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Encoded Landscapes: A Link between Inka Wall Orientations and Andean Geomorphology

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Abstract: While some Inka structures and motifs align with astronomical and horizon markers, a significant portion of their constructions exhibit different patterns. We examined the potential correlation between the orientation patterns of the Inka walls and Andean geomorphology, aiming to uncover the extent to which the physical landscape guided these ancient architectural design methodologies. Using geospatial technology and specially developed peak detection and recognition software, we extensively and meticulously analyzed over 40,000 m of surveyed Inka walls and 20,000 mountain peaks across 11 distinct geographical areas. The analysis revealed a significant correlation between key wall orientations and the parallel peak alignment of the Andean Mountain Range. This suggests a purposeful encoding of landscape orientations into Inka architecture. These findings propose a novel perspective on the intricate relationship between Inka culture and the Andean highlands' topography. Furthermore, this research introduces a distinctive methodological approach to exploring the impact of natural landscapes on architectural planning, establishing a foundation for comparative studies among other ancient civilizations.

Keywords: Inka architecture; geospatial analysis; Andean geomorphology; mountain-peak alignment



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1. Introduction

The Andean region, stretching from Colombia to Chile, is an emblematic testament to the indomitable spirit and adaptability of the Inka civilization. Among South America's most distinguished pre-Columbian cultures, the Inkas forged an empire that, in terms of architectural grandeur and geographical dominance, remains unparalleled. Their constructions, originating from the first half of the 13th century during the dawn of the Inka empire, were born out of a confluence of engineering knowledge, settlement planning, and a respect for nature [1,2].

The hallmark of Inka architecture is its amazing precision in stone wall masonry. This precision, coupled with their ability to sculpt structures that seamlessly merged with the mountainous topography, symbolized their advanced knowledge. Their constructions were not just functional or ornamental but were also calibrated, often aligned with astronomical and geographical elements, and showcased their holistic understanding of the cosmos [3,4].

The Inka architectural repertoire was diverse. Temples, shrines, *tambos*, *kanchas*, *kallankas*, and an extensive road network—the *qhapaq ñan*—depict a highly organized society [5]. Each of these structures, despite serving similar utilitarian purposes, exhibited a distinctive Inka blueprint. In contrast to the repetitive motifs prevalent in European architectural paradigms, Inka constructions exhibit a variety of layout configurations while maintaining distinct characteristic elements [6].

Past research narratives have primarily painted the Inka empire's expansion as a military endeavor, emphasizing conquests and territorial annexations [7]. However, a deeper view of archaeological findings and ethnohistorical accounts reveals a broader context, one where spirituality, geography, and architecture converge cohesively [8,9].

The Andes highland territory, a geological marvel spanning seven countries from Venezuela to Chile, offered more than just a backdrop to the Inka civilization. This mountain range, with its sedimentary, igneous, and metamorphic rocks, is a window into Earth's diverse geological history [10]. The Andes' fractal nature, a result of repetitive structures within the Earth's crust, offers a fascinating perspective on the potential inspirations behind Inka architectural designs [11,12]. This fractal characteristic, observable in the spatial organization of mountain peak location as well as in coastlines and valleys, underscores the recurrent patterns inherent in natural formations. Intriguingly, fractal designs and repetitive patterns were also widely utilized and depicted across various ancient civilizations.

The historical evidence suggests a deliberate intent by ancient cultures around the world to mirror the recurring natural fractal motifs in their architectural endeavors, embedding them into their architecture and meticulous urban layouts [13,14]. Moreover, numerous studies have explored the intricate relationship between geomorphology, astronomical orientation, and settlement planning, recognizing the relevance of natural landforms in the development and structure of urban spaces by ancient and modern cultures [4,15–17].

The Inkas perceived mountains not just as geological formations, but as living entities. They believed in animism, in which natural objects possessed souls [18]. This reverence was likely complemented by their advanced understanding of the physical properties of these mountains, given their extensive mining expeditions [19,20]. Their sanctification of the peaks of the Andean Mountains, especially the highest ones, was multifaceted. The snow-capped summits, melting into rivers and glaciers, were life-sustaining. Spiritually, these mountain peaks were home to the Apus, revered mountain deities believed to control elemental forces [21,22].

This study explores the relationship between highland morphology and Inka wall patterns, aiming to ascertain the extent to which the geomorphological orientations of the Andes shaped Inka architecture. With an emphasis on the azimuthal directions, this exploratory study sought to unearth the possible relationships between the orientations of the straight walls and terraces constructed by the Inka and the patterns of mountain peak alignments [23]. Our results suggest a complex relationship between the Inka civilization and its geographical setting, contributing to a more detailed comprehension of their architectural methodologies, cultural beliefs, and legacy.

2. Materials and Methods

2.1. Inka Site Selection

Inka sites spanning the diverse regions of the Inka empire, known as *Tawantinsuyu*, were carefully chosen under a well-defined set of selection criteria. The following list of selection criteria was used to choose the sites:

- **Geographic Distribution across *Tawantinsuyu*:** We sought to include sites from across the vast expanse of the Inka empire, spread over various South American countries.
- **Reported Site Function:** Sites were chosen to represent all types of Inka constructions—religious, residential, administrative, and agricultural. This diversity allows for a multifaceted view of Inka society and its various functional spaces.
- **Evidence from Prior Archaeological Studies:** We selected sites with confirmed Inka origins, based on previous archaeological research. This criterion lends historical accuracy and validation to the selected Inka architecture.
- **State of Preservation:** The preservation state of each site was considered, preferring sites with well-preserved features as they provide more reliable data and insights into original Inka architecture.
- **Availability of Photogrammetric Survey Data or High-Quality Orthorectified Satellite Imagery:** The presence of detailed survey data or clear satellite images is crucial

for accurate remote assessments of the sites and a detailed analysis of their walls. Good orthorectification ensures correctly aligned images representing the true surface geometry, which is necessary for correct measurements and analyses.

- Absence of Obstructive Vegetation: Sites with less vegetation cover offer unobstructed views, which are crucial for the architectural study.

In Cusco, Peru, known for its intricate and well-preserved Inka architecture, we limited our selection to four key sites to ensure that our study focused on the most representative and information-rich locations.

Additionally, we sought sites showcasing Inka architecture within diverse geological and altitudinal contexts, thus providing a deeper understanding of how they adapted their building techniques to different environments. After this selection process, we finalized a list of 20 Inka sites (Figure 1 and Table S1).

Hence, we aimed for an arbitrary, yet structured, selection representing a broader sample of all possible Inka archaeological sites to create a small representative database for the orientations and lengths of the walls and straight terraces.

2.2. Inka Architecture Analysis

The length of walls and azimuths (angular deviation, 1–180°) were studied and calculated using the Geographic Information System platform (ArcGIS Pro 3.0.3). The architecture of each site, specifically the walls and straight terraces, was analyzed using satellite imagery (Google Satellite, [GS]) and georeferenced orthomosaics obtained by performing photogrammetry with Agisoft Metashape Professional 1.6.1 (Agisoft LLC). Aerial photographs for generating orthomosaics were captured using DJI Mavic 2 Pro drones with a Hasselblad Sensor 1" CMOS 20 MP camera during survey campaigns conducted by the Código Andino Foundation (CA). Drone flights were planned and executed using Map Pilot from www.mapsmadeeasy.com/map_pilot (accessed on 2 February 2023), ensuring an 80% overlap of images both along and across flight tracks. Only nadir images were acquired with constant low speed flights of 2 m/s and constant altitude of 60 m or more from the ground. Photogrammetric reports with all parameters used for each site surveyed by CA are freely available at www.codigoandino.org (accessed on 21 March 2023) and upon request. Other orthomosaics were downloaded through Open Heritage 3D (openheritage3d.org, accessed on 3 April 2023) or provided by the National Museum of Natural History of Chile (MNHN, with permission from Francisco Garrido). The references were appropriate in each case.

2.3. Mountain-Peak Detection and Filtering

Our in-house software, Peak Mapper 3.0, extracts mountain-peak data objectively from Digital Elevation Models (DEMs). It computes the isolated heights of peaks based on their prominence and dominance, ranging from those with low-elevation peaks in areas of gentle relief to the most prominent ones in rugged terrain. Peak Mapper conducts an automated geomorphometric analysis of the landscape to systematically extract terrain features, culminating in the precise identification of peak locations within a specified territory (Figure S1). The objectivity of this method substantiates any visual interpretations of further peak alignments, offering a reliable means of validation.

The DEMs used for the systematic search of peaks were the Global Multiresolution Terrain Elevation Data 2010 (GMTED2010), a global elevation model with a spatial resolution of 7.5 arc second (around 250 m) freely available from the earthexplorer.usgs.gov website (accessed on 7 November 2020). From these DEMs, 11 geographical zones of approximately 185,000 km² each were selected and analyzed in the Cassini map projection for our cartometric needs. Using relatively high-resolution DEMs for the large area of the entire Inka territory, an optimized algorithm was developed based on a combination of Python and PostGIS procedures as part of Peak Mapper. A complete dataset of all identified peaks across various filtering levels is available at the Código Andino Foundation GitHub repository [24].



Figure 1. Map of selected sites. Map of the Andes Mountain Range in South America, indicating the extent of *Tawantinsuyu* in yellow. Red circles indicate the location of the selected Inka sites. 1. Ingapirca; 2. Aypate; 3. Pariachuco; 4. Incahuasi; 5. Tambo Colorado; 6. Choquequirao; 7. Machu Picchu; 8. Ollantaytambo; 9. Tipón; 10. Raqchi; 11. Incallajta; 12. Samaipata; 13. Caspana; 14. Licancabur; 15. Shincal; 16. Punta Brava; 17. P. Incaico de la Puerta; 18. Viña del Cerro; 19. Huaca de Chena; 20. Cerro Grande de la Compañía. Blue circle indicates the location of the selected unexplored site for verification: V1. Volcán Maipo.

2.4. Mountain-Peak Alignments

We developed a mountain-peak-alignment score as a metric to quantify the degree of spatial alignment among multiple mountain peaks within a specified geographic area. It is calculated by an algorithm that evaluates both the azimuthal orientation within a specified search bin and the location and elevation of each peak. For this study, the algorithm spatially analyzed azimuths ranging from 1° to 180° , in steps of one degree, which segmented the analysis area into multiple parallel bins, with this study utilizing 5 km wide bins.

