Tracing the influence of aquatic environments on ancient pottery and knifemaking techniques across coastal civilizations

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Abstract

The intersection of water-based ecosystems and the early coastal civilization's technology is still a captivating discipline of study. This paper analyzes the extent to which shorelines and freshwater bodies shaped the capabilities in the crafting of pottery and knives in different coastal communities. This work examines the implications of environmental factors, including the presence of minerals, salinity, and humidity, as well as the configuration of the trade routes, on material selection and methods of production, drawing from archaeological, geochemical, and ethnographic studies across the Mediterranean, the Indian Ocean, and the Pacific Archipelagos.

Coastal pottery and clay, especially when made from clays deposited in coastal regions in significantly denser and mineralized portions of the marine sediments, became more durable and visually striking. Additionally, the marine abundance and saltwater corrosion on blades motivated the enhancement of alloyed and patterned blades for fishing, trade, and warfare. The independent emergence of comparable technological advancements across distinct oceanic cultures is illustrated by integrated research on artifacts, remains from pyrolysis, and metallurgy.

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Introduction

The link between aquatic environments and older technologies like pot and knife manufacture deserves attention in the coastal civilization material culture study (Kostoglou, 2010). Coastal areas vary in their exclusive ecological arrangements. Their rich brackish and freshwater fisheries and other aquatic environments influenced the aquatic cultural techniques used in the craft of knife and pottery making. The ancient peoples of these zones gained access to particular pieces of raw material resources, such as clays, saline ores, and brackish water fishes, that were critical to the production of durable, functional artifacts and pottery of varying utility. Altered and shaped artifacts were in the brackish water, marine sediments, and coastal freshwater pot and clay deposits (Hu, Jiao and Li, 2024). The fabrication of artifacts and pottery had instrumental value, but it was deeply interwoven with the trade, daily survival, rituals, and culture of the coastal populations. The natural circumstances of a locale determined the knifemaking and pottery techniques and styles of a culture, influencing the clay composition and firing of the pottery, the fabrication alloys, and the knives' corrosion resistance (Rajan and Fernandes, 2025). This research analyzes the influence that proximity to water bodies had on the technological decisions made by coastal communities and how these groups utilized and overhauled the resource networks and techniques that their industries employed to adapt to their environments (Jahangiri, Safaei and Momeni, 2024). To illustrate the idea of communities that share certain attributes and to pinpoint certain regional adaptations and innovations to comparable geographical challenges, limb research examining disparate coastal communities of the Mediterranean, Indian Ocean, and the Pacific has been drawn on. The value of the technological and artisanal production spun on natural resources, both as raw and finished products, particularly as they relate to aquatic environments, merits emphasis (Salisbury, 2017; Fening, 2015). The study of unmodified and modified natural resources reinforces the claim that the natural environment acted as an impetus for technology development in ancient societies, and centers attention on the resourcefulness of people in utilizing nature.

Figure 1 illustrates the intricate relations coastal communities have with water bodies, examined through the lenses of pottery and knife production. The exhibition was designed with a perspective of influence (Ganesan, Sethuraman and Balamurugan, 2024). The environment is the primary influence, represented by the large ocean backdrop and simulated waterway in the foreground.

