Mount Kailas: Center of the Universe

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Mount Kailas, an isolated peak in western Tibet (Fig. 1), represents the earthly manifestation of mythical Mount Meru, the center of the universe, for the 1.7 billion followers of four religions (Hindus, Buddhists, Jains, and Bonpos). As such, it is circumambulated by thousands of religious pilgrims every year. The 6638-m-high mountain consists of Oligocene–Miocene Kailas Formation conglomerate, an unusual rock formation that contains clues to the evolution of the India-Asia collision zone that formed the Himalaya Mountains, the tallest topography on Earth, and that uplifted the Tibetan Plateau (DeCelles et al., 2011). The geoheritage significance of Mount Kailas, possibly Earth's most sacred mountain, is second to none.

Figure 1. The north face of Mount Kailas viewed from Dira-puk Monastery. The mountain consists of Oligocene–Miocene Kailas Formation conglomerate, which unconformably overlies the Paleogene-aged Gangdese granite that comprises the two foreground peaks. Attribution: Lon Abbott and Terri Cook.

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CITATION: Abbott, L.D., and Cook, T.L., 2024, Mount Kailas: Center of the Universe: GSA Today, v. 34, p. 12–16, https://doi.org/10.1130/GSATG118GH.1

PARALLELS BETWEEN MOUNT KAILAS AND MOUNT MERU

Te Mahabharata, an epic poem written between the third century BCE and the third century CE, contains Hinduism's most sacred text and describes the cosmography of the universe, with Mount Meru at its center. The Hindu gods live on Meru's summit, and the mountain shines "like the morning sun and like a fire without smoke" (Allen, 1982, p. 19).

For Hindus and Buddhists, Mount Meru is transcendent, the temple at the center of the universe. Diverse religious structures and practices symbolize it. Architecturally, it is represented by the Shikhara, the spire at the center of a Hindu temple, and by the dome-shaped Buddhist stupa. In religious art, the mandala, which is used to focus meditation, often represents the universe with Mount Meru at its center, and in yoga, the central channel of psychic energy that runs along the practitioner's spinal column symbolizes the mountain (Johnson and Moran, 1989).

Mount Meru's geography is key to the identification of Mount Kailas as its earthly manifestation. It is bounded to both north and south by three mountain ranges. Meru towers above its neighbors and has four distinct faces, one each of crystal, ruby, gold, and lapis lazuli. A "stream that washes away all sin, the river Ganga" (Allen, 1982, p. 21–22) falls from the big toenail of the God Vishnu's left foot to the summit of Mount Meru, where it divides into four mighty rivers that flow to the four quarters of the Earth and purify it.

The geography of Mount Kailas bears an uncanny resemblance to that cosmography. It is hidden behind ranks of mighty mountains. It dominates its surroundings; it is crowned by a dazzling white ice cap; its four walls face the points on the compass; and it is shaped like a Buddhist stupa. On its south face, the intersection of the nearly horizontal conglomerate layers with a vertical gully is interpreted by devotees as an auspicious ancient symbol of spiritual strength (Johnson and Moran, 1989). Most significantly, the Ganges, Indus, Tsangpo/Brahmaputra, and Sutlej, the Indian subcontinent's four great rivers, the mouths of which lie almost 2500 km apart, all originate near each other, flowing in different directions like spokes on a wheel, with Mount Kailas as the hub. It's no wonder Mount Kailas became the center of the universe for followers of all four religions (Allen, 1982).

THE STORY OF MOUNT KAILAS EPITOMIZES THE KEY GEOHERITAGE CONCEPT THAT A PLACE'S GEOLOGIC HISTORY GOVERNS, IN PART, WHY HUMANS VALUE IT.

CIRCUMAMBULATION OF MOUNT KAILAS

Religious pilgrims (Fig. 2) from the four faiths have been circumambulating Mount Kailas (or Kailash in a more recent transliteration of the Sanskrit) for at least 1000 yr; the faithful believe that a single circuit erases the sins of a lifetime (Johnson and Moran, 1989).

For Tibetan Buddhists, the mountain plays the central role in the triumph of Buddhism over Bonpo, the ancient shamanistic religion practiced by most Tibetans prior to the thirteenth century CE. The story goes that the Buddhist yogi Milarepa engaged in a protracted duel with the principal Bonpo shaman over possession of the holy mountain. Finally, the two agreed they would both ascend the mountain at dawn the next day, and whoever reached the summit first would win the mountain. At sunrise, the Bonpo shaman flew toward the summit, carrying his shamanistic drum, but Milarepa remained deep in meditation and did not move. Buddhists thought all was lost, but at the last minute Milarepa soared past the shaman to reach the summit first. In the legend, the vertical gash down Kailas' south face was gouged by the shaman's drum, which he dropped in his alarm (Johnson and Moran, 1989).

