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Spatial Statistical Analysis: Decoding The Geomorphotectonic Framework Of Kathiawar-Kutchch And Karbi-Shillong Outliers

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Abstract
This research paper investigates two significant geological outliers in India—Kutchch-Kathiawar in Gujarat and Shillong-Karbi Anglong in Meghalaya—through the lens of spatial analysis and geospatial statistics. The study employs advanced multivariate statistical techniques to analyze geothermal hot spring data and its correlation with seismic zones and geotectonic settings across these regions. It highlights the challenges of spatial analysis, particularly the classification of spatial techniques and the determination of precise spatial locations. Both outliers deviate significantly from the surrounding geological formations, prompting a reevaluation of their classification within India's geological framework. The Kutchch-Kathiawar outlier is positioned as a distinct entity influenced by the Great Himalayan Orogeny, rather than an extension of the Indian Peninsula, while the Karbi-Shillong outlier is identified as a unique tectonic hotspot with a complex geotectonic history. This research contributes to a deeper understanding of India's geodynamic history, emphasizing the importance of spatial statistics in revealing patterns and correlations essential for geological analysis.

Keywords: *Spatial statistics, Kuchch-Kathiawar, Saurashtra, Shillong-Karbi Anglong, Meghalaya, geomorphotectonics, geothermal geochemistry, seismicity. Himalayas*

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I. Introduction

While conducting research for my doctoral dissertation, I came across two significant and contentious issues: the Kutchch-Kathiawar (Gujarat) and Shillong-Karbi Anglong (Meghalaya) outliers in Indian geodynamic history. Spatial analysis, or geospatial analysis in this context, involves various tools and methods, particularly spatial statistics. This field focuses on analyzing data with a spatial component, aiming to uncover patterns or correlations across different locations. Despite its potential, spatial analysis poses considerable challenges, many of which remain unresolved. One fundamental challenge is determining the precise spatial location of the entities under study. The classification of spatial analytic techniques is complex due to the vast array of research fields involved and the diversity of methodologies and data forms. Spatial statistics, which use spatial relationships like distance, area, and orientation in mathematical calculations, are applied to various analyses such as pattern and shape analysis, surface modeling, spatial regression, and spatial interaction prediction. These statistics are categorized into descriptive, inferential, exploratory, geostatistical, and econometric types.

An outlier is something that deviates greatly from the norm, whether it's a geological formation or a statistical data point. Geological outliers, for example, are portions of younger rock surrounded by older formations, often as a result of erosion. A statistical outlier, on the other hand, is a data point that deviates significantly from the rest of the data in a population.

Outliers are crucial in spatial analysis. Statistically, an outlier is an observation point distinct from others, often indicating natural population variance but sometimes resulting from errors or biases.

Fig. 1: Location Map of Outliers

Study Background

This study expands on previous work that examined spatially dependent multivariate geothermal hot spring data from two distinct geological regions: a 2,400 km-long arc in the tectonically active Extra-Peninsular Himalayan region and the relatively stable Late-Precambrian or Proterozoic mobile belts in Peninsular India's Central Highlands. This study, published in "Geostatistics Applied to Fluid Geochemistry of Geothermal Fields in Peninsular and Extra-Peninsular India" (Amitabha Roy, 2024; ISBN 979-8-89222-356-0), employed robust multivariate statistical techniques.