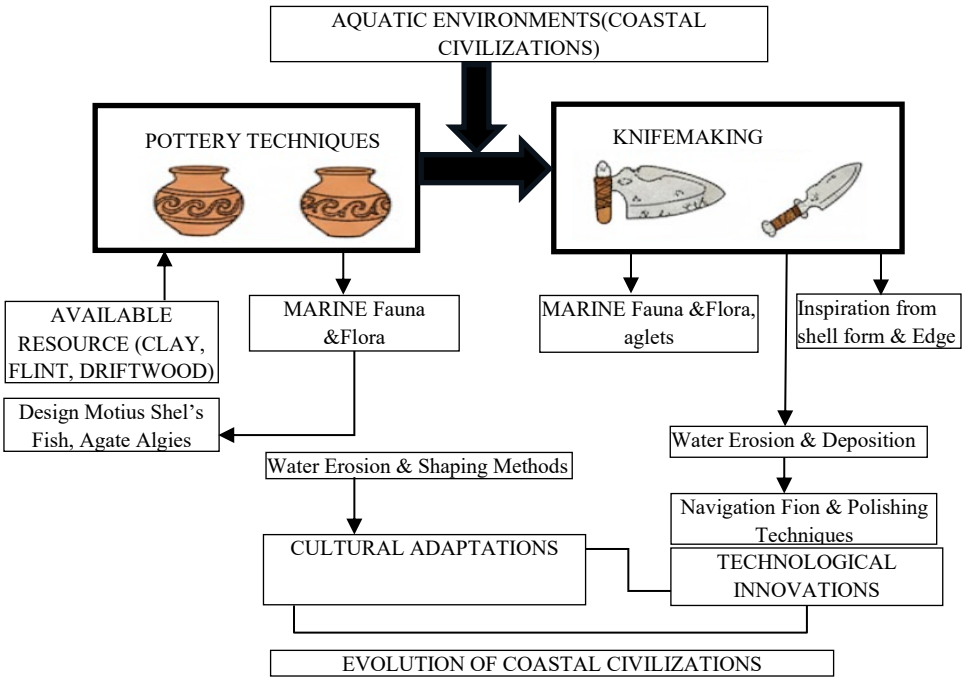

Figure 1: Coastal echoes: the symbiotic exchange between aquatic environments and artisanry.

The water body was, and continues to be, a source of materials for tools and other accompaniments, such as shells, driftwood, and various clay and mineral deposits. Not to mention the functional patterns and motifs, including fish, nets, and waves. The artifacts are ancient pottery and knives designed to be used in gutting, scaling, or otherwise working with wet materials, which showcases the direct assimilation of water influence within the intricate processes (Pouya and Başkaya, 2018; Fargher, 2009). The integration of shells as temper in clay is a testament to how living within a coastal environment propelled innovation, both in functional utility and artistry, of the ancient societies on the southern edge of the continent.

Key Contribution of the Paper

- This paper's most important contribution is the investigation of the interactions of aquatic ecosystems with the craft technologies of the ancient coastal civilizations, for example, the technologies of making pottery and knives.
- The study analyzes the specific ecology of the coastal zone, detailing how the combination of marine and freshwater resources, such as particular clays, saline ores, and fish, influenced the craft materials and techniques.
- It explains how the environmental determinism of the physical ecosystem of the coastal zone set the attributes of the artifacts, including their design, usability, and storage life, and how the specifics of the clay, the pottery, and the firing procedures were influenced by the pottery's functionality (Kvarnes *et al.*, 1987).
- The paper also broadens the understanding of the general adaptation of coastal communities and their technologies described by their environmental case studies

from the Mediterranean, Indian Ocean, and Pacific.

Literature Review

Coastal environments have long been regarded as salient features influencing the evolution of ceramic traditions, as indicated by several studies. Such regions have provided unique sources of clay, which, as a result of marine sedimentation, produced some of the more durable and distinctive pottery. Changes in clay compositions due to the addition of saline and mineral-rich substances engendered novel methods of firing and glazing, producing textured and colored pottery distinctive of certain coastal communities (Grant, 2010). Archaeological evidence, especially from Mediterranean and Pacific coastal civilizations, demonstrates that proximity to marine ecosystems altered both the materials and methods of production. Some cultures used salt to increase the pottery's durability and improve its visual appeal. Research in ancient knifemaking and metallurgy offers insights into coastal and maritime societies as being some of the first metallurgical innovators (Roberts and Berns, 2018). The marine abundance of tin and other metal ores, along with other resources, contributed to the creation of alloys used in tools and weaponry. Coastal resources allowed the production of high-quality blades and tools, thus aiding Phoenicians and Vikings in the development of advanced metalworking techniques. Furthermore, resource use and environmental influence on craftsmanship have been studied quantitatively. Local ecosystems, i.e., marine or freshwater, determine the resources available to tool and pottery makers. Freshwater and marine resources determine the firing temperature of ceramics and the hardness of tools. Beyond resource provision, water environments determine production methods, design, and the patterns of circulation and trade in the crafted goods. These findings on pole crafts reveal the environment as the primary influence, and as both catalyst and constraint in the advancement of technologies relating to coastal pottery and knifemaking.

