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# Rock Painting Symbols and Textile Design: Cultural Inheritance and Artistic Innovation

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## Article

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## ABSTRACT

*The translation of complex graphical sources into manufacturable textile patterns is a central challenge in textile design and technology. This study presents a quantitative methodology for analyzing this process, focusing on the adaptation of cultural motifs for modern wool fiber products. Specifically, it investigates the transformation of zoomorphic petroglyphs from China's Helan Mountains into contemporary woven textile patterns. A novel analytical framework based on computer-aided design (CAD) principles is proposed, utilizing three key metrics to evaluate the design transformation: a Geometric Abstraction Index (GAI) for shape simplification, a Symmetry Operation Analysis (SOA) for patterning logic, and Color Palette Deviation (CPD) based on colorimetry. The analysis, applied to 100 commercial textile products, indicates that manufacturability and market aesthetics drive designs towards significant geometric simplification (systemic GAI of 0.196) and the use of tessellation in pattern layouts (65% of samples). The color analysis further reveals a strategic shift from the source's monochrome palette to schemes optimized for modern dyeing and consumer appeal. This research provides a replicable framework for design analysis in the textile industry, linking cultural inspiration to tangible fabric production parameters and offering valuable data for quality and design process control.*

## KEYWORDS

*textile design, patterning, wool fibers, geometric modeling, colorimetry*

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## INTRODUCTION

Rock art represents one of the earliest forms of visual communication and serves as a significant record of prehistoric human expression that predates written history [1,2]. These petroglyphs and pictographs, found across the globe, are not merely archaic illustrations but complex repositories of cultural memory, cosmology, and social identity [1,3]. In the contemporary era, these ancient symbols are being increasingly adapted,

migrating from rock faces to new mediums, most notably textile design. This transference is more than an aesthetic appropriation; it is a dynamic process of cultural dialogue, where the static, sacred art of the past is re-contextualized into a functional, tactile, and commercial art form [4,5]. Textiles, as carriers of culture, provide a unique canvas for this translation, embedding ancestral narratives into the fabric of modern life. This paper explores the intricate relationship between the preservation of cultural heritage and the necessity of artistic innovation within this specific translation process [6,7].

The Helan Mountains, located in the Ningxia Hui Autonomous Region of China, house one of the world's most significant concentrations of rock art. Created by various nomadic peoples over thousands of years, including the Xiongnu, Xianbei, and the Western Xia Kingdom, these petroglyphs depict a rich tapestry of life, featuring hunting scenes, celestial bodies, and a diverse bestiary [8,9]. Among the most iconic motifs are the zoomorphic figures, particularly the Argali sheep (*Ovis ammon*), distinguished by its prominent curved horns. These images are deeply ingrained in the regional identity and have become a primary source of inspiration for Ningxia's contemporary wool textile industry. While the connection is widely celebrated, the academic discourse surrounding it has remained largely descriptive and qualitative. Studies have focused on the historical context of the rock art or provided general overviews of its use in modern crafts, but there is a significant research gap in the systematic, quantitative analysis of *how* these ancient symbols are graphically and semantically transformed [10,11]. The critical questions of what is preserved, what is altered, and why, remain underexplored from a design science perspective.

This study aims to bridge this gap by conducting a rigorous, data-driven investigation into the transformation of Helan Mountain zoomorphic rock art into contemporary Ningxia wool textile designs. We posit that this process is not arbitrary but follows discernible patterns of geometric abstraction, structural reorganization, and chromatic innovation, driven by a confluence of aesthetic trends, manufacturing constraints, and market demands. To test this hypothesis, we develop a novel analytical framework comprising three quantitative metrics: the Geometric Abstraction Index (GAI), the Symmetry Operation Analysis (SOA) and the Color Palette Deviation (CPD). By applying this framework to a carefully selected corpus of rock art images and modern textile products, this research moves beyond anecdotal observation to provide empirical evidence of the design strategies employed. The objective is to deconstruct the balance between fidelity to the cultural source (heritage preservation) and creative modification (artistic innovation), thereby offering a deeper, more

nuanced understanding of how ancient art can be sustainably and meaningfully integrated into the contemporary creative economy. This paper will first review the relevant literature, then detail the methodology for data collection and analysis, present the empirical results, discuss their implications for design theory and practice, and finally, conclude with the contributions and directions for future research.

