# An Examination of Recuay Kaolin Pottery Production and Exchange through Petrography and LA-ICP-MS (100 – 700 CE; Ancash, Peru)

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## ABSTRACT

This article examines the production and exchange of kaolin ceramics among Recuay communities in highland Ancash, Peru (ca. 100 – 700 CE). We draw upon geochemical (LA-ICP-MS) and petrographic data to investigate raw material use, provenance, and intraregional trade. We present data on 115 decorated and plain ceramics sampled from nine archaeological sites, which we compare with data on raw kaolin clays. The results indicate a complex network of production and exchange, which included: 1) local production near almost all sites; 2) the limited exchange of ceramic vessels; and 3) the possible distribution of kaolin clay from at least two sources.

KEYWORDS

Andes; Early Intermediate Period; ceramic production; exchange networks; kaolin; LA-ICP-MS; petrography

## 1. INTRODUCTION

During the Early Intermediate Period (EIP), Recuay communities (ca. 100 – 700 CE) established diverse settlements across the Ancash region in Peru's north highlands. Recuay politics, economy, and social life centered largely on kinship ties (Bria 2017; Gero 1991; Lau 2011) and nascent Recuay communities engaged this new social world by developing novel monuments and artistic media. Antecedent peoples created elaborate temple centers (e.g., Chavín de Huántar) (Burger 2008), but the Recuay are notable for building subterranean tombs and mausolea in and near their villages for the purposes of ancestor veneration and religious practice (Lau 2002; 2016, 105-110). Recuay villages and ritual spaces served as loci for the negotiation of politics and social life by marking the status of particular lineages within ancestral lands and serving as spaces for political feasts. Ceramics were critical fixtures of religious and political celebrations. Potters crafted sumptuous vessels that depicted prominent leaders or scenes of people consuming food and drink, often within or next to architecture (e.g., house compound, mausoleum). Such scenes reinforced lineage-based politics (Carrión Cachot 1955; Gero 1999; Moretti 2017). Fine bowls and accompanying utensils were also important items for feasting and everyday eating in public ritual and domestic settings. For their fine wares, Recuay artisans relied on kaolin, a white clay not used by previous or subsequent groups in Ancash. Because of its new and widespread use, it stands to reason that kaolin comprised a valuable material for Recuay communities. Yet we know little about how potters used kaolin, where they procured it, and how production was organized. Moreover, it is unclear whether Recuay communities exchanged valued kaolin vessels to negotiate political relationships. Studies have previously identified shared iconography and styles on pottery, stone sculpture, and metalwork across highland Ancash during the EIP (Lau 2011). Simultaneously, there is minimal evidence for the exchange of prestige goods (e.g., obsidian, *Spondylus*), particularly when compared to the strong interaction networks of previous and subsequent periods (e.g., Burger et al. 2006; Lau 2017). An evaluation of kaolin ceramic production and exchange should therefore help illuminate Recuay cultural patterns and politics.

This paper brings together geochemical and petrographic data on decorated and plain Recuay kaolin pottery for the first time. Many Recuay ceramic studies have focused on design style and iconography (e.g., Amat 2004; Reichert 1977; Smith 1978; Wegner 2004), which is eclectic and not easily typed. Such studies indicate that kaolinite ceramics were not mold-made and are heterogeneous in vessel shape, size, thickness, surface treatment, and painted/modeled imagery (for pottery variability, see Lau 2011, 127-157). Open bowls are the most common form, but even intra-site bowl variability is high (e.g., Jecosh, see Grávalos 2021, 366-387). Recuay potters created many hand-modeled composite vessels that portray human, animal, and architectural forms. Positive and negative painted geometric motifs frequent bowl forms, but similarly, stroke thickness and color are irregular. The lack of standardization suggests that production was not centralized. We test this hypothesis through the combined geochemical and petrographic analysis of Recuay kaolinite wares from nine archaeological sites in the Callejón de Huaylas valley (Figure 1).

Compositional analysis of Andean kaolinite pastes is in its infancy. Two previous studies examined Recuay kaolin wares using x-ray fluorescence (Czwarno 1983; Schwartz 2010). Czwarno (1983) compared a small sample of Recuay kaolin pottery to that of Cajamarca and Marcahuamachuco, largely coeval cultures north of Ancash. Through an analysis of eight trace elements, Czwarno compared ceramic data to raw clays from Ancash, Cajamarca, and Huamachuco; ultimately, he could not correlate kaolin clays to pottery. Schwartz (2010) characterized 13 elements for Recuay kaolin wares excavated from the Santa Rita B site (Chao valley), comparing them to raw clays. She argues that the ceramics were locally produced (Schwartz 2010, 55). Other studies of kaolin pottery produced by later neighboring polities have been small in sample/scale or reliant on a single method (e.g., Cajamarca; Toohey 2019).

Here, we compare ceramic analysis results with data on raw kaolin clays from highland Ancash to 1) determine the composition of Recuay kaolin fine wares; 2) propose possible areas of raw material provenance; and 3) evaluate the organization of production and exchange. Many archaeologists use instrumental neutron activation analysis (INAA) to study ceramic composition in South America (see Glascock et al. 2019). INAA provides a bulk characterization of the clay paste by homogenizing the ceramic into powder. The Recuay case warrants a different approach due to the common practice of mixing kaolin and non-kaolin clays. We thus combined geochemical and mineralogical techniques: Laser ablation – inductively coupled plasma – mass spectrometry (LA-ICP-MS) and thin section petrography. We utilized LA-ICP-MS to target the clay matrix of ceramics; this point-based method intentionally avoids paste inclusions

(Dussubieux et al. 2007; 2016). In addition, we conducted petrographic thin section analysis to qualitatively identify and describe aplastic inclusions and clay matrices through polarized light microscopy (Quinn 2013). Taken together, these methods revealed the diversity of Recuay kaolin ceramic production and exchange.

