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Historical seismicity of the province of Chimborazo

Sismicidad histórica de la provincia de Chimborazo

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ABSTRACT

This study analyzes the impact of gamification as a methodological strategy in the teaching of mathematics at the Basic General Education level. The research is based on the need to transform traditional pedagogical practices through innovative approaches that promote meaningful learning and the development of logical-mathematical skills. A qualitative approach with a descriptive design was used, applying interviews and direct observation with teachers and students from an educational institution in Ecuador. The results show that gamification enhances student motivation, engagement, and active participation in the classroom. Additionally, improvements were observed in the understanding of mathematical concepts, problem-solving, and collaborative work. It is concluded that integrating playful elements into teaching activities strengthens the teaching-learning process and contributes to a more dynamic, inclusive, and student-centered education. The study recommends training teachers in the use of digital tools and gamification strategies, as well as promoting educational policies that support active methodologies within the school curriculum.

Keywords: Ecuador, earthquakes, history, testimonies and natural disasters

RESUMEN

El presente estudio analiza el impacto de la gamificación como estrategia metodológica en la enseñanza de las matemáticas en el nivel de Educación General Básica. La investigación se fundamenta en la necesidad de transformar las prácticas pedagógicas tradicionales mediante enfoques innovadores que favorezcan el aprendizaje significativo y el desarrollo de habilidades lógico-matemáticas. Para ello, se empleó una metodología de enfoque cualitativo con diseño descriptivo, aplicando entrevistas y observación directa a docentes y estudiantes de una institución educativa en Ecuador. Los resultados muestran que la gamificación potencia la motivación, el compromiso y la participación activa de los estudiantes en el aula. Asimismo, se evidencian mejoras en la comprensión de conceptos matemáticos, la resolución de problemas y el trabajo colaborativo. Se concluye que integrar elementos lúdicos en las actividades didácticas fortalece el proceso de enseñanza-aprendizaje y contribuye a una educación más dinámica, inclusiva y centrada en el estudiante. El estudio recomienda capacitar a los docentes en el uso de herramientas digitales y estrategias de gamificación, así como fomentar políticas educativas que promuevan metodologías activas en el currículo escolar.

Palabras clave: Ecuador, terremotos, historia, testimonios y desastres naturales

INTRODUCTION

In Seismic Risk Analysis, historical seismicity studies provide important information, as they correspond to a long period of time (approximately 400 years for the province of Chimborazo, more representative over time, than instrumented studies carried out over a shorter period in relation to the slowness with which seismic events occur.

However, historical data presents some drawbacks, such as the fact that small earthquakes are often overlooked; records are available only from inhabited areas, which means that epicenters are often poorly located. Due to the uncertainty of the information available, in some cases, the intensity is exaggerated, which is why: " *It is essential to dedicate time and effort to first understand the construction systems of the period...* "

But despite its imprecision, its analysis and interpretation can provide scientific data regarding seismic intensities and magnitudes, as well as their location, the periodicity of seismic activity over time, etc. However, this activity has not been well received by researchers and has been somewhat neglected in the conduct of seismic hazard studies based on instrumental information.

This paper analyzes the main seismic movements that shook the province of Chimborazo, attempting to provide a scientific explanation of the impact of the geological phenomenon on the buildings of the time and its consequences on the mortality of the population based on historical evidence.

Seismic intensity

It is defined as follows: " *the effects produced by earthquakes on structures and people are measured by means of seismic intensity* ", it is a subjective description of the destructive potential of earthquakes. there are several intensity scales, one of them is called "modified mercalli", which is indicated in summary form in table 1, the same one that was developed by wood and newman in 1931 and is a modification of the one developed by mercalli in 1902.

macroseismic intensity scales in a publication by goula, starting with the rossi-forel scale that appeared in 1873 up to the i msk scale proposed by medvedev, sponheuer and karnik, which is widely used and accepted worldwide. it is observed that there is a good approximation between the i mm and i msk scales . 2