Inference

The coastal environments had a major impact on the emergence of pottery and knife-making technologies among early societies (Murray, 1943). Coastal clays had unique properties as a result of marine sedimentation, which permitted the development of unique and durable clays, along with different firing or glazing techniques, using clays with varied properties. Salt was an additive that produced durability and visual aesthetic for textiles, so those ceramics could endure. Likewise, tin and other metal ores were readily available to a coastal environment, which supported advanced metallurgy (Coetzee, 2015; Dugan, 2007). The coastal environments of societies such as the Phoenicians or Vikings enabled those cultures to make and develop durable tools and weapons. Local ecosystems; state-environment (marine), or wing, directly affected available material by each artisan, in addition to potential forms of production (e.g., utensils versus trade vessels).

Methodology

An application of various archaeological approaches allows for an understanding of the impact aquatic settings have on pottery and knifemaking techniques of

past societies. These approaches include the excavation of shards of pottery, remains of kilns, and metallurgical residues. The shards attest to the manufacture of the ceramics, while the remains of the kiln reveal techniques employed in the control of firing and the temperature in the pottery production. Slag and tool fragments constituted metallurgical residue, which provides evidence of the metalworking practices of ancient coastal societies. After the collection of the residues, the composition of the clays and metal alloys was assessed, and the preliminary composition of the clays associated with the pottery and the alloys of the ancient knives was examined. While the fragments of ancient coastal knives attest to the use of maritime resources, the tin and copper coastal deposits testify to how maritime resources shaped alloy composition. Geochemical studies on the clay associated with the pottery also reveal how the environment, particularly seawater, modified raw materials and minerals (Rahimipour, Attarian and Didehban, 2020; Tung, 2018). The study of various coastal regions is important for analyzing the influence of specific geographical contexts on the spatial distribution of specific technologies.

Examining the Mediterranean, Indian Ocean, and Pacific coastal regions illustrates the ways in which similar ecological features and available resources led to the development of similar technological solutions. Such an approach makes it possible to differentiate between cross-cultural diffusion and independent regional innovation.

```
# Step 1: Excavation and Collection
    artifacts = excavate_sites('coastal_regions')
    # Excavation of pottery shards, kilns, and metallurgical residues
    # Step 2: Geochemical Analysis of Clay and Metal Samples
    def geochemical_analysis(artifact):
     if artifact.type == 'pottery':
    # Conduct XRF analysis to determine mineral composition of clay
      clay_composition = XRF_analysis(artifact)
      return clay_composition
     Elif artifact. type == 'metal':
      # Conduct ICP-MS to analyze metal alloys for trace elements
      metal_composition = ICP_MS_analysis(artifact)
      return metal_composition
    # Step 3: Comparative Analysis Across Regions
    def comparative_analysis(artifacts_from_region_1, artifacts_from_region_2):
     # Compare clay compositions and metal alloy characteristics from two regions region_1_technological_patterns = analyze_patterns(artifacts_from_region_1) region_2_technological_patterns = analyze_patterns(artifacts_from_region_2)
     # Identify common patterns or differences influenced by local environments
      comparison_result = compare_technological_patterns (region_1_technological_patterns, region_2_technological_patterns)
      return comparison_result
```

```
# Step 4: Execute Analysis
artifacts_from_mediterranean = collect_artifacts('Mediterranean')
artifacts_from_pacific = collect_artifacts('Pacific')
# Analyze materials from both regions
Clay Mediterranean = geochemical_analysis(artifacts_from_mediterranean)
metal_pacific = geochemical_analysis(artifacts_from_pacific)
# Compare technological innovations across regions
result = comparative_analysis(artifacts_from_mediterranean, artifacts_from_pacific)
# Display results of the comparison
print(result)
```