## 2. GEOLOGICAL SETTING

The Callejón de Huaylas is an intermontane valley defined by the upper Santa River and its tributaries. The Santa is flanked by two mountain ranges, the glaciated Cordillera Blanca to the east and the Cordillera Negra to the west, which are made up of discrete geological formations of varying ages and petrographic compositions (Figure 1).

The Cordillera Blanca comprises a Late Miocene-era batholith, consisting of granite, granodiorite, and tonalite (Cobbing et al. 1981, 83-84) and is almost completely emplaced in shales from the Upper Jurassic Chicama Formation. Volcanic episodes along the Cordillera Blanca Fault have produced abundant ignimbrites and tuff in the Callejón de Huaylas (Cobbing et al. 1981, 85). Much of the Cordillera Blanca is defined by the Cohup stock, consisting of leucogranodiorite (Cobbing et al. 1981, 83). Some tonalites and granodiorites are partially metamorphosed into mica schist, like those affected by thermal metamorphism in the northern Callejón de Huaylas near the archaeological site of Hualcayán (Cobbing et al. 1981, 84). The

Callejón de Huaylas valley bottom is generally filled with material from the Cordillera Blanca Batholith (Bonnot 1984; Giovanni et al. 2010), consisting mainly of Quaternary glacial deposits, mixed with some granitic clasts and sedimentary and volcanic rocks/minerals (e.g., sandstone, siltstone, quartz, plagioclase, biotite, pyroclastic conglomerates, and rhyolites). East of the Cordillera Blanca (Callejón de Conchucos), sedimentary rocks are common due to the Santa, Carhuaz, Celendín, Chimú, Jumasha, Oyón, and Chicama formations (Druc 1998, 10; Cobbing et al. 1981, 8). These formations are composed primarily of dark gray shale, quartzite, sandstone, siltstone, and limestone layers.

The Cordillera Negra, which forms the western flank of the Callejón de Huaylas, is less uniform than the Cordillera Blanca and is comprised of the Coastal Batholith. The Coastal Batholith has a complex lithostratigraphy with diverse, small stocks (Cobbing et al. 1981, 30); its composition is mafic, including intrusives like diorites and hornblende-tonalites with common biotites. The Cordillera Negra is largely covered with extrusive material from the Calipuy Volcanic Group, including andesites with intercalation of pyroclastic rocks and ignimbrites, as well as dacite and rhyodacite (Cobbing et al. 1996, 113-115). Isolated rhyodacite and dacite outcrops exist in the southern and central portions of the Cordillera Negra, near the archaeological sites of Chinchawas and Jecosh. The northern portion of the Cordillera Negra is more heterogenous than the south, comprised of the Late Jurassic Grupo Goyllarisquizga, the Oyón Formation, and the Pariahuanca Formation (Cobbing et al. 1981, 8-13). These formations include sedimentary (e.g., sandstones, limestone, and shale) and metamorphosed (e.g., slate, quartzite, and quartz-mica-schist) materials.

Because of the area's complex geology, people who lived at each settlement in this study would have had access to similar as well as distinct geological resources. This diverse landscape allowed for kaolinite minerals to form in small pockets and as large clay deposits. Kaolinite is an alumina-rich clay mineral with a restricted chemical composition resulting in its white color ($Al_2Si_2O_5(OH)_4$; Druc and Velde 2021, 49). Kaolin deposits form through the advanced weathering of felsic parent material (e.g., granite; Rice 2015, 51). Kaolin occurs as primary and secondary deposits. Primary, or residual, kaolin usually exhibits low plasticity and has impurities, including remnant parent rock (Rice 2015, 52). Secondary kaolin is "purer" with higher plasticity and few inclusions. For example, sedimentary deposits usually lack impurities (e.g., iron) and are more fine-grained and well sorted due to transport and deposition (Rice 2015, 52-53).

## 3. MATERIALS AND METHODS

### 3.1 Samples

This research analyzes kaolin ceramic fragments sampled from nine archaeological sites in highland Ancash (*n*=115; Table 1, Figure 2). The assemblage pertains to domestic, mortuary, and communal spaces, representing a random, stratified sample (Table 2). By communal spaces, we refer to non-mortuary areas where community-wide gathering likely took place, such as feasting events in plazas and mounds. While randomly selected, samples are representative of excavated contexts. For example, all but one sample from Jecosh pertain to residences. This is because nearly all undisturbed Recuay-era contexts at Jecosh were domestic spaces (Grávalos and Sharp 2022). Similarly, Hualcayán's sample mainly represents communal spaces, reflecting its excavations (Bria 2017). The sites included in this study also have significant differences. For example, Chinchawas, Chuchun Punta, Jecosh and Queyash Alto are small settlements, while Hualcayán is a large community center. And while all sites have cemeteries, Llanganuco, Marka Kota, Marka Kunka lack known domestic components. Similarly, sites such as Hualcayán, Keushu, and Queyash Alto have communal gathering areas like mounds and plazas, which other sites do not. Despite these differences, we feel that the comparison of samples from across these sites nonetheless advances an understanding of Recuay political economy.

