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Jan Nyssen

jan.nyssen@ugent.be

Ghent University

Tesfaalem Ghebreyohannes

Mekelle University

Yonas Meheretu

Mekelle University

Wolbert Smidt

Mekelle University

Seifu Gebreslassie

EthioTrees project

Michael Gervers

University of Toronto

Sofie Annys

Ghent University

Frances Williams

Adelaide University

Miruts Hagos

Mekelle University

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Religious communities as custodians of geoheritage: towards a culturally grounded approach to geotourism in Dogu'a Tembien (Tigray, Ethiopia)

Jan Nyssen^{1,2,*}, Tesfaalem Ghebreyohannes², Yonas Meheretu^{4,5}, Wolbert Smidt^{6,7}, Seifu Gebreslassie⁸, Michael Gervers⁹, Sofie Annys¹, Frances Williams¹⁰, Miruts Hagos¹¹

¹Department of Geography, Ghent University, Ghent, Belgium (jan.nyssen@ugent.be)

²Department of Geography, Environment and Population Studies, Mekelle University, Mekelle, Tigray, Ethiopia

⁴Department of Biology, Mekelle University, Mekelle, Ethiopia

⁵Department of Wildlife, Fish and Environmental Studies, Swedish University of Agricultural Sciences, Uppsala, Sweden

⁶Faculty of History and Cultural Studies, Mekelle University, Mekelle, Tigray, Ethiopia

⁷Research Centre Ancient South Arabia and Northeast Africa, Friedrich Schiller Universität Jena, Germany

⁸EthioTrees project, Mekelle, Tigray, Ethiopia

⁹Department of Historical and Cultural Studies, University of Toronto, Scarborough, Canada

¹⁰Department of Earth Sciences, Adelaide University, Adelaide, Australia

¹¹Faculty of Mining and Geosciences, Mekelle University, Mekelle, Tigray, Ethiopia

CRediT authorship contribution statement

Conceptualization: JN, MH, FW, WS; Methodology: JN, YM; Investigation: JN, TG, SG, MG; Formal analysis: JN, YM, SA; Data curation: JN, MG; Resources: TG, SG; Writing – original draft: JN, WS, MH; Writing – review & editing: All authors; Visualization: JN, SA; Supervision: JN; Project administration: JN.

Abstract

Geotourism integrates geological heritage with ecological and cultural dimensions, yet its interaction with living religious systems remains insufficiently explored. This study examines the relationship between geotourism and Orthodox Christian practices in Dogu'a Tembien (Tigray, northern Ethiopia), a region characterised by extensive geoheritage and a dense network of active sacred sites. Based on long-term interdisciplinary fieldwork, the paper combines participatory observation, site documentation, and qualitative analysis of geotourism opportunities and challenges to analyse synergies and tensions between development and religious life. A central case study is the previously undocumented rock-hewn church of Debre Sema'it Yohannis, illustrating the close integration of geological setting, architectural practice, and spiritual function. More broadly, sacred forests, holy water sites, caves, pilgrimage routes, and environmental tales demonstrate how geomorphological features are embedded within religious meaning systems and actively conserved through Orthodox religious practice. Annual church patronal feasts (*'ametu*) further show that domestic tourism already follows established pilgrimage networks that could provide a foundation for future geotourism. The study also identifies challenges related to access, gender norms, visitor behaviour, conservation practices, perceptions of time and landscape, and the interpretation of sacred sites. The findings indicate that successful geotourism depends on community engagement, culturally

sensitive interpretation, visitor preparation, and interpretative signage that combines scientific and spiritual narratives. The study demonstrates that Orthodox religious practice functions not only as an intangible cultural dimension of geoheritage but also as a long-term mechanism of geoheritage stewardship. Recognising this role provides a basis for geotourism that supports both conservation and community livelihoods.

Keywords: rock-hewn churches, church forests, community participation, holy water, pilgrimage, *tsebel*, living religious systems

1. Introduction

Geotourism is a form of nature-based tourism centred on landscapes and geology that integrates abiotic, biotic, and cultural components, recognising that geological heritage is best understood within its ecological and cultural context (Hose 2012; Newsome and Dowling 2010). In Tigray (northern Ethiopia), Orthodox Christianity constitutes a dominant cultural framework that strongly shapes the perception and use of the natural environment (Hendrie 1999), thereby enhancing the visibility and significance of geological features. Here, “Orthodox Christianity” refers to the Ethiopian Orthodox Tewahedo Church, an Oriental Orthodox Church distinct from Eastern Orthodox and Roman Catholic traditions. In older European literature, it was sometimes imprecisely referred to as “Coptic”, reflecting its historical ecclesiastical dependence on the Coptic Patriarchate of Alexandria, which continued until the establishment of an independent Ethiopian patriarchate in 1959. The Ethiopian Church developed its own long-standing theological, liturgical, and cultural traditions, deeply embedded in Ethiopian history and society (Binns 2016; Chaillot 2002; Crummey 2000). Its theology and liturgy are rooted in Ge’ez, an ancient Semitic language no longer used in daily communication but preserved as the principal liturgical and scholarly language of the Church. Religious practice emphasizes sacred landscapes (churches, forests, springs, and mountains) as integral to spiritual life, embedding religious meaning within the physical environment (Finneran 2009, 2012; Kaplan 1984). Following the Tigray War (2020-2022+), ecclesiastical structures in the region have undergone partial reorganisation, with Tigray Church authorities functioning with greater autonomy from the national leadership of the Ethiopian Church, although this institutional situation continues to evolve (Anonymous 2024; Istratii and Laamann 2024).

Contemporary geotourism increasingly emphasises sustainable development and local livelihoods while recognising the cultural values associated with geological and ecological features (Hose 2012; Newsome and Dowling 2010; UNESCO 2021). In rural Tigray, where Orthodox Christianity is deeply embedded in everyday life and shapes relationships with the landscape, geotourism therefore needs to engage explicitly with religious beliefs and practices. This paper examines this interaction across sacred geosites (rock-hewn churches, monasteries, sacred forests and springs) in the Dogu’a Tembien district and the wider Tigray region. The study builds on longstanding interdisciplinary research, conducted through multiple field campaigns on physical geography, geology, and socio-cultural context. This work initially supported the preparation of a comprehensive geoguide to the district (Nyssen et al. 2019), and later exploratory work towards a potential UNESCO Global Geopark designation (Henriques and Brilha 2017; Patzak and Eder 1998).

The most widely known Ethiopian rock-hewn churches are those of Lalibela (See Figure 1 for the locality of all places mentioned), carved into scoriaceous basalt (Asrat and Ayallew 2011). However, the greatest concentration occurs further north, in the central and eastern parts of the Tigray region, where more than 120 churches have been identified (Asrat 2002; Bussert and Nyssen 2019; Plant and Buxton 1970).