Pseudocode presents a methodical way of exploring the impact of water bodies on the archaeology and geochemistry of ancient pottery and the knifemaking tradition. By means of a constructed example, the pseudocode describes the integration of some (archaeological) excavation techniques followed by geochemical analysis, and concluding with a comparative analysis (Anderson-Holmes, 2017). In the initial step, the function excavate_sites () imitates the archaeological excavation of artifacts such as pottery shards and remnants of kilns and metallurgy of ancient pottery and knifemaking traditions from a coastal region. This represents tangible proof of ancient artistry. Next, the function geochemical_analysis () performs the analysis of the artifacts' Euclidean geometrical and geochemical composition, via X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS), to analyze the pottery and alloys to trace the constituents and understand the local influences of the geochemical environment that shaped the raw materials.

Environmental Contexts

The ecosystems provide a wide assortment of natural resources, including the building blocks of marine minerals, salt, and clay, influencing the construction of indispensable tools and the pottery of a given locality (Pharr, 2002). For instance, coastal Mediterranean regions are renowned for their clay deposits richly endowed with marine sedimentation that contributed to the creation of pottery of considerable durability and elevation quality. At the same time, the different coastlines of the Indian Ocean allowed the formation of unique coastlines and the acquisition of different minerals, particularly clay and salt, needed in the production of porcelain glazes and alloys. The coast of the Pacific region also possessed diverse coastal ecosystems and an abundance of marine resources. In addition to the clay and metals that were of terrestrial origin, local ecosystems were enriched with corals and shells that were integral to toolmaking. In pottery, coastal peoples used marine minerals to enhance the durability and aesthetic quality of the fired pottery. The coastal deposits of tin and copper gave rise to the production of advanced metallurgy, which was capable of manufacturing tools and knives that withstood corrosion and were highly durable.

