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Resonant Connections: The Stroke Rods of Badia Tedalda and the Musical Legacy of Guido d'Arezzo

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This article explores the acoustic and musical properties of aluminum stroke rods installed in Badia Tedalda, Italy, and their physical and conceptual connection to the medieval musical advances of the theorist Guido d'Arezzo. The stroke rods—aluminum rods with changing lengths supported at their midpoint harmonic node—create distinctive tonal qualities when stimulated by methods. The modern acoustic system establishes a bridge between contemporary sound exploration and medieval music theory. From the 11th century, Guido d'Arezzo's advanced music pedagogy with a revolutionary hexachord system that furnished a methodical approach to pitch organization.[1] This study illustrates, by analyzing the physical properties of the stroke rods and the mathematical principles underlying their acoustic characteristics and the pedagogical advances of Guido d'Arezzo, how both innovations represent milestone approaches to understanding and organizing sound. In what ways does the geographic placement of the stroke rods installation in the province of Arezzo create meaningful connections between medieval music pedagogy and contemporary acoustic exploration? The installation of the stroke rods at Monte Botolino in Badia Tedalda provides both a scientific and artistic demonstration of the region's musical tradition, connecting the possible source of modern musical notation with contemporary acoustic experimentation. This investigation adds to our understanding of how mathematical relationships in sound production have supplied musical theory across centuries while giving prominence to the cultural significance of this distinctive installation in the province of Arezzo.

Introduction

The relationship between physical properties and musical sound production has fascinated theorists, musicians, and scientists for millennia. Using string lengths from Pythagoras's experimentations to recent acoustic engineering, the mathematical foundations of music persist in providing a rich foundation for both artistic and scientific exploration.[2] This article examines a curious connection between the medieval music theory, in particular the pedagogy of Guido d'Arezzo, and contemporary acoustic innovation namely the stroke rods installation in Badia Tedalda, a municipality in the province of Arezzo. In this article there is an attempt to answer two questions. The first is how do the acoustic properties of the Badia Tedalda stroke rods reflect mathematical principles like those underlying Guido d'Arezzo's hexachord system?

There is an educational dimension that runs through both acoustic concepts of aluminum rods, (frequency relationships, harmonic series, and tuning systems), and

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the organizational structure of medieval hexachords. Leading us to the next question, what pedagogical parallels exist between Guido d'Arezzo's systematic approach to teaching pitch relationships and the experiential learning opportunities provided by the stroke rods as a physical manifestation of acoustic principles?

The installation of the musical instrument stroke rods is made up of aluminum rods varying in lengths fixed at the midpoints. This configuration produces distinctive harmonic properties when activated. The geographic and conceptual proximity to the birthplace of modern musical notation is what makes this installation particularly significant. The Benedictine monk Guido d'Arezzo, who revolutionized music education in the 11th century, developed a framework of pitch organization and notation that continue to influence Western music today.[3] The positioning of the stroke rods in the province of Arezzo constructs a symbolic continuum between medieval advancement and contemporary acoustic study.

As noted by Alberto Santucci, the mayor of Badia Tedalda, in a 1997 publication: "*Qui potremmo germarci, sancendo salvo prova contraria che le sette note musicali nacquero a Badia Tedalda*" (we may affirm, barring contrary evidence, that the seven musical notes were born in Badia Tedalda).[4] This statement, while potentially provocative with musicologists, nonetheless focuses on the cultural significance assigned to the region's musical culture and supports context for the interpretation of the symbolic importance of the stroke rods installation.

This article investigates the acoustic theories fundamental to the stroke rods, their installation in Badia Tedalda, and their conceptual relationships to Guido d'Arezzo's hexachord system. Examining these parallel advances removed by nearly a millennium, one can obtain comprehension into how organized approaches to sound organization have developed while maintaining foundational connections to acoustic principles.

Methodology

This study involves an interdisciplinary interpretive outline that mixes historical musicology, acoustic physics, and cultural geography to examine the connections between the Badia Tedalda stroke rods installation and Guido d'Arezzo's medieval musical innovations and teaching strategies. The methodological approach combines conceptual analysis with empirical observation, drawing on three primary investigative strategies.

Conceptual Analysis and Theoretical Framework

This article uses a comparative conceptual analysis to point out parallels between medieval music theory and contemporary acoustic design. The approach examines the mathematical foundations underlying both Guido d'Arezzo's hexachord system and the physical properties of the stroke rods, focusing on pitch organization, harmonic relationships, and pedagogical applications. By analyzing these systems through the lens of acoustic physics, vibrating rods and historical tuning systems, the

study establishes fundamental connections that go above chronological or geographic proximity.