The landscape of this region is largely controlled by a gently dipping Mesozoic sedimentary succession conformably overlying the Enticho Sandstone of Palaeozoic fluvio-glacial origin (Online Supplementary Data S1). Resistant sandstone and limestone units form extensive plateaus and mesas, separated by steep escarpments and deeply incised valleys (Bosellini et al. 1997; Bussert 2010; Bussert and Nyssen 2019). These sedimentary units are locally overlain by Cenozoic basaltic lava flows and associated intrusive rocks (Hagos et al. 2019). These geological contrasts created the cliff faces, ledges, and elevated viewpoints that later became characteristic settings for rock-hewn churches and monastic settlements. The churches are typically carved into the cliffs bordering sandstone mesas (*imba* in Tigrinya), with individual *imbas* often hosting multiple sites. Although well known within the Ethiopian Orthodox tradition, their setting within the rugged mountain terrain long hindered access by outsiders and they remained largely unknown outside Ethiopia until the seventeenth-century account of Manuel Barradas (1634/1996), and scientific expeditions from the 19th century onwards (Gerster 1972; Lamesa et al. 2022; Lefebvre 1845; Plant and Buxton 1970; Sauter 1976; Yosef 1969). Most churches are excavated in the thick, cliff-forming Adigrat Sandstone, which provides favourable settings for monastic occupation and the creation of rock-hewn churches (Bussert and Nyssen 2019; Gervers 2006), while a smaller number occur in the older Enticho Sandstone (Figure 2).

*** Figure 1 ***

*** Figure 2 ***

Within Tigray, the rock-hewn churches are grouped into four main geographical clusters, including around Atsbi, Sinqat’a-Adigrat, Hawzen-Ger’alta, and Tembien (Asrat 2002; Bussert and Nyssen 2019; Klyuev and Semenova 2020). A fifth cluster occurs in the central zone of neighbouring Eritrea, forming part of the same cultural and religious tradition (Breton 2016). Tigray and the adjacent highlands of Eritrea share long-standing Tigrinya-speaking cultural, ecclesiastical, and historical ties rooted in the Kingdom of Aksum, although political divisions between Tigrinya-speaking provinces are longstanding and became a disruptive modern border in the case of Eritrea (Erlich 1982; Smidt 2010; Woldemariam and Gebreluel 2025).

The chronology of the rock-hewn churches remains uncertain. On architectural and stylistic grounds, many are assigned to the 13th-15th centuries, while some may be considerably earlier, perhaps as early as the 10th century (Lepage and Mercier 2005; Phillipson 2009; Plant and Buxton 1970). Ethiopian ecclesiastical tradition attributes the oldest religious sites with the arrival of the Nine Saints from the eastern Mediterranean in the late fifth or early sixth century. Building upon the earlier Christianisation of the Kingdom of Aksum by Frumentius (Abba Selama), these monks are traditionally credited with establishing monasteries in remote and inaccessible locations and with promoting the spread of Christianity throughout the northern Ethiopian highlands (Hable-Selassie 1972; Phillipson 2012). This tradition continues today, with new rock-hewn churches still being created (Gervers and Philipp 2015-2026; Lamesa et al. 2022). Although architectural forms vary, most

churches follow a basilica layout, with three naves, a vestibule, pillars, arches, and high ceilings. Interiors are often decorated with carved elements and painted frescoes (Gerster 1972). Nearly all these medieval churches remain active places of worship and continue to host Orthodox ceremonies (Bussert and Nyssen 2019).

The present paper examines the interaction between geotourism and living Orthodox Christian practices, using Dogu'a Tembien (the uplands of the wider Tembien region) as a case study of a region with high geoheritage value but limited international tourism. Particular attention is given to the previously undescribed rock-hewn church of Debre Sema'it Yohannis. Its selection was not based on an assumption that it is representative of Tigrayan rock-hewn churches, but on the unusual opportunity it provided to follow the emergence of a potential geotourism site almost from the beginning. This included locating and documenting the church, establishing dialogue with the local community and clergy, negotiating access, and participating in the local 'ametu pilgrimage. The process provided insights into both the opportunities and sensitivities involved in developing geotourism around a living sacred site. The study further explores how similar interactions occur across a wider range of sacred geosites, including churches, holy water sites, caves, and pilgrimage routes, through an exploratory qualitative assessment of opportunities and constraints for future geotourism development (Gössling and Scott 2012; Swart et al. 2004).

Methodologically, the research is grounded in long-term field observation and repeated engagement with local communities, religious leaders, and landscapes in Dogu'a Tembien. Observations included rock-hewn churches, sacred forests, holy water sites, caves, and pilgrimage routes, complemented by informal discussions with local stakeholders and pilgrims (Nyssen et al. 2019). The approach is iterative and reflexive, combining field observation, cross-disciplinary interpretation, and local knowledge. Rather than viewing geological features solely as attractions for visitors, we examine religious communities as long-term custodians of geoheritage and consider how their stewardship, knowledge, and practices shape the possibilities and limits of geotourism. We argue that centuries of Orthodox stewardship have conserved sacred geological sites, while also preserving forests, cultural landscapes, and associated intangible heritage, thereby creating conditions for contemporary geotourism.

2. Synergies between geotourism and Orthodox religion

2.1 Debre Sema'it Yohannis as an example of Tembien's rock-hewn churches

Rock-hewn churches are a major point of convergence between geotourism and Orthodox religion in Tigray, attracting both pilgrims and visitors. While official inventories list approximately 120 such churches, field observations indicate that many remain undocumented; in Dogu'a Tembien alone, at least ten previously unrecorded sites were identified by local communities (Klyuev and Semenova 2020; Nyssen et al. 2019). Although every Tigrayan rock-hewn church is unique, they share numerous characteristics. Debre Sema'it Yohannis is examined here as an illustrative case because its recent documentation enabled us to follow, almost from the beginning, how a little-known sacred site may develop into a potential geotourism destination.

The Adigrat Sandstone reaches considerable thickness in the Debre Sema'it area (Bosellini et al. 1997) (Figure 2), where the church is carved into a narrow pinnacle, occupying almost the entire

summit and leaving only about one metre of rock between the interior and the cliff edge (Figure 3). Access requires climbing to the summit and traversing a narrow path along a steep drop. The church is dedicated to John the Apostle, locally known as Yohannis Welde Negodguad ("John Son of Thunder"; Mark 3:17).

*** Figure 3 ***

Its architecture broadly dates from the late medieval to early modern period, although more precise dating remains uncertain (Lepage and Mercier 2005; Phillipson 2009). Detailed description of the church in Online Supplementary Data S2.

The church was abandoned for several centuries and used as a cave until its reconsecration in 1975, following resettlement in the area. Its present form reflects both historical interpretation and geomorphological processes. Local tradition attributes damage to the western end of the church to a catastrophic lightning event during the period of imam Ahmad al-Ghazi, popularly called "Gagn Ahmed", whose military campaigns affected large parts of the Ethiopian highlands during the sixteenth century. Geomorphological evidence suggests partial toppling of the sandstone pinnacle, possibly facilitated by structural weakening during excavation (Figure S5; Online Supplementary Data S3). At a lower position on the same pinnacle, local craftsmen are currently excavating a new church, continuing the rock-hewn tradition (Philipp 2020).

The site also illustrates how geological features become integrated into religious practice: resonant stones are used as bells near the church, exploiting local lithology for acoustic purposes (Figure 4; Hagos et al. 2019). Together, these features illustrate the close interaction of geological setting, religious practice, local knowledge, and continuing landscape modification that underpins the geotourism potential of Tigray's rock-hewn churches.