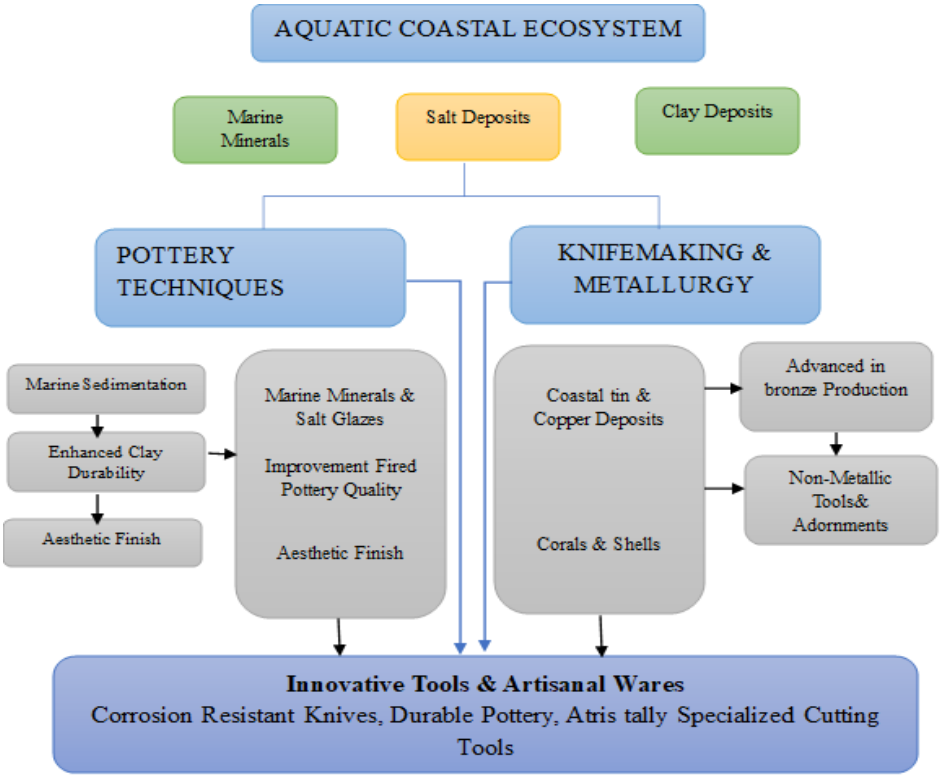

Figure 2: Aquatic influence on ancient craftsmanship: resource flow from coastal ecosystems to artisan wares.

Figure 2 shows the direct influence of different Aquatic Coastal Ecosystems on pottery and knifemaking & metallurgy in ancient coastal cultures. The flowchart starts off with the primary natural resources for these ecosystems: Marine Minerals, Salt Deposits, and Clay Deposits. These branches diverge into either of the two craft areas. For Pottery Techniques, Marine sedimentation enhances the durability and aesthetic finish of clay. Marine Minerals and Salt Deposits are useful for glaze making, instigating Improved Fired Pottery Quality and durability, particularly seen in the Mediterranean. Resources also affect Knifemaking & Metallurgy, in terms of access to shore-side marine ecosystems or propel seafaring communities to islands or coastal areas that possess various marine, salt, and clay resources.

Software Tools Used

A few software tools can assist in understanding the influence coastal ecosystems had on some ancient pottery and on knife making. For example, XRF and ICP-MS geochemical analysis software can assess the coastal milieu's influence on pottery and coastal metal alloys by identifying the marine minerals, salts, and metals. GIS tools like ArcGIS and QGIS enable researchers to catalogue archaeological sites and evaluate distance to coastal clay, salt, and metal resource locations. Environmental factors affecting the design of tools and ceramics can be studied using 3D modeling software such as AutoCAD or SketchUp, which reconstructs tools and ceramics. Additionally, excavated material culture and its regional variations can be analyzed using Microsoft Access or SQL, which serve as database management

systems. These types of software tools assist in understanding the extent to which coastal materials shaped ancient craftsmanship.

Impact of Aquatic Environments on Pottery Techniques

The development of unique styles of pottery and of increased durability within ancient civilizations can be attributed to pottery made from coastal clays with alterations as a result of marine sedimentation (Gholi, 2023). The clays created and deposited along coastal areas due to the fine minerals and organic matter transported via marine currents enriched the clays and made them ideal for the creation of pottery. Textures, colors, and strengths of the finished products were altered due to coastal clays being combined with seaweed and other organic matter. The firing of the pottery within saltwater environments created even more unique characteristics to the finished coastal pottery (Petrov, 2016; Anderson-Holmes, 2017). Cultures along the coast and of saltwater had the strengthened ability to use salt along with the pottery for firing, resulting in the creation of more durable pottery with a glossy appearance, improved moisture resistance, and lasting for longer periods of time. The ancient Greeks are an example of a culture and society along the coast of the Mediterranean Sea with marine layered clays for the creation of fine and decorative pottery. During antiquity, Phoenicians utilized Mediterranean maritime resources, engaging almost globally in trade, and produced exquisite, functional pottery that utilized firing salt due to the coastal salt availability. Indigenous Pacific Islanders were able to create pottery with favorable characteristics for the humid, coastal environments, integrating the local marine minerals. The use of marine resources, particularly clays of sedimentary origin and salt, developed specialized techniques for pottery in coastal regions.

Table 1: Impact of aquatic environments on pottery techniques across coastal civilizations.

