EGU25-7819

Mexico City Sinkhole Formation: Development of a Conceptual Model in a Non-Karst Environment

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Huitzi, I., (2022, diciembre 11).

Luna, E., (2023, diciembre 11).

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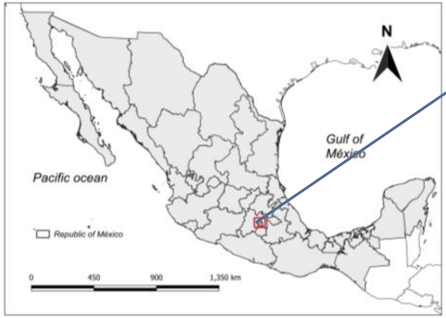
Geographic context

Mexico City is one of the most populated urban territories on the world, with more tan 9 million residents (INEGI, 2020).

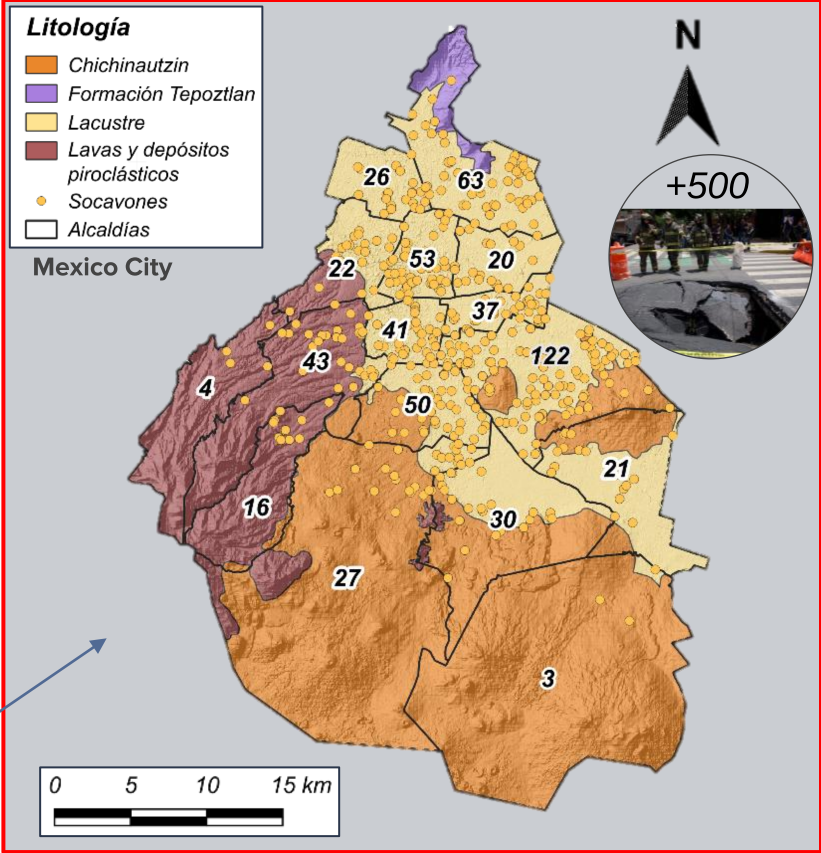
For its geographic location, the city is a hot zone to the presence of different natural hazards (García-Soriano et al., 2020; Novelo-Casanova et al., 2021).

Sinkholes formation stands out from the other phenomena for its strong presence in the city, where it has been recorded more than 500 events that have affected different routs of communication, homes and residents in the entire city since 2017 (SGIRPC, 2023).

Animal Político (2017).



Country of México



Lacustrine and pyroclastic deposits with lava intercalations.

Volcanic field with andesitic basaltic rocks, basalts, andesites and dacites.

Stratovolcanoes and domes, associated with epiclastic and pyroclastic deposits, of andesitic to dacite composition.