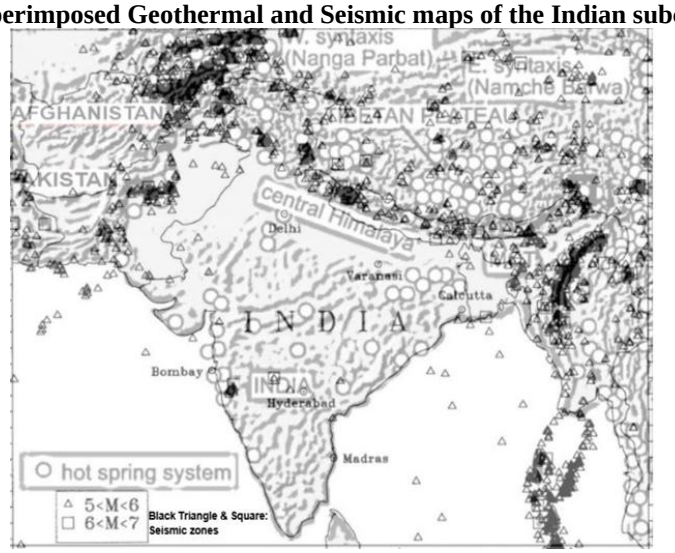
India's geological regions exhibit unique physical features:
1. The Himalayas, or Extra-Peninsula, form large, crescent-shaped mountain ranges along the northern edge of the Indian subcontinent.
2. The Indo-Gangetic Alluvium Plain.
3. The Peninsular shield, shaped like an inverted triangle, is bounded by the Arabian Sea, the Bay of Bengal, and the Vindhya and Satpura ranges.
4. Two outliers: the Shillong-Karbi Anglong or Meghalaya plateau in the east, and the Kutchch-Kathiawar (Saurashtra) plateau in the west (Fig. 1).

Geothermal fields, seismic zones, and geotectonic setting of India and adjacent areas

The Himalayan system, which comprises of enormous crescent-shaped mountain ranges with a pronounced southerly convexity, encircles the whole northern edge of the Indian subcontinent. The world's highest and youngest mountain ranges cover 2400 kilometres, from Nanga Parbat (8114 m) in the west to Namcha Barwa (7755 m) in the east.

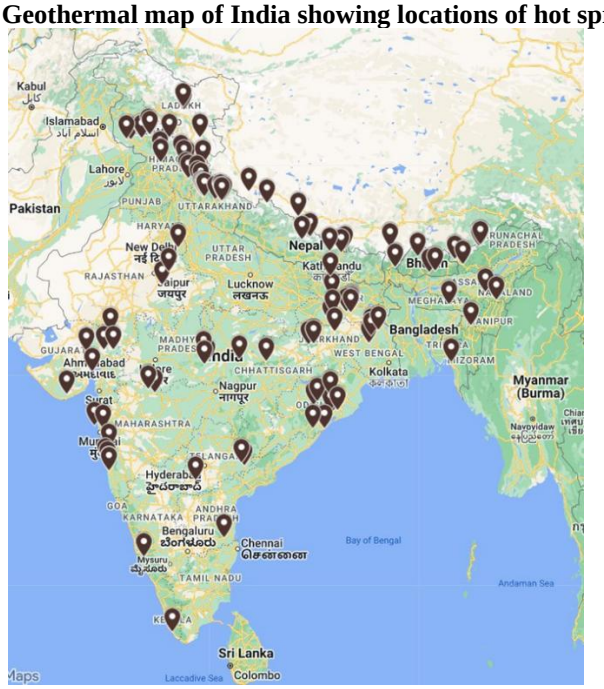
The central Himalayas curve north-southwesterly towards the western end, meeting the Karakoram-Hindukush Ranges of Pakistan and Afghanistan and joining the north-southerly trending Indo-Myanmar Arc, represented by the Naga Hills and the Arakan Yoma, with a similar strong bend at the eastern end as a result of the convergence of the Indo-Australian Tectonic Plate with the Eurasian (Asian) Tectonic Plate, building on to the formation of the mighty Himalayas several million years ago.