Radiocarbon evidence and ceramic design style place these samples within the EIP (see Bria 2017; Gero 1992; Grávalos 2021; Grávalos and Sharp 2022; Lau 2010a). Field Museum of Natural History (FMNH) ceramic samples lack radiocarbon evidence. Five kaolinite sherds have painted Cajamarca-related iconographic motifs (CHI001, CHI002, CHI010, CHI011, and QUE019). We include them in this study to assess whether Recuay potters imitated or imported Cajamarca design styles. FMNH ceramics were not permitted to undergo destructive petrography and were thus solely analyzed via minimally invasive LA-ICP-MS. A more detailed explanation of the sampling strategy and archaeological provenience is available (Grávalos 2021, 143-145).

Our study also includes a comparative analysis of kaolin clays. To evaluate possible raw material procurement zones (Sharratt et al. 2009; Vaughn and Neff 2004), we analyzed 24 clay samples from highland Ancash via LA-ICP-MS. Kaolin samples were originally obtained and analyzed by Czwarno (1983). Czwarno left a portion of the collected clays in Huaraz, Peru under the care of Steven Wegner, who later gave them to the first author for LA-ICP-MS. Czwarno recovered clay samples from five industrial kaolin deposits (Figure 1; see Grávalos 2021, 128-131 for further explanation of raw material survey and analysis).

## 3.2 LA-ICP-MS

The first author conducted LA-ICP-MS at the Elemental Analysis Facility at the FMNH, following established protocols (see Dussubieux et al. 2007). To calculate elemental concentrations, we averaged 10 measurements for each of the 58 detected elements. These 10 measurements ensure that a representative portion of the clay matrix is characterized. To evaluate result consistency, we calculated the relative standard deviation (RSD) of New Ohio Red Clay (NORC), which was analyzed during each day of analysis. We removed the following elements from statistical analysis because they exhibited a RSD above 30%: chlorine (Cl), copper (Cu), silver (Ag), antimony (Sb), gold (Au), and holmium (Ho). Lab protocols dictate that selenium (Se) and cadmium (Cd) are not calculated, resulting in 50 elements for statistical analysis (see SI, Data S1 for ppm values).

Prior to statistical analysis, we converted the parts-per-million (ppm) data into log (base-10) values to minimize variations between major, minor, and trace elements (Harbottle 1976, 45). Multiple statistical procedures allowed us to understand compositional heterogeneity and identify groups. For a quick data assessment, we conducted a Hierarchical Cluster Analysis (HCA) using Ward's method and a Principal Component Analysis (PCA). These methods create hypothesized compositional groups that can be tested with more rigorous statistics, such as Mahalanobis distance (Baxter 2001, 135-136; Glascock 1992; Neff 1994). Mahalanobis distance determines the probability samples belong to a specific group; we used the samples' Principal Component values to calculate Mahalanobis distance (Baxter 2001, 135-136). This process relies on "jackknifing", which removes samples from a group and proposes a new group to which the sample is more likely to pertain, making it a rigorous approach for testing chemical group validity (Glascock 1992, 20). We set potential group membership to >5% and reprojected samples with values <5% into new groups (Glascock 1992, 18). We projected the final Mahalanobis distance groups into a Canonical Discriminant Analysis (CDA) and attempted to reintegrate outlier samples that were removed during the jackknifing process. Finally, we examined raw clay samples by calculating their Mahalanobis distanced-based probabilities relative to each identified ceramic chemical group (Sharratt et al. 2009, 811-814).

### 3.3 Qualitative petrography

Spectrum Petrographics in Vancouver, Washington prepared thin sections. Specimens were sliced, ground to 30 μm, and mounted on glass slides to permit examination with a polarizing light microscope and subsequent analysis by the first author in the FMNH's Petrographic Microscopy Lab. To identify aplastic inclusions and qualitatively describe the overall ceramic fabric of each sample, Grávalos followed Quinn (2013). She used visual charts to estimate grain percentages and measured grain size using the Udden-Wentworth scale. All thin sections were studied via plane (PPL) and polarized light (XPL) to classify mineral and rock features. Grávalos conducted petrographic analysis without reference to the sample's chemical group, archaeological context, or design style. Finally, we relied upon the published geological literature (e.g., Cobbing et al. 1981, 1996) as well as our own field surveys of sites to make assessments about possible resource zones for tempers (e.g., shale).

## 4. RESULTS

### 4.1 Chemical groups

The HCA and PCA showed possible compositional groups, with samples falling into two groups that roughly correlate with their provenience from sites in the southern vs. northern Callejón de Huaylas, as well as a possible third group with raw clay samples. To calculate the Mahalanobis distance, we split the ceramic samples into two groups and utilized the nine PC scores with eigenvalues greater than one (88.3% of overall variance). We identified eight samples with <5% probabilities as outliers; the remaining samples demonstrate group membership probabilities >5% and strongly suggest northern and southern compositional groups (SI, Data S1 and S2). To understand this pattern through time, when statistical parameters allowed, we segregated data by identified Recuay phase (Table 2) and found that the two northern and southern compositional groups were maintained. CDA reaffirms the two previously identified kaolin compositional groups, with the original outliers as remaining separate. The results of the CDA are statistically significant (Wilks' $\lambda$ =0.0009), showing strong separation between Groups 1, 2, and the outliers. Elements such as dysprosium (Dy) and samarium (Sm) are heavily loaded for Group 1 and neodymium (Nd) and terbium (Tb) for Group 2.