Table 1

Modified Mercalli Intensity Scale I MM

1 MM	DEFINITION
Yo	Detected only by instruments.
II	Felt by people at rest.
III	Felt by people inside a building.
IV	You feel outside the building.
V	It's noticed by everyone. Unstable objects fall.
VI	

VII	People walk with difficulty. Windows and glass objects break. Structures with weak masonry crack.
VIII	Moderate damage to well-designed structures, and severe damage due to poor construction.
IX	Light damage to well-designed structures, considerable in regular and severe in poorly designed ones.
X	General panic. Structures with earthquake-resistant design are seriously damaged. Damage to the foundations.
XI	Major destruction to well-built buildings. Large landslides.
XII	Almost nothing remains standing. Cracks in the floor. Underground pipes out of service. Almost total destruction. Catastrophe. Large masses of rock displaced.

Seismic intensity depends on the following factors 2 *:*

The distance from the site to the epicenter: the further the population is from the epicenter, the lower the intensity will be, since the damage will be less.

The type of soil in the affected areas; soft soils amplify seismic waves, increasing their effects, while firm soils can attenuate them, thereby reducing damage.

The topography of the site; buildings constructed on the edge of slopes are more likely to be damaged than those located on completely flat terrain.

It depends on the strength of the structures; buildings designed with earthquake-resistant criteria will experience less damage than others.

It depends on the level of people's preparedness and government campaigns to prevent natural disasters.

It should be noted that the intensity assessment carried out later has the particularity of being applied to buildings made of adobe, lime and stone, which do not withstand seismic actions in the same way as concrete. Furthermore, it refers to periods in which adequate construction techniques did not exist, so we will cite descriptions of the homes of the time in order to adequately estimate the intensity value.

Analysis of the main historical earthquakes

The Earthquake of 1645

In order to correctly analyze and evaluate the impact caused by this seismic event, we must try to have a clearer conception of the city and the buildings destroyed at the time, for which the following description of the Villa de Riobamba dating from the year 1605 is stated:

> " *The town belongs to Spain; it has four main streets in length and four in width, and a plaza. The residents' houses are low, built from adobe and roofed with thatch, with only three or four having tiled roofs. They use the lower ones because they are more comfortable and safer from the strong winds and the cold climate* ."

With this description, we have an idea of the buildings of the Villa before the earthquake of 1645, the summaries given by eyewitnesses of the catastrophe refer to the poor soil on which Riobamba had been founded:

> “ *...this said town is founded on bad soil very close to a large swamp that borders it, and many of the houses have collapsed due to the earthquakes that began last March of this year, and the temples, like those that remained standing, are very dangerous to enter because they are open and damaged, both in the main chapels and in their bodies.* ”

It is also indicated that the monasteries of Santo Domingo, La Merced, San Francisco and San Agustín were seriously damaged, of which the following is *reported* :

> *“... The church of the convent of San Agustín is falling down due to the said earthquake... because it is all... cracked so much that no man or woman dares to enter it or pass by the said church and some of the cells are fallen down and others are falling down and the walls of the corals and orchards of the said convent have fallen down, due to which the religious of the said convent live in huts... they moved the Blessed Sacrament to the royal street where they made a ramada in which they have celebrated until now...”*

Taking into account the material of the buildings, the poor quality of the soil on which the town was founded, which resulted in the amplification of seismic waves and the damage caused by soil moisture in the foundations, so much so that it is claimed that some buildings fell down without the need for earthquakes, where a Modified Mercalli intensity with a value of I MM = VI, would be enough for the earthquake to cause cracks in the houses and some to collapse as stated in historical archives, according to the Ecuadorian Earthquake Catalogue, provided by the Geophysical Institute of the National Polytechnic School, the epicenter was found at the coordinates - 1.68S and - 78.55W , very close to the town.