An alignment score is conferred to each bin, contingent on the peak count within it and the assigned elevation weights of those peaks. A bin receives an alignment score only if it contains two or more peaks; bins with fewer than two peaks are assigned a score of zero. Subsequently, the scores of all parallel bins are summed to calculate the final peak-alignment score for the entire area at each specified azimuth. This comprehensive process yields a table of peak-alignment scores ranging from 1° to 180° .

The elevation of each peak is factored into the score; peaks with higher elevations are given a greater weight, thereby exerting more influence on the score. The weight assigned to peaks increases with elevation as follows: peaks below 3500 m above sea level (masl) have a weight of zero; 3500–4000 masl, a weight of 1; 4000–4500 masl, 2; 4500–5000 masl, 3; 5000–5500 masl, 4; 5500–6000 masl, 5; 6000–6500 masl, 6; and peaks above 6500 masl have the greatest weight of 7. The peak-alignment score of a bin increases with the presence of more peaks, especially those at higher elevations. The processing for all geographical zones was performed with a Mercator map projection. The mountain-peak alignment module and code is available at the Código Andino Foundation GitHub repository [24].

2.5. Statistical Analysis

For the statistical analysis, the data procured through GIS and the alignment scores of peaks were analyzed using SigmaPlot 10.0 (Grafitti, Palo Alto, CA, USA). We employed histogram and column plots to depict the frequency or lengths of walls across various azimuth degrees. Regarding the peaks, we created plots that graphically represent peak-alignment scores as a function of an azimuth. Additionally, we performed correlation analyses to examine the relationship between the peak-alignment scores and azimuth orientations of walls and terraces.

3. Results

3.1. Inka Site Selection and Wall-Orientation Analysis

To explore the potential relationship between Inka architecture and Andean geomorphology, we first selected various Inka sites spread across the expanse of the *Tawantinsuyu* (Figure 1) based on a defined set of criteria (detailed in Section 2).

A brief overview of the twenty selected Inka sites, including hallmark characteristics and distinctive features inherent to the Inka architecture, is provided in Appendix A. According to archaeological and anthropological studies [25–42], all twenty sites present evidence of Inka origin or occupation.

Geospatial tools and software were employed to analyze and map the straight walls and terraces within the architectural layout of the sites. This step determines the approximate length of each wall and terrace, as well as its angular orientation (Eazimuth). Table S1 provides a list of the sites with their names, coordinates, elevation, site type, and the image source used for the layout analysis. Site V1 was selected for validation as an uncategorized, possible Inka site.

The floor plans of each Inka site were generated based on the surveyed layouts of their walls (Figure 2). Additionally, an azimuth frequency histogram (Figure 3) and wall-length bar graphs (Figure 4) were generated for each site. A color palette was designated for intervals of 10° , ranging from 1° to 90° . This color palette was then replicated for the range of 91° to 180° to enhance the visualization of azimuth pairs with a 90° difference. For each site, the two to three most predominant and preferred azimuths were highlighted (Figure 3 and Table 1). In many instances, pairs of azimuths, approximately 90° apart,

dominated the tendencies at each site, as expected from the rectangular layout of most Inka buildings. Regarding wall length, over half of the sites display a distinct azimuth based on the orientation of their longest wall (Figure 4). Numerous sites feature walls that extend beyond 100 m in length, and the longest wall is usually not part of a building enclosure.

Table 1. Analysis of Inka wall lengths and preferential site azimuths. V1, uncategorized site for validation.

Site #	Name	Number of Walls	Min. Length (m)	Max. Length (m)	Sum of Lengths (m)	Pref. Azimuth (°)	Longest Wall Azimuth (°)
1	Ingapirca	110	2.8	90.4	1486	12; 102; 112	144
2	Aypate	95	1.5	115	1285	59; 144	144
3	Pariachuco	32	3.3	58	468	69; 158	157
4	Incahuasi	523	1.4	116	8386	69; 157; 166	156
5	Tambo Colorado	140	2.8	139	2230	75; 166	135
6	Choquequirao	147	2.4	109.6	2281	20; 108	29
7	Machu Pichu	592	1.7	71	3871	65; 157	19
8	Ollantaytambo	132	3.1	335	4691	19; 135	135
9	Tipón	210	1.9	89.6	3644	41; 135; 166	134
10	Raqchi	346	1.2	162	4528	20; 111	173
11	Incallajta	136	1.5	150	2470	112; 128	125
12	Samaipata	193	1	73	1494	3; 93	93
13	Caspana	15	2.7	58	202	14; 105	14
14	Licancabur	46	2	39	374	132; 149	54
15	Shinkal	35	4.8	202	1368	3; 93	3
16	Punta Brava	49	1.4	16	219	14; 144	144
17	P. Incaico de la P.	39	2.6	34	408	3; 103	104
18	Viña del Cerro	54	1.4	58	562	60; 145	157
19	Huaca de Chena	26	1.7	60	251	8; 85	173
20	La Compañía	38	1.3	69	450	20; 112	21
V1	Volcán Maipo	48	2.7	58	471	122; 166	134

We aggregated data from all twenty sites, documenting both the wall lengths and their corresponding azimuths. This comprehensive database was then prepared for an in-depth analysis, ensuring a structured approach to understanding the patterns and insights from these measurements.

3.2. Inka Wall Database Analysis

A summary is presented in Table 1 with the parameters of the analyzed walls and terraces in each site, along with the preferred azimuths (two–three most frequent) of the site and the azimuth of the wall or terrace with the greatest length in the entire site. Certain preferred azimuths were repeated across different sites. A total of 40,671 m of walls and terraces was analyzed. Subsequently, a generalized analysis incorporated all the azimuth data obtained from the walls into a count histogram (Figure 5A), revealing a non-uniform distribution with clear count spikes regardless of site localization. To clearly visualize the data of the main and most prominent architectural features, we reselected walls and terraces greater than 5 m (Figure 5B) and greater than 40 m (Figure 5C) in length. Finally, the wall lengths were summed for each azimuth degree, and a bar graph was plotted to display the sum of the wall lengths versus azimuth (Figure 5D).

Across all the evaluated sites, the most frequent wall azimuth ($\pm 1^\circ$) was 20° , with subsequent spikes observed at 111° , 166° , 68° , 157° , and 135° (Figure 5A). When examining the most extended wall at each site, the most commonly identified azimuth ($\pm 1^\circ$) was 135° , which was repeated in four sites. In addition, 144° and 157° were present at three sites (Table 1). The longest terrace was found in Ollantaytambo with a length of 335 m and azimuth at 135° , followed by walls in Shincal and Raqchi, with lengths of 202 and 162 m and azimuths at 94° and 174° , respectively. Regardless of the site's location, walls exceeding a length of 100 m exhibit azimuths at 3° , 20° , 29° , 78° , 125° , 135° , 144° , 156° , and 174° (Figure 5B,C).

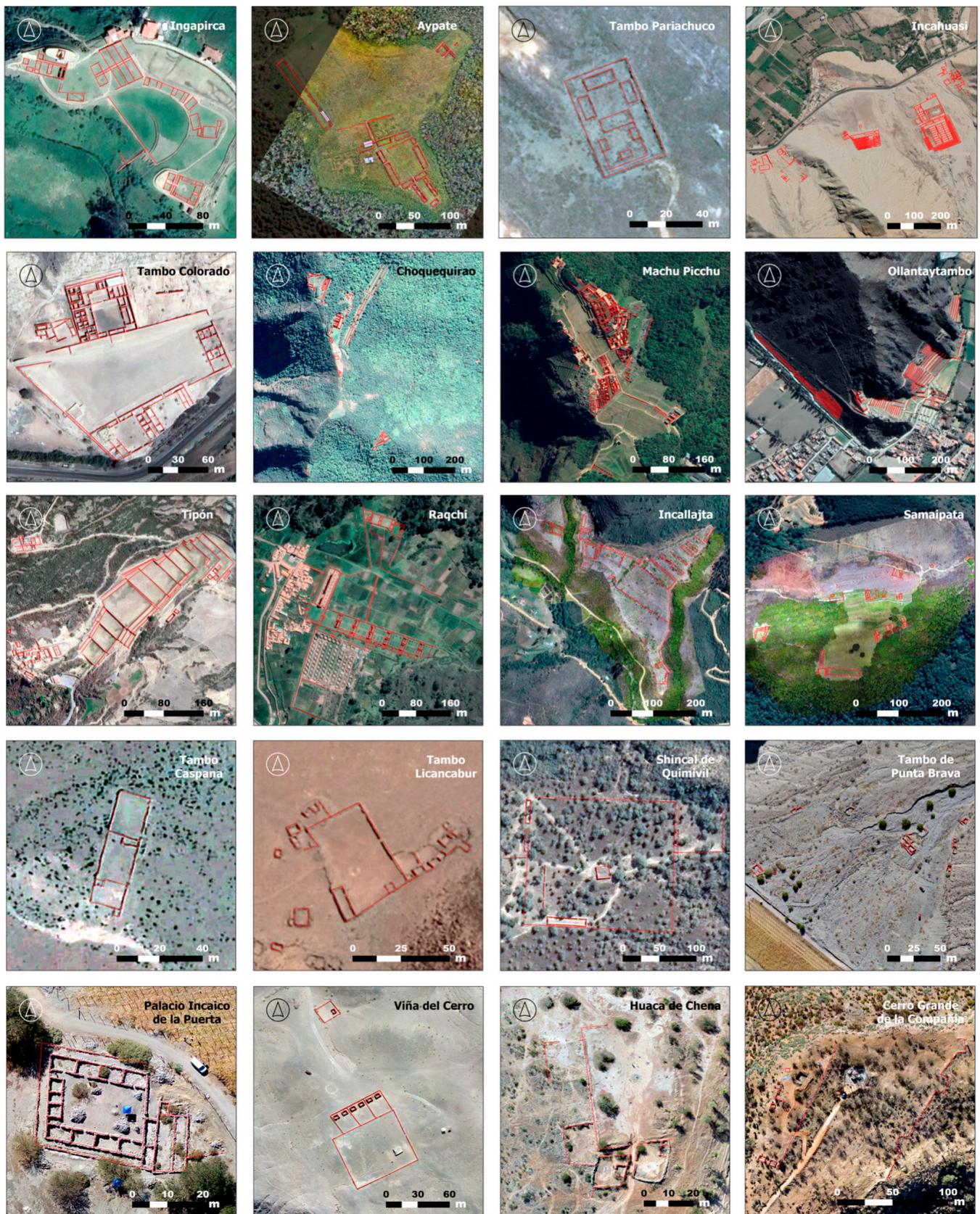


Figure 2. Planimetric survey of Inka sites. Maps of selected Inka sites with straight walls and terraces marked in red. High-definition maps are provided in the Supplementary Materials.