Analysis of the raw kaolin samples demonstrates that clays from specific deposits can be chemically differentiated, except for the Paloma Blanca mine. A comparison of PC1 and PC2 (53.93% of variance) shows that Paloma Blanca is the most heterogenous clay group, with MEGC116 and MEGC037 overlapping with Ferrol 21 and Ferrol 206 (SI, Data S2). A biplot of log-base 10 ppm values of cesium (Cs) and tungsten (W) also indicates that clay groups are differentiated at the level of individual elements. Due to their small sample sizes, the calculation of Mahalanobis distance-based probabilities of kaolin clays was not possible. Instead, we determined the PC scores for clay samples relative to the variance-covariance matrix of the kaolin pottery. We then used the first nine principal components to calculate group membership probably of kaolin clays relative to the ceramic groups identified above. This calculation shows a <5% probability of kaolin clay group membership with the ceramic groups, indicating that ceramics were likely not produced using clays from any of the sampled deposits. A CDA summarizes the results of this overall analysis (Figure 3A).

## 4.2 Petrographic fabrics

The sampled ceramics represent a diverse array of geological resources and cultural practices (Figure 4). Many of the identified fabrics indicate that potters relied on impure kaolin sources, or clays from primary (i.e., residual) deposits, located near the parent material. Pure kaolin is completely white and fires white due to iron leaching during deposit formation (Druc and Velde 2021, 49). However, when iron leaching is incomplete, this results in an impure, heterogenous kaolin with many iron oxides. The impure nature of the kaolin helps explain the variability in paste color among Recuay fine wares (e.g., white/cream, light orange, and light pink). The other contributing factor to paste color variability is the practice of clay mixing—this is most prevalent at Jecosh, but was also observed at Hualcayán, Keushu, Llanganuco, Queyash Alto, and Chinchawas. The identification of composite pastes created through the purposeful mixing of two clays can be difficult because naturally variegated clays sometimes display similar features to that of intentionally mixed clays (Ho and Quinn 2021). In our study, kaolin and non-kaolin clays look qualitatively different under polarized light. Clay domain streaks and laminations clearly demonstrate the use of two or more mineralogically distinct clays, similar to those described by Quinn (2013, 170). Below we summarize the main features of fabrics by site. Full qualitative descriptions are available in the Supporting Information (Data S3) of this article.

4.2.1 Hualcayán  The Hualcayán sample represents four unique fabric groups. HUA-Kaolin A (*n*=1) is very fine with 30% inclusions (well sorted with a unimodal grain size distribution). It is quartz dominant, with frequent muscovite, few opaque minerals and textural features (i.e., clay pellets and argillaceous rock fragments), and rare granite, slate, and polyquartz grains. The clay matrix is homogenous. It is possible that potters added quartz-mica-schist sand as temper. HUA-Kaolin B (*n*=1) is very fine-grained with 5% inclusions. This well sorted fabric consists of predominant quartz, frequent muscovite, and common clay pellets that merge into streaks, indicating clay mixing. HUA-Kaolin C (*n*=1), which also has 5% inclusions, and prominent clay pellets and probable kaolin clay stones. HUA-Kaolin C is well sorted with predominant quartz, common clay stone, iron oxides and clay streaks, and few plagioclase grains. We suggest that the clay stones are dehydrated kaolin clay fragments that did not fully rehydrate when the potter created the wet clay paste. HUA-Kaolin C also has isolated areas of clay mixing with iron oxides throughout. HUA-Kaolin D (*n*=1) is relatively coarse-grained, with 35% inclusions that are poorly sorted with a bimodal distribution. The coarse fraction consists of predominant shale, common muscovite, few schist grains (probable quartz-mica-schist), and very few biotites. The clay matrix is homogenous with dehydrated clay stones like HUA-Kaolin C. It seems that potters tempered the kaolin with metamorphic sand, consisting primarily of slate and schist. Given Hualcayán's location near several metamorphic geological formations, it is possible that potters utilized locally available tempering materials (i.e., within a 9-km radius of the site).

4.2.2 Llanganuco  The three kaolin petrogroups from Llanganuco illustrate differing tempering practices. The first group, LLA-Quartz Sand Kaolin (LLA-QSK; (*n*=1) has 30% inclusions (well sorted). It has dominant quartz and muscovite, common iron nodules, very few polyquartz grains, and very rare schist. LLA-QSK has a higher proportion of inclusions than Llanganuco's two other petrogroups. The angularity of LLA-QSK's quartz grains indicates the use of a quartz sand as temper. The muscovite and schist, which are rounded, are likely part of the clay. LLA-Slate/Shale (*n*=1) has 15% inclusions (poorly sorted) with a homogenous clay matrix. The coarse fraction contains predominant slate/shale and quartzite grains, frequent muscovite, and rare textural features. The size, roundness, and shape of shale/slate grains suggest that it was added as temper. LLA-Mixed Clay (*n*=4) exhibits the mixing of clays as a tempering method. This group has 10-30% inclusions (well to moderately sorted). The coarse fraction consists of predominant muscovite and quartz alongside common-few slate, metamorphic rock, and textural features. The clay matrix is heterogenous with opaque domains intermixed with optically active areas. The opaque, optically inactive clay domains juxtaposed with highly active clay domains suggest partial vitrification of the clay body, where some clay minerals began to sinter and others did not. The partial vitrification indicates that firing temperatures likely exceeded 850°C (Quinn 2013, 190-191) and demonstrates the mixing of a non-kaolin clay with kaolin. The presence of metamorphic rock may mean that potters procured non-kaolin clay near Llanganuco, as it sits near Chicama Formation shale/slate and quartzite outcrops.