The 50-km-long, clockwise pilgrimage circuit around the sacred mountain (Fig. 3) begins in the town of Darchen at 4575 m elevation and ascends the valley west of the mountain, passing two monasteries. The path then crosses the 5636-m-high Drolma La pass and descends another valley east of the mountain, passing yet another monastery. The circumambulation typically takes three days to walk, but many Tibetan pilgrims take weeks because they prostrate themselves, laying down on the ground and praying every step of the way to gain extra merit.

Figure 2. Religious pilgrims circumambulating Mount Kailas. Two of them are prostrating themselves in prayer. Attribution: Lon Abbott and Terri Cook.

A BLANK SPOT ON WESTERN MAPS

Although the legend of Mount Kailas and the headwaters of the four great rivers diffused throughout Asia centuries ago, it was little known in the West. In 1580, the great Mughal Emperor Akbar invited Jesuit missionaries from Portuguese-held Goa to visit his court. There, the missionaries heard stories of people living near Mount Kailas and its equally sacred companion, Lake Manasarovar, whose religious practices sounded strikingly Christian.

A widespread European legend held that a wealthy Christian king, Prester John, lived somewhere in India; the Jesuits concluded that Prester John's kingdom lay waiting to be discovered at the lake. In 1624, Father Antonio de Andrade, the head of the Jesuit mission to the Mughal court, led an expedition to find the lake and its inhabitants. He eventually reached the then-powerful Tibetan Kingdom of Guge, the capital of which stood near the lake. In 1625, Andrade founded the first Christian church in Tibet, but he didn't find any Christians, and as the years passed, details of his exploits were forgotten. However, they did fuel rumors in the West of a sacred mountain at the hub of the regional drainage network and an adjacent sacred lake somewhere in the blank spot between China and India that existed on western maps (Allen, 1982).

Throughout the nineteenth century, the British and Russians vied with each other for influence in Central Asia, a contest known as "the Great Game." Considering the high geopolitical stakes, many western explorers tried to fill in that blank spot, but the terrain was unforgiving, and entry to Tibet was forbidden. Finally, during an expedition between 1905 and 1908, the Swedish explorer Sven Hedin succeeded in locating the sources of the four great rivers and became the first Westerner to complete the circumambulation of Mount Kailas (Allen, 1982).

GEOLOGY WORTHY OF A SCIENTIFIC PILGRIMAGE

In 1936, Augusto Gansser, the first known geologist to explore the area, disguised himself as a religious pilgrim to successfully skirt the prohibitions to entry imposed at the time by both the Indian and Tibetan authorities. Gansser's description of the fundamental geologic relationships in the Kailas region remains unchanged to this day (Heim and Gansser, 1939). He observed three main belts of rock arranged from north to south (Fig. 3).