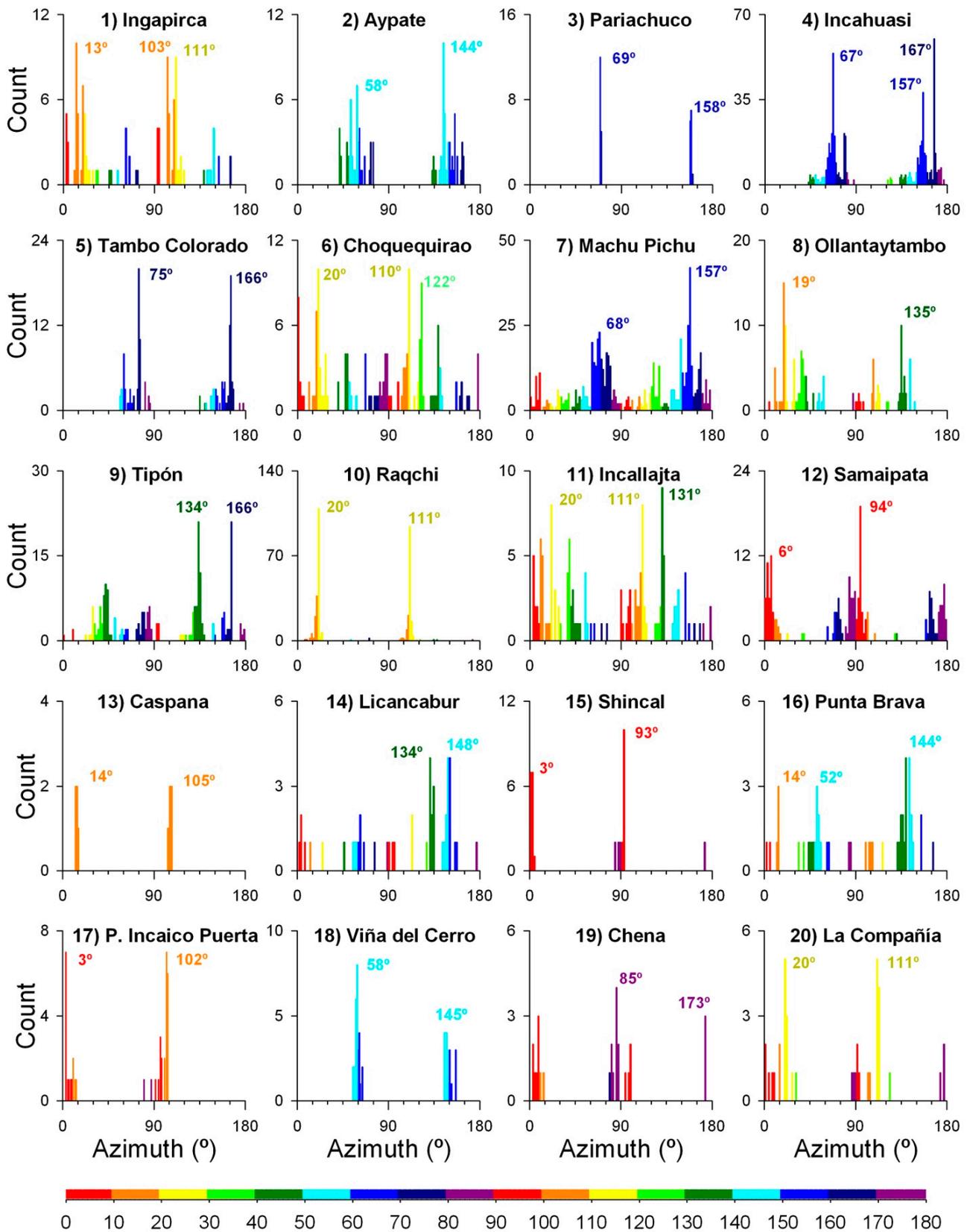


Figure 3. Frequency analysis of Inka wall orientation. Histograms from wall azimuths calculated for each Inka site. Numbers in degrees denote preferential azimuths. A color palette was designated for intervals of 10°, ranging from 0° to 90°, and replicated for 90° to 180°.

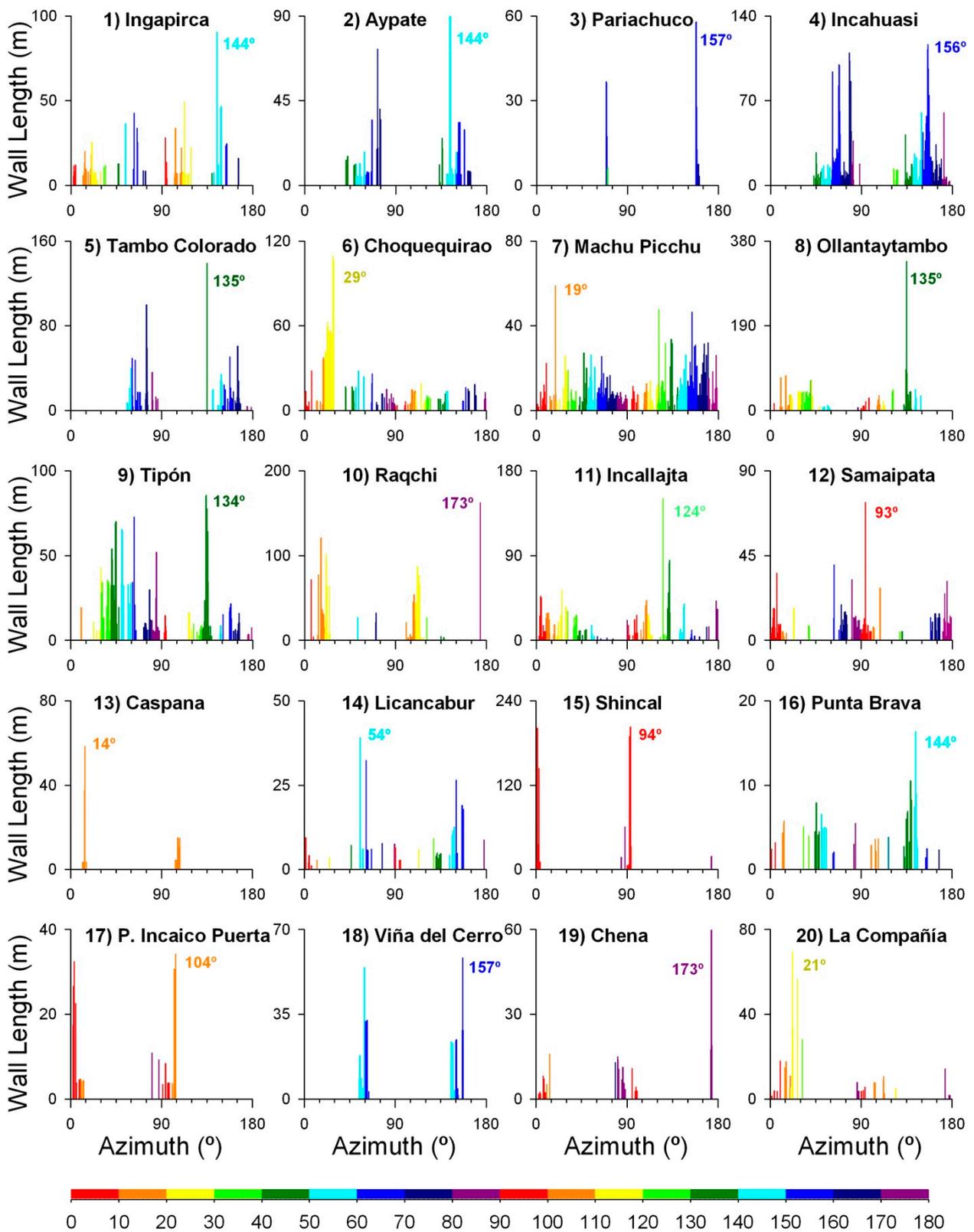


Figure 4. Distribution of Inka wall lengths. Bar graphs show the distribution of wall lengths by azimuths obtained for each Inka site. The azimuth of the longest wall is indicated with numbers in degrees. A color palette was designated for intervals of 10°, ranging from 0° to 90°, and replicated for 90° to 180°.