The Earthquake of 1698

June 20, 1698, a massive earthquake shook the central region of Quito's Sierra de la Audiencia. Historical documents agree that the cause was the collapse of the Carihuairazo snow-capped mountain.

> This earthquake caused the destruction of Ambato, and its effects extended to neighboring towns. In the town of Riobamba, the consequences of this "terrible cataclysm," as history describes it, affected both religious buildings and private homes. The following is literally stated: "... *although the buildings suffered significant damage and several collapsed, the danger from the ruins was extremely rare* ..."

Taking into account the poor soil on which the Villa de Riobamba was founded and the construction materials, mainly adobe, lime and stone, when evaluating the damage, the intensity is I MM. = VII in the area of the town of Riobamba, since according to historical accounts it is specified that the greatest damage occurred in Ambato because the aforementioned population was very close to the epicentral zone that according to the Ecuador Earthquake Catalogue is located at coordinates - 1.45S and - 78.25W , supporting the greatest damage, of such magnitude that after this event the most convenient solution was to relocate rather than rebuild Ambato.

The inhabitants of Riobamba also approved the relocation of the Villa to the Gatazo plain: "*... in order to build the new city they took materials from the old one ...*", but the government of the Audience did not agree to this relocation and also: *"...this left them with bitter experiences when this sector was flooded..."* so the inhabitants of Riobamba had to return to take up positions on their old lots in the Villa.

1797 earthquake

As previously stated, it is important to devote time and effort to learning the construction techniques of the period. To this end, we will cite testimonies that indicate what the Villa de Riobamba looked like before this earthquake. Around 1736, the city's appearance still reflected its former opulence, an impression captured as follows:

"The *main square and streets of this town are very regular and spacious. The houses are made of lime and stone; although the latter is light, it is not as light as the pumice used in Latacunga. Some are high, and this is more regular in those facing the square and its surroundings; but the rest are all low due to the fear of earthquakes ...*"

There is another description closer to the earthquake, since the Italian Jesuit father, Mario Cicala, wrote the following in 1767:

"*... The entire city is certainly majestic, beautiful, ornate, and noble... the Governor's and Magistrate's houses are truly beautiful and immaculate, and are located in the main square, with magnificent and richly furnished halls... but there are many single-story houses, almost all of which are made of lime and stone, and a few of adobe. The roofs of the houses in the city center are tiled; but most of the houses in the suburbs, especially those of the Indians, are covered with thatched straw ...*".

The two testimonies coincide in the fundamentals with which one has a more or less clear vision of the situation, the form and distribution of the Villa, with respect to the popular architecture of the period in question in a very objective way one can have an idea since many of the houses that were built during the reconstruction of the city have lasted until the present day:

"The houses were generally one-story, and some two-story, with a hallway, a large main courtyard, and often a backyard or orchard and stables. The rooms were arranged around the porticoed courtyard. In two-story houses, the staircase, usually made of stone and brick, was located at one of the corners. The pillars supporting the upper floor were made of stone and were octagonal or circular. The houses of the wealthy had essentially the same design, but were distinguished by their larger dimensions, better materials, and sumptuous finishes.

The front structure of the house, facing the street, had a gabled roof, while the other sections had a single slope, known as "half-pitched." Depending on the owner's economic *power, the walls were built of brick or sun-dried mud adobe mixed with chopped straw. The main walls were quite wide, while the secondary walls, which bore less weight, were thinner and sometimes made of wattle and daub. The walls were covered with a plaster of mud with chopped straw and plastered with a layer of fine mud. The use of stone was rare in popular houses, but not so in stately homes, public buildings, and especially in churches. The two-slope roofs were built in the form of wooden scissors, the ends of which rested on rib beams embedded in the main walls. The apexes of the scissors were joined to the ridge beams, from which thin timbers and longitudinal strips were stretched for the tiles. The room ceilings were made of reed cloth or matting lined with materials similar to those used for plastering the walls.*

In large churches, convents, and stately homes, the building materials were of higher quality. They were generally constructed of bricks bound with mortar (lime, sand, and water). Stone was widely used in the plinths of facades, doorways, and porches. The thickness of the walls varied, but they were generally very wide, depending on the desired consistency of the construction, reaching up to a meter thick and even more in large spaces. Tile was the common roofing material. In rural areas, this type of construction could be found on large estates and workshops. However, in many cases, buildings of this type also had adobe walls with a unique mortar of stone (quarried or river stone), brick, or some other type of material mixed into the fill.