4.2.3 Keushu  This site's two samples represent discrete fabrics. KEU-Quartz Sand Kaolin (QSK) consists of 22% inclusions (well sorted). It has predominant quartz, few plagioclase, muscovite, and argillaceous rock fragments, and rare pyroxene. The clay matrix is heterogenous with moderate optical activity; it contains unmixed kaolin clay domains, which were likely particles of dried clay not fully rehydrated during paste preparation. Color differentiations under XPL (silver to golden/beige), as well as some parallel alignment of angular quartz and plagioclase grains, indicate tempering with a sandy sediment. KEU-Mixed Clay is well sorted with 5% inclusions. KEU-Mixed Clay has predominant quartz alongside common muscovite and iron nodules/textural features. The clay matrix is heterogenous, displaying gray sediment/sand streaks and rare red clay streaks, with high optical activity. The angular quartz and alignment with clay streaks suggest tempering with sand/sediment alongside the mixing of two discrete clays.

4.2.4 Queyash Alto  The only sampled kaolin fabric from Queyash Alto, QUE-Mixed Clay, is very fine overall, has 20% inclusions (very well sorted). QUE-Mixed Clay has predominant quartz and muscovite with red and white/gray (kaolinite) clay pellets. These clay pellets include dried kaolin that was not completely rehydrated. QUE-Mixed Clay's matrix is heterogeneous with clay and iron oxide streaks throughout, moderate optical activity, and a parallel striated birefringent fabric. This indicates that potters used micaceous non-kaolin clay as temper. Because Queyash Alto is situated on the mica-abundant Goyllarisquizga Group, it possible that potters procured micaceous non-kaolin clay within a <1km site radius.

4.2.5 Chinchawas There are seven kaolinite fabrics from Chinchawas. CHI-Kaolin A (*n*=1) is coarse-grained with a bimodal distribution. The coarse fraction consists of predominant shale clasts, few slate, sandstone, and quartz inclusions, and very few rhyodacites. Because of its bimodal distribution, and the fact that there are few muscovite laths in the paste's fine fraction, which we expect in shale-based clay, the slate/shale was likely temper. Unlike at Llanganuco and Hualcayán, where slate temper is common in non-kaolinite ceramics (Grávalos 2021, 240-261), slate/shale is not part of Chinchawas's surrounding geology. CHI-Kaolin B (*n*=1) has a bimodal distribution with dominant quartz, frequent rhyodacites and clay pellets, and few plagioclase inclusions in the coarse fraction. CHI-Kaolin C (*n*=1) is a very fine paste with predominant quartz and a heterogenous clay matrix. Opaque clay domains near the sample's margins with merging clay pellets suggests either clay mixing or an impure kaolin source. CHI-Kaolin D (*n*=1) is unusual in the assemblage because of carbonate inclusions. It has a bimodal distribution with predominant carbonate, common quartz, and rare calcite and textural features; the kaolin clay was tempered with crushed carbonate rock. CHI-Kaolin E (*n*=1) is fine with predominant quartz, frequent muscovite, few clay pellets and red iron nodules, and very few pyroxenes and schist clasts. Overall, CHI-Kaolin E has a higher proportion of quartz and muscovite. The parallel alignment of quartz inclusions not fully incorporated into the clay paste indicate a sand-based temper. Limited red clay streaks also suggest the use of mixed clay or an impure kaolin source. CHI-Kaolin F (*n*=4) is a poorly sorted with a bimodal distribution; rhyodacite clasts are predominant, followed by frequent quartz and plagioclase, common amphiboles and textural features, and few to rare shales and pyroxenes. The clay matrix is slightly heterogenous with some opaque clay domains and red streaks, possibly pointing to clay mixing. Finally, CHI-Kaolin G (*n*=1) is poorly sorted. The coarse fraction has dominant quartz, common muscovite and rhyodacite, few feldspars and textural features, and very rare amphiboles. CHI-Kaolin G is like CHI-Kaolin F, but it has a higher quantity of sand-sized inclusions and a more heterogenous matrix.

4.2.6 Jecosh There are four primary kaolin fabric groups from Jecosh: 1) Impure Kaolin; 2) Schistose Kaolin; 3) Quartz Sand Kaolin; 4) and Mixed Clay. Impure Kaolin has two subgroups, JE-Kaolin A (*n*=14) and JE-Kaolin B (*n*=10). Impure Kaolin is very fine with predominant quartz, frequent-common clay pellets/iron nodules, and common-rare rock clasts (e.g., dacite). JE-Kaolin A and JE-Kaolin B differ because B has more inclusions overall, a higher frequency of rock clasts, more poorly sorted grains, and a cloudier/more heterogenous clay matrix. Overall, Impure Kaolin clay matrices are heterogenous, with optical activity/inactivity in the same thin section (i.e., partial vitrification), opaque/cloudy zones, and occasional streaks. We suggest these fabrics consist of "impure" kaolin because of their moderately-poorly sorted grain size distribution, remnant parent material (Rice 2015, 52), and partial clay vitrification.