## **LITERATURE REVIEW**

### **Semiotics and Significance of Helan Mountain Rock Art**

The study of rock art, or petroglyphology, has established these carvings as a vital record of prehistoric human cognition, belief systems, and social structures. Scholars such as Jean Clottes have argued for a shamanistic interpretation of many rock art sites, suggesting the images are records of spiritual visions or rituals [11-13]. In the context of the Helan Mountains, Chinese researchers like Gao Wei and Li Xiangshi have conducted extensive cataloging and typological studies, identifying distinct periods and cultural influences in the art. Their work establishes the zoomorphic figures, especially the sheep and goats, as central motifs, likely tied to hunting magic, clan totems, or fertility rites [14,15]. The visual language of this art is characterized by its stark, expressive lines, minimal internal detail, and a focus on capturing the essential form and movement of the subject. These images possess significant semiotic value. Research indicates they function beyond mere representation, serving as carriers of spiritual concepts and totemic meanings associated with the depicted animals. This primal semiotic function is a critical baseline from which any modern design adaptation must be assessed.

### **Textiles as Carriers of Cultural Identity**

Textiles have long been recognized as a primary medium for the expression and transmission of cultural identity. As explored by scholars like Christopher Tilley in his work on material culture, objects, including textiles, are not passive artifacts but are actively involved in the construction of social meaning. In many cultures, woven and embroidered patterns serve as a “language” that communicates lineage, social status, and cosmological beliefs [16]. For instance, the intricate geometric patterns in Berber carpets or the narrative embroidery of the Hmong people function as historical documents and markers of belonging [17]. The application of rock art symbols to textiles, therefore, represents a contemporary extension of this ancient

function. However, as argued by Diana Crane, the globalization of design and consumer culture introduces new complexities [18,19]. The meaning of a cultural symbol can be diluted or altered when it is removed from its original context and enters a commercial marketplace. This creates a tension between authenticity and marketability, a core theme this paper investigates through quantitative means.

### **Digital Methodologies in Pattern Analysis**

The advent of computational tools has revolutionized the analysis of visual patterns. In fields ranging from art history to computer vision, researchers are now able to quantify aesthetic features that were once only describable in subjective terms [20]. Methodologies such as Shape Grammar, developed by George Stiny and James Gips, provide a formal system for describing and generating designs based on a set of rules [21,22]. More recently, digital image analysis techniques have been used to classify pottery patterns, analyze the fractal dimensions of artistic works, and quantify stylistic evolution over time. For example, computer-aided analysis has been successfully applied to study the geometric properties of Islamic tiling patterns, revealing their complex mathematical underpinnings. These approaches demonstrate the potential for quantitative methods to bring new rigor to the study of design and cultural graphics [23-25]. Yet, such methodologies have been sparsely applied to the specific domain of textile design, particularly concerning the adaptation of archaeological motifs. This study draws inspiration from these digital humanities and computational aesthetics approaches to build its analytical framework, applying a similar level of quantitative precision to the rock art-to-textile translation process.

## **METHODOLOGY**

To empirically investigate the transformation of rock art symbols, a multi-stage methodology was designed and implemented. This involved the systematic collection of source and target images, the development of a quantitative analytical framework, and the statistical analysis of the collected data.

### **Corpus Compilation**

A dedicated research corpus was compiled, consisting of two primary datasets:

- **Rock Art Source Corpus (RASC):** A set of 50 high-resolution, monochrome photographs of distinct zoomorphic petroglyphs was selected from the Helankou gorge area of the Helan Mountains. The

selection was standardized to focus exclusively on the Argali sheep motif to ensure a consistent basis for comparison. The images were sourced from the official digital archives of the Yinchuan Rock Art Museum and were chosen based on clarity, completeness, and recognizability of the form. This sample size (N=50) was determined to reach typological saturation, covering all distinct stylistic variations of the Argali motif recorded in major archaeological surveys of the Helankou region, thereby ensuring a representative baseline for geometric analysis.