Fig.2. Superimposed Geothermal and Seismic maps of the Indian subcontinent



India has over 340 hot springs spread across the peninsular and extra-peninsular regions (Fig.3). Similarly, the seismotectonic belts of Sulaiman-Kirthar, Hindukush, Himalaya, Arakan-Yoma, the Shillong massif, and Kuchch-Kathiawar region produce the highest probabilistic accelerations, with values above 70% g (Imtiyaz A et al., 2003), indicating a close relationship between geothermal fields, seismic zones, and geotectonic settings. Geothermal hot springs and seismic zones generate a shimmering image of the Indian subcontinent's Queen's Necklace in Central Asia (Fig.2).

Fig.3. Geothermal map of India showing locations of hot springs



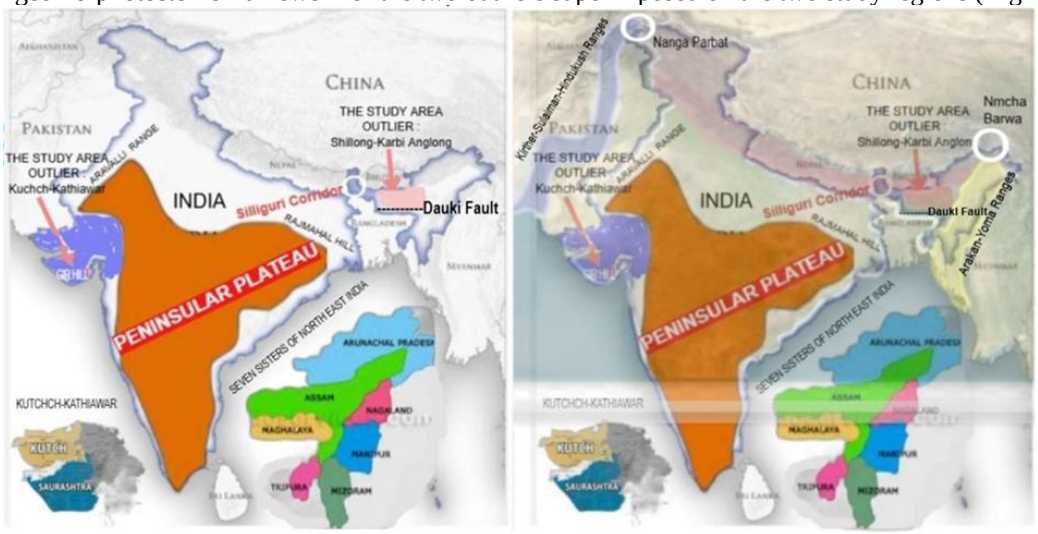
This study integrates geotectonic settings with hot spring disposition and fluid geochemistry to determine the geomorphotectonic evolution of the Kutchch-Kathiawar and Karbi-Shillong outliers. Statistically, these outliers represent geospatial data points that contrast significantly with other far away observations (Amitabha Roy, 2024; 2025)

The Study Areas

The Kuchch-Kathiawar Outlier

The Saurashtra (Kathiawar) outlier, in southwestern Gujarat, India, is surrounded by different physical features and has a history reaching back to the third millennium BC. It is associated with the Harappan civilisation, which includes archaeological sites such as Lothal and Prabhasa Patan (Patan Somnath).

Fig. 4. The research area: Kuchch-Kathiawar and Karbi Anglong-Shillong Outliers (Left) and the geomorphotectonic framework of the two outliers superimposed on the two study regions (Right)



