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Mendoza from a geological perspective aplied to urban planning from the 16Th to the 18Th century

Mendoza desde una perspectiva geológica aplicada al urbanismo del siglo XVI al XVIII

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ABSTRACT

This research has been of interest to identify the past geological and environmental processes that triggered and accentuated the ecological, social and historical transformations of the urban sector of Mendoza between the sixteenth and eighteenth centuries. In the present research, the following were taken as objects of analysis: geological processes, topography, hydrogeological management and land use. These variables were measured through indicators such as the use of natural resources, alluvium, floods, seismic events, landforms and erosive agents. The techniques of documentary and content analysis were used, in addition to the observation technique, in order to gather the necessary resources to obtain data for the analysis of each variable.
A historical zoning of geological hazards was elaborated, through the occurrence data documented in the historical records analyzed. Five units were obtained, resulting in the area with potentially damaging processes occurring in the urban area of the foundational city of Mendoza. This is located in the area of cones and alluvial fans of the Mendoza River, i.e. it is part of the environment where the discharge of sedimentary material from the foothills of the foothills is generated. Consequently, the processes involved were: floods, alluvium, salinity and active faulting through the Cerro de la Cal fault, whose trace crosses the city. In short, framing the environmental processes of a city from urban geology is essential to establish the threats or hazards and potential damage that affect or may affect the territory.

Palabras clave:
urbanismo, geología urbana, medio ambiente, historia.

RESUMEN

Ha sido de interés identificar los procesos geológicos y medio ambientales del pasado que desencadenaron y acentuaron las transformaciones ecológicas, sociales e históricas del sector urbano de Mendoza entre los siglos XVI y XVIII. En la presente investigación se tomaron como objetos de análisis: los procesos geológicos, la topografía, el manejo hidrogeológico y el uso del suelo. Estas variables fueron medidas a través de indicadores como el uso de recursos naturales, aluviones, inundaciones, eventos sísmicos, formas del relieve y agentes erosivos. Se utilizaron las técnicas del análisis documental y de

contenido, además de la técnica de la observación, con el propósito de recabar los recursos necesarios para obtener datos de análisis de cada variable.
Se elaboró una zonificación histórica de peligrosidad geológica, a través de los datos de ocurrencia documentados en los registros históricos analizados. Se obtuvieron cinco unidades, resultando el área con ocurrencia de procesos potencialmente perjudiciales la que comprende el casco urbano de la Ciudad fundacional de Mendoza. Esta se emplaza en la zona de conos y abanicos aluviales del río Mendoza, es decir que forma parte del ambiente donde se genera la descarga del material sedimentario del piedemonte precordillerano. Por consiguiente, los procesos actuantes fueron: inundaciones, aluviones, salinidad y fallamiento activo a través de la falla Cerro de la Cal, cuya traza atraviesa la ciudad. En suma, enmarcar los procesos ambientales de una ciudad desde la geología urbana es fundamental para establecer las amenazas o peligros y los daños potenciales que afectan o pueden afectar al territorio.

Introduction

The urban development of Mendoza took place within a growth that involved the interaction between society and the natural environment. The dynamics of this process is presented in three stages marked by different events and events in the founding history of the city. Initially, a pre-Hispanic period (prior to the 16th century) where the inhabitants belonged to local cultures, with little impact on the demand for the natural resource. Then the foundation process was installed, manifesting the interest of colonization and exploration of the territory (XVI-XVII centuries) progressing towards a consolidation of a society in an effective way between the XVII-XVIII centuries, to give place, in the XVIII century, to the process of growth and urban expansion. The city of Mendoza began to transform itself into an urban ecosystem increasingly dependent on natural resources for its subsistence. In this sense, environmental issues should be analyzed as a symbiosis of social and natural sciences, contextualizing the topographic, geological, economic, political, and anthropic situation in the history of a region that was the axis of communication between two worlds (Spain and the American colonies) and its strategic link as a transportation network since its foundational beginnings. It is for this reason that the city of Mendoza serves as an example to address the development of its city and how it varied according to its degree of urbanization in these historical times. This issue has been studied from an environmental, archaeological and social history perspective by Chiavazza (2012), Prieto, and Chiavazza (2005), Prieto (1989), Prieto et al. (2012), Prieto (1997), Abraham and Prieto (1991), Abraham and Prieto (1981).

The main motivation of this work is to approach the historical environmental processes of this city from a geological point of view applied to urban planning. How are geological and environmental processes linked to the morphological characteristics of the city of Mendoza consolidated between the 16th and 18th centuries?

We will take into account that every urban system is surrounded by ecosystems of various types (vegetation, soil, crops, grazing fields, water basins) which, when integrated, form the necessary support for its subsistence. Within this framework, we intend to analyze the role played by this settlement in the exploitation of resources and its direct link with natural phenomena associated with floods, earthquakes and alluvium. Thus, the present work would show the changes that urban activity has developed to adapt to the new circumstances of its ecosystem. Associated with this approach, we also contribute from a geological-environmental perspective to geological risks in order to predict and prevent natural phenomena that may harm the population or the settlement of a population in a given geographical site.

Method

The research design to be followed is non-experimental, using the bases of projective type research, whose objective is to describe, analyze and explain how geomorphological and environmental processes are linked to the morphological characteristics of the city of Mendoza consolidated between the 16th and 18th centuries.

Through qualitative analysis, we intend to address and study the variables involved in the geomorphological and environmental processes that occurred in the urban sector of Mendoza, such as geology, topography, hydrogeology, and soil.

As can be seen in the table of operationalization of variables (Table 1), we intend to use the techniques of content analysis, documentary, and observation. The data obtained through these techniques will be recorded by means of measuring instruments.

As shown in Table 1, the research strategy is based on understanding and interpreting the natural scenarios that took place in the process of urban expansion through the reconstruction of the paleoenvironment and natural resources from a diachronic environmental perspective. By resorting to the methodology of environmental history, which is fundamentally aimed at obtaining reliable ecological data from historical sources.

Natural indicators such as vegetation distribution and coverage, local flora and fauna species, droughts and extraordinary precipitation, the increase and decrease of river flows, swamps, alluvial channels, soil erosion, floods, alluvium, and the analysis of seismic events will be tracked. With respect to anthropic indicators, we will investigate settlements, occupation and abandonment of land, use of natural resources, introduction of new plant and animal species, new crops, construction of canals and/or drains, and water use.

For the description of the population situation, historical documents from the Chapter Acts of the Cabildo of Mendoza, the General Archive of the Nation and the General Archive of the Indies (Seville) Spain, corresponding to the 16th, 17th, and 18th centuries, will be taken into account.