The construction techniques for stately homes were obviously the best known at the time. Each owner strove to demonstrate his financial means with the solidity, sumptuousness, and ornamentation of his dwellings, just as religious orders did in churches and convents as a demonstration of faith and to attract the faithful. It is also true that there was already awareness of earthquakes, and efforts were made to ensure the solidity of buildings.

In the poor houses of cities and towns, or in rural areas, adobe, bahareque, and rammed earth dominated the construction of dwellings, with tile or thatched roofs and brick floors. As is logical to assume, if many important buildings were built by hand, this type of house was even more so, and consequently, their construction techniques were extremely poor, with no interlocking (confinement) between the walls, at the corners, or with the interior walls, and a precarious connection with the beams of the roofs and floors.

The above gives us an idea of the materials used to construct the buildings and their size, as well as the construction techniques of the time, allowing us to understand the structures that withstood the earthquake and analyze the reasons for their collapse.

Between seven and eight in the morning of February 4, 1797, the earthquake occurred on such a large scale that, as historical documents report, there was total desolation and devastation of the town of Riobamba and some other nearby towns. To get an idea of the catastrophe, we will mention the following testimonies, which fundamentally coincide with the other accounts of the witnesses:

Don Ignacio Lizarzaburu on February 22, 1797 declares the following:

" *That he has seen the town ruined, its streets and squares covered by fallen buildings with no traffic on them except for the destroyed roofs, without finding a house or church standing due to all the destruction caused by the collapse of the Cullca hill , with whose mass a third or more of the town was buried, without any houses or living people being saved in the three neighborhoods of Sigcho Guayco , Barrionuevo and La Merced.*

That its ground is entirely open, its streets, as has been said, covered with ruins and the entire floor gushing water, in addition to the lakes that have been formed both by the torrent named Quilloyaco , and by the river that was dammed by the landslide and that has taken its course through half the town...".

Don Luis Nájera's story says the following

" ...He found Riobamba in such a pitiful state that he could not recognize the parts that previously comprised it, nor the houses that adorned it because they were overturned from their foundations and so joined together in what were previously streets, nothing was noticeable but destroyed roofs, and he also saw the mountain named Cullca overthrown from its foundations , taking under its collapse a large part of the population ...".

But this must be analyzed in a very objective way so as not to overvalue the intensity, since there were already references about the poor soil on which the Villa de Riobamba was founded, and in some accounts it is understood that although they were seriously damaged, not all the buildings collapsed as stated in other testimonies such as the following account of the investigation by González Suárez that points out 19:

"The scene of the greatest devastation was the city of Riobamba and its province, where not a single church remained standing, not a single house that wasn't reduced to rubble or cracked and threatening ruin...."

Furthermore, it is difficult to establish the magnitude of what is described as "precipitous landslides" and "landslides of all the surrounding hills," as reported in most affected towns, since it can be interpreted as a genuine catastrophe or as small landslides that obstructed communication routes. We must also take into account that the main accounts recorded in history are those of the authorities of the Audiencia and the towns, informing the Spanish authorities, in most cases requesting financial aid and tax exemptions due to the catastrophe, perhaps making it seem larger than it actually was. Thus, after evaluating the testimonies not only from Riobamba but also from the other affected towns, an average intensity of 1 MM = IX was established, which, given the materials used to build the houses and the swampy soil of the town, would define the great destruction described in the story.