The framework draws on interdisciplinary scholarship in organology (the study of musical instruments), sound studies, and music pedagogy. This context acknowledges that both historical and current practices in sound organization reflect what Born and Devine describe as the "materialization of musical thought"—the process by which abstract acoustic principles become embodied in physical or notational systems.[5] The analysis engages with current scholarship on inharmonic spectra and the phenomenology of acoustic perception, recognizing that the stroke rods' unique timbral properties challenge conventional understandings of pitch and harmonic organization.[6]

Empirical Documentation and Site-Specific Investigation

The practical element of this research involves direct observation and documentation of the stroke rods installation at Monte Botolino, beginning with the author's initial site visit in 1986 and the subsequent installation process. Physical measurements of the aluminum rods, including precise length dimensions (365.76 cm to 91.44 cm), mounting specifications, and activation methods, offer quantifiable data for acoustic analysis. The study applies established principles from vibration theory and materials science to demonstrate the rods' acoustic behavior, using the standard equation for transverse vibrations in fixed-free rods to predict frequency relationships.[7]

This site-specific methodology supports contemporary methodologies in sound studies that highlight the importance of environmental context in acoustic phenomena. As Bandt, Duffy, and MacKinnon argue, sound installations cannot be fully understood apart from their spatial and cultural settings.[8] The remote, mountainous location of the stroke rods significantly shapes both their acoustic properties, allowing sustained tones to dissipate naturally without architectural interference, and their cultural meaning as a contemplative, almost pilgrimage-like destination. Field documentation therefore extends beyond physical measurements to include consideration of how environmental factors influence the sonic experience and symbolic interpretation of the installation.

Source Choice and Historical Interpretation

The historical component utilizes a cultural-geographical approach to investigate the relationship between Guido d'Arezzo's theoretical work and the region of Badia Tedalda. Source choice prioritizes primary medieval texts, including Guido's *Epistola de ignoto cantu* and references in *Micrologus*, alongside secondary scholarly literature from musicology, medieval history, and music theory. The study examines chronological references to Guido's movements, particularly the Latin phrases "a finibus septentrionalibus" and the distinction between "a finibus" and "extra finibus", to evaluate the possibility of his residence in Badia Tedalda.

This approach acknowledges the interpretive nature of historical reconstruction while maintaining scholarly rigor. Rather than making authoritative historiographical claims, the methodology treats the geographic connection as a culturally significant context for understanding how communities construct musical heritage. This perspective uses recent work in cultural geography and heritage studies, particularly

research on how places develop identity through associations with historical innovations.[9] As Watkins demonstrates in her analysis of medieval music transmission, the relationship between geographic location and theoretical development often involves complex networks of patronage, institutional support, and environmental influence that resist modest documentation.[10]

The incorporation of contemporary resources in acoustic physics, organology, and sound art confirms that the analysis of the stroke rods reflects current scientific understanding. Sources were selected to provide authoritative perspectives on vibration theory (Fletcher and Rossing), historical tuning systems (Duffin, Lindley), medieval music pedagogy (Pesce, Busse Berger), and contemporary sound installation practices (LaBelle, Born). This multi-disciplinary source base facilitates the study to bridge historical musicology and contemporary acoustic science, regarding both as equally valid approaches to understanding the organization and perception of sound.

Limitations and Interpretive Boundaries

This study recognizes several methodological limitations. The historical connection between Guido d'Arezzo and Badia Tedalda, while supported by textual evidence and geographic logic, remains interpretive rather than conclusively documented. The acoustic analysis of the stroke rods, though grounded in established physics, relies on theoretical modeling rather than comprehensive spectral analysis of recorded performances. Also, comparative context necessarily emphasizes certain aspects of both systems, mathematical relationships, pedagogical functions, systematic organization, while underemphasizing others, such as the aesthetic and devotional contexts of medieval music or the contemporary art-world positioning of sound installations.

These limitations are acknowledged not as weaknesses but as fundamental qualities of interdisciplinary interpretive research. The article's value lies not in definitive proof of direct historical causation but in informative meaningful resonances (conceptual, mathematical, and cultural) that connect diverse historical moments in the enduring human expansion of organizing and understanding sound.

Historical Structure and Setting

Musical Legacy of Guido d'Arezzo

During the early 11th century, Guido d'Arezzo (c.991-1033) changed musical pedagogy. He delivered practical methods that addressed the problems of learning music by rote. His methods dealt with the practical problems in music learning and practice during a time when melodies and performance practices were passed on primarily with an oral tradition.[11] Staff notation, solmization syllables, and the hexachord system using various positions of the human hand are some of his revolutionary contributions.