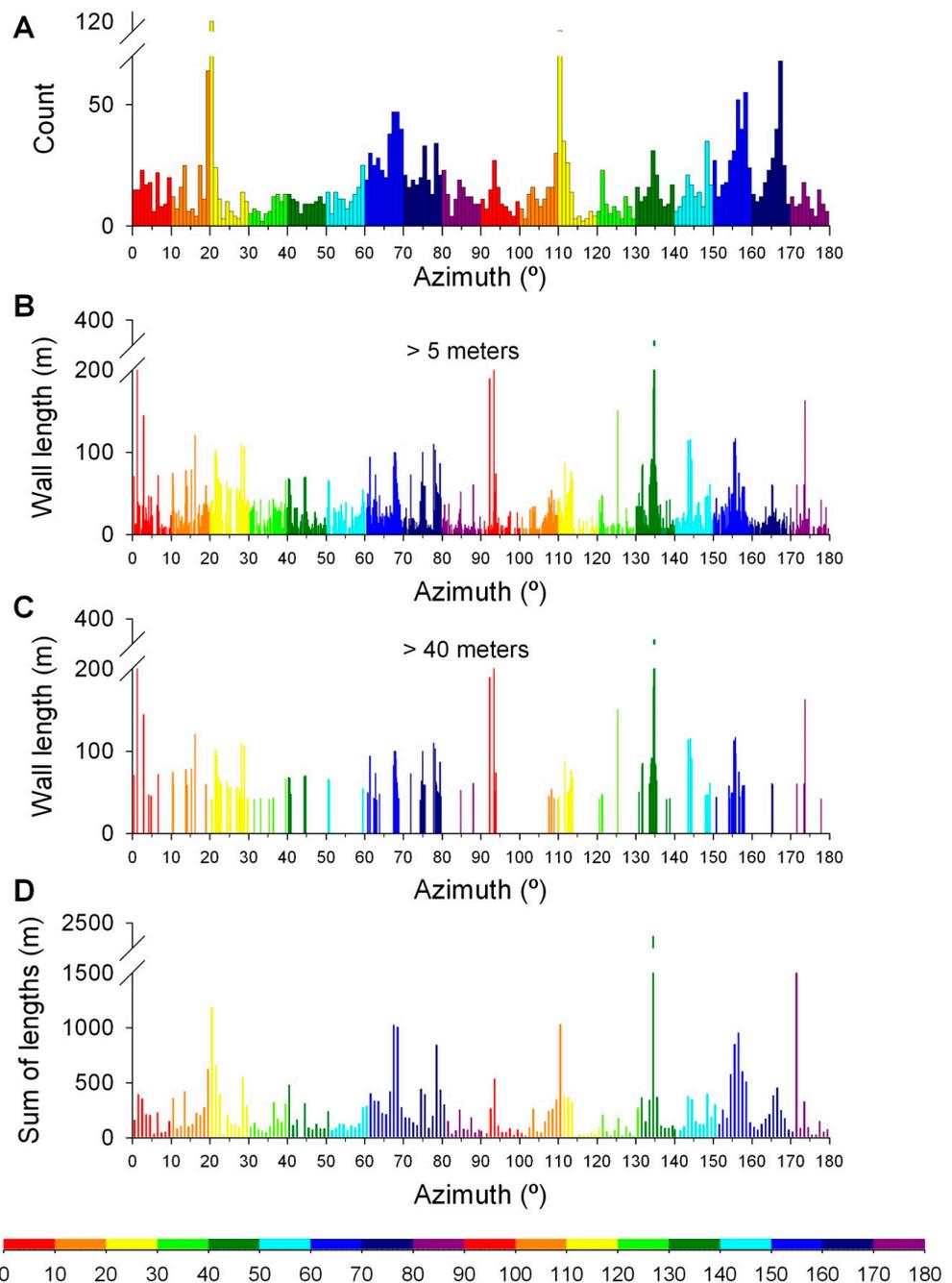


Figure 5. Integrated analysis of all Inka walls for all twenty sites. **(A)** Histograms of wall count vs. azimuths. **(B,C)** Bar graphs show the distribution of wall lengths above 5 m **(B)** and 40 m **(C)**. **(D)** Bar graphs of the sum of all wall lengths grouped by azimuth from all twenty sites. A color palette was designated for intervals of 10°, ranging from 0° to 90°, and replicated for 90° to 180°.

Analyzing the cumulative lengths of all walls, the greatest summed length was oriented at the 135°, followed, in descending order, by azimuths at 20°, 111°, 68°, 156°, 78°, and 166° (Figure 5D). Undoubtedly, many of these preferred azimuths are differentiated by roughly 90°, reflecting the most frequent angle found between the rectangular enclosures of Inka buildings, e.g., 20–111°, 29–125°, 68–157°, and 78–166°.

3.3. Geomorphological Analysis of Andes Mountain Range

The orientation patterns of Inka walls in relation to the surrounding Andes topography could offer compelling insights. To unveil these intricate relationships, we employed

modern computational methods, specifically leveraging an algorithmic approach to dissect the geomorphological complexities of the Andes.

Utilizing our proprietary algorithm and software, Peak Mapper (Figure S1), we comprehensively mapped and selected mountain peaks across the Andes Mountain Range from Colombia to central Chile (Figures 6 and S2). The detection of prominent (topographical, visual, and even social attributes of mountain peaks according to their neighborhood) and dominant (their independence according to their neighborhood) mountain peaks and analysis of their azimuthal alignment were executed through a specially designed algorithm rooted in the DEM.

The detection algorithm identifies peaks based on both geomorphological and topographic parameters [43]. These peaks are characterized by slopes identified through grid analyses, such as differences from mean values in a circular kernel of various sizes, applying a certain threshold to select peaks in non-flat areas. We ensured a minimum distance between identified peaks, which in our analysis, ranged from 10 to 35 km. Furthermore, the relative elevation of a peak was defined as the vertical distance between the peak itself and its nearest saddle point, with a benchmark of 250 m in our study.

Adopting a multi-scale approach, we analyzed the data using three distinct spatial resolutions of the DEM: 500, 1000, and 2000 m. At a 500 m resolution, the initial calculation of local peaks yielded 1,393,498 peaks, serving as the positional reference for the peaks across all resolutions. The calculation of peak selection was segmented into three sub-algorithms (steps 1, 2, and 3; Figure S1): the first emphasizes geomorphologic parameters, the second introduces the criteria of inter-peak distance, and the third adds topographic vertical distance criteria. For each resolution, the peaks were calculated considering only the third criterion, the first and third criteria, or all three criteria, resulting in nine different sets of peaks.

After this, the nine sets of peaks underwent rasterization at a 250 m resolution. They were given equal weights, creating a grid with values ranging from 1 to 9 based on the peak frequency. The peaks were also weighted according to their absolute elevation and categorized into four segments ranging from 0 to 6880 m. This signifies that the peaks with higher elevation carried a larger weight compared to their lower counterparts, resulting in final filtering values spanning between 1 and 13. For this study, we used peak datasets filtered at peak levels 5 and 8 (F5 and F8), plus the raw dataset without filtering (F1). The total number of peaks was 44,669 for level 1 (F1) and 18 for level 13 (F13), which delineates their prominence and dominance, such that the peaks of level 1 are only prominent, and the peaks of level 13 are also remarkably dominant over the others (Figure S2).

To study the Andes' geomorphology and determine the parallel orientations of mountain peak alignments in different geographical regions, 11 areas of analysis, of approximately 185,000 km² each, were selected, covering more than 85% of the Inka Empire territory, which is approx. 2,500,000 km² (Figure 6).

A total of 20,794 (F1), 6494 (F5), and 1524 (F8) mountain peaks were included in these areas of analysis (Figure 6 and Table 2). Then, for each of these areas, mountain peaks were analyzed with our own peak-alignment algorithm to determine an alignment score for each azimuth degree and estimate the pattern orientation of the geomorphology (Figure 7). We implemented an alignment algorithm beginning with the calculation of a "circular bounding box", a technique adapted from Ritter [44], to encompass all relevant data points within a defined two-dimensional space. This bounding circle set the stage for further segmentation along the *x*-axis, in which, we divided the space into "bins" or sectors, aiding in the systematic categorization of the spatial data.

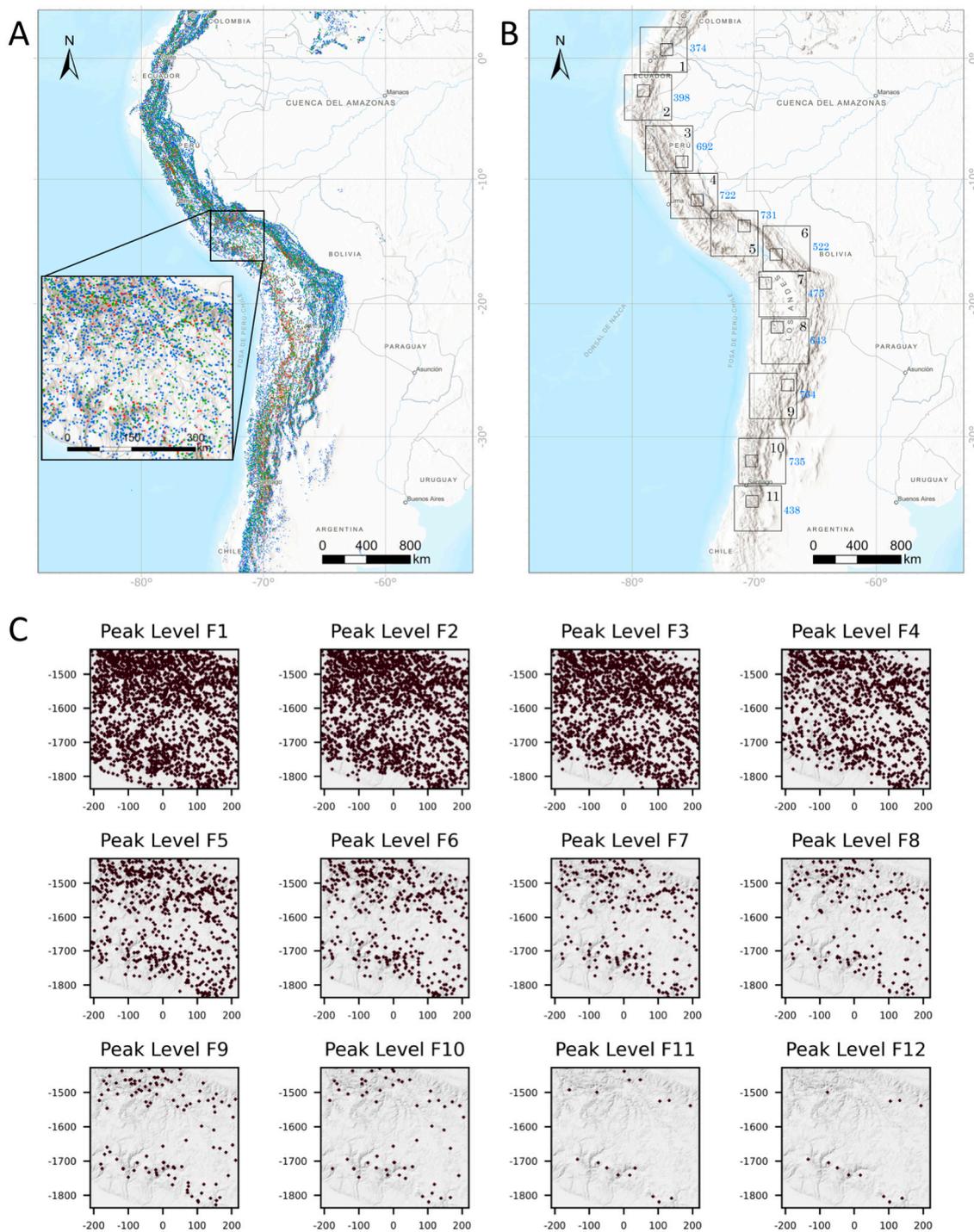


Figure 6. Map of detected mountain peaks and geographical zones of study. (A) Detected peaks are shown in blue, green, and red dots representing filtering values of levels F1, F5, and F8, respectively. The inset displays an area approximate to area #5 Cusco shown in B. (B) Areas of analysis are indicated by squares and numbered from 1 to 11. The total number of peaks per zone filtered at F5 is indicated in blue. Each area includes a smaller sub-area of study. (C) Detected mountain peaks on same area shown on inset in A at different peak filtering levels from F1–F12. Graticule numbers are in km. Peak Level 13 is not shown because, in this selected area, only one peak is left. Peak levels (1–3) are categorized as local, merely prominent; (4–10) as regional, dominant and prominent; and (11–13) global, remarkably dominant over the others. The positional resolution of these peaks is set at 250 m, consistent with that of the GMTED DEM, in the Cassini map projection.