Jecosh's Schistose Kaolin (*n*=3) is characterized by a predominance of muscovite, with common metamorphic rock fragments, including quartz-mica-schist and slate. The Schistose Kaolin has 40% inclusions, consisting of medium to coarse sand-sized grains. The clay matrix shows low optical activity with cloudy/opaque areas. Clay pellets and iron nodules are common, with few red streaks, suggesting clay mixing or an impure kaolin source. JE-Quartz Sand Kaolin (*n*=3) consists of very fine, angular and sub-angular quartz sand, with frequent round and sub-round muscovite, and very few coarse, round shales. The quartz grains show zones of parallel alignment; this line of evidence, combined with the angularity of the quartz compared to the muscovite and shale, indicates that quartz sand was temper. Red streaks in the clay matrix and clay pellets suggest soil mixing; it may be that potters collected sandy sediments from a riverbed, taking with it some clay components, leading to limited clay streaks in the paste.

Jecosh's Mixed Clay petrogroup consists of five subgroups which exhibit silver and red streaks. The Mixed Clay subgroups represent differences in paste preparation, including the proportions of distinct clays and whether an additional temper was added. All subgroups have remnant dacite parent material. JE-Mixed Clay A's (*n*=3) clay matrix has zones of optically inactive, deep red clay with angular felsic minerals. Striations of golden-colored, highly optically active clay with rounded dacite grains are mixed throughout. If the zones of golden clay represent an impure kaolin, with remnant dacite parent material, it is likely that the clay had insufficient plasticity, leading the potter to temper the material with this dark red, sandy sediment with angular felsic minerals. JE-Mixed Clay B's (*n*=2) matrix is optically active throughout, with few silver kaolinite streaks—perhaps representing the complete mixing of the two discrete clays. JE-Mixed Clay A is coarser-grained than JE-Mixed Clay B. At least one of the clays used in JE-Mixed Clay B may have had a granodioritic source, evidenced by a predominance of biotite mica and very rare granodiorite grains. We suggest that the kaolin in both JE-Mixed Clay A and JE-Mixed Clay B was a residual clay deposit near a dacite outcrop, which was tempered with a sandy sediment (JE-Mixed Clay A) and a granodioritic clay (JE-Mixed Clay B). JE-Mixed Clay C (*n*=4) has striking white-silvery kaolinite streaks. It is more fine-grained, with fewer inclusions overall and consisting of very fine sand to fine silt sized particles. JE-Mixed Clay D (*n*=5) differs from the previous subgroups due to its inclusions and clay matrix. It has a higher proportion of clay pellets with a less streaky/birefringent matrix. Finally, JE-Mixed Clay E (*n*=6) is most like JE-Mixed Clay D but has two features which differentiate it. It is a fine-grained paste consisting of predominant quartz, alongside dominant to frequent very fine sand-sized muscovite and biotite. The granulometry and quartz grain orientation indicate that potters added a sandy silt as temper, in addition to clay mixing. Potters who made JE-Mixed Clay E ceramics clearly had a distinctive firing regime relative to other wares. These ceramics have reduced exteriors and darker colors overall in thin section.

## 5. DISCUSSION

### 5.1 Summarizing the analyses and thinking through provenance

Geochemistry and petrography have yielded information about Recuay kaolin pottery production and exchange. Geochemical data from LA-ICP-MS led to two key findings. First, we identified two statistically distinct ceramic groups, indicating a significant difference in their paste geochemistry. In general, the samples separate by site geography: southern sites (Group 1) and northern sites (Group 2). There are three exceptions to this. HUA058 has a high membership probability for Group 1, despite its northern provenience. Similarly, JE004 and CHI004 are statistically similar to Group 2. This indicates the trading of ceramics or raw materials between communities in the northern and southern Callejón de Huaylas. Additionally, we note that two of the Cajamarca-related wares, which have motifs like that of Cajamarca Cursive styles (CHI002, CHI011, and QUE019) are statistically similar to Group 2 ceramics. These samples may be part of Group 2 due to some inherent geological similarities between kaolin clays in the Cajamarca region north of Ancash and those in the northern Callejón de Huaylas. The remaining Cajamarca-related wares (CHI001 and CHI010) are a derivative style (Lau 2010a, 254) and are statistical outliers, suggesting the use of raw materials from outside of the Callejón de Huaylas, such as the coast or elsewhere in the highlands. Petrographic evidence supports this idea; CHI001 has a unique carbonate fabric, which aligns with the limestone/marl geology of the Cajamarca region (Reyes Rivera 1980). Similarly, CHI010's mafic paste may indicate a provenance in the mid-coastal valleys of the Coastal Batholith. Other outliers exhibit mixed clay qualities (e.g., CHI006, QUE029, JE016, KEU038), which would change paste geochemistry, making them dissimilar from samples with a kaolin-only clay base.

Second, LA-ICP-MS data indicate that there are no chemical similarities between the kaolin ceramics and raw clays from the sampled industrial deposits in highland Ancash. This strongly suggests that potters did not use kaolin from those specific locales. There is no geomorphological evidence indicating that these large deposits did not exist in antiquity (Czwarno 1983, 6). We thus propose that this study's ceramics do not overlap with the kaolin clays because they were produced with clays from impure kaolin deposits. Ceramic petrography, which identified partial vitrification of the clay body alongside remnant parent material, points to the use of clays from a primary, impure source. Is it thus reasonable that there are not statistically meaningful chemical similarities between the pure kaolin clays and the sampled pottery.