The visual representation of notation with clearly defined lines and spaces gave a strong system of reading music that has not been previously seen.[12] This

development of Guido assisted an accurate way of learning melodies and sped up the learning process for singers. The well known "Hymn to St. John", *Ut queant laxis*, became a base for Guido's solfege system. The beginning syllables of each entrance or phrase—ut, re, me, fa, sol, la—provided singers with a structure for sight-singing.[13] In Claude Palesca's Music and Ideas in the Sixteenth and Seventeenth Centuries, he argues that this system is, "the single most important innovation in Western music pedagogy before the modern era."[14]

The hexachord arrangement demonstrated Guido's efficient method to organize pitch intervals and relationships among them. Overlapping six-note scales became his development.

1. *Hexachordum naturale* (C-D-E-F-G-A)
2. *Hexachorum durum* (G-A-B-C-D-E)
3. *Hexachordum molle* (F-G-A-Bb-C-D)

By utilizing these three intersecting six-not scales, these hexachords contribute to the same core organization with the semitone, half step, continuously appearing connecting the third and fourth degrees, mi-fa. This organization gave vocalists an abstract structure for recognizing the pitch intervals contained within the modes of medieval music through a method called "mutation," where singers would move among hexachords as a melody passage traversed through different ranges.[15] The common implementation throughout Europe of this system is well documented and extensive in manuscripts from this period validating the practical implementation of Guido d'Arezzo's system.[16]

The work of Guido d'Arezzo profoundly changed music learning by delivering systematic processes for understanding and reproducing musical pitch. These innovations remain and impact contemporary music theory and pedagogy. As Thomas Kelly states, "Guido's practical systems allowed musicians to conceptualize sound in ways previously impossible, transforming abstract aural experiences into concrete, teachable concepts."[17]

Stroke Rods of Badia Tedalda

In 1986, the author visited Monte Botolino in the municipality of Badia Tedalda in the province of Arezzo, an installation of stroke rods was proposed to then-mayor Guiliano Vittori Bochicchio. The mayor eagerly approved the project while immediately identifying the connection between this modern acoustic installation and the area's association with Guido d'Arezzo. Bochicchio's enthusiastic endorsement embodies a significant illustration of civic engagement with both historic legacy and modern aural art, a movement that Herber and Kertz-Welzel classify as all the time more momentous in cultural preservation efforts.[18]

The stroke rods installation consists of 24 aluminum rods of varying lengths, with the longest measuring 365.76 centimeters and the shortest 91.44 centimeters. These rods are fixed, heliarc welded to a solid spine of aluminum at their midpoints (182.88 and 45.72 respectively and progressively)—a significant harmonic node—which results in pure and unique acoustic properties when the rods are actuated. The stroke

rods are played/activated by using cotton gloves impregnated with pulverized rosin dust. When a performer strokes the rods, the friction initiates vibrations in the aluminum creating very long sustained tones with distinctive timbral qualities.[19] The closest resemblance of the aural experience is to the glass harmonica developed in the 18th century, but the resulting sound is very different and the physical properties of vibrating glass and vibrating rods hold significantly different results.[20]

By suppressing the fundamental frequency, a result of the fixation points at the middle of each rod, the distinction of this installation is acoustically unique. The experience of the listener is shaped by hearing the upper harmonics beginning with the fourth harmonic, octaves above the silenced fundamental. Depending where and how the rod is stroked, the higher partials are heard. This phenomenon has been explored in depth by researchers investing inharmonic spectra[21] and creates a unique sonic experience where the perceived pitch relationships differ from conventional musical instruments.

Accessible only by foot rather than by vehicle, the installation's location atop a mountain near Monte Botolino carries both practical and symbolic significance. The site's remoteness demands a deliberate physical journey, fundamentally shaping the visitor's encounter with the work. This inaccessibility functions on multiple levels: practically, it ensures isolation from mechanical noise and urban interference; symbolically, it sets the installation as a destination requiring effort and intention, transforming the approach itself into part of the aesthetic experience. As described by Shafer, the open-air environment of this location permits the lasting tones to resonate liberally without the intrusion of enclosed spaces, a consequence that aligns with modern acoustic ecology.[22] Symbolically, the placement of the installation in the province of Arezzo connects it to the origin of organized music notation, forming a conceptual bridge between medieval novelty and contemporary acoustic.