*** Figure 4 ***

Other underground spaces, including caves and tunnels, provide further examples of the interaction between geology, religion, and human ingenuity in Tigray. Some have long served religious purposes, while others have been excavated for access, shelter, warfare, or other practical uses; their continued excavation and use demonstrate that rock-hewing remains a living tradition (Kaplan 1984; Phillipson 2009). Examples including the Zeyi cave (Nyssen et al. 2020b), the headquarters of the Tigray People's Liberation Front (TPLF) excavated in the 1980s (Bussert and Nyssen 2019), and the Siquerto foot tunnel (Nyssen et al. 2020a) illustrate how natural and artificial underground spaces have become integrated into the cultural landscape (Online Supplementary Data S4). The continued excavation and use of rock-hewn churches (Figure 5) demonstrate that rock-hewing remains a living tradition in Tigray (Gervers and Philipp 2015-2026; Lamesa et al. 2022).

*** Figure 5 ***

2.2 Sacred forests and religious environmental stewardship

Most churches in Tigray are typically surrounded by sacred forests (Figure 6), ranging from small groves to forests exceeding 1 km² in area (Aerts 2019; Aerts et al. 2016; Binns 2016). These forests represent remnants of original Afromontane vegetation and are deliberately protected through

religious practices, contributing to soil stabilization, microclimate regulation, and biodiversity conservation.

*** Figure 6 ***

The sacred forests function as ecological sanctuaries protected by faith, providing habitats for native biodiversity while retaining profound spiritual significance. Their conservation reflects the Ethiopian Orthodox distinction between sacred and worldly space, whereby the church compound and its surrounding forest are regarded as consecrated landscapes (Gebreslassie 2014). Maintained through community stewardship rather than statutory protection, church forests serve as reservoirs of native plant species, seed sources for surrounding landscapes, and habitats for birds, pollinators, and other wildlife in an otherwise intensively cultivated environment (Aerts et al. 2016; Klepeis et al. 2016). Comparable sacred church forests occur throughout the Ethiopian and Eritrean highlands, reflecting a shared Orthodox Christian tradition of environmental stewardship.

For geotourism, these forests enrich the visitor experience by combining geological heritage with opportunities to observe characteristic highland vegetation, birds, and other elements of Ethiopia's natural heritage (Aerts et al. 2019; Newsome and Dowling 2010). Orthodox respect for nature extends beyond forests to rivers, springs, and wildlife. For example, doves, symbolizing the Holy Spirit, are sometimes provided with nesting boxes incorporated into homestead walls (Figure 7), reflecting a worldview in which nature is regarded as divine creation deserving care.

*** Figure 7 ***

2.3. Holy water

In Tigray, numerous springs and small streams, often located in remote or scenic settings, are regarded as sacred and believed to possess healing properties for both physical and spiritual ailments. Their significance for geotourism derives partly from the geological and geomorphological settings in which they occur: springs are often associated with limestone formations, fractures, and other pathways through which groundwater reaches the surface, while woodland, rugged topography, and flowing water contribute to the attractiveness of these landscapes. At the same time, these are living religious sites whose primary function is healing and worship rather than tourism. Their potential geotouristic interest therefore lies in the possibility of interpreting the interaction between geology, water, ecology, and Orthodox religious practice without displacing their religious function (Finneran 2009).

Pilgrims travel from distant villages, sometimes on foot for hours or even days, both on major religious feast days and throughout the year to seek healing, often accompanied by relatives who provide practical and spiritual support. Many are women as well as men, seeking relief from a wide range of physical and mental ailments. Some come after biomedical treatment has proved unsuccessful, while others visit holy-water sites alongside ongoing medical care, reflecting the complementary roles of religious and biomedical healing in local health-seeking practices (Gebremedhin et al. 2024). Holy water (*may ch'ellot*, variant: *minch'ellot*) is commonly combined with soil from the sacred site (*tsebel*, "sacred substance") before it is taken home or used in healing rituals (Gori 2010). According to local belief, it is this blending of water and sacred earth that conveys the site's healing power (Schirripa 2010). In everyday usage, however, *tsebel* also refers to the holy

water itself, reflecting the close conceptual association between the sacred spring and the consecrated ground from which it emerges (Gori 2010).

For example, the Dabba Hadera spring, situated within a dense woodland, emerges from bedrock and forms a small stream. A stone wall with multiple openings has been constructed to create natural showers, allowing visitors to bathe in the sacred water (Figure 8). The site is both functional and scenic, illustrating how geological, ecological, and religious values converge in a single landscape. Similarly, in the May Lomin gorge, a spring flows through a narrow valley where people gather regularly for healing rituals. Over time, small settlements have developed around some such sites, providing accommodation and basic amenities for pilgrims and their accompanying relatives. These existing facilities could potentially support carefully managed visitor access, while remaining centred on religious practice. Beyond their religious role, holy-water sites regularly also function as places of communication and knowledge exchange, and therefore are centres of regional networking.

*** Figure 8 ***

From a geotourism perspective, the geological origin and landscape setting of these springs provide opportunities for interpretation. Many of the larger sacred springs emerge as resurgences in limestone terrain, where groundwater moves through fractures, fissures, and other macropores before reaching the surface as substantial flows. The combination of rugged topography, woodland cover, and flowing water can make such sites attractive to visitors while also providing opportunities to explain local geology and hydrology. Holy-water sites thus illustrate particularly clearly how geological processes can become embedded in religious meaning and practice.

Importantly, however, access and use are guided by religious protocols. Priests and local custodians conduct rituals, visitors are expected to follow established behavioural norms, and the water itself should not be boiled even when taken home for later use. Small groups of visitors, particularly when accompanied by a local guide or community member, may be welcomed provided they behave respectfully, avoid disturbing healing rituals, avoid photographing individuals, and recognise that the bathing facilities are intended exclusively for religious healing rather than recreation. Large tourist groups would be incompatible with the atmosphere and primary function of these living religious sites.

Collectively, holy-water sites, churches, and sacred forests illustrate how, across Tigray's semi-arid landscapes, religious traditions have helped sustain culturally protected refuges in which geological, biological, and spiritual values remain closely interconnected.

2.4. Popular geomorphic myths inspired by religion

Across Dogu'a Tembien, as in wider Tigray, numerous landforms and environmental features are embedded in rich oral traditions that link geomorphological features to religious beliefs, pre-Christian traditions, local historical memory, and everyday environmental knowledge (Gebreselassie and Lanckriet 2019). Following Smidt (2011), Dogu'a Tembien may be regarded as an *Erinnerungslandschaft* ("landscape of memory"), in which prominent landforms function as repositories of local history and cultural practice (Online Supplementary Data S5).

For instance, a cluster of rock forms near Hech'i is locally interpreted as a wedding procession turned to stone after neglecting to pay respect to a nearby church, while a nearby imprint shaped like a horse's foot recalls the sole individual spared through prayer. Other features are explained through narratives of exceptional human agency, such as the large boulder of Imni Ilyas, said to have been carried from the lowlands by a man of extraordinary strength and cast aside in anger when he found that the church of Hech'i had already been completed before his arrival.

A notable example is the linear vegetation feature near Ch'elaqo, locally interpreted as the path of a destructive serpent whose story is linked to the Queen of Sheba. Such serpent traditions occur widely in Tigray and have been interpreted as reflecting elements of pre-Christian beliefs associated with the Serpent King Arwe (Manzo 2014; Smidt 2025). The Ch'elaqo feature thus illustrates how geological and geomorphological features can become embedded in religious and historical traditions.