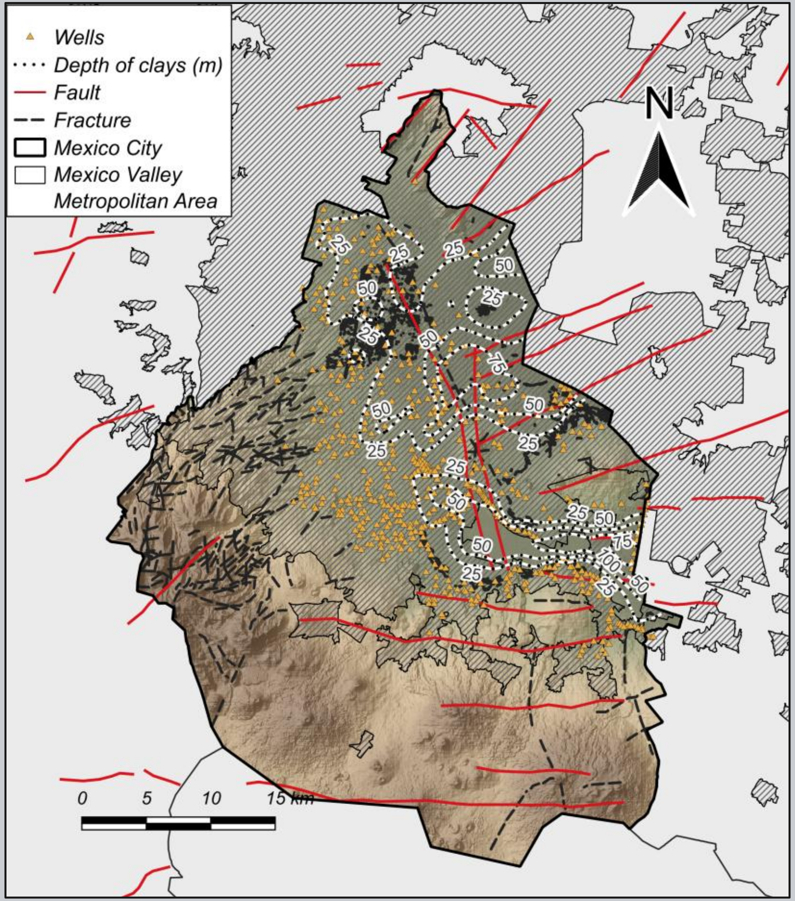
Volcaniclastic sequence and epiclastic deposits, interspersed with basaltic lava flows and andesite.

Research questions

how do hydrogeological, geological factors and antropogenic activities interact in the formation of sinkholes in Mexico City?

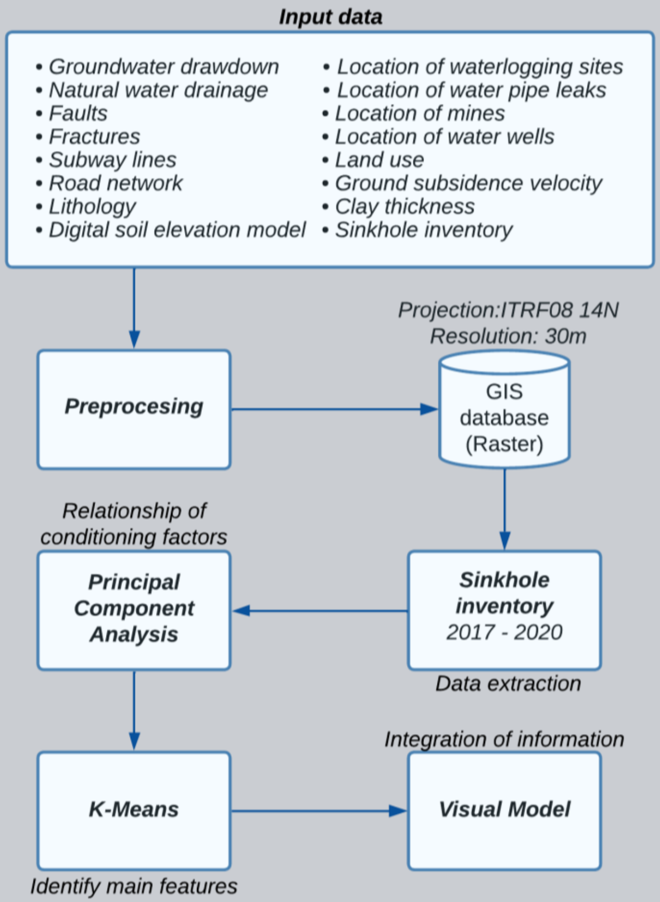
Objective

The objective of this study is to develop a conceptual model that integrates and explains the formation of sinkholes in a non-karst environment, addressing the interplay of geological, hydrogeological, and anthropogenic factors in Mexico City



Methodology

1. Data preprocessing and storage in GIS database
2. Data extraction
3. Analysis of the relationship between conditioning factors
4. Identification of predominant factors
5. Information integration



Principal component and K-Means cluster analysis

Principal Component Analysis (PCA) reduces the dimensionality of a dataset while retaining the maximum possible information.