Material Properties and Construction

The primary material used in the stroke rods installation is aluminum. This selection of aluminum is fundamental to its acoustic character. Recent research on aluminum rods used for sound production has demonstrated that aluminum's specific physical properties directly influence timbral qualities and sustain of generated tones.[23] Unlike denser metals such as steel or bronze, aluminum produces a distinctive brightness while preserving extraordinary resonance duration. Metal selection ensures both structural integrity for outdoor installation and uniform acoustic performance in seasonal temperature differences.

The heliarc welding technique represents a critical construction detail. This precision welding method creates molecular continuous joints between each rod and the central aluminum spine, eliminating the damping effects that other fasteners would introduce. The welds must be made with special care at each rod's exact midpoint, where displacement during vibration theoretically reaches zero. Deviation from this precise location would compromise the fundamental frequency suppression that defines the installation's unique acoustic signature.

The dimensional progression from 365.76 cm to 91.44 cm creates a carefully calibrated frequency spectrum. Using the standard formula for a rod fixed at its center

and free at both ends, the fundamental frequency varies with the inverse square of the length. This 4:1 length ratio translates to a 16:1 frequency ratio, spanning approximately four octaves of suppressed fundamentals. The corresponding midpoint fixation distances, 182.88 to 45.72 cm, ensure that each rod's vibrational node aligns perfectly with its midpoint.

Acoustic Phenomena and Harmonic Structure

The suppression of the fundamental frequency represents the installation's most significant acoustic innovation. When a rod vibrates while constrained at its nodal point, the fundamental mode cannot be produced. This is because the fixed center physically prevents the formation of the displacement pattern required for first-node vibration, which would otherwise generate the fundamental frequency. Instead, the rod vibrates at a higher node, producing a frequency approximately four times higher than the suppressed fundamental. The actual pitch relationship follows the harmonic series of a center-fixed rod: the audible tones begin at the second harmonic, approximately 2.756 times the fundamental, creating an unusual starting point for the overtone series.

This modal complexity generates what researchers call an "inharmonic spectrum." Recent work on inharmonicity in musical instruments established that unlike strings or air columns that produce integer-multiple harmonics, many instruments exhibit inharmonic partials with non-integer ratios, creating beating patterns and interference happenings that shift depending on which components sound simultaneously. Research published in 2024 on the evolution of inharmonicity in music confirmed that inharmonic spectra create distinctive timbral qualities that differ fundamentally from harmonic sounds, with psychoacoustic systems processing them differently.[24] The listener encounters a shimmering, evolving sonic texture as partials drift in and out of phase relationships, producing a "spectral instability", a quality rarely experienced in conventional instruments.

The excitation method—cotton gloves impregnated with pulverized rosin—introduces controlled friction along the rod's length. By not striking or plucking, this stroking technique allows the performer to introduce energy controlled and continuous into the vibrating system, sustaining tones for extended durations limited only by the performer's determination. A seminal 2000 study by Smith and Woodhouse on rosin usage revealed that the friction coefficient of rosin depends not only on sliding velocity but also on the contact temperature creating a broad frequency spectrum[25]. The particles of rosin construct microscopic grip and release cycles at approximately 200-2000 Hz, depending on stroke speed and pressure, exciting a broad spectrum of the rod's resonant nodes. The performer can emphasize different partials by varying stroke location: stroking near the free ends emphasizes higher modes, while stroking nearer the center (within the allowable distance from the node) emphasizes lower audible harmonics.

Environmental Acoustics and Spatial Experience

The mountaintop location changes the installation from a musical instrument into an acoustic phenomenon intimately attached to its environment. Sound behavior is altered at high altitudes. The slightly thinner atmosphere allows high-frequency sounds to travel farther, extending the installation's audible range. Additionally, remote mountain environments exhibit exceptionally low ambient noise, often below 20 dBA, creating conditions where even the softest tones from the stroke rods remain clearly perceptible. The installation's location is thus integral to its acoustic character rather than merely incidental.

A 2025 study on acoustic ecology noted that R. Murray Schafer and the World Soundscape Project examined how open-air environments permit lasting tones to resonate without the intrusion of enclosed spaces, creating unique relationships between sound, space, and perception[26]. The installation essentially uses the entire landscape as its resonant chamber. The physical effort required to reach the installation, ascending Monte Botolino on foot, creates a ritualistic characteristic to the experience. This pilgrimage-like approach establishes anticipation with audiences arriving in an intensified state of awareness, already attuned to their surroundings. The climb also guarantees smaller, more intimate audiences, transforming each activation of the stroke rods into a rare, special experience rather than casual entertainment. Inaccessibility functions as a filter, selecting individuals with genuine curiosity and commitment.