- **Textile Motif Target Corpus (TMTC):** A collection of 100 contemporary Ningxia wool textile products was surveyed. These items, produced between 2020 and 2025, included woven tapestries, scarves, and cushion covers that explicitly featured motifs inspired by the Helan Mountain Argali sheep. From these products, 100 corresponding motif instances were digitally isolated. The selection was curated to represent a wide range of manufacturers, from state-supported craft centers to independent design studios, to ensure a representative sample of current design practices. It is important to note that the datasets are independent rather than paired. Contemporary designers typically reference the general stylistic schema of the Helan Mountain petroglyphs rather than copying specific individual carvings. Therefore, this study treats the RASC (Source) and TMTC (Target) as two distinct statistical populations representing the archaeological style and the modern commercial style, respectively.

### **Symbol Extraction and Vectorization**

Each image in both the RASC and TMTC underwent a standardized digital processing workflow. To ensure objective geometric analysis, the core symbols were processed into binary silhouettes using a standardized thresholding algorithm (Otsu's method). This process extracted the precise boundary of the motif directly from the raster data, eliminating the subjective bias associated with manual vector tracing. This process intentionally ignored the texture of the rock or fabric, focusing solely on the geometric form of the design. The resulting binary silhouettes allowed for precise measurement of geometric properties (Area and Perimeter) independent of variable vector node densities. To ensure comparability, all vectorized symbols were normalized to a standard height of 1,000 units while maintaining their original aspect ratio. This normalization eliminates scale as a variable, allowing for direct comparison of geometric complexity and form.

### Quantitative Analytical Framework

Three novel metrics were developed to quantify the key dimensions of transformation between the source rock art and the target textile motif.

- **GAI:** To objectively quantify the simplification of the motif's form, this study adopts a morphological complexity metric based on the relationship between perimeter and area. Unlike vector anchor counts, which can vary based on software settings or operator technique, this metric relies on the intrinsic geometric properties of the shape. First, the Shape Complexity (C) for each motif is calculated using the following equation:

$$C = \frac{P^2}{4\pi A}$$

Where P represents the perimeter of the motif's contour, and A represents its area. For a perfect circle (the most compact shape), C=1. More complex, irregular, or rough-edged shapes (such as raw petroglyphs) yield significantly higher C values. To strictly adhere to the independent nature of the datasets (as established in Section 3.1), the GAI is redefined not as an individual score for each sample, but as a systemic transformation coefficient. It is calculated as the ratio of the median complexity of the target textile population to the median complexity of the source rock art population:

$$GAI = \frac{\text{Median}(C_{TMTC})}{\text{Median}(C_{RASC})}$$

- Using the median rather than the mean provides a more robust metric that minimizes the influence of outliers (e.g., unusually simple rock carvings or unusually complex textile patterns). This coefficient quantifies the macroscopic degree of geometric regularization occurring across the entire industry adaptation process. **SOA:** To analyze the structural organization of the motifs, this study treats symmetry as a nominal variable rather than an ordinal score. Recognizing that complex textile patterns often employ hybrid symmetries, each sample was classified based on its Primary Dominant Structure—the defining operation that governs the overall visual logic of the fabric surface. To ensure reproducibility in

classifying complex or nested designs (e.g., a tessellated background featuring an isolated central medallion), a Surface Area Dominance criterion was applied. The symmetry operation covering the largest percentage (>50%) of the visible fabric surface area was designated as the Primary Dominant Structure. Secondary decorative elements were subordinated to this global structural logic.