Subsequently, the K-Means algorithm clusters the data into groups by minimizing the distance between each data point and its assigned cluster centroid (Forsyth, 2017).

The first 8 principal components from the PCA capture sufficient variance to enable the identification of meaningful patterns through the K-Means algorithm.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Standar deviation	2.13	0.18	1.39	1.27	1.21	1.11	1.06	0.98
Variance portion	0.22	0.15	0.09	0.08	0.07	0.06	0.05	0.05
Cumulative variance	0.22	0.37	0.46	0.54	0.61	0.67	0.72	0.77

Figure 1. Principal component análisis. Most representative variables. PC1: Groundwater drawdown, elevation, natural drainage, waterlogging sites, mine, subway, clay thickness. PC2: waterleaks, water wells, fractures, faults, roadways, soil deformation.

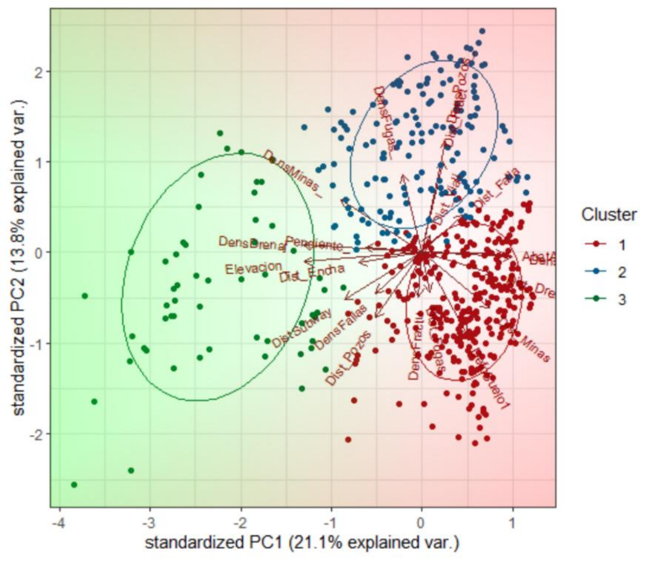
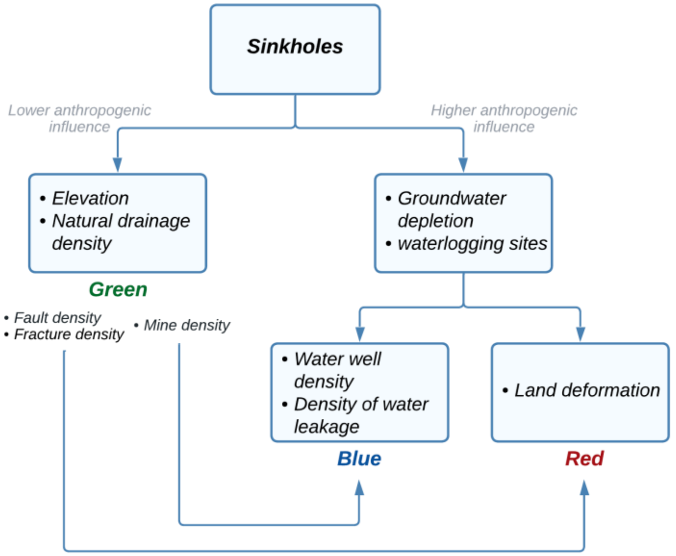
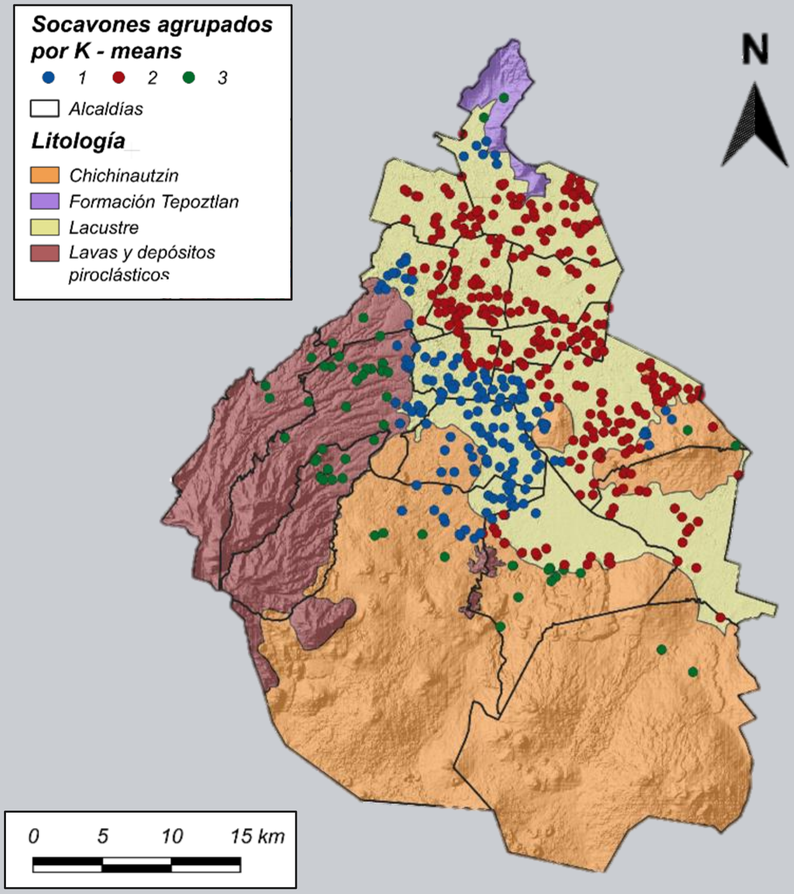