The petrographic data is more complex than that of LA-ICP-MS, and indicates several important trends. First, we did not document a uniform kaolinite paste for the region. Mineralogically, Recuay kaolin fine wares are diverse. Potters used various materials to temper kaolin clay, including slate/shale, quartz sand, micaceous/schistose sand, and even non-kaolin clay/sediments. Second, although the assemblage consists of distinctive pastes, some important inter-site connections can be drawn, which point to limited intraregional ceramic exchange.

For example, LLA010 and CHI004 are both slate/shale tempered kaolinites and pertain to chemical Group 2. Because Llanganuco has non-kaolin ceramics that were tempered with slate/shale (Grávalos 2021, 256-258), and the site is situated near the shale rich Chicama Formation, it seems possible that Chinchawas obtained CHI004 from potters working at or near Llanganuco. This is further supported by the fact that CHI004 is a pedestal base fragment, a common design feature of Llanganuco's pottery (see Figure 2).

Chinchawas seems to have also engaged in trade relations with Jecosh. CHI008 is most similar to Jecosh's JE-Kaolin B group, which is an impure kaolin with (rhyo)dacite parent material. Meanwhile, CHI007 is most similar to JE-Kaolin A, which is a very fine, impure kaolin with iron oxides and rare other inclusions. These fabrics pertain to chemical Group 1, suggesting a shared clay source. Notably, Jecosh potters utilized dacite resources to craft non-kaolin pottery (Grávalos 2021, 215-218), so it is possible that the potters at Jecosh who made kaolin fine wares procured kaolin from a source near these same dacite outcrops. Additionally, CHI008 and CHI007 are both open bowls with painted line motifs, which bear resemblance to Jecosh's decorated bowls (see Grávalos 2021, fig. 149). Taken together, the petrographic and design features indicate that potters near Jecosh produced CHI007 and CHI008. Due to the shared mineralogical, chemical, and design qualities of Chinchawas's kaolin wares with other sites, it stands to reason that Chinchawas did not have locally based potters working with kaolin clay and instead obtained kaolin wares through trade, probably from the nearby Huaraz region (c.30-km away). Considering the settlement's evidence for other prestige goods and stylistic links to Huaraz (Lau 2005, 2010a), this seems likely.

Meanwhile, one of Jecosh's kaolin wares, JE004, which has a Quartz Sand Kaolin fabric, is qualitatively similar to LLA005, another Quartz Sand Kaolin fabric. Both samples pertain to chemical Group 2, suggesting a northern origin for these wares, indicating that Jecosh had limited access to kaolin wares produced offsite. Moreover, JE004 has a unique painted color combination not observed among Jecosh's other kaolin bowls, further supporting its offsite provenience. Among the northern Callejón de Huaylas sites, QUE029, KEU038, and LLA004 have a similar mixed clay paste. This signals that the inhabitants of Queyash Alto, Keushu, and Llanganuco had access to a shared source of kaolin pottery or that potters from these sites shared knowledge about proportions of clay mixing and how to successfully produce mixed clay wares. Taken together, LA-ICP-MS and petrography demonstrate that Recuay communities engaged in a complex cultural and economic network that involved the exchange of pots, knowledge, and raw materials.

## 5.2 Movement of ceramics, raw materials, or potters?

With the exception of Chinchawas, we suggest that all sites in the study had a group of locally based potters who made kaolin fine wares. The first author documented the use of locally available (<9-km site radius) raw materials to produce non-kaolin pottery at each site during Recuay times and beyond (Grávalos 2021). The heterogeneity of ceramic pastes presented here indicates that multiple (groups of) potters made Recuay kaolin ceramics across several centuries during the EIP. Simultaneously, LA-ICP-MS revealed two chemical groups. Within each chemical group, the petrographic data demonstrate different kinds of inclusions, many of which are intentionally added tempers (Figure 4). This suggests that potters used chemically similar kaolin clays to create different pastes. We thus hypothesize that there were two kaolin sources from which potters obtained clay, which may have been distributed by northern and southern Recuay political groups. Because potters used kaolin clay to model ceremonial scenes, feasts, and political leaders—and kaolin vessels featured in public ritual and offerings—it is reasonable to suggest that kaolin held political and religious significance for Recuay peoples. The valorization of key substances, resources, and geological formations is and was a salient feature of highland Ancash life. Today, potters often have preferred sources for potting materials, and may be guarded about knowledge of these special places (e.g., location/distance, proprietary costs), which are crucial for their livelihood and distinguish regional technical styles. We also know of an early colonial potting community near the present-day town of Recuay that venerated and held a local clay deposit as their most sacred place (Hernández Príncipe 1923). Like distinctive mountains and stone (Lau 2018), kaolin deposits may have signified powerful places, and were thus politically and economically valuable for Recuay communities.

The distribution of kaolin from two sources would explain why ceramics that are chemically similar have qualitatively different petrographic fabrics. The mixing of kaolin and non-kaolin clays was clearly a specific technique to temper clays with low plasticity. However, it may have also been a strategy to make small amounts of valuable kaolin clay extend over as many vessels as possible, resulting in light pinkish, beige, and light orange kaolin fine wares, which people used in domestic settings. Attempts to utilize precious bits of kaolin in as many vessels as possible would make sense in the context of highly valuable yet possibly controlled kaolin deposits. Additionally, dry clay clumps (i.e., argillaceous inclusions/clay stones) in samples such as HUA054, HUA057, KEU007, and QUE029 supports the idea that kaolin was distributed in its dried, raw form. The distribution of kaolin from deposits on ancestral lands may have been associated with events in which people gifted and exchanged pottery, such as labor feasts (Bria 2017; Gero 1992).

