor Alamabrado Oriental, Sequitor Alambrado Acequia, Sequitor Alambrado Oriental, Solcor 3, Solcor Nueva Población, Solcor Plaza, Solor 3, Tchecar, Yaye 2), V—Socaire-22, W—Soria-2, X—Tchapuchayna, Y—Toconao Oriente, Z—Toconce, AA—Tulán-54, BB—Yánimas-1, CC—Yungas de Jujuy (Arroyo Colorado, Fraile Pintado), DD—Yungas de Salta (La Candelaria, Pampa Grande). Details in *SI Appendix, Supporting Information 6*.

and at least one tube on bird bone were excavated from the Wacheqsa sector, a large stratified midden deposit located north of the monumental area (81). Burger (82) reported one bone tube, most likely from Artiodactyla given its width (about 1 cm), from his excavations in a domestic sector below the modern town of Chavín. Finally, three tubes made of bird long bone, of a similar length (12.8 cm) and width (0.5 to 0.8 cm) as those found in Gallery 3, were recovered in the nearby Ofrendas Gallery by Lumbreras (40). This may be the most similar context to that of Gallery 3 in terms of architecture and date, i.e., a formal underground structure dating to ca. 850–500 BCE.

The tubes from the Ofrendas Gallery and those from Gallery 3 reported here highlight the fact that one of the foci of ritual activity at Chavín was restricted-access interior spaces. The most well known of these are the Gallery of the Lanzón, which houses a >4 m high carved granite monolith, the Ofrendas Gallery, from which nearly 700 ceramic vessels were excavated (40), and the Caracolas Gallery, from which 20 complete Strombus shell trumpets were excavated (18). Galleries were apparently foci of ritual activity, access to and content of which were institutionally controlled and managed. The findings reported here argue that at least some of that ritual activity involved psychoactive substances, confirming proposals about Chavín ritual based on iconography (15).

The use of psychoactive substances for ritual purposes is well known from shamanistic practices, both in the Andes and worldwide (83–86). However, while Chavín and contemporary Middle-Late Formative sites in the Central Andes may derive their psychoactive plant usage in part from a heritage of such practices, shamanistic use of psychoactive substances is not associated with the types of large and formal architectural settings that characterize the period (13). In addition, as noted above, bone tubes of the type examined here are found in multiple contexts at Chavín, but most are concentrated in restricted-access settings, rather than scattered as might be expected if they had been used in informal, individually performed ritual in openly accessible spaces. This distribution argues that a) many of these objects were deposited at or near their locations of use, rather than disposed of with other refuse (note their relative scarcity in the middens of the Wacheqsa sector), and b) consumption of psychoactive substances was organized and perhaps controlled, rather than occurring at the whim of visitors to the site. Moreover, the gallery contexts from which bone tubes were recovered are in close association with floors, offerings, and human burials; these associations with *use* rather than storage or disposal contexts further argue for deposition resulting from ritual activity in or very near Gallery 3.

While the consensus that Chavín was a locus of ritual is well established, the specifics of ritual activity have remained elusive (2, 4, 5, 18, 40, 87). Nevertheless, ritual at Chavín can now be characterized as involving costumed processions that traversed architectural spaces that varied in accessibility and visibility (18). Participation was probably not open to all, and at least some parts of these activities were even restricted to particular audiences; a spectrum of architectural accessibility can be defined from the relatively open space of the Square Plaza at one end to the restricted-access and invisible-to-audiences interior spaces of the galleries at the other (4, 18, 87, 88). In at least some of those spaces, particularly the galleries, manipulation of light and sound formed part of ritual activity (18, 89, 90). Finally, diverse evidence (5, 18, 40, 41, 91) argues that offering or sacrifice of objects was part of ritual activity within the monumental center.

Based on the evidence presented here, we can now strongly infer not only that ritual at Chavín involved consumption of psychoactives but more specifically that the ritual activity taking place in and around the galleries—the primary restricted-access ritual spaces at Chavín—included such consumption. Privileged access, then, might include not only entry into restricted spaces and participation in offering or sacrifice that established "contact and contract" (92) with the supernatural, but also consumption of controlled substances that produced altered mental states.

Psychoactive substances likely contributed to the perceived efficacy of these ritual practices, which occurred in spaces apparently themselves designed to affect their occupants. The effects of vilca and *Nicotiana* vary, according to clinical tests on animals and reports of ethnographers and psychonauts, and also vary according to the quantity administered and the conditions of administration. In consequence, effects range across proprioceptive disorder, torpor and semilethargy, depersonalization, visual and auditory synesthesia, and purgative reactions (45, 47). These effects, in combination with affective spaces and ritualized practice, made the efficacy of ritual manifest in the experiences of the participants.

Conclusions

The research presented here provides the northernmost direct evidence of vilca and *Nicotiana* use in the pre-Hispanic Andes and also a report on contents of psychoactive paraphernalia from 1st millennium BCE Peru (Fig. 7). These results, from independent chemical and microbotanical analyses, substantiate previous suggestions based on iconography that the use of psychoactive plants formed part of ritual practice at Chavín. Direct associations of diagnostic remains and compounds on multiple instruments of ingestion in archaeological contexts of ritual activity, moreover, argue that use of psychoactive plants was intimately associated with institutionalized ritual, and not limited to the individualized contexts of ecstatic shamanism. The chemical and microbotanical remains recovered from the interior surfaces of five tubes and one semicylinder demonstrate that ritual consumption of psychoactive plants (or at the very least disposal of the involved paraphernalia) was occurring in the small, constrained spaces within the galleries, where ritual took place in institutionally controlled contexts accessible only to select participants.