Figure 2. Results of k-means, 3 different groups were recognized (Green, blue and red).

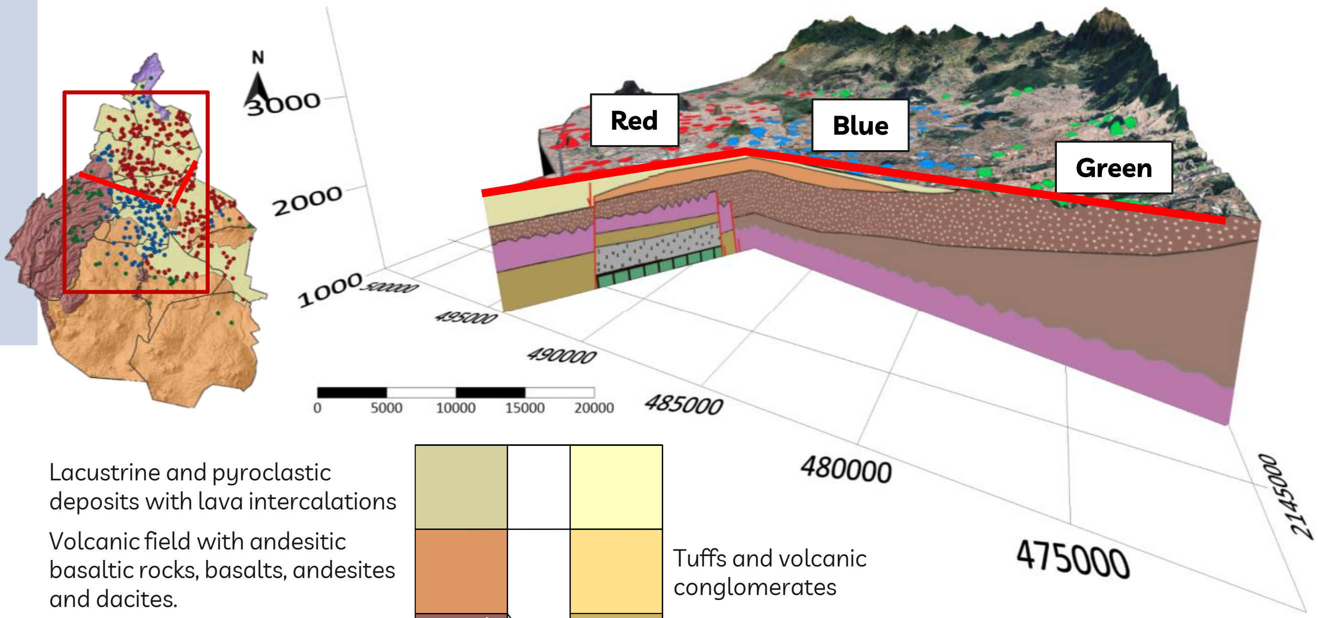
Conceptual model

The clusters identified through PCA and K-means algorithm exhibit variations in the predominant influence of conditioning factors.