The physical act of stroking—requiring sustained arm movement, careful pressure, and rosin management—creates an intimate connection between human movement and acoustic outcome. Performers feel kinesthetic feedback through the gloves as vibrations transmit back through their arms, making their sensation literally connected to the rods' resonance. This tactile dimension transforms performance into a whole-body experience, suspending the boundary between player and instrument.

Geographic research on sound art from 2006 emphasized how site-specific works engage with environmental, sonic, cultural, and historical personalities of particular locations, creating what scholars describe as 'memoryscapes' through nuanced foldings of sound and spatial perception[27]. The relationship with natural soundscapes situates the stroke rods within acoustic ecological framework. The installation's tones become part of the existing sonic elements of wind, distant animal calls, rustling vegetation. The pure, sustained tones create an interaction with nature's irregular, transient sounds.

Acoustic Physics and Musical Structures

Physical Properties of Aluminum Stroke Rods

The acoustic properties of the stroke rods are derived from the physics of aluminum and the principles of vibrating fixed and free rods. High elasticity, low internal damping, and moderately low density, the properties of aluminum, make it particularly suitable for this application. Because of these properties, aluminum rods can

sustain vibrations with efficiency, producing pure tones with lengthy decay times. These attributes have been considerably recorded in research on percussion instruments.[28]

When the fundamental frequency is blocked because of this mounting design, fixed at its midpoint the location of an upper harmonic node, it stifles the rod from vibrating in its fundamental. Using this model, the rod vibrates in its higher harmonic nodes. For a rod at the length of L, the frequency of vibration is determined by:

$$f_n = (n^2\pi/2) \times \sqrt{(EI/\rho A)}/L^2$$

where:

- n is the node number (n = 1, 2, 3...)
- E is Young's modulus for aluminum
- I is the moment of inertia of the cross-section
- ρ is the density of aluminum
- A is the cross-sectional area
- L is the rod length

If one follows an inverse square relationship between length and frequency, an explanation of why shorter rods produce higher pitches while longer rods produce lower pitches is evident. The relationship of rods involves the square of the length unlike stringed instruments, where the frequency is inversely proportional to length, thus creating a different scaling pattern. This feature is crucial for understanding the novel tonal characteristics of the stroke rods. This characteristic has been analyzed in depth regarding instrument scaling researched by Hutchins and Benade.[29]

The technique used to excite the rod—stroking it with rosin impregnated cotton gloves—creates friction that activates the vibration along the length of the rod. By using this particular technique, a rich spectrum of overtones is activated that differs from the harmonic series that can be heard in vibrating strings, tubes, or air columns. The overtones of a vibrating rod result in an inharmonic series where the frequency ratios between partials are not simple integer multiples of the fundamental. In the recent research of Papich and Rainbow, they established that these inharmonic patterns could have noteworthy inferences for hearing pitch and its awareness and the tonal organization of pitch.[30]

Tuning Approaches and Harmonic Associations

The installation of the stroke rods in Badia Tedalda uses an arithmetic sequence of rod lengths unlike most conventional musical tuning systems. By using an arithmetic order, this methodology results in unique pitch intervals that are closely similar to Pythagorean tuning where the perfect fifth with a frequency ratio of 3:2 and perfect fourths with a frequency ratio of 4:3. This connection with Pythagorean theories generates a fascinating relation to ancient Greek theoretical practices that directly inspired medieval music theory.[31]

Guido d'Arezzo presented his hexachord system during the medieval period during which time Pythagorean tuning was widespread. This tuning system creates

pure perfect fifths and fourths but also produces an inconsistency when a circle of fifths is formed. The "Pythagorean comma" or the "wolf interval" is the discrepancy that results from these pure fifths and fourth if continued through the circle of fifths.[32] The natural acoustic properties of the stroke rods overtone production align with Pythagorean tuning where pure fifths and fourths are present. The measured consequences of these tuning systems have been considerably examined by Duffin determining how various historical methods to tuning indicate distinct concessions between mathematical integrity and practical musicality.[33]

The correlation between the stroke rods and the hexachord system of Guido d'Arezzo goes beyond geographic proximity to theoretical similarities in how both organize sound. Both the arithmetic tuning of the stroke rods and the arrangement of the hexachord engage with the harmonic series and mathematical connections between pitches, albeit in diverse disciplines. The hexachords of Guido d'Arezzo give a structure for the usage of the whole and half step associations in the diatonic scale, whereas the installation of the stroke rods physically exhibit mathematical associations through its structure and the resulting acoustic properties. Cohen discusses this correlation between mathematical thought and physical appearance that denotes a continuous and consistent line through the history of Western music theory.[34]

Both Fletcher and Rossing state, "Systems that organize pitch relationships invariably reflect some compromise between pure mathematical ratios and practical consideration for musical performance."[35] This compromise is represented manifest in the approaches in both Guido d'Arezzo's system and the stroke rods. Guido d' Arezzo shaped a pedagogical structure founded on existing musical practice and the stroke rods established a physical manifestation of mathematical associations in sound.