A basic task will be to express the categories associated with the processes (relief, geomorphology, soil, vegetation, geological processes, lithology and Quaternary deformations) and their relationships in space through cartographic representation. Maps will be made based on current knowledge of the geomorphology, vegetation cover, soil, and neotectonic deformations acting in the area and will be compared with historical documentation, information materials obtained from archaeological finds, and characteristic plans of the study period.

The cartographic representation of the current state of the ecosystems involved will be carried out through the analysis of satellite images, 3D reliefs (DEM) and longitudinal profiles of the different sites of interest to be analyzed.

Table 1
Table of operationalization of variables

Variables	Indicators	Techniques	Measuring instruments
Geological Processes	Use of natural resources. Alluvium. Flooding, Seismic events and quaternary deformation.	**Documentary analysis**	Database and software storage.
		Content analysis	Baseline, log charts and category classification.
		Observation	Geological mapping, Gis software (QGIS)
Topography	Natural relief elevations. Occupied surfaces. Relief shape. Relief morphologies.	**Content analysis**	Record charts and category classification
		Remarks	Thematic mapping and geological mapping. Gis software (QGIS).
Hydrogeological Management	Construction of canals and drains. Location. Proximity to urban sectors. Water use.	**Documentary analysis**	Database and software storage.
		Content analysis	Baseline, log charts and category classification.
		Observation	Geological mapping, Gis software (QGIS)
Land uses	Crops. Occupied surfaces. Erosive agents. Land occupation and abandonment.	**Documentary analysis**	Database and software storage.
		Content analysis	Baseline, log charts and category classification.
		Observation	Geological mapping, Gis software (QGIS)

Note: Adapted from Mazzeo 2021

Results

The aim is to achieve a historical zoning of geological hazards, through the occurrence data documented in the historical records analyzed for the sector called "the foundational area of the city of Mendoza", located in the current city of Mendoza, Argentina (Figure 1). The foundational city is located in the area of the fourth section of the capital of this province (Figure 2). It covers an area of 25 blocks around the current Pedro de Castillo square, to the west of the Cacique Guaymallén canal (Chiavazza, 2009). (Figure 3).

Geological hazard can be understood as the probability of occurrence of a potentially damaging phenomenon (geological process) within a given period and in a specific area. Varnes (1984).

The following elements were basically used for the zoning: geological processes, lithology, geomorphology, information about recurrences and intensity or magnitude of the processes, and characteristics of the triggering agents. (Figure 4). The zoning is at a local scale since we only wish to present the hazards associated with the study sector.

For a better understanding, it was classified into the following units (Gonzáles et al., 2002) (Figure 5):

• **Area with occurrence of potentially damaging processes**. This area includes the urban area of the Foundational City of Mendoza (Figure 3). It is located in the sector of cones and alluvial fans of the Mendoza River (Figure 6 and Figure 7), where the discharge of sedimentary material from the Precordilleran foothills is generated. Processes: floods, alluvium, salinity and active faulting through the Cerro de la Cal fault, whose trace crosses the city.

• **Area with occurrence of moderately damaging processes**. The archaeological site, Memorial de la Bandera site, is located there. The zone includes small areas distributed in the southwest and northeast whose geological environments are similar to the area described above. Processes: floods, alluvium and salinity.

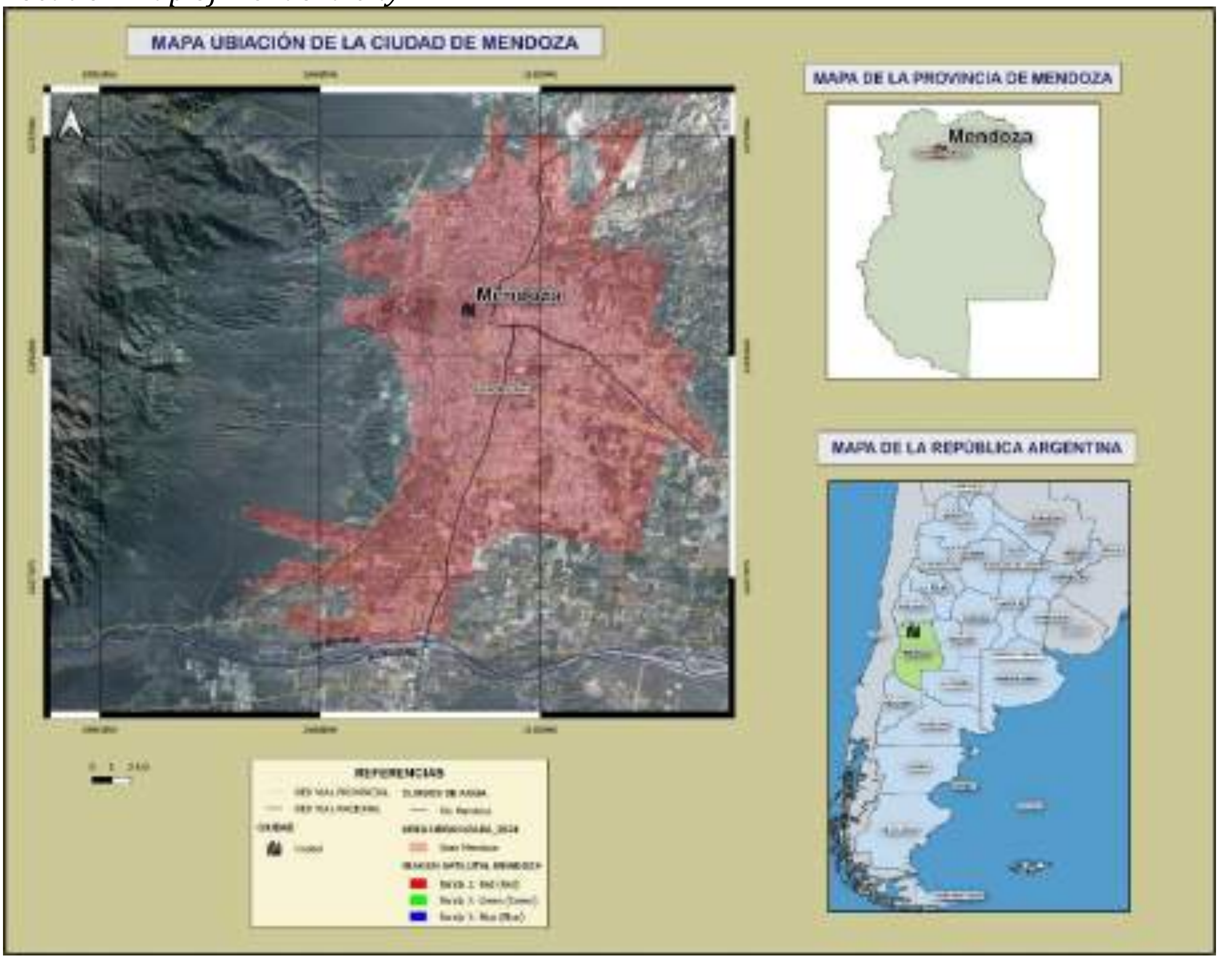
• **Area with occurrence of moderately to slightly damaging processes**. The Arroyo Tulumaya archaeological site (PA70) is located. It includes the foothills of the Precordillera, the central sector of the Maipú Cone, and a large part of the Tulumaya and Rosario Plains (Figure 7). Processes: erosion (carcavation) and fluvial sedimentation, flooding, liquefaction, and salinization.