Table 2. Geographical areas and sub-areas of analysis and number of peaks detected. Coordinates are in Mercator projection in meters.

Area #	Name	Upper Right x	Upper Right y	Lower Left y	Lower Left x	Min-Max Elev.	# Peaks (F1)	# Peaks (F5)	# Peaks (F8)	Highest Align. Azimuth
1	Quito	-8403033	286740	-8833084	-129744	743–5862	1552	374	81	33°
s1	Quito	-8534724	134229	-8646157	26254	869–4176	179	47	9	46°
2	Cuenca	-8545303	-153031	-8975354	-569524	720–6239	1716	398	77	13°
s2	Cuenca	-8745950	-245057	-8857382	-353032	981–4471	184	54	10	96°
3	Cajamarca	-8352630	-622010	-8782681	-1038541	754–6525	2562	692	133	157°
s3	Cajamarca	-8395975	-897819	-8507408	-1005794	816–2499	147	22	1	158°
4	Huancayo	-8124806	-1057264	-8554857	-1473856	757–5803	2470	722	124	142°
s4	Huancayo	-8256265	-1250819	-8367698	-1358794	943–5448	299	105	21	134°
5	Cusco	-7757108	-1403640	-8187159	-1820305	792–6407	2297	731	173	105°
s5	Cusco	-7827370	-1489011	-7938803	-1596986	998–6275	195	89	17	121°
6	Titicaca	-7282930	-1542982	-7712981	-1959688	794–6325	1895	522	93	134°
s6	Titicaca	-7537615	-1750833	-7649047	-1858808	1237–6275	235	97	24	136°
7	Uyuni	-7319541	-1962979	-7749592	-2379788	1035–6524	1397	475	127	166°
s7	Uyuni	-7634115	-2014900	-7745548	-2122875	3274–6524	125	61	19	29°
8	Atacama	-6983905	-2384989	-7413956	-2801892	1121–6184	1504	643	218	165°
s8	Atacama	-7525474	-2421368	-7636906	-2529343	3201–6082	142	100	36	136°
9	Copiapo	-7403977	-2898592	-7834028	-3315652	894–6870	1924	764	222	31°
s9	Copiapo	-7430858	-2952249	-7542290	-3060224	3244–5964	113	48	14	14°
10	Los Andes	-7504407	-3496853	-7934458	-3914109	676–6880	1978	735	168	174°
s10	Los Andes	-7759889	-3649963	-7871321	-3757938	1771–6635	260	114	35	165°
11	Rancagua	-7542634	-3933173	-7972685	-4350576	613–6049	1499	438	108	19°
s11	Rancagua	-7754822	-4022352	-7866255	-4130327	1001–5228	258	94	28	14°

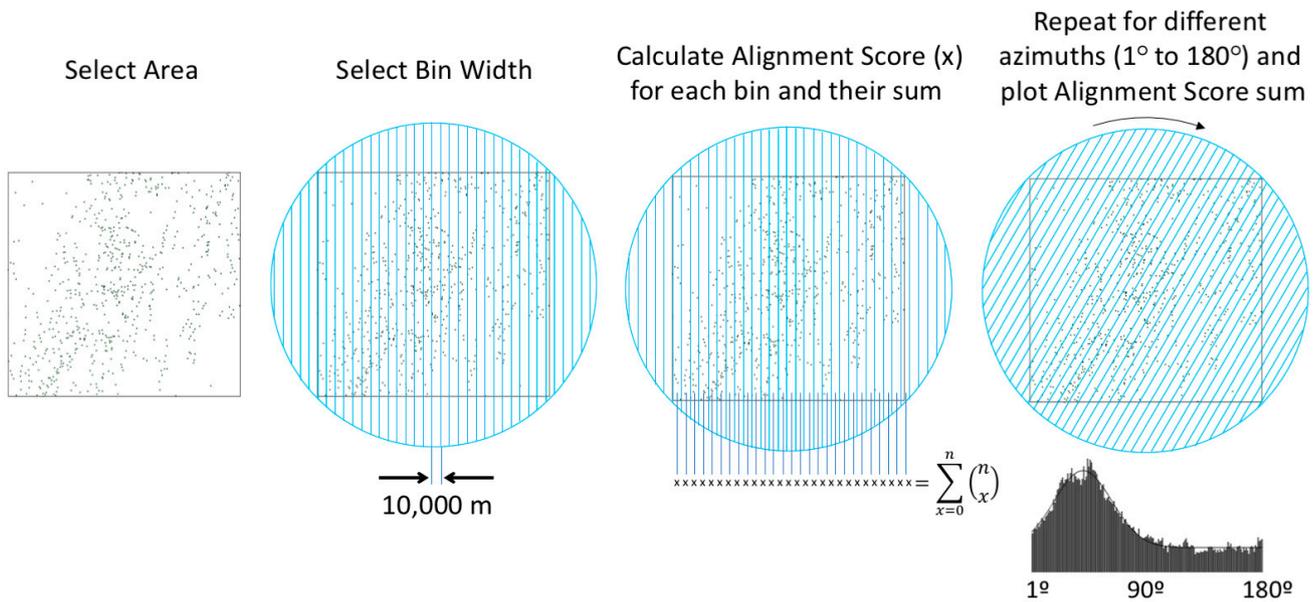


Figure 7. Illustration of peak-alignment score calculation. From left to right: selection of area of analysis with detected peaks (green dots); selection of bin width, usually between 1 and 10 km; calculation of alignment score for each bin by adding the number of peaks within the bin, while each peak value is weighted by elevation with a factor of 0, 1, 2, 3, 4, 5, 6, and 7 for peaks with elevation of <3500, 3500–4000, 4000–4500, 4500–5000, 5000–5500, 5500–6000, 6000–6500, and >6500 masl, respectively; repeat for each degree from 1° to 180° and plot the alignment score for each degree and find the maximum score for the area.

Upon establishing a bin width, we utilized a specific template to identify and quantify intersections between our sample peak data and the individual bins. A weight value

for peak elevation was also included in the quantification. This intersection analysis was pivotal, allowing for a detailed enumeration of the samples within each sector, and preparing the data for the next phase of analysis. A score for peak alignment at each specific azimuth degree was produced and noted (Figure 7).

We then engaged in a rotational analysis, methodically turning the circular bounding box from its central axis and hence, reorienting the bins for the next peak-alignment score quantification. By maintaining consistent rotation increments of one degree, we could scrutinize the data from various iterative alignment scores from 1° to 180° (Figure 7). This methodical combination of spatial segmentation and rotational analysis allowed for an in-depth, yet efficient, exploration of parallel orientations of peak alignments over the area of analysis.

To find a good set of parameters and sharp tendencies for the peak-alignment scores, we first tested different values for peak filtering (F1, F5, and F8) and bin width (1, 5, and 10 km) in area #1 (Quito) (Figure S3). A bin width of 5 km and F5 reasonably distributed the peak-alignment score. Therefore, we used this set of parameters to completely analyze all selected areas (Figure 8). Each graph was fitted to a Gaussian or Lorentzian curve to find the maximum peak-alignment value of the area (Figure 8 and Table 2).

We further refined the scope of the investigation by designating smaller sub-areas, each encompassing roughly 12,000 km², within the broader regions under analysis. This step was undertaken to meticulously evaluate the peak-alignment values in different sub-areas (Figures S4–S6). We strategically selected these sub-areas based on their distinctive geomorphological characteristics, which are representative of their larger regions. The primary aim was to elucidate the variability in peak-alignment scores across different landscapes and to test the robustness of our analytical methods on multiple scales.

Intriguingly, our findings revealed considerable heterogeneity in the alignment patterns among these sub-regions. For instance, both area and sub-area #6 (Titicaca) exhibited a pronounced propensity for a singular preferential peak-alignment azimuth at $135^\circ (\pm 1^\circ)$, which corresponds with the most commonly identified azimuth in the longest walls and terraces in Inka architecture (Table 1). Conversely, sub-area #3 (Cajamarca) presented several azimuths, in which, the peak-alignment scores revealed consistent spikes, recurring at intervals of approximately $10\text{--}13^\circ$ (Figure S7).

3.4. Correlation Analysis between Inka Wall Orientations and Mountain-Peak Alignments

Considering the count frequency, preferential orientations, and longest wall azimuth, the most representative azimuths found in Inka architecture ($\pm 1^\circ$) were $4^\circ, 14^\circ, 20^\circ, 29^\circ, 41^\circ, 68^\circ, 78^\circ, 93^\circ, 111^\circ, 122^\circ, 135^\circ, 144^\circ, 156^\circ, 166^\circ,$ and 174° (Figure 5). On the other hand, the prominent geomorphological axes in the Andes obtained from the regional peak-alignment score on different geographical areas ($\pm 1^\circ$) were $14^\circ, 20^\circ, 31^\circ, 105^\circ, 134^\circ, 142^\circ, 157^\circ, 166^\circ,$ and 174° (Figure 8). In addition to these peak-alignment orientations from large areas, the sub-areas displayed additional azimuths at $4^\circ, 46^\circ, 95^\circ, 112^\circ,$ and 121° (Figure S6).