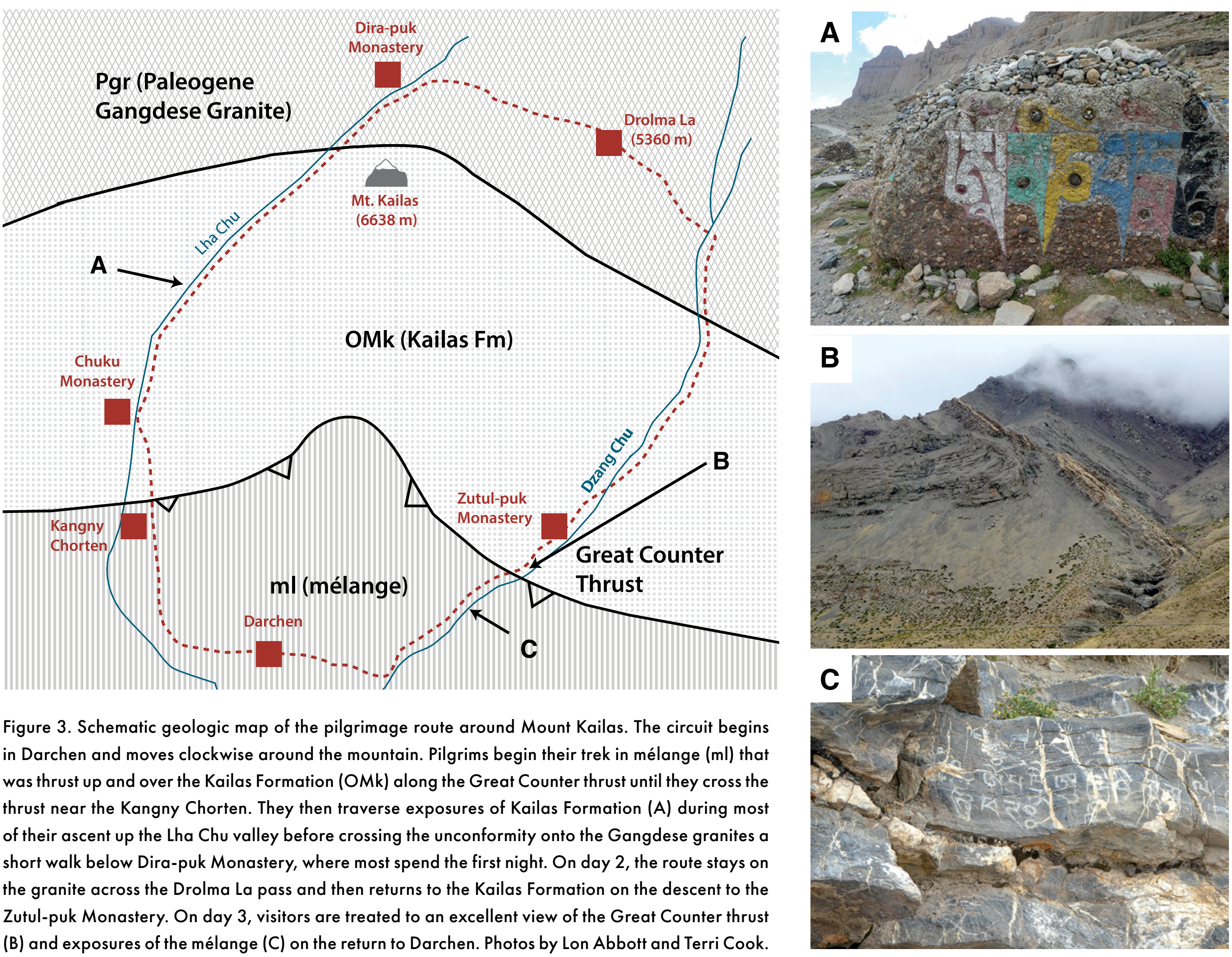

Figure 3. Schematic geologic map of the pilgrimage route around Mount Kailas. The circuit begins in Darchen and moves clockwise around the mountain. Pilgrims begin their trek in mélange (ml) that was thrust up and over the Kailas Formation (OMk) along the Great Counter thrust until they cross the thrust near the Kangny Chorten. They then traverse exposures of Kailas Formation (A) during most of their ascent up the Lha Chu valley before crossing the unconformity onto the Gangdese granites a short walk below Dira-puk Monastery, where most spend the first night. On day 2, the route stays on the granite across the Drolma La pass and then returns to the Kailas Formation on the descent to the Zutul-puk Monastery. On day 3, visitors are treated to an excellent view of the Great Counter thrust (B) and exposures of the mélange (C) on the return to Darchen. Photos by Lon Abbott and Terri Cook.

Mount Kailas rises in the middle belt, composed of Kailas Formation conglomerate; the rock north of the mountain is granite (Figs. 1 and 3). To the south, a jumble of sedimentary and low-grade metasedimentary rocks intermixed with blocks of serpentinite forms a mélange that was thrust northward over the Kailas Formation along a fault Gansser named the Great Counter thrust (Fig. 3; Heim and Gansser, 1939). In spotting serpentinite, he had discovered the ophiolites of the Indus-Tsangpo suture, which mark the boundary between India and Asia along the length of the collision zone.

FEW PLACES ARE VALUED MORE THAN MOUNT KAILAS, AND IT IS THE GEOLOGIC EVOLUTION OF THE INDIA-ASIA COLLISION ZONE THAT HAS IMBUED THE MOUNTAIN AND ITS SURROUNDINGS WITH THE UNIQUE GEOGRAPHY THAT HAS INSPIRED RELIGIOUS PILGRIMS FOR OVER A THOUSAND YEARS.

Subsequent work, much of it conducted during a multidisciplinary study by University of Arizona researchers, has added detail to the geologic framework Gansser deduced during his extraordinary geologic pilgrimage (DeCelles et al., 2011, 2016; Carrapa et al., 2014; Leary et al., 2016). The rock of the northern belt, the Gangdese granite, forms the roots of a continental margin volcanic arc that was active between 120 and 50 Ma as Indian plate oceanic lithosphere subducted northward beneath the Asian continental margin. When collision began ca. 55–50 Ma, activity in the arc ceased, and it was uplifted and eroded. That erosion exposed the granite, which, along with its volcanic carapace, supplied the bulk of the detritus to the Kailas Formation, which unconformably overlies the granite. The Kailas Formation was deposited 26–21 Ma, revealing that, by then, km-scale exhumation had exposed the granitic roots of the Gangdese arc.