• **Area with occurrence of slightly damaging processes.** It occupies part of the Tulumaya plain and the Huanacache lagoons. The most important processes are: erosion (carving) and fluvial sedimentation, liquefaction and salinization.

• **Area where no harmful processes have been detected**. It coincides with flat or low slope and height reliefs, in resistant rocky massifs. (Figure 10)

Figure 1.

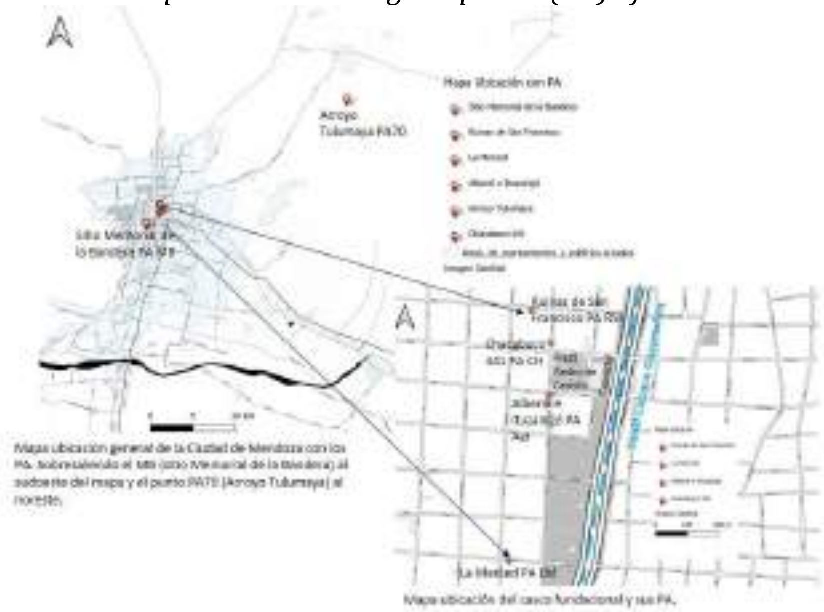
Location map of Mendoza city



Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), National Geographic Institute (IGN). Google (https://www.idera.gob.ar/).

Figure 2

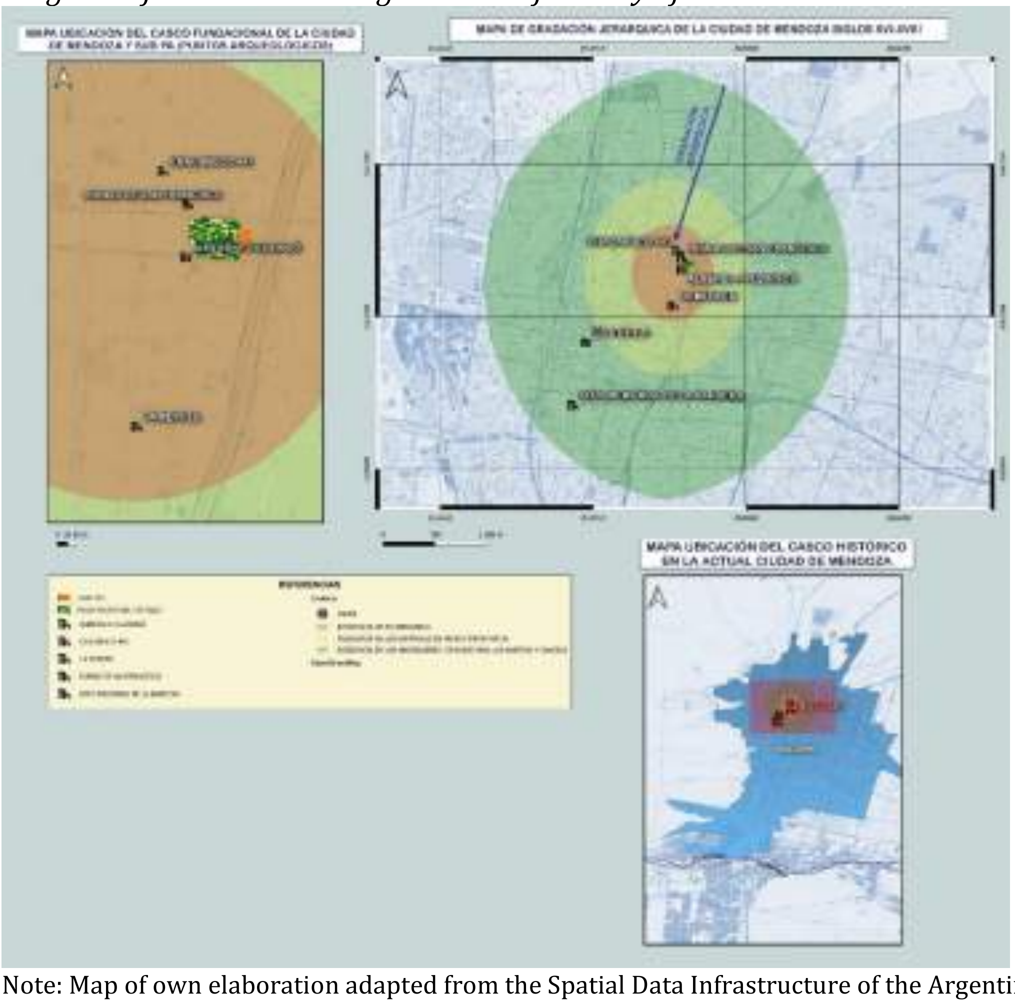
Location map with archaeological points (AP) of the urban center and its periphery



Note: Own elaboration adapted from Chiavazza (2012).