Meteorological phenomena are likewise incorporated into local explanatory frameworks, with lightning, thunder, and other weather events interpreted as manifestations of divine judgement capable of transforming the landscape. From a geoscientific perspective, the landforms concerned can be explained by processes such as karstification (lapiez formation), rockfall, and tectonic fracturing. Rather than assessing these narratives in terms of empirical accuracy, they illustrate how communities interpret and integrate environmental processes into broader cultural and spiritual belief systems, reinforcing the significance of geoheritage as a nexus of natural and cultural values (Pijet-Migoń and Migoń 2022; Reynard and Brilha 2025).

2.5. Domestic tourism and pilgrim routes

Many sacred sites in Tigray serve as popular domestic tourism destinations, combining religious observance with scenic beauty. Notable examples include Dabba Salama and Dabba Hadera, named after revered Christian figures, among other monasteries in Dogu'a Tembien, which attract thousands annually (Figure 9). The popularity of such spiritual sites is also reflected in the dedication of other sacred places elsewhere in Tigray to the same holy figures, such as the holy-water spring (*minch'elot*) of Dabba Hadera in the mountain valleys nearby 'Adwa, which likewise attract pilgrims and visitors, a pattern widespread in Christian pilgrimage landscapes (Eade and Sallnow 2013).

All churches, including Debre Sema'it Yohannis, but also less-known, inconspicuous village churches host such annual gatherings, aligned with their '*ametu* (yearly church patronal feast) dates, during which residents from surrounding villages (typically within a 10 km radius) travel to participate in communal worship, procession, social visits, and festivities. Relatives and pilgrims may travel from much farther away. Structured lists of saints tied to specific days of the Ethiopian month show, for example, that the 4th day is traditionally dedicated to Yohannis Wolde Negodguad, providing a liturgical basis for annual patronal feasts observed on such dates (E.O.T.C. Pathway N.D.; Hablesellassie and Tamerat 1970). A comprehensive local almanac compiled through long-term participatory research documents village-specific church names and '*ametu* dates across Dogu'a Tembien, providing the basis for the seasonal and spatial patterns of pilgrimage observed here (Nyssen et al. 2016).

The influx of pilgrims has catalysed small-scale local entrepreneurship, including pensions, eateries, transport services along the footpaths, local vendors, and microbreweries producing *suwa* (local

beer). During *'ametu*, people often arrive a day early, staying with relatives or sleeping in church-provided spaces, or spending the night in the open. These temporary concentrations of visitors illustrate the broader role of churches and monasteries in Tigray as social spaces extending beyond purely religious functions (Smidt 2006). The celebrations combine worship, social gathering, and in some cases, challenging journeys to cliff-top or cave churches, reflecting both spiritual and recreational aspects of local practice. Online Supplementary Data S6 documents the annual pilgrimage at Dabba Selama.

*** Figure 9 ***

Pilgrimage routes form a complementary layer where geotourism and Orthodox Christianity intersect. Rock-hewn churches, monasteries, and holy water springs are often located in remote places reached by semi-fixed trails used for centuries, along which resting points and basic facilities have developed organically. Villagers accustomed to pilgrims' presence may perceive geotourists as similarly non-intrusive, allowing visitors to experience the landscape with limited disruption.

The footpaths traverse valleys, cliffs, and ridges, offering panoramic views of the surrounding terrain. Despite the large crowds on some days, these trails retain much of their natural charm, providing visitors with both spiritual and environmental experiences. For example, the trail to Dabba Hadera combines striking topography with culturally meaningful stops (Figure 10), illustrating the integration of natural and religious heritage. These pilgrim routes remain largely unexplored in systematic research, representing untapped potential for understanding the intersection of geomorphology, culture, and tourism.

*** Figure 10 ***

Across these examples, recurring patterns emerge. Rock-hewn churches, sacred forests, holy water sites, caves, pilgrimage routes, and geomorphic traditions are consistently embedded within distinctive geological settings and remain active components of contemporary religious life. Together, they demonstrate that geological features in Tigray are not isolated natural attractions but form part of living cultural landscapes in which spiritual practices, environmental stewardship, and local landscape knowledge are closely intertwined. These observations provide the empirical basis for examining their implications for geotourism in the Discussion.

3. Observed challenges

While geotourism offers an opportunity to showcase Tigray's geological and cultural heritage, field observations also reveal challenges arising from the religious significance of many geosites. Rock-hewn churches, holy-water springs, church forests and caves are living sacred places, and access may be temporarily or permanently restricted on religious grounds, including for non-believers or outsiders (Smidt 2006).

Beyond common constraints such as limited infrastructure, inadequate visitor facilities, and language barriers, field observations revealed additional social dynamics. For instance, children may gather around visitors on the way to popular rock-hewn churches, requesting gifts; giving to one child can trigger a chain reaction, potentially encouraging school absenteeism in pursuit of handouts.

Field observations also revealed tensions arising from the overlapping functions of sacred geosites, particularly regarding visitor behaviour, local perceptions, and the management of places that serve simultaneously as religiously sanctuaries and potential geotourism destinations.

3.1. Access to churches, forests, and caves

Access to sacred sites is often regulated by religious authorities, reflecting both spiritual protocols and local hierarchies. Visitors may arrive at a church only to be told, *“This is not the moment,”* or *“You must return another day.”* The Debre Sema’it Yohannis church exemplifies this: repeated visits and formal letters from senior priests were required before entry was granted. Such restrictions are rooted in tradition and authority (Lamesa et al. 2022; Smidt 2006), and access is rarely immediate, even if a priest is physically present.

Sacred forests and caves face similar access challenges. Many are located in remote terrain or on church grounds, requiring negotiation and respect for both religious and social protocols.

3.2. Gendered access and religious norms

Within Ethiopian Orthodox practice, access to sacred space is strongly gendered. Men and women occupy separate areas within churches, and women may refrain from entering when they consider themselves subject to ritual restrictions, for example during menstruation, for a period after giving birth, or following sexual relations. The latter restriction also applies to men. Some religious sites, including Dabba Selama monastery (Figure S21) and the cave at Zeyi, are entirely closed to women (Nyssen et al. 2020b). In certain cases, even designated areas for women may be inaccessible to foreign women, reflecting assumptions about unfamiliarity with local ritual norms. These practices reflect broader gendered norms within Ethiopian Orthodox religious and social life (Cherinet and Mulugeta 2002).

Such restrictions can generate misunderstanding among foreign visitors. Instances have been observed where tourists, particularly women and their companions, react with frustration when denied access, occasionally leading to conflict or to the avoidance of certain sites altogether (Getnet 2018).

3.3. Tourist behaviour

Visitor behaviour did not always conform to local expectations at sacred sites. Orthodox churches in Tigray follow established norms of dress and conduct, which typically require modest clothing (e.g. covered shoulders and legs, and head coverings for women) as well as the removal of shoes before entering church buildings (Binns 2016; Chaillot 2002). However, such expectations are not always observed by visitors, particularly in the context of high temperatures and a leisure-oriented tourism mindset. In our field observations, removal of shoes was the only such requirement that was consistently enforced.