Civilization	Region	Key Materials Used	Techniques/Characteristics	Impact on Pottery
Ancient Greeks	Mediterranean Coast	Marine layered clays, seaweed, salt	Used marine layered clays for fine and decorative pottery, enhancing durability and strength	Improved durability, strength, and aesthetic appeal with a glossy finish and moisture.
Phoenicians	Mediterranean Coast	Marine resources, Mediterranean maritime resources, salt	Produced exquisite, functional pottery with firing salt, using the coastal salt availability	Enhanced durability, glossy appearance, and longer-lasting pottery with improved moisture resistance
Indigenous Pacific Islanders	Pacific Coast	Local marine minerals, coastal clays	Created pottery suited for humid coastal environments, integrating local marine minerals	Favorable characteristics for humid environments, incorporating marine minerals for texture and durability

This tool may serve as an indicator of pottery durability based on materials used for making pottery (i.e., marine-layered clays, salts) and firing methods.

$$D = \frac{(Strength)X(Moisture\ resistance)\ X(Longevity)}{(ClayType + Firing\ Method)}$$

Strength, Moisture Resistance, and Longevity may be evaluated using a rating system (such as a 1-10 scale), and factors including Clay Type and Firing Method affect durability.

This metric is a measure of the surface aesthetics and textural diversities of the pieces of pottery as characterized by glossiness, color variability, and design intricacy.

$$AQI = \frac{(Glossiness) + (TextureVariation) + (Color\ Appeal)}{(Material\ Complexity)}$$

Items related to Glossiness, Texture Variation, and Color Appeal could receive a numeric rating (ex., 1-10), and Material Complexity could reflect the diversity of materials, such as seaweed, minerals, or salt.

Assesses the extent to which the pottery was well-adapted to specific environmental conditions in the area (e.g., the humidity or exposure to saltwater).

$$EAS = \frac{(MaterialSustainability\ for\ Climate)X(Adaptationto\ Environmental\ Challenges)}{(Resource\ Availability)}$$

Material Suitability for Climate could be scored on a scale from 1 to 10, Adaptation to Environmental Challenges would assess a variety of pottery's resistance to use through local environmental factors (e.g., moisture, corrosion), and Resource Availability measures the ease of obtaining the resources needed.

Table 1 illustrates how the different coastal environments impacted different ancient societies' dealings with different coastal resources to create pottery. Ancient Greeks, Phoenicians, and Indigenous Pacific Islanders are highlighted as coastal civilizations, and the table demonstrates how each culture adapted its pottery-making practice based on the materials that were available from their unique coastal environments. The table describes the main materials used by each civilization, the methods/techniques of their pottery, and how these methods/techniques affected the pottery's strength, durability, functionality, and aesthetics. This data illustrates the role of marine sedimentation, seaweed, and salt in increasing the strength, durability, and aesthetics of pottery, along with its function within the unique environmental conditions present for the respective civilization.

Impact of Aquatic Environments on Knifemaking Techniques

Corrosion Resistance and Metallurgical Innovation

Metallurgy before 2023 focused on backward corrosion resistance as a basic function of metallurgy. Consider coastal regions, especially coastal regions with high levels. Developing alloys of higher quality becomes a basic aspect of coastal metallurgy. Developing alloys that resist corrosion and withstand extreme coastal conditions has become a primary goal. For instance, trace alloys like tin and copper become corrosion-resistant blades of superior quality, cutting tools that have become core for knives and warfare tools.

Marine Resources for Toolmaking

Marine coastal resources in the form of bone, shell, and metals shaped the design and functionality of knives. Unlike bone, which was made for lightweight and sturdy handles, some cultures used shell for an ornamental cutting edge. Coastal

metallurgists acquired tin, which was used extensively in the production of bronze, and was also used in the making of knives. This economically empowered coastal communities to design functional tools with an artistic flair, which displayed the tool makers' artistry and the society's innovation.