Information integration



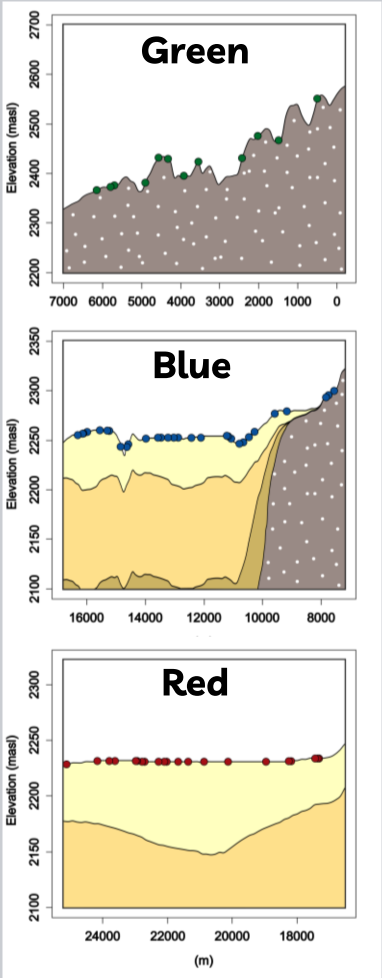
Lacustrine and pyroclastic deposits with lava intercalations

Volcanic field with andesitic basaltic rocks, basalts, andesites and dacites.

Stratovolcanoes and domes, associated with epiclastic and pyroclastic deposits, of andesitic to dacite composition.