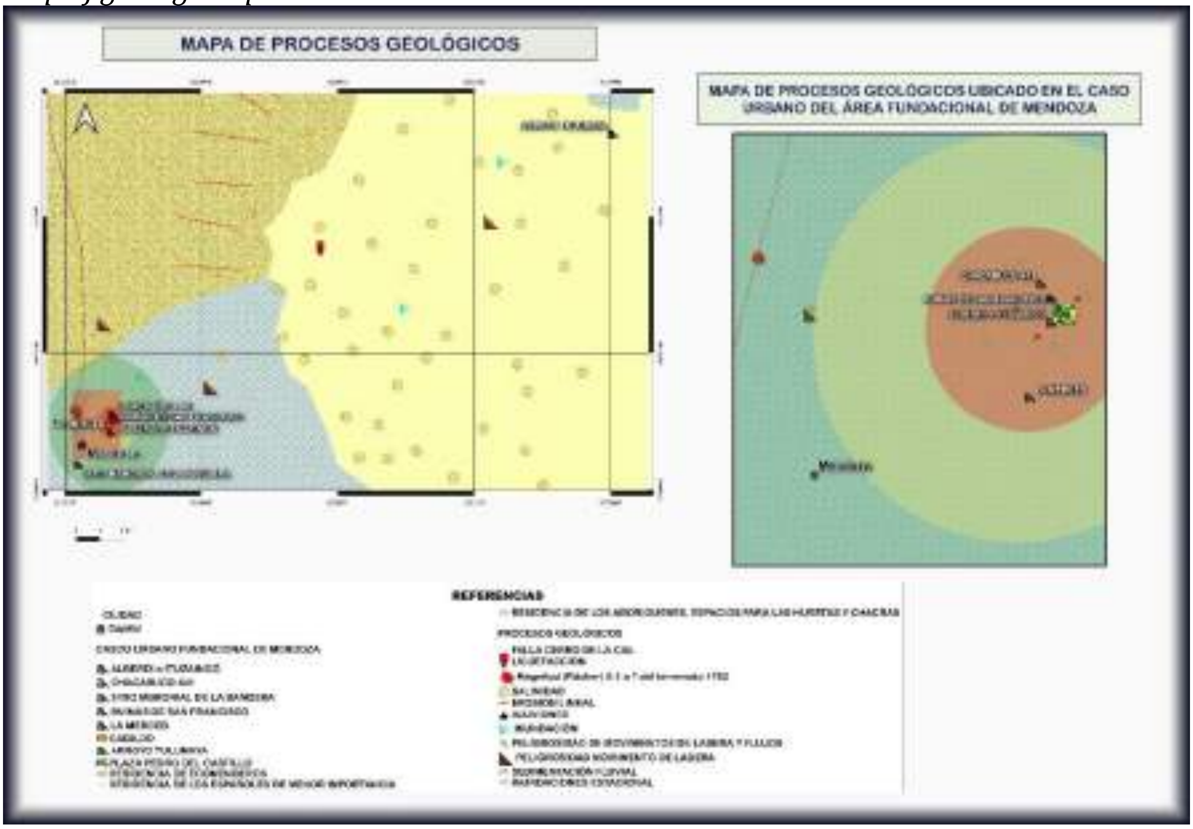
Figure 3

Diagram of the hierarchical gradation of the city of Mendoza in the XVI-XVIII centuries



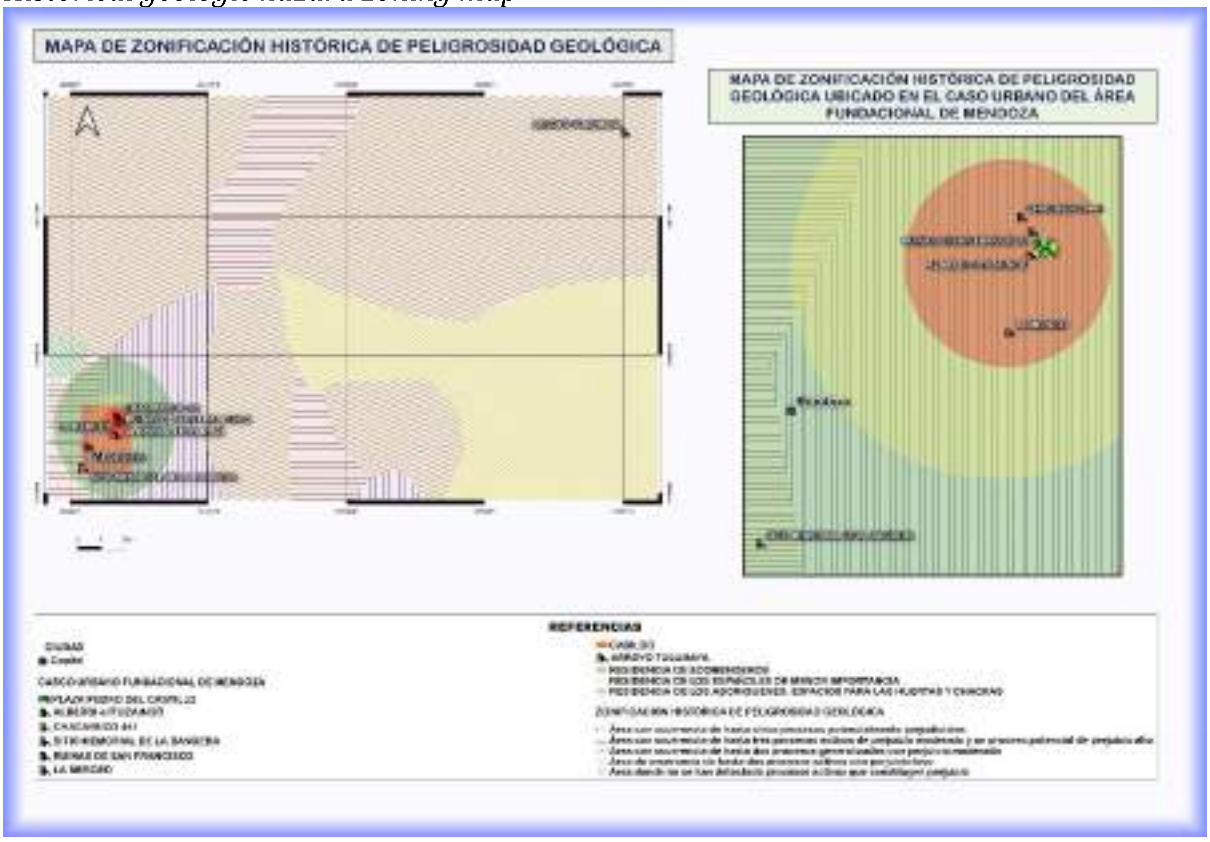
Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), National Geographic Institute (IGN). Google (https://www.idera.gob.ar/).