Due to the devastating effects suffered by the town of Riobamba with the earthquake, the survivors were forced to take refuge in the neighboring parish of Cajabamba:

"After the earthquake...they built miserable huts out of wood and straw...in which they spent the day weeping and wailing. A few days after the earthquake, the rains began; the lack of shelter, the dampness, and above all the putrefaction of the hundreds of corpses lying under the rubble caused malignant fevers, and the plague was added to the misery, finishing off the remnants that had survived the catastrophe."

The migration of the survivors to other regions of the Audiencia such as Guayaquil and Cuenca then began, which led the corregidor of the Villa to call a Public Assembly or Open Council that took place on March 21, 1797 in order to establish a suitable site for the relocation and construction of the Villa since it was not possible to build it on the same site since according to reports the ground was: " swampy, broken and threatened by landslides from the nearby hills . "Two possible sites were finally proposed for the relocation of the city: Tapi and Gatazo. To analyze the advantages and disadvantages of each of the sites, the town's mayor appointed a commission made up of Dr. Andrés Falconí, Don José Antonio Lizarzaburu, Don Vicente Antonio de León and Don José Larrea y Villavicencio, who were to present a report indicating the most favorable site. The report was presented on March 30, 1797, in which the Tapi plain was indicated as the most suitable for the construction of the town. However, in response to this report, the town's attorney, Don Ignacio Velasco y Unda , pointed out that the information presented by the commission lacked objectivity since the inspection carried out in the presence of the mayor on the Tapi plain demonstrated otherwise.

The decision between Tapi and Gatazo was influenced by the interests of wealthy landowners, who even steered the decisions of the open town council in their favor. Gatazo was not a place that benefited their interests; rather, they were threatened, since building the town there would entail selling their land to a population mired in an acute economic depression, which, at best, could only offset a portion of the land's real value. For their part, the religious communities that owned large estates in the area did not welcome the move, but they did not speak out either. The Tapi plain, on the other hand, was uninhabited and largely royal land; that is, it belonged to the king, and acquiring the plots for the construction of the new town would cost them nothing. Ignacio Velasco y Unda stated that only twenty wealthy people would be interested in moving to Tapi and not to Gatazo because their estates would be closer to the city. Based on these arguments, a new meeting was called for the town to express its decision on July 12, 1797:

"Having gathered a considerable or majority of the people, at approximately four in the afternoon, as a result of what was ordered in the order that was published regarding the positions convenient for their benefit, they said resolutely and openly where they wanted to be transferred, whether to Tapi or Gatazo, to which they unanimously expressed that they wanted to go to Gatazo."

With the unanimous opinion of the people to move the city to Gatazo, Velasco y Unda asked that the decree issued by the president of the Court on June 17, 1797, by which the transfer of the town to Tapi was established, be revoked.

The president of the Court, Luis Muños de Guzmán, appointed an impartial and proven person to inspect the two sites of Tapi and Gatazo. Don Bernardo Darquea, mayor of Ambato, was assigned. After inspecting the area, he decided that Tapi was the area that presented the best conditions for the relocation of the village. He drew a plan for the new settlement, delineated it, and laid out a regular layout. Despite this confirmation, disputes among the village residents continued, with no consensus being reached.

To calm the town's residents, the Court appointed a new delegate to carry out the inspection. This responsibility fell to Don Antonio Pastor, the Royal Administrator of the Town's Taxes. The new survey was carried out on August 6, 1798, with the participation of the Town Council authorities, the town's principal residents, and the prelates of the religious orders. It was concluded that the definitive location for the town's relocation was the place called San Martín de Tapi. This site was close to the Chibanca River creek and had sufficient water, stones, and other materials needed to build the houses. Furthermore, the San Juan irrigation ditch, which supplied water to the town, was being worked by Antonio Lizarzaburu, who stated that the water could be introduced within a maximum of two months.