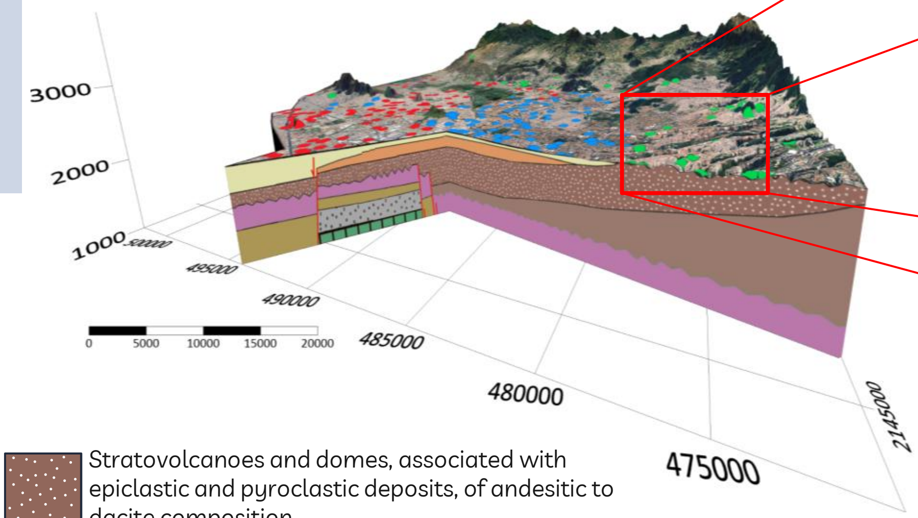
Tuffs and volcanic conglomerates

Sandy tuffs, volcanic conglomerates with basalts and plastic clays

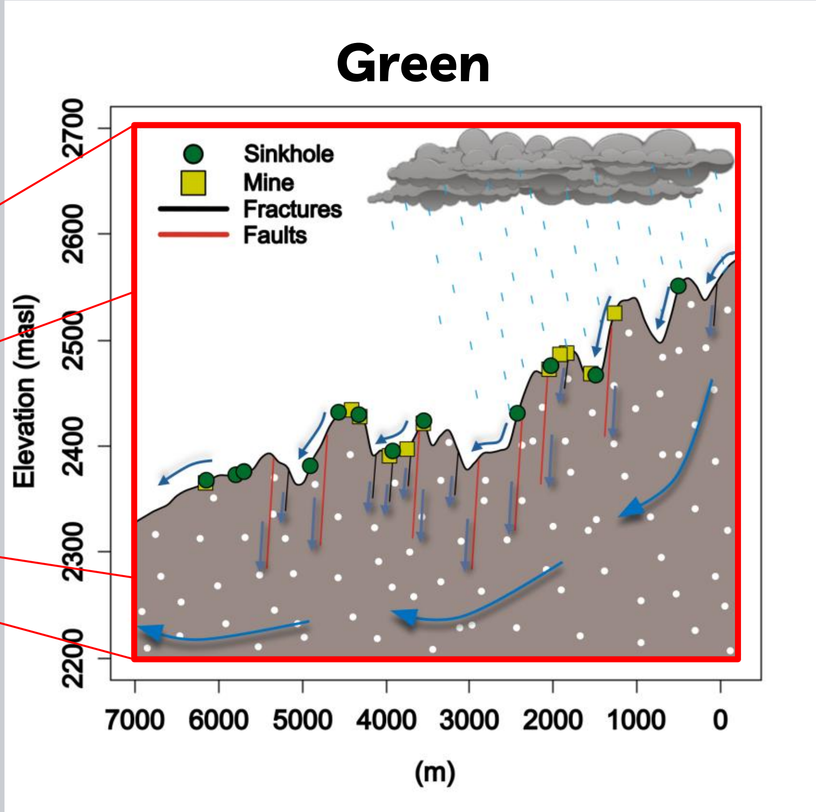


Information integration

These sinkholes form when water flows quickly through weak zones (like faults or old mines) in volcanic deposits, causing erosion inside the ground.

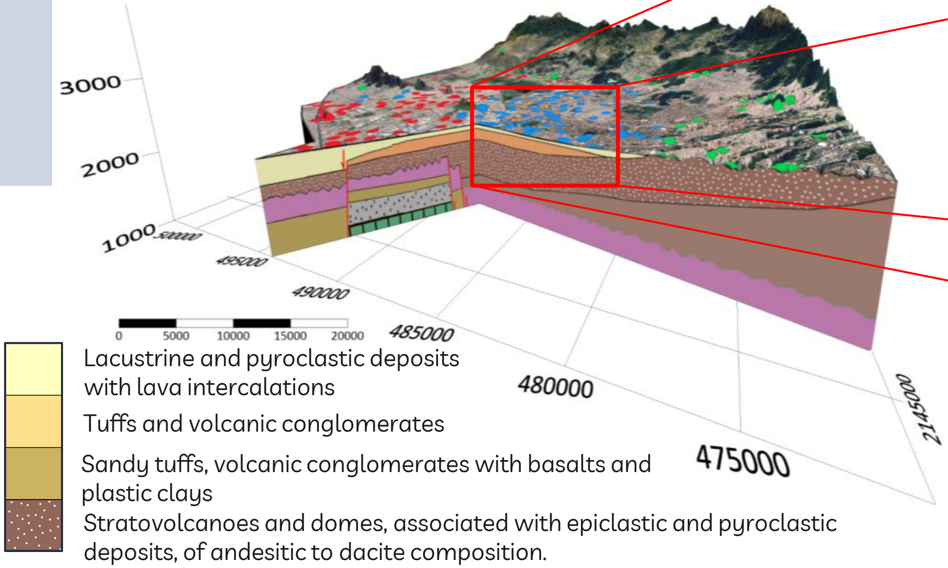


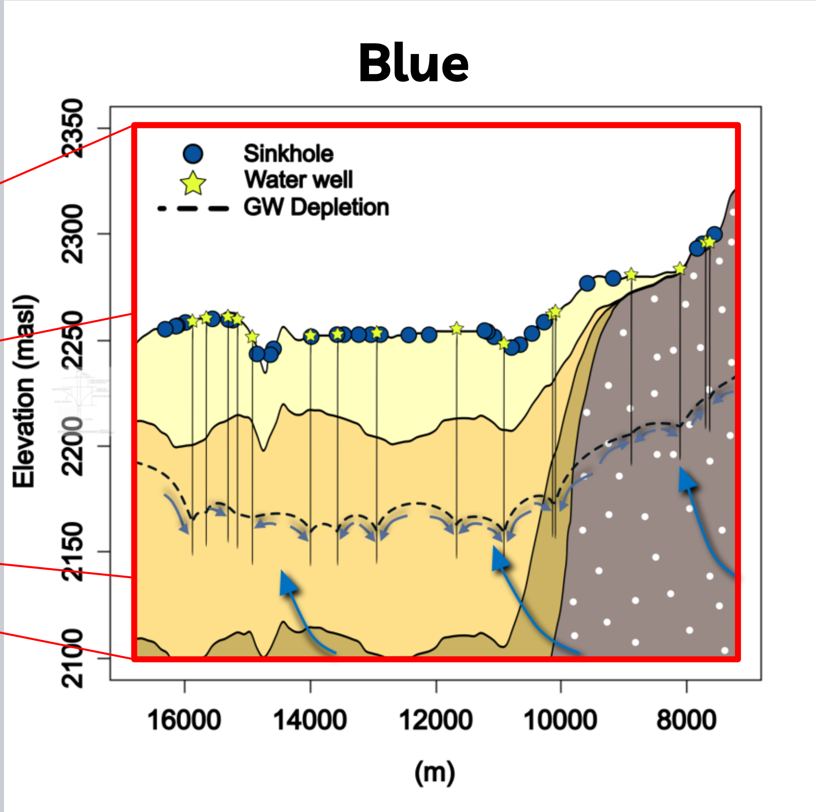
Stratovolcanoes and domes, associated with epiclastic and pyroclastic deposits, of andesitic to dacite composition.