In addition, particularly within larger visitor groups, our field observations documented instances of behaviour perceived locally as inappropriate, including smoking within church compounds or in their

immediate surroundings, posing humorously with church bells, deliberately mixing the shoes of other visitors left respectfully outside the church, staging mock biblical scenes, or using sacred objects as props for photography. These observations were recorded at several sites and involved different groups of visitors; the examples are described here rather than illustrated, so as not to identify or shame individual visitors. Such behaviour may reflect a mismatch between visitors' perception of churches as places of cultural or recreational interest and local understandings of them as living sacred spaces. Although possibly intended as playful or harmless, these actions can be experienced as disrespectful within the local religious context.

In practice, however, clergy and custodians may tolerate certain forms of inappropriate behaviour because of the economic benefits associated with tourism. Such tolerance should not necessarily be interpreted as acceptance and may become a source of tension within local communities. During discussions with Tigrayan interlocutors, photographs showing inappropriate visitor practices at sacred sites sometimes elicited surprise that clergy or custodians had not intervened. This response illustrates the gap between local expectations of appropriated conduct in sacred spaces and visitor's perceptions of acceptable behaviour. Without appropriate visitor guidance, such mismatches risk undermining the sanctity attributed to these sites and weakening trust between communities and visitors.

3.4. Conservation vs. 'modernisation' of rock-hewn churches and sacred sites

Increased financial resources, derived from tourism, local donations or broader economic development, have facilitated modifications that alter the historical authenticity of some churches. In numerous, perhaps even a majority of rock-hewn churches traditional bamboo mat flooring has been replaced with concrete, and iron doors have replaced wooden ones (Figure 11). While these changes may improve durability or convenience, they reduce the aesthetic and historical appeal for geotourists seeking authentic experiences.

*** Figure 11 ***

Similarly, cemeteries associated with churches may increasingly contain modern cement graves, which limit natural vegetation regrowth, impoverishing the ecological integrity of sacred church forests (Klepeis et al. 2016). These developments may alter both the historical authenticity of the sites and the ecological character of sacred church forests.

3.5. Billions of years of earth history vs. 6,000 years since Genesis

Field observations indicate that scientific and biblical understandings of landscape commonly coexist. Geoscientific interpretations attribute the Adigrat Sandstone, in which most of rock-hewn churches are excavated, to the Late Triassic-Middle Jurassic (ca. 200 Ma) (Bussert and Nyssen 2019). Such interpretations frame the landscape as the result of long-term geological processes including sedimentation, uplift, and erosion. In contrast, Biblical narratives describe a much younger Earth created by God. In urban settings, visitors may encounter individuals who explicitly question or reject scientific interpretations of Earth history and biological evolution, reflecting literal readings of scripture.

However, field observations suggest that in rural areas, particularly at rock-hewn churches and other sacred sites, these contrasting perspectives frequently coexist without overt tension. Farmers commonly possess detailed knowledge of geomorphological processes, while conspicuous or striking landforms may become embedded in specific local narratives and myths. By contrast, less conspicuous geomorphic features, such as river terraces or traces of ancient landslides, tend instead to be placed within a broader biblical chronology and attributed to “Noah’s time” or the Flood. Scientific explanations were generally received with interest rather than rejection. This form of coexistence is not unique to Ethiopia: until the emergence of modern geology in eighteenth- and nineteenth-century Europe, the Noachian Flood likewise served as a widely accepted framework for explaining the origin of many landforms, before geological and biblical interpretations gradually diverged through an “amicable dissociation” (Dal Prete 2022; Rudwick 2009).

3.6. Signage at sacred geosites: science and faith in dialogue

Developing interpretive signage at sacred geosites presents a particular challenge, as these locations are not primarily visitor attractions but living spiritual environments. Churches, holy water sites, and sacred forests are actively used for religious practice, and interpretive material must acknowledge this status. At the same time, geotourism seeks to convey geological and ecological knowledge, creating an inherent tension between scientific interpretation and local religious expectations.

In many cases, local communities expect information boards to prioritise religious narratives, including the lives of saints, biblical stories, or the history of the church itself. This became evident at Debre Sema’it, where local inhabitants initially requested a signpost along the main road indicating the church’s presence and direction, ideally incorporating religious symbolism. When the discussion turned to on-site interpretation, the expectation was that the content would explain the story of the locally venerated Saint John (Figure S23). From a geotourism perspective, however, interpretive panels typically emphasise geological heritage, geomorphological processes, and landscape evolution while relating these to the site’s broader natural and cultural significance (Newsome and Dowling 2010; UNESCO 2021).

3.7. Preparation of appropriate and site-specific souvenirs

Souvenirs are another area of potential conflict and opportunity. Across Ethiopia, generic souvenirs, such as coffee pots, trinkets, textiles, and mass-produced items dominate the market (Weldegebriel and Kebede 2024; Wondirad et al. 2022). Geotourism encourages site-specific artifacts (‘geoproducts’) that reflect the local culture, handicraft, rock type, or landscape (El Hamidy et al. 2025; Hose 2000).

For example, motifs from church carvings could be reproduced on wood or stone, creating authentic souvenirs while preserving the traditional artistic heritage. Additionally, monasteries and churches historically produced manuscripts and parchments. Contemporary production of new parchments for visitors on the original sites could satisfy tourism demand while preventing the sale and loss of historic items.

Taken together, these observations demonstrate that the principal challenges for geotourism in Tigray arise less from the geology itself but from the religious character of the landscape. Access restrictions, gender-specific practices, visitor behaviour, changing conservation practices, contrasting understandings of geological time, interpretive expectations and the commercialisation of cultural products illustrate the diversity of issues documented during fieldwork. These observations form the basis for the discussion of how geotourism can engage respectfully with living sacred landscapes.

4. Discussion

4.1 Community ownership and benefits of geotourism

The findings indicate that the principal value of Dogu'a Tembien does not lie solely in the presence of remarkable geological landforms. Rather, the Orthodox communities and institutions have functioned for centuries as custodians of both the physical landscape and the cultural meanings attached to it.

Geotourism is more likely to be sustainable when local communities participate actively in its development and share equitably in its benefits, without compromising spiritual or cultural practices (Gordon 2018; Matshusa et al. 2021). Examples from Tigray indicate that elements of such inclusive models are already merging. Community lodges, small restaurants, local guides, and transport services provide income opportunities while allowing communities to retain control over access and visitor behaviour (Chase and Chase 2019). In Dabba Hadera, local entrepreneurs have established accommodations and eateries along pilgrimage routes (Figure 12), illustrating how pilgrimage infrastructure can support local economic activity. Before the 2020–2022 Tigray War, local lodges and trekking services had also been established at various locations to serve international visitors. International tourism, however, came to a complete halt during the war and has not yet resumed. Although a formal cessation of hostilities was agreed in November 2022, continued armed clashes and recurrent drone strikes, together with prevailing international travel advisories against travel to Tigray, continue to constrain the return of international tourism. Employment opportunities for guides, porters and pack-animal handlers provide additional local income while supporting visitor access (Figure 13). Participatory development should ensure that local communities retain ownership of geotourism initiatives and are involved from the outset in anticipating potential social impacts (including visitor behaviour, expectations, and local educational or social dynamics) so that tourism strengthens rather than disrupts existing community structures. While geotourism could contribute to post-war economic recovery, its revival will also depend on a stable security situation and the gradual restoration of international visitor confidence. Similar observations have been made for Lalibela, where local communities traditionally maintained the churches through local masons and artisans before modern conservation programmes became dominant (Ayalew 2016; Weldegiorgis et al. 2018).