- **Type-Iso (Isolation):** The motif functions as a singular, focal element (common in engineered placement prints). **Type-Ref (Reflection):** The primary logic is bilateral or quadrilateral mirroring. **Type-Rot (Rotation):** The design is organized radially around a central point. **Type-Tes (Tessellation):** The motif serves as a repeating module in a translation grid (linear or all-over repeat). **CPD:** This metric measures the degree of chromatic innovation. The original rock art is inherently monochrome. The CPD quantifies the introduction of color in the textile motifs. Using Adobe Photoshop's color analysis tools, the dominant color (excluding background) of each textile motif was identified and its coordinates were plotted in the CIELAB color space. To ensure ecological validity, the reference baseline for colorimetry was established not as an arbitrary neutral gray, but as a standardized Archetypal Rock Tone derived from the geological characteristics of the Helan Mountains. The rock surface, typically characterized by oxidized desert varnish on sandstone, presents a deep, warm-brown hue. Based on colorimetric sampling of site documentation, the reference coordinates were standardized to  $L_{ref}^* = 45, a_{ref}^* = 10, b_{ref}^* = 12$  (representing a typical oxidized ochre-brown). The CPD is thus calculated as the deviation between the textile motif's dominant color and this ecological baseline:

$$\Delta E_{00}^* = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C} \frac{\Delta H'}{k_H S_H}}$$

This metric specifically measures the chromatic shift from the naturalistic artifact to the designed commodity. The CIEDE2000 formula, which better reflects human color perception, was used for this calculation. A higher CPD value signifies a greater departure from the original monochrome palette.

## RESULTS

The application of the analytical framework to the RASC and TMTC corpora yielded quantifiable data on the nature of the design transformations. The results are presented across the three key metrics.

### Analysis of Geometric Abstraction (GAI)

The analysis of the GAI for the 100 textile motifs revealed a strong and consistent trend towards geometric simplification. The quantitative analysis revealed a drastic reduction in morphological complexity during the translation process. The comparative analysis of Shape Complexity (C) reveals a distinct separation between the two populations. The Rock Art Source Corpus exhibited high variability and high complexity (Median  $C_{\text{rock}} = 24.5$ , IQR = 5.2), reflecting the irregular, fractal nature of hand-pecked stone carvings. Conversely, the Textile Motif Target Corpus showed a tightly clustered, low-complexity distribution (Median  $C_{\text{textile}} = 4.8$ , IQR = 1.1). Consequently, the systemic GAI is derived as 0.196 ( $4.8 / 24.5$ ). This indicates that the translation from artifact to product involves a systemic reduction in geometric information density of approximately 80%, regardless of the specific motif variation. A Mann-Whitney U test confirmed that this difference in complexity distributions is statistically significant ( $p < 0.001$ ). This confirms that geometric regularization is not merely an aesthetic preference but a fundamental constraint of the textile medium. Using the Rock Art Corpus mean complexity ( $\bar{C}_{\text{RASC}} = 24.5$ ) as the standardized denominator, the GAI distribution highlights a systemic shift. Individual textile samples fluctuated around the mean systemic GAI baseline, suggesting that while specific designs vary, the industry-wide standard is to reduce the visual information density to approximately one-fifth of the archaeological original.

The distribution of GAI scores was unimodal and skewed towards lower values, with 88% of the samples having a GAI below 0.6. Only 3% of the samples had a GAI at or near 1.0, representing very high-fidelity reproductions, while no samples registered a GAI significantly above 1.0, suggesting that adding complexity is an extremely rare design choice. The lowest recorded GAI was 0.18, representing a highly stylized, minimalist interpretation of the Argali sheep form. This overwhelming trend towards simplification is a primary characteristic of the adaptation process.

Table 1. Descriptive Statistics for GAI

Metric	Value	Interpretation
N (Source)	50	Rock Art Sample Size
N (Target)	100	Textile Sample Size
Mean Crock (Source)	24.5	High Complexity Baseline
Mean Crock (Target)	4.8	Low Complexity Adaptation
Systemic GAI	0.196	Ratio of Medians (4.8/24.5)
p value	0.196	Mann-Whitney U Test