Those architectural contexts, and indeed the monumental center in which they were embedded, are striking evidence of mobilization of labor and raw materials. They represent challenges of collaborative action and were constructed during the Middle and Late Formative Period, a time when the processes through which collaborative projects were undertaken were changing. Among these changes were shifts toward institutionalized ritual practice and increasing sociopolitical differentiation (12). Ritual practice involving consumption of psychoactive substances, the evidence we have presented here suggests, was a component of this process. Perceived ritual efficacy arising from this combination of structured activities, including consumption of psychoactive substances in designed and restricted spaces inside monumental structures, may have contributed to the credibility of the hosts of those rituals, potentially facilitating increasing social differentiation and the role of Chavín de Huántar as a major center of public ritual activity. Thus, this evidence fits well within, and helps explain, the striking development in the later Formative Period of iconographic traditions, ceremonial architecture, extensive production and exchange of objects made of rare raw materials at high labor cost, and differentiated sociopolitical structures that were foundational to later Andean societies.

These results should prompt additional research into the context and significance of consumption of psychoactive substances in the Central Andean Formative, following the lead of investigations into their use in the Middle Horizon (67, 93). Further investigation into the role(s) of psychoactive substances at Chavín can now build on a firm foundation of direct evidence.

Methods

Excavation. Excavations of Gallery 3 occurred in 2017–2018 under the auspices of the Programa de Investigación Arqueológica y Conservación Chavín de Huántar (PRIACHAVIN). The 1.2 m-wide gallery was divided into five excavation units, each a 1 m segment of its 5 m long principal east-west section. The excavation was carried out following the stratigraphy of anthropogenic sediments that completely filled the >2 m height of the gallery at its west end, tapering downward to the east. Stratigraphic units were subdivided according to observed elements such as funerary contexts, features, and architectural elements. Carefully controlled methodologies of excavation and artifact recovery as well as sediment sampling and handling minimize the risks of contamination of these samples.

Additional details are available in *SI Appendix*, *Supporting Information 1*.

Residue Sampling. Residue sampling took place in the facilities of the Centro Internacional de investigación, conservación y restauración of the Museo Nacional Chavín, in a clean laboratory not used for the analysis of organic material. Materials were handled with disposable nitrile gloves. Artifact scrapings were carried out with metallic tools that were washed with distilled water and 96° alcohol after each extraction. Liquid extraction was carried out with graduated micropipettes and distilled water, using disposable tips.

Subsequent analyses (*SI Appendix*, *Supporting Information 5*) were carried out in Córdoba, Argentina. A total of 65 slide preparations were mounted and observed. Each preparation was completely observed at 100× and 400× magnification with an optical microscope in transmitted and polarized light. The observed remains were documented with an integrated digital camera and coupled software for measurement and generation of indices.

Additional details are available in *SI Appendix*, *Supplementary Information 5*.

Chemical Analysis. Chemical analyses of the residues on twenty-four objects were performed using gas chromatography coupled with mass spectrometry (GC-MS); one was determined to be an unmodified bone and excluded from further analyses. The solid residue from archaeological objects was extracted with 500 μL of a mixture of chloroform-methanol 2:1 (HPLC grade, J.T.Baker) by maceration in an ultrasonic bath (Power Sonic 405, Hwashin Technology, Korea). GC/MS analysis was performed with a Shimadzu model GCMSQP 2010 Ultra gas chromatograph (Shimadzu, Kyoto, Japan). Peak identifications were performed using the NIST14 mass spectral database, published mass spectra, retention characteristics (viz. comparison to reference standards and published retention indices), and mass spectral deconvolution (using GCMS solution software Version 4.20, Shimadzu Corporation, Japan).

Microbotanical Analysis. Eleven of the artifacts subjected to chemical residue analysis (nine bone tubes, one bone artifact, and one shell) were also processed for microbotanical analysis, as was control sediment obtained from the surrounding contexts and from scraping the external surfaces of the tubes. An internal scraping of the tubes (or of the face assumed to be active in the case of the shell) was performed, and then a sample was obtained with a micropipette by suspension and dragging of sediment in a liquid medium. From the eleven artifacts, twenty-nine samples were collected, from which sixty-five microscope slides were made, keeping equal representation of each artifact. The slides were observed under an optical microscope using polarized light. The observed microremains were recorded by digital camera with coupled software for measuring and obtaining indexes and were compared with V. Lema's collection of psychoactive plant references and with bibliographic background in order to taxonomically classify them.

See also *SI Appendix*, *Supplementary Information 4*.

Zooarchaeological Analysis. Osteological atlases (48–50, 94, 95) and the PRIACHAVIN comparative faunal collections were used to identify the bone artifacts anatomically and taxonomically. Dimensions and color were also recorded for each bone artifact.

Data, Materials, and Software Availability. All study data are included in the article and/or *SI Appendix*.

ACKNOWLEDGMENTS. Excavations at Chavín by the Programa de Investigación Arqueológica y Conservación Chavín de Huántar are possible thanks to the permission of the Ministerio de Cultura del Perú. The program relies on too many individuals to name them all here, but the contributions of Rosa M. Rick, María Mendoza, and Lisseth Rojas Pelayo were especially vital to this research, and Lucero Sánchez and Jimmy Luzuriaga helped excavate Gallery 3. Excavations and subsequent analyses were possible thanks to the financial support of the Compañía Minera Antamina and Archaeology in Action, and the administrative support of the Patronato Cultural del Perú. The analyses carried out by Verónica Lema were supported by Argentina's Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET). We would also particularly like to thank Miguel G. Ortiz Mestanza for Figs. 1 and 2, Gabriela Bertone for her help with the early stages of analysis, and John Southon for his support with radiocarbon dating. The thoughtful and constructive comments of three anonymous reviewers have improved the manuscript.

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