*** Figure 12 ***

*** Figure 13 ***

At the same time, field observations indicate that the distribution of these benefits varies considerably between tourism models. While many locally based initiatives generate substantial benefits for surrounding communities, some organised tours visiting rock-hewn churches in Tigray

show patterns of exclusion and unequal benefit-sharing, with only a limited proportion of the revenue retained locally (typically by churches; clergy, guides and small businesses), while a substantial share may accrue to operators based in Mekelle or Addis Ababa. These observations reflect broader structural imbalances documented in Aksum and elsewhere in African tourism systems (Ashley et al. 2001; Matshusa et al. 2021; Messele 2010; Mitchell and Coles 2009). Unless governance arrangements explicitly promote community participation and equitable benefit-sharing, geotourism risks reinforcing rather than reducing local perceptions of exclusion and marginalisation.

Comparable patterns have been documented elsewhere in Ethiopia, where tourism and conservation initiatives have not always achieved equitable outcomes; at times, they have been implemented through exclusionary approaches that limited local participation and local control over resources. Such approaches reflected not only international conservation ideals of an "untouched" African wilderness but also longer-standing centre-periphery relations in which peripheral communities exercised little influence over decisions concerning land and natural resources (Blanc 2022; Markakis 2011; Weldemichel 2022). A frequently cited example is Nech' Sar National Park, near Arba Minch' in southern Ethiopia, where conservation policies since the 1970s have restricted access to land and resources for local communities and generated long-standing grievances (Tsegaye et al. 2017). Tourism associated with the park has likewise provided relatively limited opportunities for neighbouring communities, with much of the economic benefits accruing to external operators, park authorities, and urban businesses (Tsegaye et al. 2017; Woyesa 2013). Comparable concerns have also been raised in the World Heritage town of Lalibela, where externally driven conservation and tourism-development programmes have at times been criticised for insufficient involvement of local communities and for prioritising heritage valorisation over local livelihoods, including proposals to relocate residents from the vicinity of the churches (Ayalew 2016). Taken together, these examples from protected areas and living heritage sites indicate that the long-term success of geotourism depends as much on inclusive governance as on the conservation of landscapes and monuments.

Our findings reinforce this broader pattern. Respect for religious practices, transparent communication of visitor expectations, conservation that values traditional materials and knowledge, and equitable sharing of tourism revenues are interdependent elements of participatory governance. Reliable pre-visit information on access conditions, behavioural expectations and the living religious character of sacred sites is an important component of this governance. When addressed through collaboration between local communities, church authorities, tourism operators, and public authorities, such governance approaches can strengthen both heritage conservation and local livelihoods (Martínez Yáñez et al. 2022; Timothy 2011).

4.2 Religion and geotourism

In Tigray, the close interconnection between Orthodox Christianity and the natural landscape has created a distinctive geo-cultural heritage. Rock-hewn churches, holy water springs, sacred forests, caves, and other sacred geosites have been preserved not only because of their spiritual significance but also as expressions of community identity and divine protection.

International geotourism literature generally considers religion as part of the cultural and intangible heritage associated with geosites, enriching their interpretation and visitor experience (Coleman and Olsen 2021; Reynard and Brilha 2025). The present findings complement the broader literature on

sacred natural sites, which has demonstrated that religious beliefs and custodian communities can play an important role in conserving biodiversity and culturally significant landscapes (Verschuuren et al. 2012). In Tigray, however, this stewardship extends equally to geoheritage. Orthodox religious institutions have contributed not only to the preservation of sacred forests but also of rock-hewn churches, caves, holy-water springs, and other geosites. The Tigrayan case therefore suggests that religion should be understood not merely as a cultural attribute associated with geoheritage or as an interpretive resource for tourism, but also as a long-term mechanism of geoheritage stewardship. The findings also suggest that scientific and religious understandings of the landscape are not necessarily experienced as mutually exclusive. Geological explanations of landscape evolution and Orthodox interpretations of creation frequently coexist in local practice as complementary rather than competing ways of understanding place. For geotourism, this implies that interpretation should communicate geological knowledge in ways that acknowledge, rather than dismiss, the cultural and spiritual meanings attached to the landscape.

This relationship provides a strong foundation for geotourism, provided that visitors recognise these places as living sacred spaces, and communities retain authority over access and religious practice. Such authority also encompasses gendered religious practices. Orthodox Christianity in Tigray is embedded in social norms that differentiate access to spaces and practices by gender (Biseswar 2008; Hannig 2013; Persoon 2002; Stefanos 2000). These arrangements, rooted more broadly in gender socialisation within Ethiopian society (Cherinet and Mulugeta 2002), may conflict with the largely gender-neutral expectations of geotourism. Experience from Lalibela suggests that tensions between conservation authorities and local communities may partly reflect the absence of effective intermediary institutions capable of mediating between heritage managers and local stakeholders (Ayalew 2016).

Sacred church forests preserve ecological values, while rock-hewn churches preserve exceptional geological, architectural and artistic heritage. Tourism development should therefore avoid creating incentives for inappropriate modernisation of sacred sites; conservation approaches that continue to value traditional materials, craftsmanship, and local knowledge are more consistent with both heritage authenticity and community identity.

Respect extends beyond physical access to sacred sites. Visitors should be informed about local practices such as *tsebel* (holy soil), holy water rituals, and gendered access to sacred spaces. Simple symbols or signage, culturally appropriate and carefully designed, can guide visitor behaviour without disrupting the sanctity of the site (Coleman and Olsen 2021). More broadly, similar tensions between visitor practices and the values attributed to religious heritage sites have been documented in pilgrimage and heritage tourism contexts (Eade and Sallnow 2013; Vukonić 1996). Geomorphological and religious narratives frequently operate simultaneously within the same landscape, shaping how both local communities and visitors perceive and engage with geosites. The challenge is therefore less to defend scientific interpretations against religious perspectives than to communicate geological knowledge in ways that respect the cultural and spiritual meanings attached to landscapes (Reynard and Giusti 2018; Wynne 1992).

Rather than presenting scientific and religious interpretations as mutually exclusive narratives, interpretive materials should place them in dialogue. Experiences from other sacred geosites demonstrate that this is feasible: at Meteora (Greece), Uluru (Australia), and the Batu Caves

(Malaysia), visitor information combines geomorphological explanations with culturally embedded meanings and behavioural guidance (Clarke and Waterton 2015; Georgousis et al. 2021; UNESCO 2015). Such examples show how scientific and spiritual interpretations can be presented in parallel, allowing visitors to engage with both dimensions of the landscape. In Tigray, this could include culturally meaningful, site-appropriate Orthodox imagery alongside geological interpretation (Online Supplementary Data S7). Interpretive signage can thus serve as a mediating interface between scientific knowledge, religious meaning and visitor experience, balancing education with respect for the sacred character of the landscape (Newsome and Dowling 2010; Tilden 1977). Well-designed interpretation can therefore function as an “open-air classroom”, enriching visitors’ understanding while reinforcing local appreciation of geoheritage (Reynard and Brilha 2025).