### Analysis of Symmetry Operations (SOA)

The classification of symmetry operations reveals the dominant structural logic of the commercial adaptations. While some designs exhibited hybrid features, the Type-Tes (Tessellation) category emerged as the overwhelming dominant structure, accounting for 65% of the corpus. The classification of symmetry operations reveals a fundamental structural shift between the source and target corpora. Analysis of the (RASC confirmed that 100% of the original petroglyphs are classified as Type-Iso (Isolation), appearing as singular, non-repeating entities. In contrast, the commercial adaptations in the TMTC show a divergent logic. While some designs exhibited hybrid features, the Type-Tes (Tessellation) category emerged as the overwhelming dominant structure, accounting for 65% of the corpus. This indicates that the fundamental grammar of these textiles involves converting the singular petroglyph into a repeating module. Type-Iso (Isolation) was the second most frequent category (21%), typically reserved for centered compositions on cushion covers. Type-Ref (9%) and Type-Rot (5%) appeared less frequently as primary structures, often acting as internal organizers within larger layouts. This distribution confirms that while the source material (rock art) is inherently Type-Iso, the target medium (textiles) necessitates a shift toward translational repetition. The data strongly suggests that the functional requirement of textiles to cover a surface with a coherent pattern is a major driver of the structural transformation.

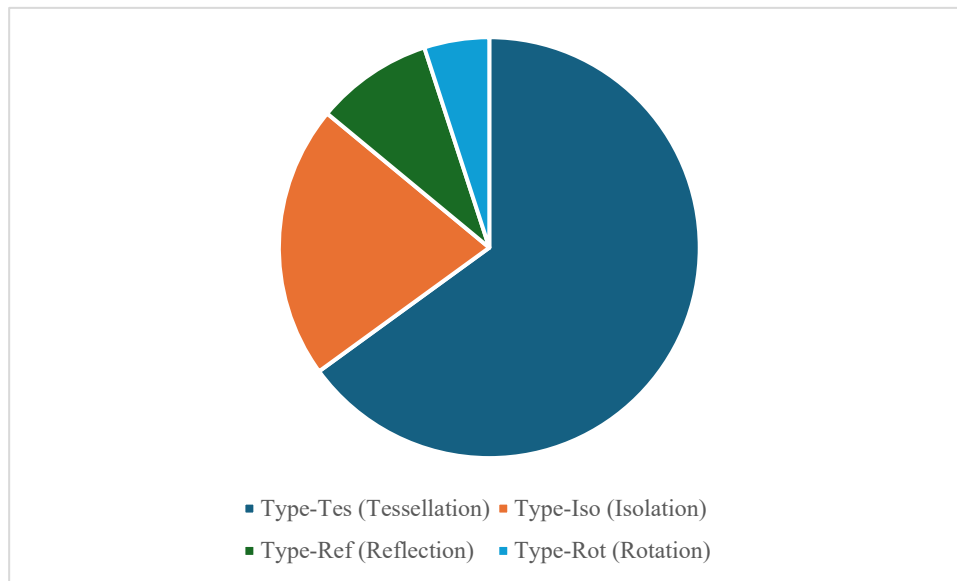


Figure 1. Frequency Distribution of SOA. Note: Percentages reflect the primary dominant structure of the textile samples

### Analysis of Color Palette Deviation (CPD)

The CPD analysis confirmed a universal departure from the monochrome nature of the source material. The analysis of CPD quantifies the strategic departure from the artifact's natural materiality. The mean CPD was calculated to be 54.2 (based on the Archetypal Rock Tone). More importantly, the vector of deviation reveals two distinct design strategies. While the original rock art is characterized by low-chroma earth tones ( $L^* = 45, C^* \approx 15$ ), the textile adaptations systematically shift towards distinct poles:

**Hyper-Chromaticity:** 32% of samples (Deep Blues/Reds) show a significant increase in Saturation ( $C^* > 40$ ), moving away from the muted geological palette to attract consumer attention.

**Luminosity Shift:** 25% of samples (Cream/Beige wool) show a drastic increase in Lightness ( $L^* > 80$ ), effectively bleaching the heavy historical weight of the dark stone into a lighter, softer domestic aesthetic.