Information integration

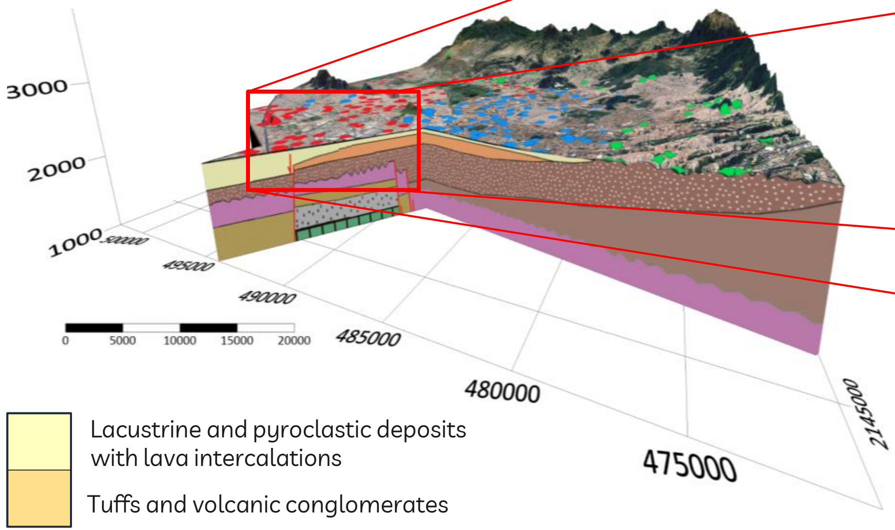
Esta zona se caracteriza por la sobreexplotación del agua subterránea, que reduce el nivel freático bajo los depósitos lacustres superficiales.

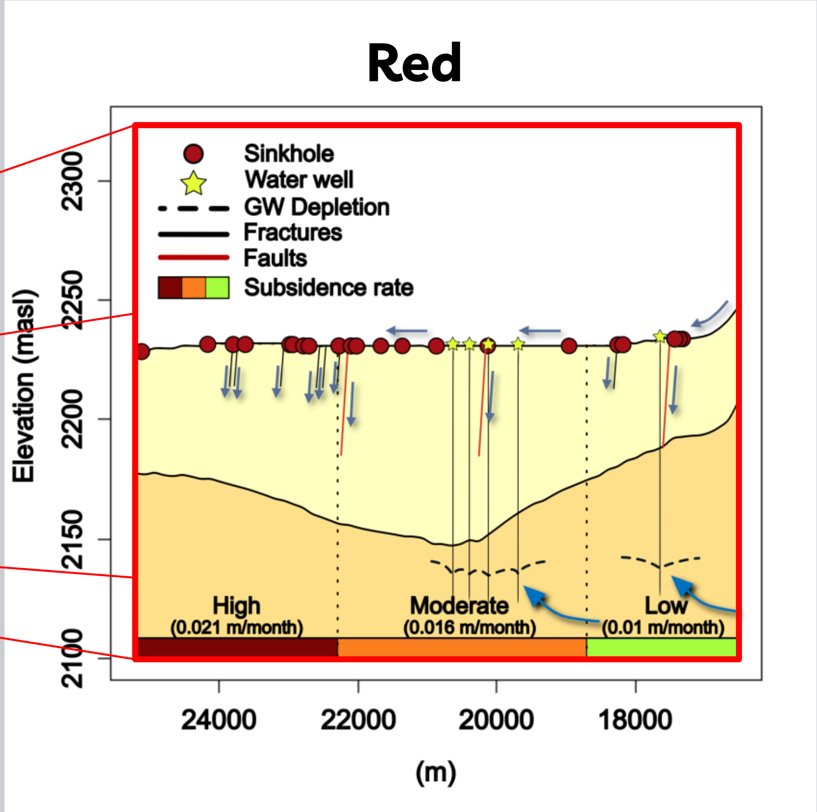




Information integration

This zone is characterized by the land subsidence due to the compaction of lacustrine materials due to the overexploitation of groundwater, generating deformation and surface cracks.