While we think it is most likely that raw kaolin clay, and occasionally finished vessels, were exchanged between communities, there are other explanations for the diversity of pastes within a single chemical group. Ramón (2008, 2011) has documented potter itinerancy in present-day and historic Ancash. Such potters migrate seasonally to produce wares for differing communities, often carrying their tools and sometimes raw materials with them. This practice would certainly have been possible in the ancient past (Druc 2013, 503). However, considering the archaeological data for Recuay feasting and exchange, Recuay pottery's stylistic diversity, as well as the evidence in this study, the most parsimonious interpretation presently is that raw kaolin clay was moving, not potters.

Questions remain about where ancient peoples extracted kaolin and to what extent the clay and finished objects can be linked to Recuay political and social organization. Recuay material culture generally shows great variability, and there is no evidence for state integration, a single dominant political center, or a ‘capital’. The larger Recuay settlements, such as Pashash and Yayno (Grieder 1978; Lau 2010b), may have been influential population centers of production or distribution (ca. 300-700 CE). Both contain monumental house compounds of wealthy Recuay groups with dense built-up cores (ca. 30 ha) on hilltops, surrounded by nearby hamlets and production areas (fields, canals, corrals, pastures).

The material culture styles at and around Pashash and Yayno (northern area) and Huaraz and Katak (southern area), are sufficiently different to suggest largely coeval but independent crafting groups, including of stone carving (Schaedel 1952); stonemasonry and layouts in monumental architecture (Grieder 1978); and pottery (Lau 2011; Grávalos 2021). Grieder (1978:76-101) argued for locally based artisans at Pashash due to potters’ marks, possibly wheel-thrown ring bases, and patterns in hand-modeling and painting. It is not yet clear, however, whether these settlements grew in power or prominence owing to their access to and control of resources, such as kaolin deposits. Notwithstanding, the quantity of kaolin ceramics at Pashash and Yayno alongside other kinds of elaborate material culture found in and around their immediate vicinities (e.g., monumental architecture, large house compounds, monolithic sculptures, and metalwork) suggest privileged access to kaolin. Interestingly, sites in the southern Callejón de Huaylas were largely disconnected from the northern network and had their own kaolin procurement patterns. Future comparative work on Pashash, Yayno, and additional southern Callejón de Huaylas sites will further clarify the political economies and social relationships between Recuay settlements.

Our updated picture of Recuay raw material exchange and multiple production locales differs from coeval EIP cultures and their pottery economics. For example, ceramic production on Peru's south coast appears to have been centralized near the Nasca ceremonial center of Cahuachi, where pilgrims gathered and were gifted fine wares (Vaughn et al. 2006, 687). Meanwhile, semi-attached craft specialists lived at the urban site of Moche, the Southern Moche state capital (Bernier 2010). The present study shows that Recuay kaolin pottery production was simultaneously connected through shared clay sources, but heterogenous in terms of tempering practices and overall paste recipes. The paste variability in kaolin-bearing ceramics is consistent with clear regional differences in painting style. These observations, and taking into account the great stylistic variability in other media (e.g., architecture, stone carving), lend support to an emerging picture of a relatively fractured political landscape for Recuay pottery production, despite the exchange of kaolin clays. Our evidence for the movement of kaolin clays and limited finished vessels thus reveals that Recuay communities with variable political integration came to value shared kaolin deposits, despite the absence of widespread exchange of non-kaolin material goods. This nuanced interpretation would have been impossible using a single analytical method; our study thus highlights the importance of multisite sampling and multidisciplinary analyses.

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## DATA AVAILABILITY STATEMENT

The data from this study are available in the Supporting Information associated with this article.

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Table 1. Ceramic and clay samples by site/deposit and type of analysis.

Table 2. Ceramic sample distribution by archaeological context and cultural period

Figure 1. Left: Map of Ancash, Peru showing archaeological sites and kaolin deposits; Right: geological map of highland Ancash.

Figure 2. Ceramic samples included in this study

Figure 3. A) Discriminant function plot summarizing the results of LA-ICP-MS of kaolin ceramics and clays. B) Ceramic samples in each chemical group.

Figure 4. Petrographic fabric groups. A: CHI-Kaolin A (CHI004); B: CHI-Kaolin B (CHI008); C: CHI-Kaolin C (CHI007); D: CHI-Kaolin D (CHI001); E: CHI-Kaolin E (CHI006); F: CHI-Kaolin F (CHI053); G: CHI-Kaolin G (CHI010); H: HUA-Kaolin A (HUA026); I: HUA-Kaolin B (HUA003); J: HUA-Kaolin C (HUA057); K: HUA-Kaolin D (HUA054); L: JE-Kaolin A (JE163); M: JE-Kaolin B (JE126); N: JE-QSK (JE164); O: JE-Schistose (JE170); P: JE-Mixed Clay A (JE021); Q: JE-Mixed Clay B (JE154); R: JE-Mixed Clay C (JE008); S: JE-Mixed Clay D (JE155); T: JE-Mixed Clay E (JE132); U: KEU-Mixed Clay (KEU038); V: KEU-QSK (KEU007); W: LLA-QSK (LLA006); X: LLA-Slate/Shale (LLA010); Y: LLA-Mixed Clay (LLA004); Z: QUE-Mixed Clay (QUE029).