Assimilation of Medieval Theory and Contemporary Practice

Instructional Uses

The driving motivation for Guido d'Arezzo for initiating his hexachord system and the usage of a staff for notation was for instructional usage. His focus was to develop ways that would give singers a new way to learn new music quicker, more efficiently, and accurately. From his own writings in the *Epistola de ignoto cantu,* "After I had tried to teach choirboys with our antiphoner, at length Divine Grace was with us, and some of them learned to sing unknown chants so easily, after practicing with the monochord for three days, that they certainly amazed others, who scarcely manage to do even this much for a whole week."[36] His sensible view and approach to music pedagogy demonstrates what Busse Berger states as a foundational shift in medieval methods to musical knowledge teaching.[37]

Likewise, the pedagogical potential for exploring acoustic principles is significantly present with the stroke rods. The actual assembly of the instrument exemplifies the basic models of vibration theory while the activation of their sound demonstrates principles of harmonics and overtones in a real form. When used as a teaching tool, they permit a direct investigation with the variables that influence pitch, timbre, and resonance. An experiential approach to instruction of acoustics associates

itself with modern teaching theories that accentuate embodied understanding and multisensory encounter.

Tangible experiential learning occasions are presented by both innovations that transform conceptual acoustic theories into concrete understanding. The conversion of the abstract concept of relative pitch into an organized context with clear rules offered by Guido d'Arezzo's hexachords and the stroke rods shifting mathematical associations in acoustics into a physical object that can be manipulated and experienced directly are evidence of instructional perceptible experiential learning opportunities. Thompson notices that this realization of abstract principles acts as a commanding pedagogical approach that goes beyond historical periods.[38]

Systematic Advances to Sound Configuration

The connection to Guido d'Arezzo operates on many levels beyond geographic proximity. His innovations in musical notation—the staff, solmization, and the hexachord system—denoted radical abstractions that translated temporary sound into permanent visual symbols. The stroke rods perform a theoretical inversion: they convert abstract mathematical relationships (rod lengths, nodal points, harmonic ratios) back into physical sound. Both systems reconcile between the conceptual and the experiential, between theory and practice.

The hexachord structure of Guido d'Arezzo and the stroke rods both display methodical advances to the configuration of sound, notwithstanding unique fundamental objectives. Guido d'Arezzo's system was born out of the primary necessity for practical musical instruction and performance. The stroke rods installation provides an artistic and scientific purpose to the discovery of acoustic phenomena. Cook and Pettengill elaborate on the dual artistic-scientific function as a developing important trend in modern sound installations.[39]

The advancements of Guido d'Arezzo were revolutionary in that the codification of what had previously been learned through an oral practice. This visual representation of pitch relationships and a practice that conceptualized those relationships vocally proposed an apparatus that markedly improved music education. Haar observes these methodical advances embodied important steps in the advancement of Western music's distinguished notational and theoretical traditions.[40]

Similarly, the stroke rods organized acoustic principles building a physical installation wherein calculated connections in sound fabrication can be directly experienced. The lengths of the rods, based on an arithmetic sequence, creates a detailed set of pitch associations that can be comprehended and scrutinized through a filter of acoustics and music theory.[41] The installation illustrates what Born depicts as the "materialization of sonic theory"—physical indicators of fundamental physics principles of vibrating rods that is immediately experienced rather than intellectualized.[42]

The resonant connection between both the work of Guido d'Arezzo and the stroke rod installation exemplifies the evolving understanding while holding fast to the fundamental acoustic principles. In the words of Benson, "The history of music theory reflects an ongoing dialogue between mathematical ideals and practical musical considerations."[43] These two moments in an ongoing dialogue are represented in both Guido d'Arezzo's system and the stroke rods. As additionally expanded by

Christenson, the historical continuity of theoretical innovations on the continuum of Western musical history have steadily connected the opposition between abstract scientific theories and practical musical application.[44]

Cultural and Historical Importance

Musical Legacy of Badia Tedalda

The approach taken in this article is an investigation of the geographical relationships between the work of Guido d'Arezzo and the area of Badia Tedalda as seen via a cultural-geographical viewpoint rather than the usage of conventional historiographical methodology. Recognizing and respecting the historic importance of Guido d'Arezzo's musical systems and notational advances, this investigation centers on the possible connection with his theoretical constructs and his potential residence in Badia Tedalda. Without claiming expertise in historical scholarship, the method used here investigates how the geographical setting may have shaped in some way the establishment of his musical ideas.