The color palette of the textile motifs was diverse, but certain dominant trends emerged. The most frequently observed colors were deep blues (32% of samples), earthy reds and oranges (28%), and natural wool tones like beige and cream (25%). These color choices are not random; they align with regional aesthetics, drawing from colors used in other local crafts such as Tibetan-influenced weaving and natural dye traditions. These color choices reflect a measurable alignment with regional heritage. Specifically, the CIELAB coordinates of

the dominant blues ( $L^* \approx 28$ ,  $b^* \approx -20$ ) show a strong correlation with the spectral characteristics of traditional indigo-dyed (Indigotin) wool used in historic Ningxia carpets. Similarly, the earthy red hues correspond to the characteristic alizarin palette of madder root (*Rubia cordifolia*) commonly found in regional biological dyes. This confirms that the chromatic shift is not arbitrary but is anchored in the material history of local craftsmanship. The introduction of vibrant color is a fundamental innovative step, transforming the stark, graphic quality of the rock art into a warmer, more decorative element suitable for interior design and fashion.

## DISCUSSION

The quantitative results presented in the previous section provide a clear and detailed picture of the adaptive strategies used to translate Helan Mountain rock art into contemporary textile designs. This discussion will interpret these findings within the broader context of cultural heritage and artistic innovation, exploring the underlying reasons for the observed transformations. The data suggests that the process is a sophisticated negotiation between preserving the symbolic integrity of the ancient art and meeting the practical and aesthetic requirements of a modern commercial product.

The dominant trend of geometric abstraction, as evidenced by the low systemic GAI of 0.196, represents an involuntary technical mandate rather than a purely artistic preference. Firstly, this simplification is a forced compromise driven by the technical constraints of textile production. Unlike the continuous lines of rock carvings, woven designs are discretized by the grid structure of the fabric, defined by the Warp and Weft Density (PPI/EPI). The original high-frequency fractal details often exceed the resolution capability of standard manufacturing, necessitating the filtering of details to ensure readability within the minimum repeat size of the loom. Secondly, while primarily a technical necessity, this resultant simplification coincidentally aligns with modern minimalist design sensibilities. By transforming raw archaeological data into regularized geometric forms, the design satisfies the mechanical requirements of the loom while simultaneously appealing to the aesthetic preferences of the contemporary market. The low GAI confirms this optimization process: the reduction in the perimeter-to-area ratio directly correlates to a reduction in the mechanical complexity required for jacquard weaving or screen preparation. The process of abstraction, therefore, is also a process of optimization for the medium. Importantly, this simplification does not erase the identity of the symbol. The core recognizable features—the exaggerated, curving horns of the Argali sheep—are almost

always retained, acting as the key signifier that anchors the design to its cultural source. This strategy allows the design to be both modern and recognizably from Helan.

The prevalence of tessellation (Type-Tes), found in 65% of the samples, highlights a fundamental shift in the function of the symbol. A rock art petroglyph is typically a singular, static entity with a potential narrative or ritualistic purpose. A textile, by contrast, is often a surface that requires rhythmic, repeating patterns to achieve visual harmony and coherence. The transformation from an isolated figure to a tessellated pattern is a direct response to this functional demand. This reorganization of space moves the symbol from the realm of pictorial representation to that of decorative art. The innovation lies in creating a new visual syntax; the designers are not just copying a sheep, they are using the sheep motif as a module to build a larger, more complex visual structure. This reflects a deep understanding of textile design principles, where rhythm, flow, and repetition are paramount. The choice to tessellate is perhaps the most significant artistic intervention, fundamentally changing how the symbol is experienced by the viewer.