Figure 4
Map of geological processes



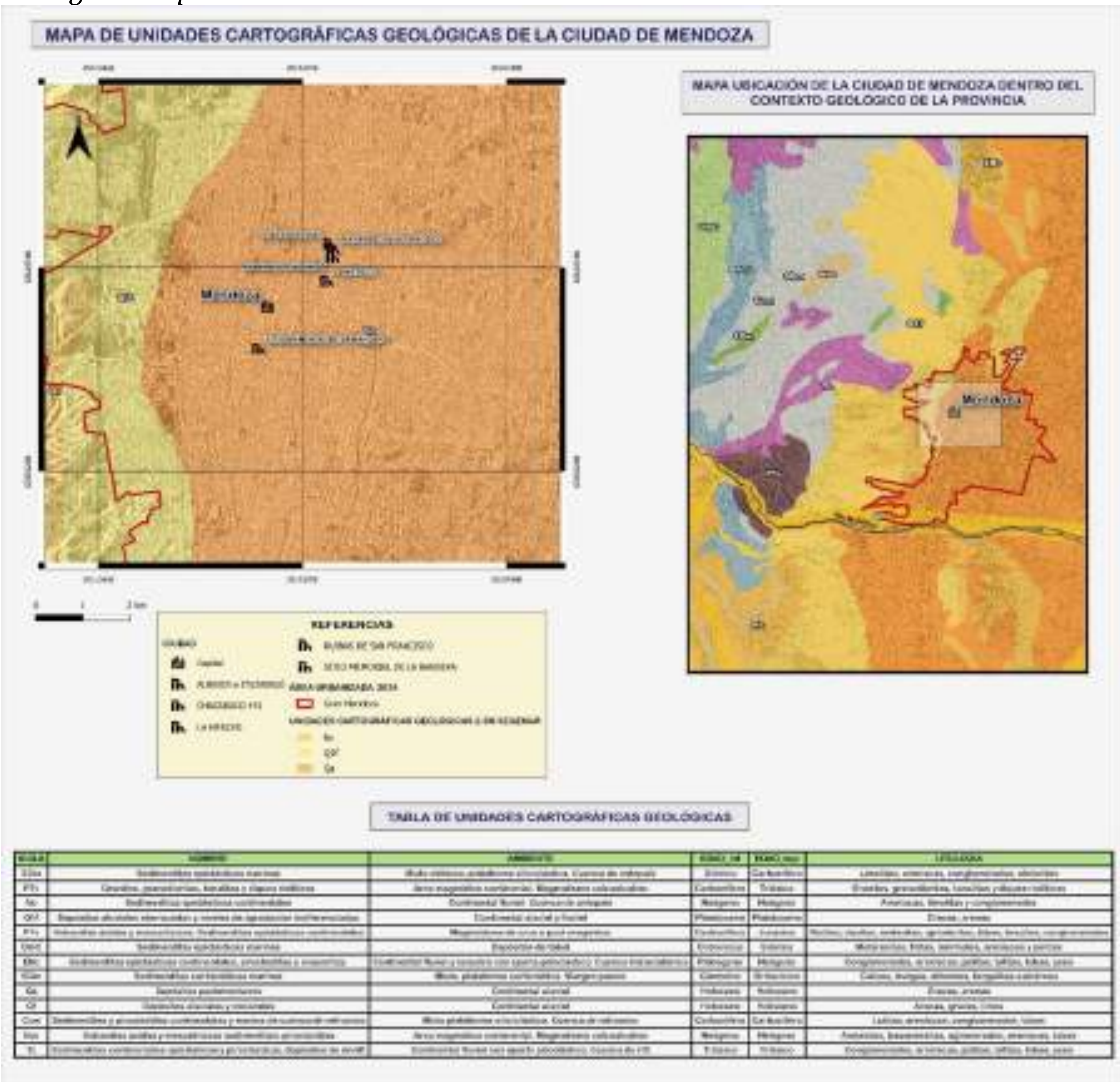
Note: Own elaboration adapted from González et al. (2002).

Figure 5
Historical geologic hazard zoning map



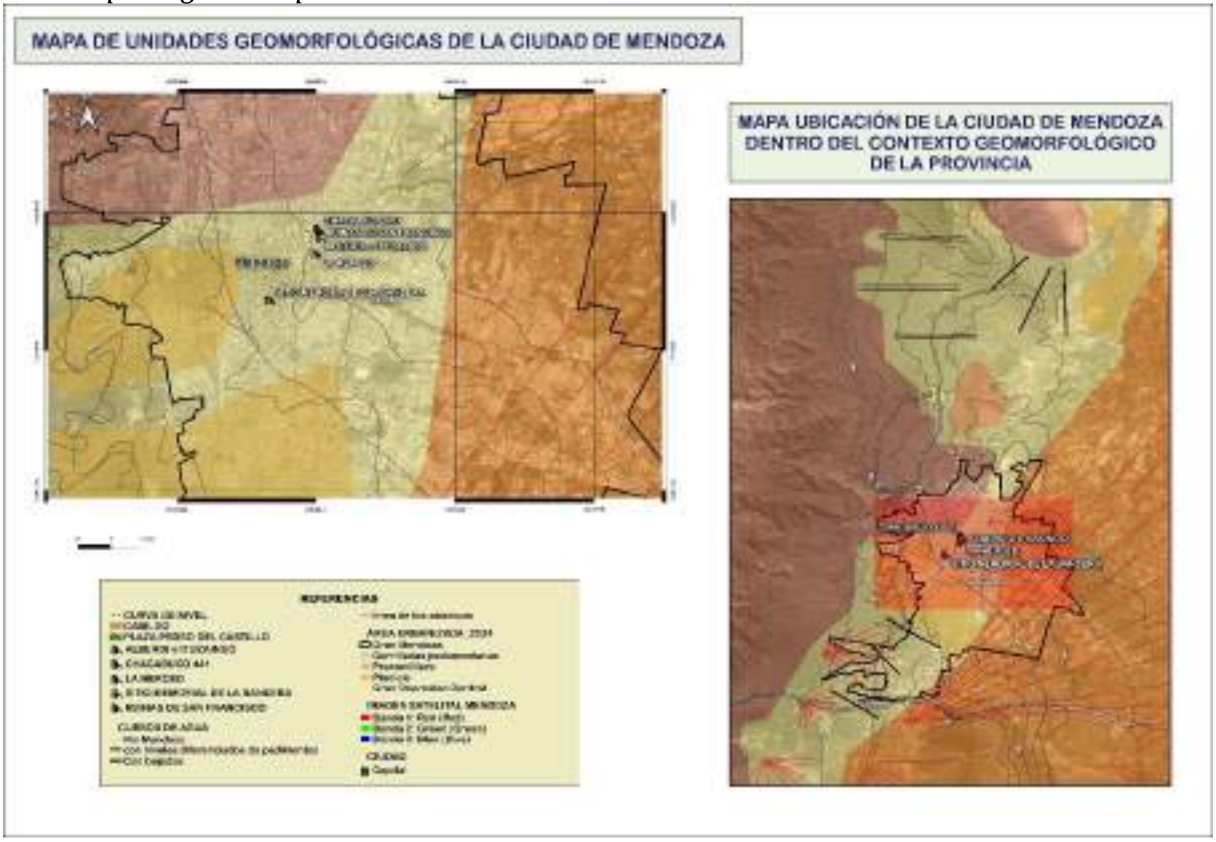
Note: Own elaboration adapted from González et al. (2002)