A proximity to the sea terrain influences the knifemaking history of various cultures, as seen in the case of the Vikings. The Vikings had access to coastal iron, traded for tin, and developed iron and steel arms that withstood the saltwater corrosion. During their time, the Polynesian islands made knives and other tools out of coral and shells. Tools that incorporated marine life and other tools marked with shells and polished wooden handles made of fish bone demonstrated a strong tool and vibrant environment relationship. The ancient Egyptians were also able to create advanced metal knives. Having access to trade routes and flourishing along the Nile, they were able to use copper, which, along with the bronze alloys that they subsequently used, was highly resistant to corrosion. This was maybe owing to their coastal trade network, which was rich in marine resources. These instances show the extent to which advanced coastal ecosystems not only influenced the materials used for tool making but also the style, form, and innovative technological advancements in knifemaking.

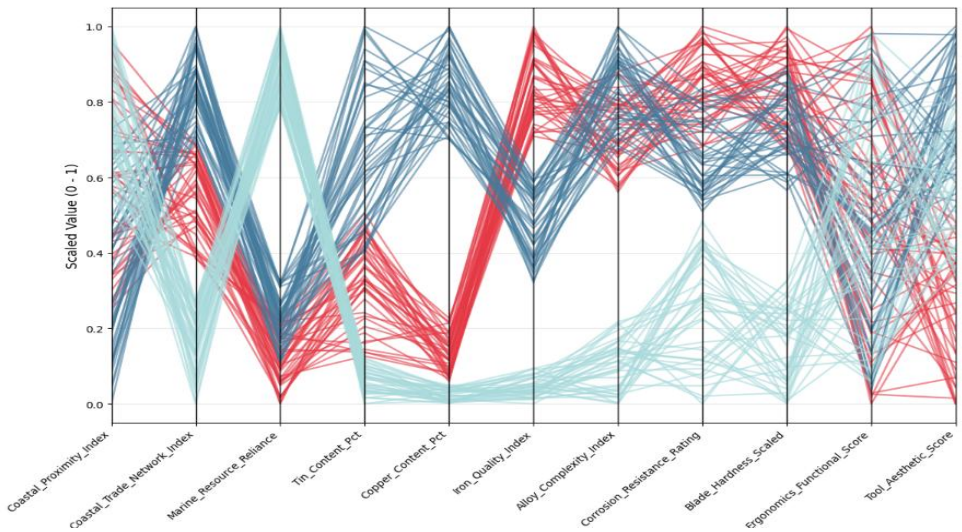

Figure 3: Tracing coastal adaptation: the multivariate profile of ancient knifemaking across vikings, egyptians, and Polynesians.

The figure 3 represents a number of variables along scaled axes (0 to 1), from input variables like Coastal Trade Network Index and Marine Resource Reliance, to output variables like Corrosion Resistance Rating and Tool Aesthetic Score, colored lines demonstrate the unique material-performance trajectories found for each of the cultures (Crimson for Vikings, Deep Teal for Ancient Egyptians, and Light Cyan for Polynesians). The graph effectively illustrates the strong inverse relationship between the metal-reliant cultures (Vikings and Egyptians) and the resource-reliant culture (Polynesian): Polynesian lines cluster extremely high for Marine Resource Reliance but extremely low for Tin_Content_Pct and Blade_Hardness_Scaled, signaling the

Polynesian adaptation using shell and coral rather than metal. In contrast, the Egyptian lines show a strong correlation as both the Coastal Trade Network Index and the Copper_Content_Pct increase along with the Alloy_Complexity_Index, reflecting the economic empowerment that allowed the Egyptians to support metallurgy and produce advanced bronze-based technology, achieving a high Tool_Aesthetic_Score.

Comparative Analysis Across Coastal Civilizations

Mediterranean Civilizations

Ancient Greek, Roman, and Phoenician cultures and civilizations were adapted to and influenced by the Mediterranean Sea. They prospered on coastlines and adapted to and thrived on the Mediterranean Sea's rich and diverse resources. Sea salt and other resources shaped the inhabitants' pottery and metalworking. The Mediterranean coast offered Greek potters superb quality marine-influenced clays, which shaped the finest and most intricately designed pottery and rich marine clays. Phoenicians and their thriving trade networks made foraging for the clays and salt for the construction and metal tool pottery trade the Mediterranean Sea worthwhile. Romans were also knifemakers, and coastal resources made it simple and profitable to manufacture high-quality blades for everyday life, warfare, and corrosion-resistant metals.