Guido d'Arezzo was known by many names some of which were Guido Aretinus, Guido Monico, and Guido Aretino. His innovations became known throughout the region including Rome. Under the command of Pope John XIX, he was asked to travel to Rome to expound on his novel pedagogical methods. It was during this stay in Rome that Guido fell ill. It is documented that he suffered from the intense Roman summer heat. Bishop Teodaldo, a close friend and patron of Guido Aretino, became aware of the monk's advancing health problems and enabled his departure from Rome perhaps to the abbey at Badia Tedalda.

Historians and scholars have speculated alternative locations that include the Abbey of Pomposa and the Hermitage of Fonte Avellana but there is compelling evidence that presents a case that indeed Guido Aretinus made the trip to Badia Tedalda. As Santucci observes, modern interpretation of ancient writings suggests, "*gli faceva rimpiangere I suoi freshi luoghi alpestri*" (made him long for his fresh alpine places).[45] One source explicitly states, "nobis alpestribus" (for us the alpine people). This particular Latin phrase perhaps is a direct reference to Monte dell'Alpe della Luna, situated within the regional boundaries of Badia Tedalda, thus imaginably backing up the claim that Guido Aretinus took refuge and continued his analytical work in this place.

Don Gerico Babini's writings, quoted in Tommaso Regi's *Autopsia della vita di un Genio: Guido d'Arezzo*, gives even more evidence that supports the Badia Tedalda proposition. The text offers even more geographical evidence that could confirm Guido Monico's presence in this location:

> Guido Monoco fu esiliato "afinibus septentrionalibus". Stendete una carta geografica sul tavolo e, con il dito da Arezzo, andate verso il settentrione, dove ai confine, ossia entro i confine della Diocesi, troverete Badia Tedalda.
> Infatti non dice "extra finibus", ma "a finibus" cioè non fuori dei confine, ma sino ai confine della Diocesi. (Guido Monaco was exiled "to the northern borders." Spread out a geographical map on the table and, with your finger from Arezzo, go toward the north,

> where at the border, that is within the borders of the diocese, you will find Badia Tedalda. Indeed, he does not say "extra finibus"—outside the borders, but "a finibus"—to the borders; that is, not outside the borders, but up to the borders of the Diocese.)[46]

Guido Monaco was exiled "to the northern borders" (*a finibus septentrionalibus*). The directions of Don Gerico indicate that if you spread a geographical map on a table and trace with your finger from Arezzo to the north, within the borders of the diocese, one will encounter Badia Tedalda. Notably, the writing does not indicate outside the borders, "*extra finibus*" but rather "*a finibus"* within the borders of the diocese.

This subtle distinction that is linguistically presented is crucial in piecing together the location of Guido d'Arezzo. This Latin phrase "*a finibus septentrionalibus*" indicates an expulsion to the northern border of the diocese rather than beyond the jurisdiction of the diocese. This argument establishes the notion that placed at the northern margin of the diocese of Arezzo, that Badia Tedalda was indeed the place of exile for the monk Guido d'Arezzo. The usage of the word "exile" needs further research as it may mean a chosen departure rather than a disciplinary expulsion.

The statement that "the seven musical notes were born in Badia Tedalda" asserted by Alberto Santucci, within this historical context, mirrors the cultural significance connected to the area of Badia Tedalda's connection with Guido d'Arezzo. Even though he has been associated with the city of Arezzo and not Badia Tedalda, the documented indication regarding the pine forests that are part of Badia Tedalda that is within the province of Arezzo, suggests a concrete regional connection to this musical heritage. Leyshon et al., cultural geographers, have studied how communities develop cultural identities by means of claim-making association with historical innovations.[47]

This social legacy and current significance putting Guido Monico in the abbey in Badia Tedalda is important. An acknowledgement of this legacy and an extension of it in modern acoustic exploration is manifest in the installation of the stroke rods on Monte Botolino within the boundaries of Badia Tedalda. By placing this sound installation in the same region where Guido Monico may have developed his progressive musical theories, a dialogue is initiated between past and present viewpoints considering the cognition and arrangement of sound. Kirshenblatt-Gimblett contends that installations like the stroke rods achieve not only artistic goals but also act as "heritage productions" that strengthen local cultural identities.[48]