Conclusions

The use of statistical techniques such as Principal Component Analysis (PCA) and unsupervised classification algorithms like K-Means represents a powerful tool for analyzing and describing the behavior of complex phenomena, such as sinkhole formation.

The K-Means analysis classified sinkholes into three distinct types:
Red and blue clusters are mainly influenced by aquifer drawdown and well density. Blue sinkholes show a stronger relationship with infrastructure failures like water leaks, while red ones are more closely linked to subsidence and terrain deformation. Green sinkholes are associated with topographic features such as elevation and natural drainage.


Luna, E., (2023, diciembre 11).


Huitzi, I., (2022, diciembre 11).

This study highlights the multifactorial nature of sinkhole formation in Mexico City, demonstrating that distinct combinations of geological, hydrological, and anthropogenic variables influence their development.

These findings contribute to a more nuanced understanding of sinkhole dynamics in urban environments and offer a foundation for improving risk assessment and mitigation strategies in Mexico City.

Thank you for your attention!

Sergio A. García

If you have any questions, please feel free to email them to me at garciacrz93@gmail.com

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Mapping sinkhole susceptibility in Mexico City using the weight of evidence method

Geomatics, Natural Hazards and Risk

Taylor & Francis

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Assessing the relationship between contributing factors and sinkhole occurrence in Mexico City

Bibliografía

- Animal Político. (2017, 7 de septiembre). ¿Por qué se han hecho socavones en la Ciudad de México? Un experto del IPN lo explica. Recuperada el [08 de febrero 2025], de https://animalpolitico.com/sociedad/experto-politecnico-socavones-ciudad-mexico
- Bi, J., Luo, X., & Shen, H. (2021). Modeling of Suffusion Considering the Influence of Soil Gradation. Transport In Porous Media, 136(3), 765-790. https://doi.org/10.1007/s11242-020-01534-6
- Caramanna, G., Ciotoli, G., & Nisio, S. (2007). A review of natural sinkhole phenomena in Italian plain areas. Natural Hazards, 45(2), 145-172. https://doi.org/10.1007/s11069-007-9165-7
- Forsyth, D. (2017). Probability and Statistics for Computer Science. En Springer eBooks. https://doi.org/10.1007/978-3-319-64410-3
- García-Cruzado, S. A., Ramírez-Serrato, N. L., Herrera, G. S., Hernandez-Hernandez, M. A., Yépez-Rincón, F. D., Villarreal, S., & Olea-Olea, S. (2025). Mapping sinkhole susceptibility in Mexico City using the weight of evidence method. Journal Of South American Earth Sciences, 105368. https://doi.org/10.1016/j.jsames.2025.105368
- Huitzi, I. (2022, diciembre 11). Este año se han detectado 112 socavones en la red de drenaje. [Fotografía]. El Sol de México. Recuperado de https://oem.com.mx/elsoldemexico/metropoli/gam-concentra-los-socavones-de-la-cdmx-16395257
- Igual, L., & Seguí, S. (2017). Introduction to Data Science. En Undergraduate topics in computer science. https://doi.org/10.1007/978-3-319-50017-1
- Luna, E. (2023, agosto 24). Se abre socavón de tres metros de profundidad en la avenida Monterrey de la colonia Roma. [Fotografía]. Milenio. Recuperado de https://www.milenio.com/politica/comunidad/socavon-3-metros-profundidad-colonia-roma
- Ramírez-Serrato, N. L., García-Cruzado, S. A., Herrera, G. S., Yépez-Rincón, F. D., & Villarreal, S. (2023). Assessing the relationship between contributing factors and sinkhole occurrence in Mexico City. Geomatics Natural Hazards And Risk, 15(1). https://doi.org/10.1080/19475705.2023.2296377
- Sinclair, W. C., Stewart, J. W., Knutilla, R. L., Gilboy, A. E., & Miller, R. L. (1985). Types, features, and occurrence of sinkholes in the karst of west-central Florida (Water-Resources Investigations Report 85-4126). U.S. Geological Survey. https://doi.org/10.3133/wri854126
- Taheri, K., Shahabi, H., Chapi, K., Shirzadi, A., Gutiérrez, F., & Khosravi, K. (2019). Sinkhole susceptibility mapping: A comparison between Bayes-based machine learning algorithms. Land Degradation and Development, 30(7), 730-745. https://doi.org/10.1002/ldr.3255.
- Waltham, T., Bell, F. G., & Culshaw, M. G. (2005a). Sinkholes and Subsidence: Karst and Cavernous Rocks in Engineering and Construction. Springer Science & Business Media.