Figure 6
Geological map



Note: Own map adapted from Servicio Geológico Minero Argentino (SEGEMAR) Google (https://www.argentina.gob.ar/economia/segemar).

Figure 7
Geomorphological map



Note: Own elaboration Adapted from Abraham (1996).

Another factor that intervened in the natural conditions of the terrain were the climatic fluctuations (periods of higher or lower humidity) accompanied by rises and falls in temperature, also these influenced the life of the inhabitants of the new city, especially in the economic aspect (droughts, the appearance of plagues and pests). The positive or negative trends in rainfall should also be taken into account, which not only affected economic activity, but also caused floods and large mudflows or torrents of mud, causing serious damage to the population (Figure 8).

Figure 8
Alluvium in Mendoza XVII-XVIII centuries

Note: Adapted from Prieto (1989). History of the occupation of space and the use of natural resources in the foothills of Mendoza (p.152).

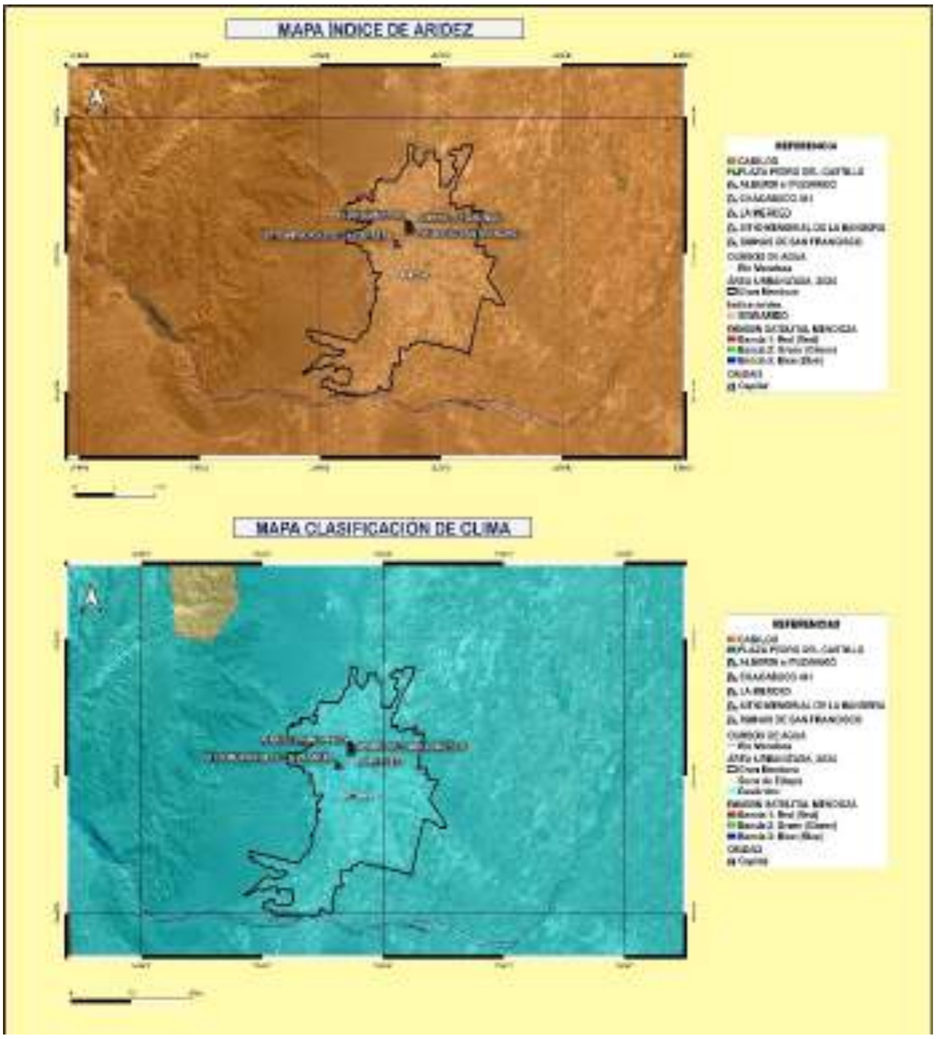
Floods have covered and currently cover large areas of the city of Mendoza, as shown in Figure 4, due to the large flood plains of the Mendoza River located to the southeast (Figure 7). The factors are mainly geomorphology (wide flood plains) and lithology (fine deposits) (Figure 6). Triggering factors are generally torrential summer rainfall and snowmelt (increased inflow causing overflows). Although they are not excessive, when concentrated in a short period of time their effects are more important. Historically, the rains that present serious damage are those greater than 40 mm/h. (Figure 9). Another factor is the excessive increase in temperatures, which causes a considerable increase in the flow, due to the thawing of snow, in the headwaters of the basins. Gonzáles et al. (2002).

It is recorded that the floods began to damage the city of Mendoza from 1661-70, but it was not until 1720-30 (beginning of the 18th century) when their quantity and intensity began to increase, and it was then that the disappearance of buildings and crops located near the riverbed was feared. (Prieto et al., 2008).

The written documentation of that time also mentions the suffering of the floods in the foundational area as detailed by Bárcena et al (1990 p. 22):

> According to the minutes of the town council, the damage to which the city was subjected to the rains is reflected: The house and jail suffered water damage since 1609, which shows, as we have seen, its location in the middle of the water evacuation line towards the so-called Zanjón or zanjón channel. The chapter minutes of the time have numerous references to these periodic landslides produced by the rains or flooding of the ditch. This was aggravated during the beginning of the 18th century, when the ditch, deepened by the diversion of other waters into its course, endangered not only the Cabildo but also the very existence of the city.