Civilizations of the Indian Ocean

Coastal regions of civilizations located around the Indian Ocean, including those in India, some African countries, and Southeast Asia, were similarly influenced because of their closeness to this body of water. Indian coastal communities constructed special pottery, some of which was high-fired for toughening, using clays of marine silt. Along the East African coastline, the Swahili and other ancient African civilizations harvested salt and shore clay and made pottery for domestic use and for trade. Southeast Asia developed advanced knifemaking technologies because of an abundant trade and advanced civilization that the land received from the Indian Ocean. With the Indian Ocean trade, Southeast Asia received raw coastal minerals to include in their knifemaking and advanced minerals to create trade valuable knives and tools made of core iron and tin, rusting knives and tools.

Pacific Civilizations

Engaged primarily with coastal environments, societies across the Pacific, especially within Polynesia, Micronesia, and Melanesia, developed distinctive styles of pottery and technologies in knifemaking. They fashioned knife and tool handles from marine resources, incorporating shells, corals, and fish bones, which illustrates the ecological interdependence of the people and the technologies they produced. Though pottery was less common in some Pacific islands and was influenced by local clay, it was readily available and often fired with natural heat from resources like volcanic rock. The integration of tectonic and Oceanic resources demonstrated the considerable skill of these societies in the refined crafting of functional and ornate tools and ceramics. Even though these coastal civilizations implemented varying materials and methods, there were notable consistencies in their

technological progress. Each civilization modified the coastal ecosystem products, marine minerals, salt, and living organisms, integrating changes in their pottery and knife production. The regions employed highly corrosion-resistant alloys, fired pottery at refined temperatures, and designed tools that integrated shells and bones. On the other hand, differences in the cultural context and specific materials take prominence. The Mediterranean civilizations' emphasis on clay and metal alloys, in contrast to the Pacific Islanders' use of marine life for handles and decoration of tools, is a prime example. The Mediterranean world's trade dominance in tin and copper contrasted with the Indian Ocean civilizations' access to diverse local minerals and regional influence on the metallurgical trade.

Conclusion

Unlike the land, the aquatic environment greatly affected the technologies of pottery and knifemaking in ancient coastal civilizations. The 'Key Coast' polymath ecosystem of the region used resources such as clay, salt, and metal ore, and significantly influenced the craft/resources. The ancient Greeks, Phoenicians, Indians, and Polynesians, as specialists in coastal pottery, complex feasting, and metalworking, advanced the techniques of pottery firing and developed corrosion-resistant alloys during the integration of ocean resources into the kerf, sea life shapes, and adornments of bias knives and tools. The integration of marine life in tool handles and connector elements, particularly in Pacific Island cultures, further demonstrates how local resources were creatively used. Additionally, the study proposes that while certain common and regionally specific patterns of technological development were driven by environmental factors, there were also significant differences in the regions regarding the sources of raw materials and the craft techniques used.

Several areas of future research can't be neglected. In particular, research that investigates the impact of climate change on ancient coastal civilizations may reveal how ancient societies coped with rising climatic changes technologically. The study of the ancient Mediterranean and Indian Ocean trade networks and the diffusion of materials and technologies along these trade networks may also help to understand the long-distance spread of technologies. Moreover, the impact of new materials such as the metals involved in long-distance trade on the coastal region's knifemaking and pottery techniques, as well as the pottery, may also be of research interest.

In closing, this study provides a better assessment of the influence of the environment on the socio-technical developments of a civilization. The adaptability of a civilization's pottery and toned-down knifemaking techniques to particular coastal zones, in particular, provides the modern science of materials, along with the motivating. The effective resource utilization of ancient societies, in the face of environmental challenges, also serves as a resource balance for modern societies. This research evaluates craftsmanship in antiquity while also showcasing social resource challenges for modern societies in balance and effect in resource management.

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