The Kailas Formation, which is about 4 km thick, was deposited in a rapidly subsiding basin that spans the length of the India-Asia suture zone (1300 km). The Kailas Formation conglomerate was deposited in alluvial fans and braided rivers, but the formation fines southward and contains lacustrine mudstone and coal, which indicate the Kailas Basin was warm, humid, and likely deposited at low elevation (DeCelles et al., 2011). The question arises: What processes could create a low-elevation basin in the heart of the collision zone and subsequently elevate it to its current height of 4500–6500 m?

TWO HYPOTHESES FOR HOW THE KAILAS BASIN ROSE

Low-temperature thermochronology is an important tool for answering this question. Those data indicate dramatic Miocene vertical movements of the Kailas Basin; the Kailas Formation was buried 4–7 km and then exhumed by a comparable amount by 18–15 Ma, a mere few million years after its deposition (Carrapa et al., 2014).

The Arizona team concluded from their work that low-angle subduction of the Indian continental lithosphere caused a high relative rate of plate convergence between ca. 45 and 26 Ma, creating the south-verging Tethyan thrust belt south of Mount Kailas, which is composed of sediments derived from the Indian continental margin. Transfer of those comparatively low-density rocks to the upper plate increased the Indian plate's density, causing it to "roll back" to a steeper subduction angle. Rollback triggered a long, narrow belt of margin-parallel extension in southern Tibet, forming the Kailas Basin. When that dense slab broke off ca. 20 Ma, strong compression resumed, thrusting the mélange of Tethyan thrust belt rocks and Indus-Tsangpo suture zone ophiolites northward over the Kailas Formation along the Great Counter thrust (Fig. 3) and triggering surface uplift that raised the Kailas Basin to its current height (DeCelles et al., 2011; Leary et al., 2016).

Peter Molnar, who spent decades pondering Tibet's uplift history, and to whom this article is dedicated, proposed an alternative hypothesis. He argued that widespread removal of Tibetan mantle lithosphere about 20 Ma triggered regional uplift far beyond the Kailas Basin confines (Molnar and Stock, 2009). Mantle lithosphere is inherently unstable because it is denser than the underlying asthenosphere; numerical models indicate it will typically "drip" off and sink where convergence has thickened it (Houseman and Molnar, 1997).

If all of Tibet except the Kailas Basin was already high before 20 Ma, as some paleoelevation studies suggest (e.g., Garzione et al., 2000; DeCelles et al., 2007), a mantle drip could not have been the cause of surface uplift (the basin is too narrow). However, paleoelevation studies using different techniques often reach different conclusions, fueling controversy (e.g., Heitmann et al., 2021). Su et al. (2019) argued that northern Tibet's Lunpola Basin, which currently stands 4600 m high, was lower than 2300 m at 25.5 Ma. If so, the widely separated Kailas and Lunpola Basins both rose rapidly after 25–20 Ma, making lithospheric removal an attractive mechanism.

The story of Mount Kailas epitomizes the key geoheritage concept that a place's geologic history governs, in part, why humans value it. Few places are valued more than Mount Kailas, and it is the geologic evolution of the India-Asia collision zone that has imbued the mountain and its surroundings with the unique geography that has inspired religious pilgrims for over a thousand years. It is fitting that studies teasing out the nuances of the mountain's unusual geology are shedding light on the collision's geodynamic evolution. This completes a cycle of scientific inquiry akin to the spiritual cycle completed by religious pilgrims, as scientists continue their quest to comprehend the geologic processes that have made Mount Kailas the center of the universe for more than 1.7 billion humans.

DEDICATION TO PETER MOLNAR (1943–2022)

We dedicate this article to Peter Molnar, a giant of earth science and dear friend. Abbott was influenced from his earliest college days by Peter's work. He was hardly alone; Molnar is one of a handful of geoscientists to have been awarded the Crafoord Prize—the Nobel Prize equivalent for earth science and three other non–Nobel Prize disciplines. Peter's wide-ranging and incisive analyses of the tectonic processes that raise mountains and the interactions between the solid earth and the atmosphere that sculpt topography have left an indelible mark on our discipline. Mountains were Peter's passion, and they motivated his science. Dearest of all to him were the mountains of Tibet, and Mount Kailas is special. In 2013, he realized a lifelong dream and circumambulated Mount Kailas (Fig. 4) with a group of family and close friends, many of them geoscience luminaries in their own right. Abbott had the great privilege of coteaching undergraduate classes with Peter that explored the geoheritage of the world's mountains, including Mount Kailas. He witnessed firsthand Peter's knack for enhancing critical-thinking skills in the next generation and inspiring them with his passion. Thank you, Peter, for all you have done for our community.

Figure 4. Peter Molnar crossing the Drolma La pass while completing the Kailas pilgrimage circuit in 2013. Attribution: Peter Molnar collection.

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