Geomorphotectonic Framework of Kathiawar-Kutchch

Recent research suggests that the Kutchch Kathiawar plateau, once considered part of the Peninsular plateau, is now seen as part of the Western Coastal Plains. The Journal of Geophysical Research proposes block faulting based on the plateau's geometric shape. Following the same statistical definition of an outlier—an outlier is an observation that differs significantly from other values in a random sample of a population—the author disputes the widely held belief that the Kutchch-Kathiawar outlier is an extension of the main Indian Peninsula, despite its distance from the unit under consideration. Kathiawar and Kutch terranes differ significantly in many ways, including litho-tectonic pattern, volcanism and magmatism (Girnar Hill granites), Girnar laccoliths, concordant body with a flat bottom and convex upward dome-shaped hills, mini-arcuate east-southern convexity, and active seismicity resembling the western extension of smaller arcs of the Himalayan extension in central and south Asia (Karakorams-Hindukush and its southern extension, Sulaiman-Kirther hills in Pakistan), and Orthophragminids foraminifera from the Bartonian Fulra Limestone in Kutch, India, as well as coeval or contemporary units in Pakistan's Sulaiman Range (Ercan Özcan et al.,2018), all of these distinguishing features of the Kuchch-Kathiawar outlier strongly suggest a stronger geotectonic connection to the Great Himalayan Orogeny, as opposed to the widely held belief that it is an extension of the main Indian Peninsula, despite its remote location (Fig. 4).

Karbi_ Anglong – Shillong Outlier

The Seven Sisters are the northeastern states of India, which include Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura. Geopolitically significant, this region shares a 5,182-kilometer international border with China, Myanmar, Bangladesh, Bhutan, and Nepal. The Siliguri Corridor, sometimes known as the "chicken's neck," connects these states to India's mainland, allowing for trade and access to international routes. Closer examination indicates three geographical units with unique geotectonic features: 1. The Ganges-Brahmaputra alluvium graben in Assam; 2. the Indo-Burmese Ranges, which include the Indian states of Arunachal Pradesh, Manipur, Mizoram, Nagaland, and Tripura; and 3. the Karbi-Shillong hotspot, a zone of intense tectonic activity corresponding with the inverted V-shaped Namcha-Barwa syntaxial bend in the northeast Himalayas.

Shillong was nicknamed the "Scotland of the East" because to the rolling hills around the town, which reminded the British of Scotland. The Shillong Plateau, located in the Himalayan foreland, is prone to earthquakes due to its lofty elevation and numerous faults and shear zones. The plateau, which lies between the Himalayan belt in the north and the Indo-Myanmar mobile belt in the east, has been subject to compressive tectonic forces. Meghalaya Shillong and Karbi Anglong are separated from the main Peninsular Block. The Shillong Plateau has an average elevation of 1 km and is surrounded by the E-W-oriented Dauki Fault to the south and the E-W-oriented Brahmaputra River Fault/graben to the north. Shillong Peak, the highest point at 6,433 feet (1,961 meters), is located 3 miles (5 km) south of Shillong. The Dauki fault, an east-west trending reverse fault inclined northward, extends along the southern edge of the Shillong Plateau and is responsible for the Shilling horst and the corresponding Rangpur (B'Desh) graben. Shillong plateau is divided from peninsular India by the Tertiary Ganges-Brahmaputra alluvium and Cretaceous Rajmahal Volcanics.

The plateau is dominantly composed of Proterozoic basement granite gneisses, granites (sensu lato), migmatites, granulites, the Shillong Group metasedimentary cover sequence, and Mesozoic-Tertiary igneous and sedimentary rocks. Cambrian granite plutons of various sizes intrude the basement granite gneisses, the Shillong Group, and at a few places the Khasi Greenstone.

Geomorphotectonic Framework of Karbi-Shillong

Referring to the Karbi-Shillong plateau as an extension of the main Indian peninsular plateau would be disrespectful to the British contribution to Indian geology, especially given the state of scientific study instruments at the time. However, other than a few modifications here and there, there have been few notable accomplishments in unravelling geosciences history in this portion of India since then.