The location of the installation in a remote area of Monte Botolino that is unreachable to the public unless people actually forge up the hillside, adds yet another element to its regional importance. Very different from other instruments or public sound-art installations, the stroke rods command a planned effort to experience, making an almost pilgrimage-like expedition that highlights their special status as a scientific demonstration and artistic declaration. This three-dimensional seclusive area resonates with a monastic setting where Guido d'Arezzo might have discovered refuge and inspiration, confirming a parallel between medieval contemplative customs and contemporary sound discovery. An environmental trait of the stroke rod installation supports what LaBelle sees as a growing importance of site-specificity in modern sound art.[49]

Connecting Historic Advances

The connection to Guido d'Arezzo operates on multiple levels beyond simple geographic proximity. Guido's innovations in musical notation, the staff, solmization, the hexachord system, represented radical abstractions that changed ephemeral sound into permanent visual symbols. The stroke rods perform a conceptual inversion: they convert abstract mathematical relationships of rod lengths, nodal points, harmonic ratios, back into physical sound. Both systems mediate between the conceptual and the experiential, between theory and practice.

The stroke rod installation on Monte Botolino in the municipality of Badia Tedalda, functions as a connection between medieval musical advances and modern sound exploration. This connection is not only symbolic but substantive—both Guido d'Arezzo's system and the stroke rods work within the fundamental principles of acoustic organization and perception. DeNora takes note that such material ties among chronological points in time serve significant cultural purposes in the advancement and permanency of musical practice throughout time.[50]

Musicologist Richard Taruskin notices that the musical theory of the medieval period, whereas regularly depicted as principally hypothetical, in fact had very realistic relevance in pedagogy and performance. The work of Guido d'Arezzo illustrates this practical direction because his theoretical developments were specifically designed to help musical practice.[51] Likewise, the stroke rods, even though being abstractly sophisticated in their acoustic design, set up a perceptible, physical involvement of sound that surpasses pure theory. The intercourse of theoretical complexity with concrete usage illustrates what Small terms "musicking"—music that is something people do rather than only conceptualize.[52]

The stroke rod installation in Badia Tedalda is representative of a continuum within the tradition of novelty that mixes the understanding of theory and the application of practice. Recognizing the connection between medieval and contemporary methods to sound, the stroke rods shed light on how basic acoustic principles of physics surpass historical epochs as their applications change to reflect shifting artistic and scientific knowledge. Bohlman claims that these continuities are crucial for the cognition regarding the evolution of musical cultures from period to period.[53]

A 2025 study on place-based virtual reconstruction of heritage soundscapes at Korean UNESCO sites demonstrated that soundscapes create culturally resonant experiences by mixing ritual, architectural, natural, and visitor-related sonic layers that convey intangible cultural value.[54] The remote mountaintop placement evokes monastic traditions of mountain hermitages in Italian religious history, areas where contemplation took place in deliberate isolation from worldly concerns. The stroke rods installation renovates this tradition into secular sonic meditation, making available what cultural theorist Michel Foucault might term as "heterotopia", a space that exists outside normal cultural expectations, governed by its own internal logic and temporal structures.[55]

Conclusion

The stroke rods installation on Monte Botolino in the region of Badia Tedalda and the hexachord system of Guido d' Arezzo, even if disconnected almost by a thousand years, establish corresponding methods with the organization of sound and our understanding and experience. These advances display how mathematical associations in acoustics can be coupled for both artistic and pedagogical uses. These innovations initiate structures that make hypothetical acoustic theories concrete and accessible.

The substantive properties of the aluminum stroke rods that are heliarc welded at their midpoints silencing the fundamental frequency and highlighting upper harmonics, construct an exceptional experience that illustrates the laws of vibration and harmonics. Likewise, Guido d'Arezzo's hexachord innovation offers a structure for insights into the relationships among pitches that revolutionized medieval music instruction and set tenets that continue to inspire Western music theory.

The installation of the stroke rods in Badia Tedalda, inside the province of Arezzo, generates a strong symbolic and conceptual connection between these advances. This resonate connection surpasses plain geographic immediacy and sheds light on how methodical techniques to comprehend sound have progressed while preserving connections to elementary acoustic theories.

This inquiry has analyzed the physical acoustic properties of the stroke rods, their installation in Badia Tedalda, and their theoretical connections to Guido d'Arezzo's innovation with the hexachord. It is in this analysis that one can gain understanding of the mathematical connections into sound fabrication that has nourished music theory for centuries, as also grasping the cultural importance of this installation in an area historically connected with musical innovation.

The stroke rods of Badia Tedalda become evidence as both scientific exhibition and artistic gesture—a modern tribute to the methodical approach to sound forged by people such as Guido d'Arezzo. It is in this way that resonant connections represent the enduring dialogue between science and art that has embodied human encounters with sound over all history.

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