Figure 9
Map of Mendoza's climatic conditions



Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), Ministry of Environment and Sustainable Development. Google (https://www.idera.gob.ar/).

The study area has been characterized by seismic activity since the end of the 18th century, which does not mean that such activity did not occur previously. This seismic activity mainly affected the colonial urban area and its surroundings. Damage to structures (houses) caused by this phenomenon was mainly induced by ground surface movements and liquefaction. (Figure 4).

The eastern foothills of the foothills coinciding with the development of an important historical seismicity. The quaternary structures are linked to the seismic activity of the area and are the surface manifestation of the deformations that suffered and suffer as a consequence of an earthquake. (Figure 7).

On May 22, 1782, the Santa Rita earthquake occurred in the city of Mendoza. Schávelzon (2007, p. 10-11) describes what happened through the following account of a religious temple:

> The rooms or dwellings of the school suffered much damage and especially its corridors, which were almost completely ruined, having opened in the middle, until most of the materials that closed them at the bottom fell, so that it was necessary to demolish what had not yet fallen.

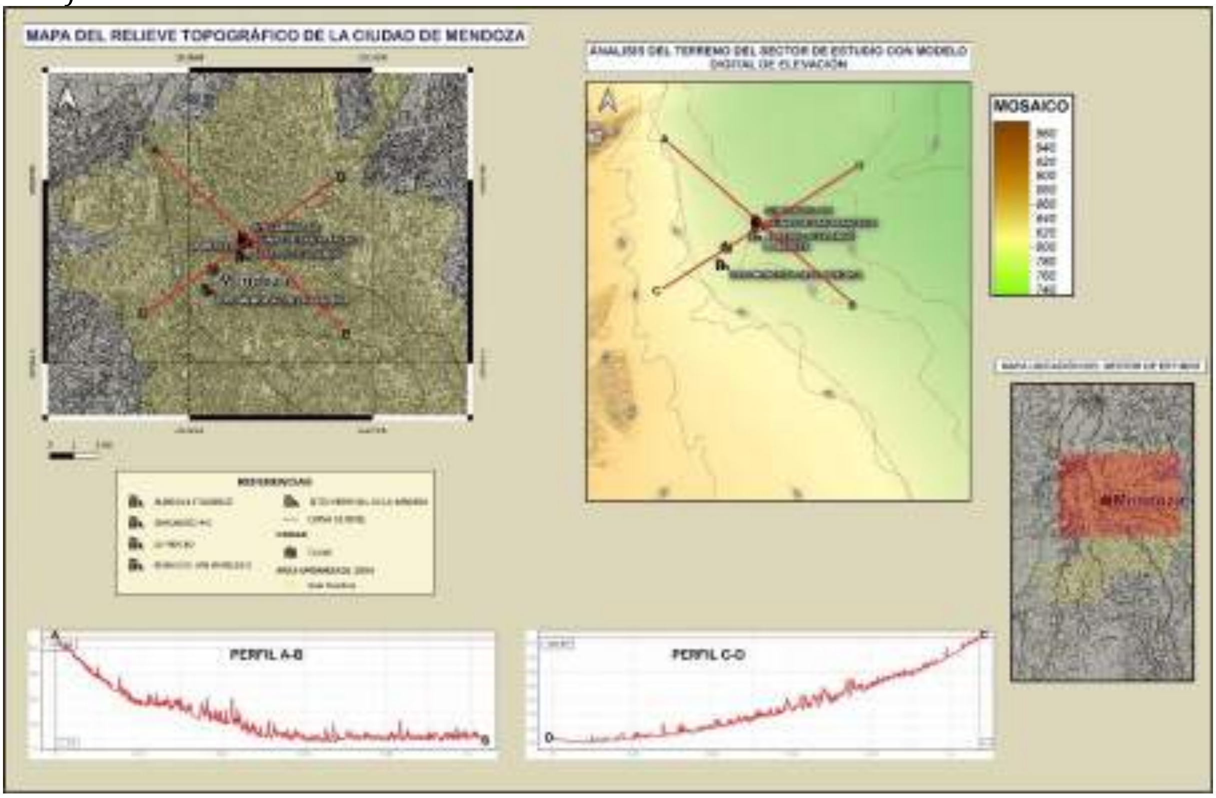
As shown in Figure 7 and Figure 10, the most relevant geoforms for the development of these flooding and alluvial processes are the central depression and the plains. Geomorphologic environments whose erosion factors are rainfall, which is enhanced by the slope and the high degradability of the surface materials. (Figure 11).

Anthropic erosion was very marked by the advance of overgrazing, unsuitable settlements, the use of carts and the felling of trees for fuel and industrial production that was beginning to develop with the wine industry. The desertification process accentuated even more the action of floods and alluviums that affected the city, due to the marked impoverishment of the vegetation cover, accelerating even more the runoff of water towards the urban area of the city.

The urbanization process that affected the city of Mendoza from its foundation in 1561 until the end of the 18th century is strongly characterized by its cattle and agricultural expansion associated with the fattening of cattle during the winter season. Thus, the period went from a period of adaptability (1561) to a period of destructuring (1561- 1700) and finally to a period of competition for natural resources (1700- 1830) (Abraham and Prieto, 1981) (Figure 12).