Representing these geomorphological orientations on a radial graph showcased an interesting pattern; they appeared to be separated by intervals of approximately 10° to 13° (Figure 9A). Remarkably, when the corresponding geomorphological axes were rotated by 90° , most offset orientations coincided with the azimuth found on Inka walls. This observation suggests that the most preferred Inka wall azimuth covers 180° in approximately 10° to 13° intervals, reflecting the geomorphological orientations of the Andes peak alignments.

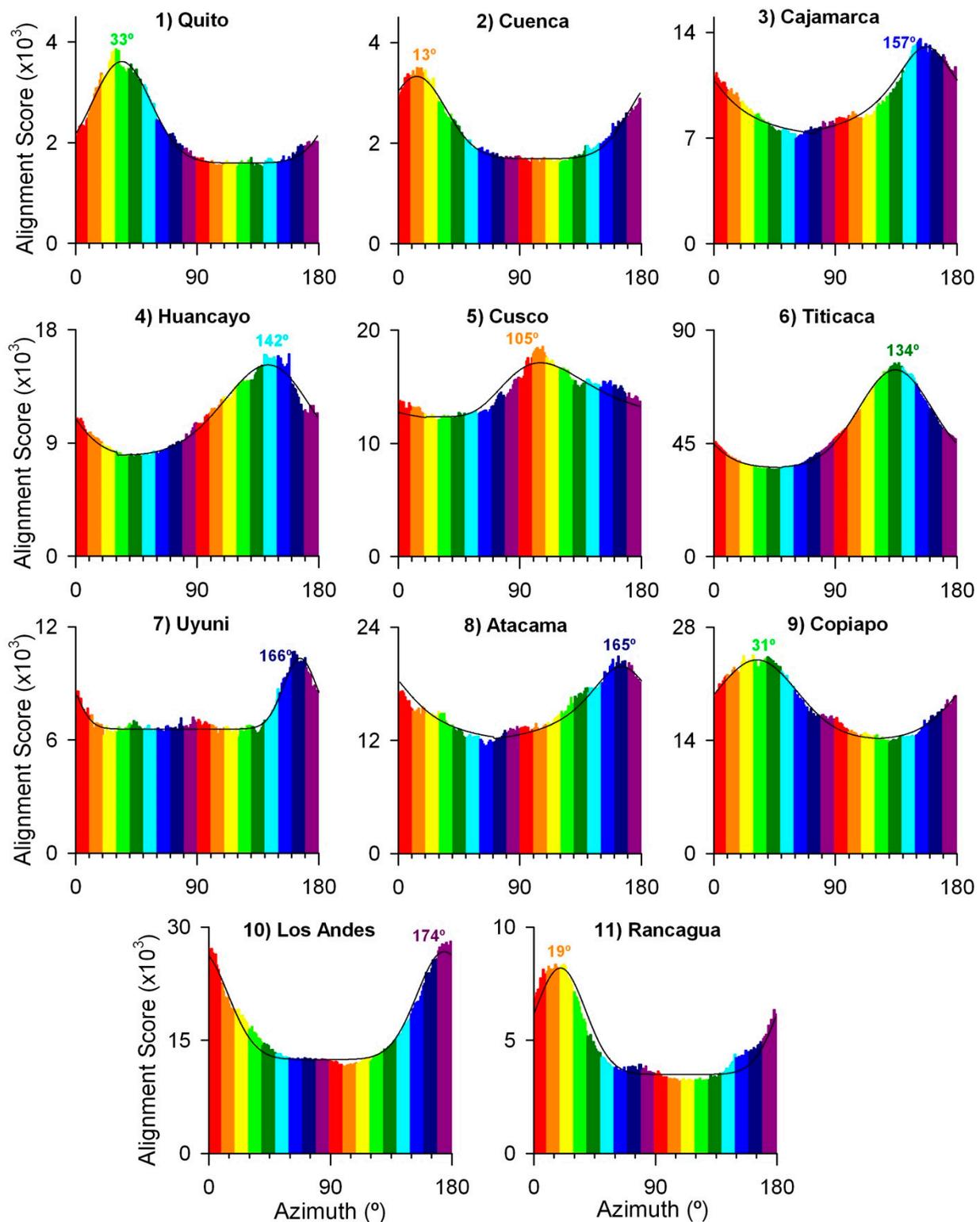


Figure 8. Regional mountain-peak-alignment score distribution. The black line displays a Gaussian or Lorentzian regression of four variables with the highest alignment score marked with its corresponding regional peak alignment azimuth in colored numbers. All areas were analyzed at a bin width of 5000 m and peak level of F5. A color palette was designated for intervals of 10°, ranging from 0° to 90°, and replicated for 90° to 180°.

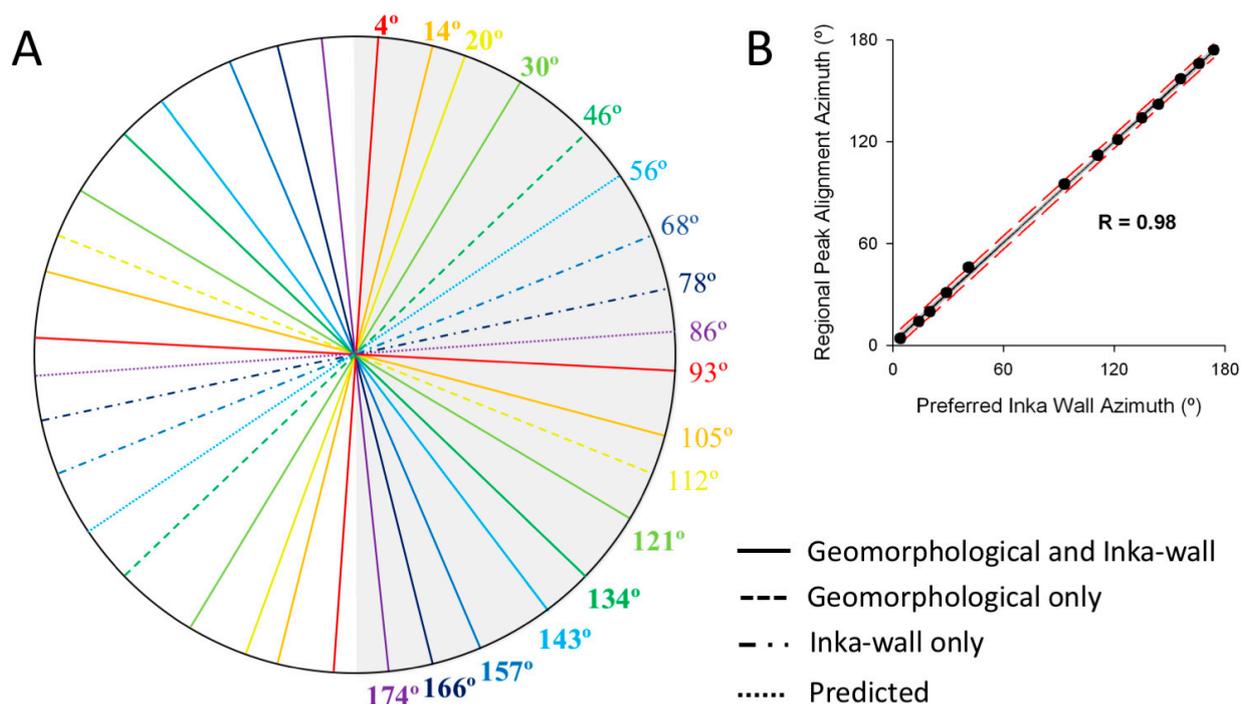


Figure 9. Radial distribution of preferred Inka wall and regional peak-alignment azimuths. (A) Representation of all prominent geomorphological peak alignments and preferred Inka wall azimuths ($\pm 1^\circ$) on a polar graph. Colors were designated for each azimuth within a 10° range from 0° to 90° , and replicated for 90° to 180° . Colored numbers show the specific azimuth for each preferred Inka wall and/or regional peak-alignment orientation. Grey half of the chart highlights the 0° to 180° range. (B) Correlation analysis between regional peak alignments and preferred Inka wall azimuth. Correlation coefficient (R); 95% confidence band (red).

The results obtained from both analyses were statistically compared using a correlation analysis (Figure 9B), revealing a correspondence between the azimuth of Inka walls and peak-alignment scores in the Andes Mountain Range. The achieved correlation coefficient was 0.98.

In summary, thirteen orientations were found for preferred peak alignments in the Andes Mountain Range. These orientations were also found in Inka wall azimuths ($\pm 1^\circ$). Thus, these results strongly support the notion that the Inkas integrated the orientations of Andean geomorphology into their architectural designs.

3.5. Employing Azimuth Analysis to Determine Potential Inka Heritage

Our research findings provide the foundation for a non-invasive method to infer the potential Inka origin of unexplored archaeological structures based on the predominant azimuth of straight walls. To test this predictive method, we analyzed the wall layout of a recently uncovered archaeological site (V1) situated on the foothills of the Maipo Volcano, near the border between Chile and Argentina (Figures 1 and 10). This significant site, nestled at an elevation of roughly 3500 masl within the Laguna Diamante National Reserve, lies within the Caldera Diamante—a prominent geomorphological feature of the Andes Mountain Range. First discovered in 2021 by Andrés Pérez, this site has been the subject of archaeological investigations since 2022.

Our wall azimuth analysis revealed that the dominant direction at this site is 165° , followed by azimuths of 122° and 76° . The longest feature is oriented at 134° , with subsequent orientations noted at 165° and 122° (Figure 10 and Table 1). Given that the wall orientations at this site coincide with several primary azimuths identified in our Inka wall analysis, there is compelling evidence to suggest that these structures are of Inka origin.

Moreover, its strategic placement suggests it served as a significant Inka shrine venerating the Maipo Volcano.