Conclusions

The evidence presented here suggests that geotourism in Dogu’a Tembien need not replace or undermine Orthodox religious practice; rather, if appropriately managed, it can complement it. Sacred geosites can simultaneously function as places of worship, refugia for biodiversity, repositories of geo-cultural heritage, and educational destinations, provided that their religious functions and community stewardship remain central.

This study further suggests that Orthodox Christianity has been a principal mechanism through which much of Tigray's geoheritage has been conserved and endowed with cultural meaning over centuries. Geotourism in such contexts therefore depends not only on interpreting geological features but equally on understanding sacred landscapes as living socio-ecological systems maintained through religious practice and community stewardship.

These findings imply that successful geotourism requires governance that respects religious traditions, conserves authenticity, provides appropriate visitor interpretation, and ensures meaningful community participation. Fundamentally, it requires the free, prior, and informed agreement and participation of the communities that have created, maintained, and continue to safeguard these sacred landscapes (Guerini et al. 2026; Martínez Yáñez et al. 2022). Community participation should therefore not be regarded as a means of improving tourism after its introduction, but as a prerequisite for deciding whether, how, and to what extent tourism should develop. Such an approach can safeguard the religious, cultural, and ecological integrity of these living sacred landscapes while supporting sustainable local development, and may also strengthen future international heritage recognition, including the potential consideration of Dogu’a Tembien within UNESCO's World Heritage framework.

Supplementary data

Online Supplementary Data include: **(S1)** a geological overview of the study area, including a geological map; **(S2)** a detailed architectural description of Debre Sema’it Yohannis rock-hewn church; **(S3)** local accounts of the church’s history, including its contested memory, together with a geomorphological interpretation of its present configuration; **(S4)** an expanded account of natural and artificial underground spaces, including caves, tunnels, and rock caverns; **(S5)** detailed accounts, with photographs, of landscape features embedded in local oral traditions, together with a map of

Dogu'a Tembien's "*memory landscape*" showing rock churches, monasteries, and locations associated with local traditions; (S6) an account, with photographs, of the 2021 pilgrimage to Dabba Selama; and (S7) an example of culturally appropriate Tigrayan Orthodox iconography for interpretation at sacred geosites. Available at xxx.

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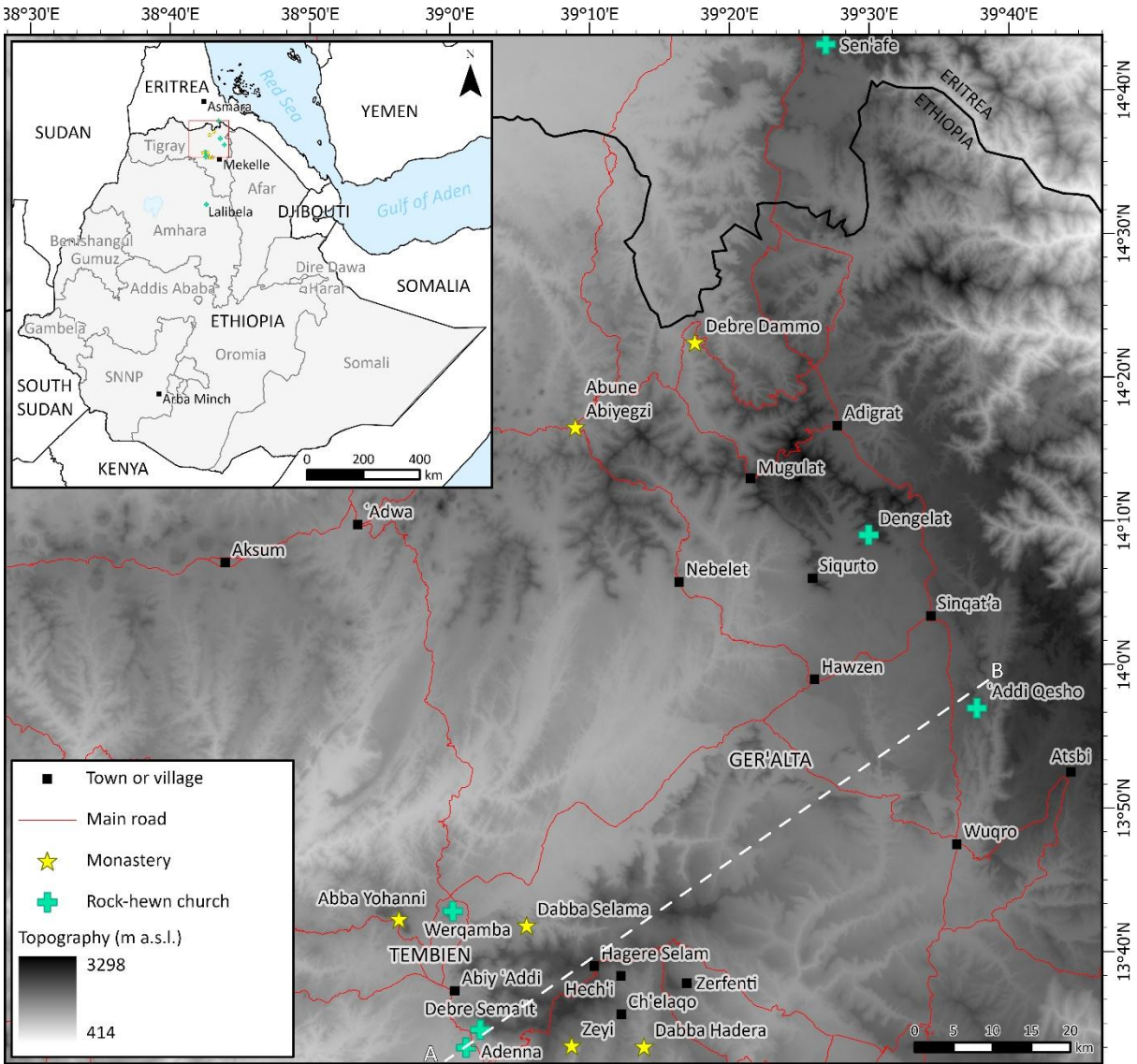
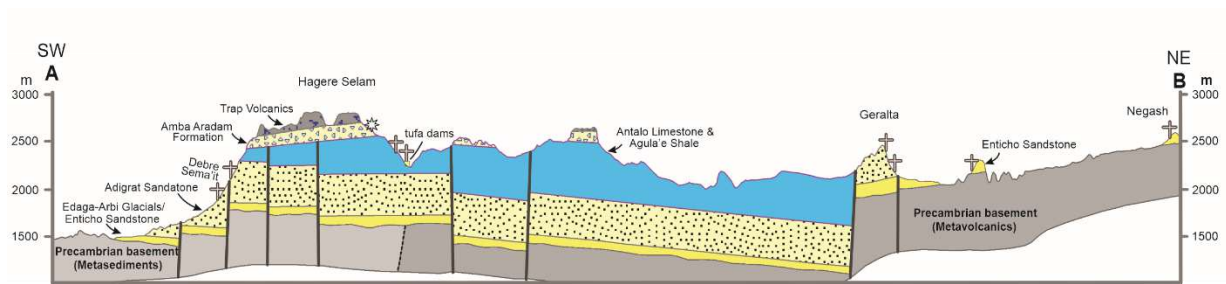