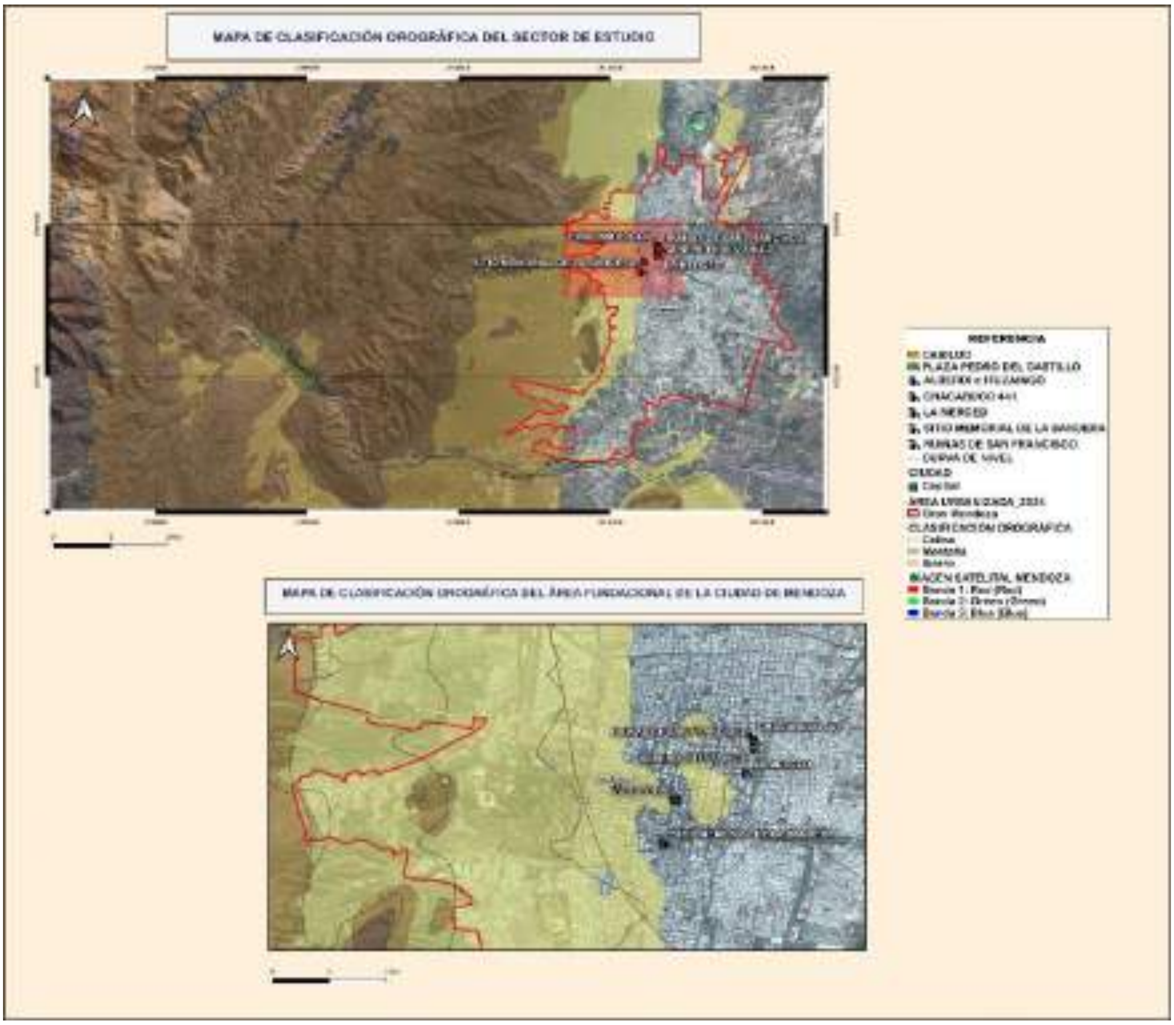
It is evident that the results of the urbanization process generate in space a new configuration of physiognomies called landscapes. These spaces (urban) and adjacent areas (peripheral-rural) are characterized by a strong dynamism that causes rapid changes in their physical, biological and human components. Alberto (2009)

Figure 10
Relief



Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), National Geographic Institute (IGN). Google (https://www.idera.gob.ar/).

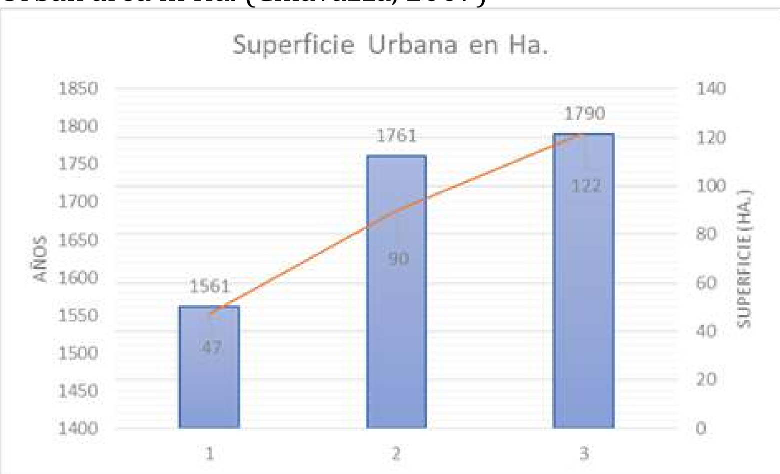
Figure 11
Orography



Note: Map of own elaboration adapted from the Spatial Data Infrastructure of the Argentine Republic (IDERA), Ministry of Environment and Sustainable Development. Google (https://www.idera.gob.ar/).

Figure 12

Urban area in Ha. (Chiavazza, 2007)



Note: Adapted from Chiavazza (2007). Theoretical bases for the archaeological analysis of religious spatiality and the processes of cultural transformation in the city of Mendoza during the colony (p.241).

Discussion and conclusions

The objective of this study was to rank and order most of the environmental events raised by Chiavazza (2012), Prieto and Chiavazza (2005), Prieto (1989), Prieto et al. (2012), Prieto (1997), Abraham and Prieto (1991), Abraham and Prieto (1981), as geological processes and zoned in a context of geological environment (lithology, geomorphology, relief, seismicity).

These results show that the geological and environmental processes that affected the foundational city of Mendoza between the 16th and 18th centuries are not monocausal. They usually respond both in the present and in the past to multiple origins.

Two key elements that favored the geological hazard of the study site stand out: one linked to morphostructural and tectonic factors, where the natural physiognomy of the relief of the study area stands out (low slope, important active fault systems, good permeability due to the fact that it is formed mostly by the sediments provided by the large floods of the Mendoza River in the summer season), and the other element, is related to the climate and its climatic variations (temperature and humidity), which also participates directly with the episodes of important river flows due to the thaw cycles in the summer seasons.

However, it is estimated that the direct cause of these processes being classified as dangerous had to do fundamentally with an anthropic factor inherent to an urban establishment "the city".

As a consequence of overgrazing, firewood extraction, the opening of roads and the indiscriminate felling of shrub vegetation, erosion processes were accelerated and their capacity to slow down surface runoff increased, thus increasing the frequency of alluvial floods. Prieto (1989, p. 151) states the following:

> There is a notable absence of information on alluvions during the second half of the sixteenth century and throughout the seventeenth century, when there were only 5 in the whole century. During the 18th century, 17 major floods have been recorded, causing numerous damages (1.7 floods per decade).

Through the vision of applied geology, an attempt was made to provide an approximation of the natural events and phenomena that occurred in a historical space, which was crucial for the development of a society. This information allows to have a key record of the geological-environmental evolution of a city, to predict future natural phenomena and to anticipate or prevent them if possible. It is important to take these historical records as a key to understanding and analyzing the future behavior of the terrain in the face of erosion, landslides, floods and seismic events.

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