Finally, the dramatic shift in color, quantified by the high CPD scores, addresses the emotional and aesthetic dimensions of the design. The calculated CPD indicates a deliberate De-naturalization process. The designers act as chromatic translators, stripping the symbol of its specific geological context (the heavy, oxidized rock face) and re-embedding it into a domestic color system. The shift from the Archetypal Rock Tone to the vibrant textile palette (CPD≈54.2) is not merely decorative; it functions to soften the primitive aggression of the hunting scenes. By replacing the hard colors of nature (stone/iron oxide) with the soft colors of culture (dyed wool), the object is transformed from a historical document into a compliant interior design element. Furthermore, the logic of color composition shifts from the monolithic monochromatic scheme of the natural environment to dynamic split-complementary or triadic harmonies (e.g., balancing deep navy blues with earthy ochres and creamy beige) in the textile medium. This harmonic restructuring is essential for introducing visual rhythm that aligns with contemporary interior aesthetics. The introduction of a rich color palette—the blues, reds, and creams—serves to domesticate the ancient symbol. These colors are culturally resonant within the region, linking the rock art to a broader palette of local craft traditions. Color adds warmth, emotional appeal, and allows the product to be integrated into diverse interior design schemes. This chromatic innovation is a critical step in re-contextualizing the symbol's meaning. It moves from being a potentially sacred or historical artifact to being a beautiful object of contemporary life, thereby ensuring its

continued relevance and visibility. In this act of colorization, the designer balances the cool authenticity of the source with the warm appeal required by the market.

In synthesizing these three points, it becomes clear that the translation of rock art to textile is a multi-faceted process of cultural and artistic reinterpretation. The designers are not passive copyists; they are active translators. They preserve the core essence of the heritage—the iconic form of the Argali—while creatively innovating in geometry, structure, and color to make it viable and meaningful for a new medium and a new audience. This balance is the key to the successful fusion of cultural heritage and artistic innovation, ensuring that the cultural heritage derived from petroglyphs is effectively preserved and recontextualized within contemporary textile production.

## CONCLUSION

This study set out to quantitatively analyze the transformation of zoomorphic rock art symbols from China's Helan Mountains into contemporary wool textile designs. By developing and applying a novel framework based on the GAI, SOA, and CPD, we have moved beyond qualitative description to provide empirical evidence of the specific design strategies at play. Our findings demonstrate that this adaptive process is systematic and predictable, characterized by three primary transformations: a significant simplification of form ((systemic GAI of 0.196), a structural reorganization from isolated figures to tessellated patterns (65% of cases), and a complete departure from the source's monochrome palette to a rich, culturally resonant color scheme.

The central argument of this paper is that these transformations represent a successful and sophisticated negotiation between the demands of cultural preservation and the imperatives of artistic and commercial innovation. The essence of the heritage is maintained by retaining the core recognizable features of the symbol, while innovation is achieved through abstraction, repetition, and colorization to suit the textile medium and contemporary aesthetic and market demands. This process should not be viewed as a degradation of the original symbol's authenticity but as a dynamic re-contextualization that ensures its continued life and relevance in the modern world. The study's primary contribution is its methodology—a replicable, data-driven approach that can be applied to other cases of cultural graphic translation in design, providing a valuable tool for both academic analysis and design practice.

While this research provides a robust foundation, it has its limitations. The study was confined to a single

zoomorphic motif from one specific region. Additionally, the classification of symmetry operations (SOA) employed a dominant-structure approach. While effective for identifying the primary visual logic, this single-label method inherently simplifies the complexity of hybrid designs, potentially underreporting secondary symmetry operations (e.g., local rotation within a global tessellation) present in multi-layered patterns. Future research should expand this analysis to include other types of symbols (e.g., anthropomorphic figures, sun gods) and other rock art sites globally to test the broader applicability of the framework. Furthermore, incorporating consumer perception studies could add another valuable layer, investigating how these design transformations are received and interpreted by the end-users. By continuing to build a scientific understanding of this creative process, we can better inform strategies for the sustainable and respectful integration of invaluable cultural heritage into the vibrant landscape of contemporary design.

#### *Author Contributions*

Mingyu Li designed, collected and analyzed the data, and drafted the manuscript. Mingyu Li conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Mingyu Li participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

#### *Conflict of Interest*

The author declares no conflict of interest.

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#### *Availability of Data and Materials*

The datasets used and/or analysed during the current study were available from the corresponding author on reasonable request.

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Not applicable.

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