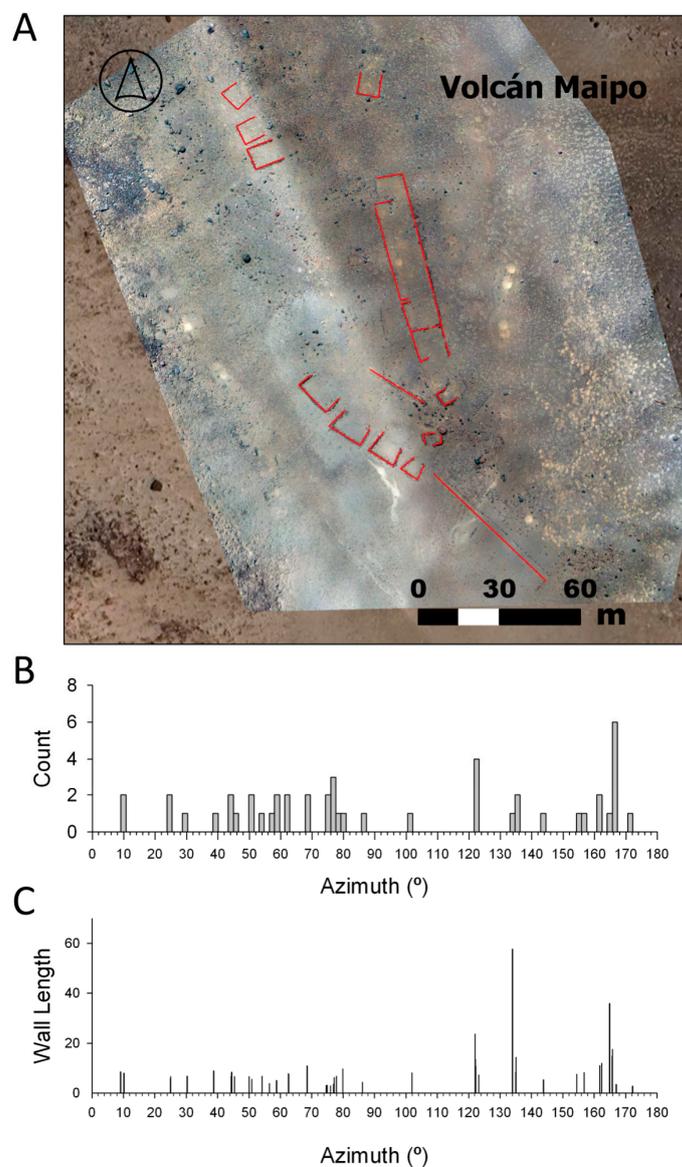


Figure 10. Wall azimuth analysis of possible Inka shrine at Maipo Volcano. (A) a map of the Volcán Maipo archaeological site and its analyzed walls in red. (B) count histogram for wall azimuth from A. (C) distribution of wall lengths with respect to their azimuth from A.

4. Discussion

Our investigation into the potential interplay between Inka architecture and the geomorphological patterns found in the Andean highlands has uncovered a promising avenue for expanding our comprehension of ancient building philosophies. Although the results of our exploratory data analysis are preliminary and await confirmation through cross-validation with an independent dataset, they indicate a discernible systematic relationship between the geomorphological context and the building patterns of the Inka. By delineating this relationship, we introduced a conceptual model that establishes a foundation for further inquiry, inviting rigorous examination and empirical validation in future studies.

Rock structures, from the tiniest grains to vast landscapes, showcase complex geometric patterns and, in some scenarios, specific crystal arrangements. These patterns can span from the microscale observable under a microscope, to a macroscale of entire

mountain ranges. Repetitive features like rock layers, fractures, and mineral lineations visually represent some of these fractal patterns [45]. The information hidden within these geometric shapes provides valuable insight into the Earth's past and the processes that have shaped it. In fact, the anisotropic patterns we observe on a large scale, such as the parallel orientation of peak alignment, might also be mirrored on a much smaller scale [45]. This suggests that the examination of rock structures during mining could unveil repetitive lineation patterns consistent with those found in broader geomorphology.

The Inkas' rich history of mining suggest an intimate knowledge of the land's geological features, such as fault lines, mineral lineations, and mountain range orientations [19,20]. Building on the premise that the Inkas identified repetitive patterns in the natural fractures and mineral lineations of rocky landscapes, we hypothesize that they could correlate this knowledge with the shape and positioning of the surrounding geography. These insights would have not only streamlined their rock extraction processes but also informed their building practices. Within this context, rocks became more than simple construction materials for the Inkas. They represented a sacred connection, a bridge between their cosmology and the tangible, intrinsic world order around them.

The unique nature of our study is highlighted not only by its perspective on Inka architecture but also by its novel methodological approach. We have investigated the parallel orientation of peak alignments in the Andes, presenting a new avenue for analyzing the inherent fractality of continental rock in mountainous regions. While this methodology was developed within the context of this Inka research, it holds significant potential for exploring other mountain-dwelling cultures around the world. Additionally, our findings suggest that the positioning of the Andes mountain peaks does not occur randomly across the geographical area. Instead, they follow fractal patterns of repetitive parallel orientations that deviate by roughly 10 to 13 degrees. This insight provides a clue about the potential internal lattice of crystal arrangements within the continental crust from which the Andes highlands emerged.

Moreover, by analyzing wall azimuths on architectural layouts, we can employ this non-invasive approach to determine the possible origins of yet-unidentified archaeological structures. We have applied this azimuth analysis at an important uncovered archaeological site near Maipo Volcano to identify its possible Inka origin (Figure 10). It also offers an avenue to unearth potential Inka influences or origins in previously overlooked or misattributed building and urban layouts. Besides wall azimuths, this predictive method can be improved by considering the relative location of sites according to nearby mountain peaks and local geomorphological orientations. This predictive capability could be invaluable for future archaeological expeditions, guiding researchers to areas of high potential significance and saving invaluable time and resources in the process.

In discussing the locational attributes and construction orientations of Inka archaeological sites, considering the topographical characteristics influencing ancient building practices is paramount. Our research indicated that 60% of the evaluated Inka sites are situated in relatively flat terrains. This prevalence suggests that the azimuth orientations identified within these sites are less likely to be a mere consequence of constructing the walls perpendicular to the prevailing mountain slopes. Instead, these findings support the hypothesis of deliberate planning in the azimuthal orientation of the walls.

However, addressing the remaining sites found in more mountainous areas is also necessary. For these locations, the local topography, particularly slope inclinations, could have influenced construction methodologies. It remains plausible that Inka builders capitalized on the natural terrain for establishing their structures, laying walls and terraces that correspond to desired azimuthal orientations. Therefore, while our data suggest a significant pattern of purposeful design in wall orientations across numerous Inka sites, we must consider the role of geographical features in shaping these ancient practices.

This study introduces a different and innovative approach, but acknowledging its limitations is essential. To thoroughly validate the results and resulting hypothesis, detailed fieldwork is necessary. We must determine that the observed peak alignment orientations

in certain regions are consistently reflected across different scales and can be identified within local rock formations. This activity requires collaborative international field research supported by in-depth geological assessments.

Regarding data collection methods, we must consider the constraints of satellite imagery and photogrammetric surveys. Factors such as the off-nadir angle and orthorectification—which adjusts the geometric properties of an image—can occasionally introduce significant errors into azimuth analyses. For instance, we meticulously chose satellite images in which straight walls were represented accurately, avoiding those appearing distorted or curved. Even minor inaccuracies can impact the reliability of the wall azimuths, which in turn can affect our broader analysis. Expanding our wall database and incorporating more sites could mitigate such errors.

The potential for these discrepancies stresses the need for diverse data collection methods. To bolster the robustness and accuracy of our predictions, on-site measurements using cutting-edge geo-positioning tools and advanced technologies are desired. Such measurements would not only validate results from remote sensing methods but also effectively bridge the gap between the different types and spatial scales of earth observations, such as satellite imagery, Lidar measurements, and tangible on-site observations.

In advancing this study, broadening the analysis beyond merely straight walls and terraces is imperative, as is incorporating a more extensive examination of various structural elements and their purposes. This might include assessing the azimuth of the main rectangular enclosure diagonals, and separately analyzing structures based on their presumed functions, such as ceremonial, residential, or administrative.

A particularly intriguing path for exploration is the orientation of Inka *ushnus*, ceremonial platforms typically characterized by rectangular or square shapes, which hold considerable cultural and religious significance. These structures are often believed to point towards the directions of the equinoxes or solstices; however, a more detailed analysis may reveal orientations corresponding to nearby summit hills [46], which could be reflected in local geomorphological peak-alignment orientations. By incorporating a more sophisticated classification of different Inka structures and examining their orientations, we can enhance the applicability of the method and also potentially discern the selection criteria for encoding different landscape orientations.

5. Conclusions

Our analysis of Inka wall orientations has yielded significant findings: the most prevalent azimuth is $20^\circ (\pm 1^\circ)$, corresponding with an extensive axis orientation of the Andes Mountain Range that stretches from central Bolivia to southern Chile and Argentina. Additionally, we identified $135^\circ (\pm 1^\circ)$ as the most frequent azimuth for the longest walls and terraces, corresponding to the predominant peak alignments found in the Titicaca basin—a region widely recognized as the birthplace of the Inka civilization. A strong correlation, with a coefficient of 0.98, between frequent wall orientations and peak alignments emphasizes the significant influence of the landscape on Inka architectural design.

This study further advances the understanding of Inka architectural practices, which traditionally focused on archaeoastronomical and horizon markers found in a subset of motifs. We propose that the Inka established a guiding principle of orientation derived from the natural geographical patterns present in the Andes highlands as a fundamental framework for organizing their architectural layouts in diverse settings across the *Tawantinsuyu* landscape. This guiding principle, reflected in the orientation of straight walls and terraces, likely extended to the layout of the Inka's urban planning and the orientation of central squares. We have noticed that this guiding principle and its main orientations appear to be encoded in the architectural layout of the walls at *Muyucmarca* in *Saqsaywaman*, an important sacred site of the Inka in Cusco.