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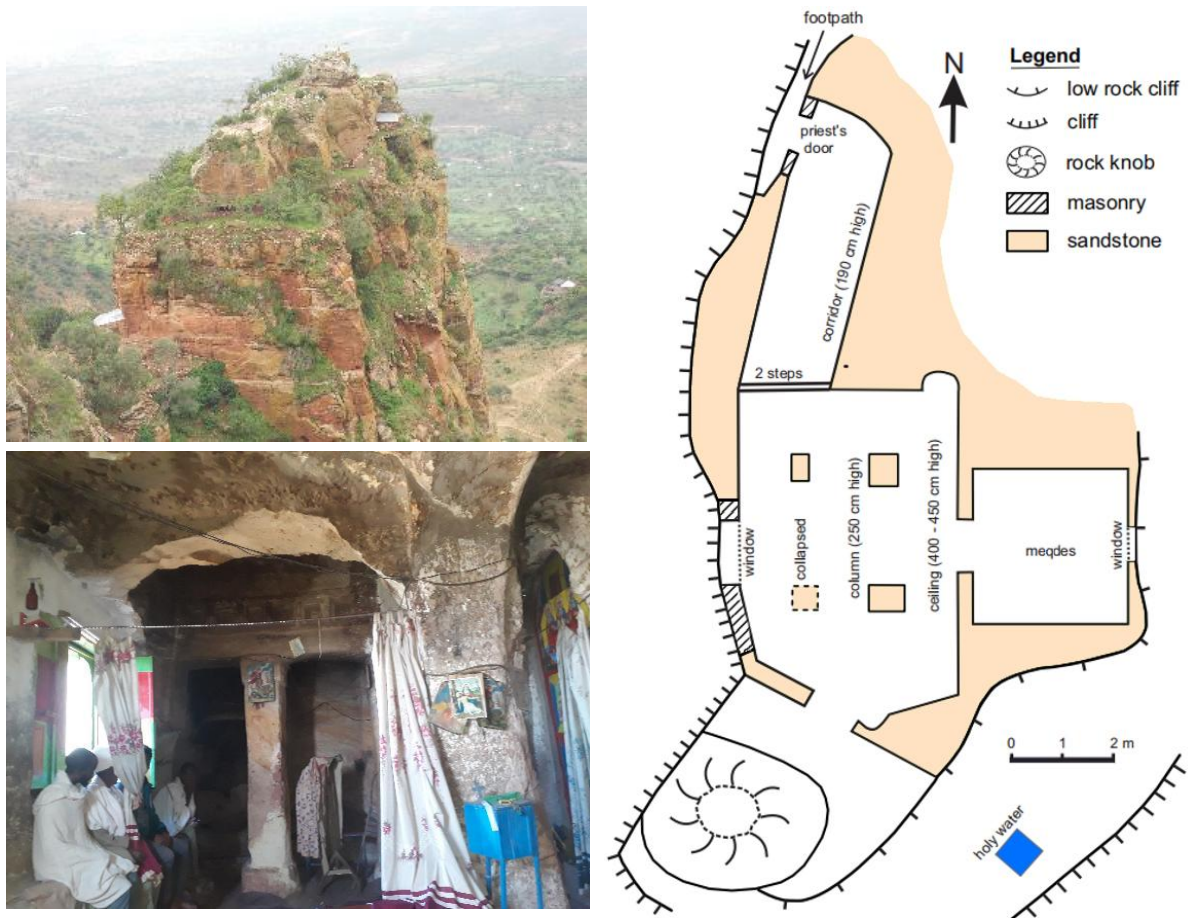
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943 southwest–northeast cross section (10× vertical exaggeration), with Debre Sema'it Yohannis position
944 represented along the southwestern escarpment (after Bussert and Nyssen 2019).

945



947 **Figure 3.** Debre Sema'it Yohannis rock-hewn church, clockwise: setting on a sandstone pinnacle
 948 (photograph by Jan Nyssen, 2017); ground plan (survey: Jan Nyssen; drawing: Sofie Annys); interior,
 949 showing columns with bracket capitals and carved decorative elements; note the masonry wall at the
 950 western end (photograph by Jan Nyssen, 2019). Detailed description, oral history, and interpretations
 951 are provided in Online Supplementary Data S2 and S3.



952

953 **Figure 4.** Stone “bells” near the church, illustrating local use of lithology for acoustic purposes.
 954 Photograph by Jan Nyssen, 2019.



955

956 **Figure 5.** Newly excavated rock-hewn church (Medhane 'Alem) in a pinnacle of Mt. Werqamba
 957 (Philipp 2017). Contrasts in rock colour reflect the local stratigraphy and are particularly visible
 958 around the column capitals with bracket-type forms. Photograph by Jan Nyssen, 2016.



959

960 **Figure 6.** Sacred forest surrounding the Kidane Mihret rock-hewn church at Adenna, illustrating
 961 preserved vegetation within an otherwise largely cultivated landscape. Photograph by Jan Nyssen,
 962 2016.



963

964 **Figure 7.** Zerfenti dove nesting box. Photograph by Jan Nyssen, 2019.



Figure 8. Holy water site at Dabba Hadera showing spring, bathing structures, and surrounding landscape. Photograph by Jan Nyssen, 2019.



Figure 9. Praying at the onset of the patron's feast of Saint Frumentius (Abba Selama; died c. 383), the Phoenician missionary traditionally credited with introducing Christianity to the Kingdom of Aksum, celebrated at the monastery bearing his name. Thousands of pilgrims from across Tigray converge on Hagere Selam (Dogu'a Tembien) and continue on foot towards the cliff-facing sandstone mesa hosting Dabba Selama monastery. The most devoted (male) pilgrims traverse narrow ledges before climbing by ropes or unstable ladders inside an open joint in the rock mass, illustrating both the spiritual significance of the site and the dramatic geomorphological setting. Photograph courtesy of the Tigray Culture and Tourism Bureau. Reproduced with permission.



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Figure 10. Pilgrimage trail towards Dabba Hadera monastery, along the Rubaksa karst resurgence and irrigation area. Photograph by Jan Nyssen, 2019.



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Figure 11. At Debre Sema'it Yohannis rock-hewn church the priests' entrance is through an age-old wooden door, whereas at the main entrance the wooden door has been replaced by a welded door from sheet iron. Photographs by Jan Nyssen, 2017 and 2019.



987

988 **Figure 12.** Aerial views of Dabba Hadera in 2011 and 2024, showing the rapid, largely spontaneous
 989 growth of pilgrim-oriented settlement around the monastery. Restaurants and pensions have
 990 developed along the two main pedestrian pilgrimage routes approaching from the north and
 991 northeast; these alleys are not accessible to vehicles but have become axes of local economic
 992 activity. A first alley with restaurants and accommodation facilities had already emerged before the
 993 war, while subsequent growth occurred in a context of limited planning and weakened regulatory
 994 capacity. The monastery is located in the southern part of the images (Google Earth imagery; scene
 995 width 575 m).



Figure 13. Trekking group arriving in a village of the Mugulat Mountains (Tigray) for a pack-animal relay exchange. A small flag above the house indicates the availability of *suwa* (local beer). In addition to the tourist-photographer, the group includes (from right to left) a translator, a local guide, a donkey handler, and a lightly loaded pack animal. The scene illustrates local guiding and transport services and highlights community involvement in tourism. Photograph © Greg & Mandy Chase (Explorer Genes), reproduced with permission.

FIGURE CAPTIONS

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