Spatial statistical analysis is the process of investigating the evolution of geographical objects/entities (such as geological features: Shillong outlier) based on knowledge of their position in relation to other geographical objects/entities (main Peninsular Plateau) by inspecting, assessing, evaluating, and modelling spatial data characteristics such as locations, traits, and their relationships, geotectonic settings, which reveal the data's geometric or geographic properties. Spatial analysis finds patterns or correlations in recorded data of a process that occurs over a distance. Using the same comparison, how can the Karbi-Shillong plateau, which is more than 1000 kilometres from the nearest border of the main peninsular plateau, be considered an extension of the main Indian peninsular plateau? The geomorphotectonic evolution of the Karbi-Shillong plateau outlier stands out as a distinct hotspot in North-East Indian geology (Fig.4). Finally, Nature performs a symmetrical balancing act, as evidenced by the two outliers—Kuchch-Kathiawar at the western end and Karbi-Shillong at the eastern end—both of which are associated with the Great Himalayan system of orogeny (Amitabha Roy, 2024).

II. Conclusion

In conclusion, this study on the Kutchch-Kathiawar and Shillong-Karbi Anglong outliers contributes significantly to our understanding of India's geological diversity and spatial dynamics. Through advanced multivariate statistical techniques, the research highlights the distinct geotectonic characteristics of these outliers, revealing their deviations from the surrounding geological formations. The Kutchch-Kathiawar outlier, influenced by the Great Himalayan Orogeny, is reclassified from an extension of the Indian Peninsula to part of the Western Coastal Plain, while the Karbi-Shillong outlier is recognized for its unique tectonic history and seismic activity. The research emphasizes the critical role of spatial statistics in uncovering patterns and correlations essential for elucidating India’s geodynamic history. This analysis not only enhances existing geological frameworks but also encourages a reassessment of how outliers are classified, highlighting their significance in the broader context of India's geotectonic landscape. Overall, the study showcases the interplay of spatial analysis and geological research, offering insights into the complex geodynamic processes shaping the Indian subcontinent.

References

[1] Amitabha Roy, 2024. The Book: Geostatistics Applied To Fluid Geochemistry Of Geothermal Fields In Peninsular And Extra-Peninsular India. White Falcon Publishing, Chandigarh, India. 2024. Pp. 1-144. ISBN: 979-8-89222-356-0

[2] A.Roy, 1994. GTHERMIS – An Information Management And Analysis System For Geothermal Data Of India, A Field Season Report (1993-94).

[3] Amitabha Roy, 2024. Geomorphotectonics Of The Kathiawar (Saurashtra) Kutchch Outlier: A Spatial Statistical Approach. J. Appl. Geol. & Geophys (Isor-Jagg), V. 12, Issue 6, Ver. I, Pp. 44-48

[4] Amitabha Roy, 2025. A Spatial Statistical Approach To Geomorphotectonics Of The Karbi-Shillong Plateau Outlier. . J. Appl. Geol. & Geophys (Isor-Jagg), V. 13 Issue 1, Ser. I, Pp. 20-22

[5] Ercan Özcan, Pratul Saraswati, Ali Osman Yücel, Nowrad Ali, And Muhammad Hanif, February 2018. Bartonian Orthophragminids From The Fulra Limestone (Kutch, W India) And Coeval Units In Sulaiman Range, Pakistan: A Synthesis Of Shallow Benthic Zone (SBZ) 17 For The Indian Subcontinent, Geodinamica Acta, 30(1).

[6] Imtiyaz A Et Al., 2003. A Deterministic Seismic Hazard Map Of India And Adjacent Areas. Geophysical Journal, Volume 155, Issue 2, Pp. 489-508.

[7] Jonathan Craig, 2013. The Hot Springs And The Geothermal Energy Potential Of Jammu And Kashmir State Northwest Himalaya, India.
[8] The Journal Of Geophysical Research: Solid Earth,Wiley And The American Geophysical Union (Earth Scences. Online ISSN-2169 9356; Print ISSN: 2169-9313).
[9] K.S.Valdiya Et Al.,1983. Sciences, Earth And Planetary. Sciences 108:107–116. Https://Doi.Org/10.1007.. Valdiya KS, Sanwal J (2017) Sabarmati Plain And Saurashtra–Kutchch. Ravi Shankar Et Al., 1991. Geothermal Atlas Of India, GSI Spec Publ.