In conclusion, our research has uncovered a statistically significant correlation between the orientations of Inka walls and the parallel orientations of peak alignments. This discovery points to a comprehensive framework for Inka architectural planning that extends

beyond the confines of archaeoastronomical considerations. The link between Inka wall orientations and Andean geomorphology suggests more than a mere coincidence; it hints at purposeful encoding of ancient knowledge that identifies a natural order within a seemingly chaotic landscape. By demonstrating this connection, our study lays the groundwork for expanded exploration into the worldviews and building principles of the Inka and other ancient civilizations.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/land13040463/s1>. Figure S1. Peak Mapper Algorithm Flowchart; Figure S2. Maps Illustrating the Distribution of Identified Mountain Peaks Across Various Levels of Filtering; Figure S3. Peak-Alignment Analysis in Area #1 Quito Using Different Bin Width and Peak Filtering Levels; Figure S4. Peak Detection on Sub-areas From #1 to #6; Figure S5. Peak Detection on Sub-areas From #7 to #11; Figure S6. Peak-Alignment Score Analysis in Sub-areas; Figure S7. Peak-Alignment Score Analysis in Sub-Areas #3 Cajamarca; Figure S8. Planimetric Survey of Ingapirca; Figure S9. Planimetric Survey of Aypate; Figure S10. Planimetric Survey of Tambo Pariachuco; Figure S11. Planimetric Survey of Incahuasi; Figure S12. Planimetric Survey of Tambo Colorado; Figure S13. Planimetric Survey of Choquequirao; Figure S14. Planimetric Survey of Machu Picchu; Figure S15. Planimetric Survey of Ollantaytambo; Figure S16. Planimetric Survey of Tipón; Figure S17. Planimetric Survey of Raqchi; Figure S18. Planimetric Survey of Incallajta; Figure S19. Planimetric Survey of Samaipata; Figure S20. Planimetric Survey of Tambo Caspana; Figure S21. Planimetric Survey of Tambo Licancabur; Figure S22. Planimetric Survey of Shincal de Quimivil; Figure S23. Planimetric Survey of Pucara de Punta de Brava; Figure S24. Planimetric Survey of Palacio Incaico de la Puerta; Figure S25. Planimetric Survey of Viña del Cerro; Figure S26. Planimetric Survey of Huaca de Chena; Figure S27. Planimetric Survey of Cerro Grande de la Compañía; Table S1. Selected Inka Sites for This Study.

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Appendix A

Site Descriptions (Site #)

Ingapirca (1) is a significant archaeological site in Ecuador that showcases the Inka legacy in the northern region of the old empire. Built in the 15th century, it served as a ceremonial and administrative center for the Inkas [28]. The Temple of the Sun, an impressive stone structure dedicated to the sun god, stands out. Additionally, it features a system of water channels that reveals the Inkas' management of water resources. The influence of the earlier Cashaloma-Cañari culture is also reflected at the site; however, for our analysis, only the later architectural stages attributed to the Inka culture were taken into consideration.

Aypate (2) is a significant archaeological site in Peru that showcases the Inka legacy in the northern region of the country. This place served as an important administrative, religious, and agricultural center during the height of the Inka Empire [41]. Its elaborate

stone constructions, including agricultural terraces and ceremonial structures, reflect the advanced architectural and hydraulic knowledge of the Inkas in this region.

Pariachuco (3) is an archaeological site located in the province of Huaylas, which has an Inka origin and represents the legacy of the Inka culture in the high terrains of the Ancash region. It was a strategic tambo used as a resting and provisioning point along the Inka routes near the Pariachuco Mountain [31]. This site exhibits a typical rectangular Inka architectural pattern in the form of a Kancha, and its location at the foot of a known Apu (sacred mountain) could reflect a ceremonial use.

Incahuasi (4) (Lunahuaná) is located in the Cañete region of Peru and showcases Inka architectural legacy, characterized by its monumentality and planning. It served as a residential and ceremonial complex for Inka rulers, and its engineering reflects the technical prowess of Inka builders [38]. Its strategic location indicates its role as an administrative and local control center.

Tambo Colorado (5) is a prominent archaeological site in Peru that stands out as one of the finest examples of Inka architecture on the southern coast of the ancient empire. It was built as a tambo, serving as a rest and provisioning point along the Inka routes, in addition to having an administrative and control function [25]. Its well-preserved adobe structures, vibrant colors, and distinctive architectural details reflect the mastery of the Inkas.

Choquequirao (6), known as the “Sacred Sister” of Machu Picchu, was built in the 15th century as a *llaqta* or urban and ceremonial complex of the Inka culture [34]. Discovered in the 19th century, with its remote location and meticulously constructed architecture, Choquequirao has been the subject of various research and conservation projects.

Machu Picchu (7) is an iconic Inka archaeological site built in the mountains of Peru, representing the grandeur and mystery of Inka culture. Constructed in the 15th century and rediscovered in the 20th century, this astonishing site reveals the architectural and engineering sophistication of the Inkas [40].

Ollantaytambo (8) in the Sacred Valley of Urubamba is considered a living Inka city [42]. The Inka architecture in Ollantaytambo is especially notable for its impressive agricultural terraces. These terraces, known as “*andenes*,” are stepped structures built on the mountainsides surrounding the site. They were precisely designed to maximize land utilization and enable agricultural production in a mountainous environment.

Tipón (9), located near Cusco, showcases the engineering prowess of the Inka culture. This walled settlement spanning 200 hectares served as an estate for Inka nobility and stands out for its impressive irrigation system and hydraulic technology [35]. The architectural design in harmony with the natural environment makes Tipón an example of Inka architecture and hydraulic engineering.

Raqchi (10) (Racchi) is an Inka archaeological site located in the Cusco region of Peru, near the town of San Pedro. It is renowned for the Temple of Wiracocha, a massive rectangular structure made of adobe and stone, standing at the center of the site. This temple is dedicated to Wiracocha, the creator god in the Inka cosmivision, and is characterized by its high walls and distinctive architectural style [30]. The site also includes various other structures like living quarters, storerooms, and agricultural terraces, providing a glimpse into the daily life and administrative functions during the Inka period. Raqchi’s architectural design demonstrates the Inka’s advanced engineering and agricultural techniques, and it is believed to have been a significant ceremonial and administrative center positioned right in the pass of the main Inka road system.

Incallajta (11) is a prominent archaeological site in Bolivia known for its impressive Inka architecture. Located in the Cochabamba department, this urban and ceremonial complex represents the splendor of Inka culture in the region. The layout and distribution of buildings and spaces in Incallajta also reveal the urban and ceremonial planning of the Inkas [32]. Central plazas, residential areas, religious enclosures, and spaces dedicated to administration and governance can be observed at Incallajta, along with one of the largest kallankas in the ancient empire.

Samaipata (12) in Bolivia is an archaeological site that was occupied by the Inka culture. Located in the Santa Cruz region, it stands out for its impressive carved rock and its use as a ceremonial and administrative center by the Inkas. The architecture combines Inka elements with local and other cultural influences, creating a unique fusion [37]. The structures include terraces, plazas, and a rock-carved platform known as the “Throne.” The Inka occupation leaves a significant imprint on the site with buildings and enclosures of classic Inka architecture.

Tambo Caspana (13) is a little-known and studied Inka site near Caspana [27]. It stands out for its architectural ensembles featuring rectangular layouts and closed enclosures, which are suggestive of domestic spaces. This site could have a domestic and ceremonial function as it is located near Tatio Volcano and the great Geysers of Tatio.

Tambo or Licancabur Inka Sanctuary (14) was originally described by Father Le-Paige [26] and is a poorly studied site located at the foot of the Licancabur Volcano. However, this site is related to the ascents made by the Inkas to the volcano and is part of a group of structures that have been studied in the Licancabur area [47].

El Shincal de Quimivil (15), located in Argentina, within the southern region of the Inka Empire, was an important political, administrative, and religious center. This site stood out for its regional capital character, with distinctive elements that identified it as such. Its large plaza, flanked by imposing kallankas, and an iconic central ushnu are testimonies to its administrative and ceremonial function [36]. In addition to its significant architecture, the surrounding landscape also played an important role at El Shincal de Quimivil. Natural elements of the environment, such as hills and mountains, became landmarks and symbolic representations, similar to what has been identified in the city of Cusco.

Pucará of Punta Brava (16), located near the town of Los Loros in Tierra Amarilla, Chile, is part of a fascinating archaeological complex that includes pre-Inka mining facilities and rock paintings. It is estimated that this site corresponds to the Inka dominance period in Chile [33]. Pucará de Punta Brava is composed of imposing stone walls built in the pirca style.

The Inka Palace of La Puerta (17), located in the Atacama region of Chile, is an important archaeological site that was part of a key settlement in the Copiapó River basin. With primarily Inka architecture, this palace may have served as an administrative center. The strategic location of the site allowed access to resources, and its economy was diversified, including livestock and agriculture. Declared a historic monument, the Inka Palace of La Puerta continues to be the subject of archaeological research to better understand its function in pre-Hispanic societies.

Viña del Cerro (18) is a metallurgical center that shows the influence of the Inkas on the Diaguita culture and their mastery of copper extraction and processing techniques [19]. Discovered in 1968, it is the only known dedicated Inka smelting site in the southern Andes. The complex consists of units with specific functions, including an administrative

platform, dwellings, and copper smelting furnaces. This site reveals the sophistication and technological skill of the Inkas and Diaguitas in copper metallurgy.

Huaca of Chena (19), located next to Santiago de Chile, has been the subject of review and study in relation to the Inka phenomenon. Through archaeological and archaeoastronomical research, its function and symbolism have been reevaluated. The intramural plaza stands out as an engineering feat where the summit of the hill was leveled, and a retaining wall of approximately 50 m in length was constructed. The possibility has been raised that the construction of Chena had geographic and symbolic aspects [39].

The Pucará del Cerro Grande de La Compañía (20) is an Inka site located in the O'Higgins region of Chile. It is one of the southernmost constructions of the Inka Empire and has been the subject of various archaeological and ethnohistorical studies [29,48]. The site stands out for its strategic location and defensive characteristics, such as panoramic visibility and the presence of perimeter walls. Remains of dwellings and an intramural plaza have been identified, suggesting the presence of an active community at the site. Its archaeological significance has led to its declaration as a historic monument.

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