Although the townspeople were not entirely in agreement with the decision to build the new town on the site of San Martín de Tapi, the authorities established it as the permanent location. However, a new alternative for the relocation emerged, presented by Don José de León y Otalora, Senior Councilor of the Riobamba Town Council. In a communication addressed to the president of the Audiencia on September 13, 1798, this official indicated the site of Chambo as a possible location for the town.

Although the president of the Court was aware of the new proposal, he reaffirmed the decision to promptly relocate the prison to the San Martín de Tapi plain. His latest statement on the matter was:

" ...that, although there are opinions in favor of Chambo, San Andrés, Cajabamba itself, the main interest is that no town in the Correguimiento loses its identity by being annexed to the New Town and that the chosen site where the waters have already been conducted will be respected...".

The streets were laid out. The nobility and religious communities were in possession of their lands, and the transfer of water under the direction of Antonio de Lizarzaburu had been completed. Despite this, a large part of the population remained in Cajabamba and in the old city.

"The Riobamba people, so attached to the land where they were born, preferred to live in poor straw huts amid the rubble of their beloved city, rather than move their homes to the Tapi plateau, even though the huts burned easily and they were left exposed to the elements."

Faced with this delay, and upon Luis Francisco Barón de Carondelet assuming the Presidency of the Quito Audience, he established April 1, 1799, as the deadline for the final relocation and took measures to ensure the mobilization of the population. Troops were sent from Latacunga to demolish the houses of the inhabitants who refused to move to the Tapi plain. Public deeds were prohibited outside the new settlement, and carpenters were prohibited from rebuilding in the destroyed city. Furthermore, the authorities prevented the introduction of food into Cajabamba. Faced with these pressure measures, the residents who remained in Cajabamba, along with the parish priest, petitioned the Audience to limit this provision on relocation, granting freedom of action to residents who did not decide to part with their ancestral lands. This request received no response from the authorities.

The population gradually settled in Tapi. Initially, religious and public buildings, such as the Mother Church, convents, administration house, town hall, and prison, were constructed on a temporary basis. The lasting stone structures were built later and took a considerable amount of time during the following century. The remains of "Old Riobamba" lie beneath the settlement now called Sicalpa.

Isosists map

After obtaining all possible information on the seismic event, in this case from the accounts recovered from historical archives, the maps are drawn using isoseismic or isoseismal lines, i.e., imaginary curves that connect points on the map of the area where the earthquake occurred, where the seismic intensity has the same value. Table 3 is presented below, containing a summary of the intensities of the different sites where the effects of the February 4, 1797, earthquake were reported, along with the respective justification for the intensity assessment, also indicating the location and reference.

Table 2

Summary of Intensities of the 1797 Earthquake

Number	Observation Site		Effects of the Earthquake	Ref.	1 MM
	Locality	Province			
1	Quito	Pichincha	Clear falls from the corridors	iv	VI
2	Quito	Pichincha	Image of the Virgin falls into chapel.	23	VI
3	Quito	Pichincha	The towers of the Cathedrals of St. Domingo, St. Augustine, and La Merced were broken.	iv	V
4	Ambato	Tungurahua	He blew down all the buildings	23	IX
5	Ambato	Tungurahua	He left no stone unturned	23	X
6	Ambato	Tungurahua	Large landslide that dammed the river.	24	X
7	Ambato	Tungurahua	There was no man able to stand up	23	VI

8	Ambato	Tungurahua	All the hills and mounds suffered collapses and divisions	23	X
9	Riobamba	Chimborazo	The houses turned over on their foundations	23	X
10	Riobamba	Chimborazo	Big cracks everywhere.	24	VIII
11	Riobamba	Chimborazo	There is no way to distinguish streets or houses	23	IX
12	Riobamba	Chimborazo	Cracks in the streets	23	VIII
13	Riobamba	Chimborazo	Landslide of Cullca Hill from its foundations	23	X
14	Guaranda	Bolivar	Few buildings standing and unusable	23	VII
15	Guaranda	Bolivar	Cliffs and landslides on the road to Guayaquil and Cuenca.	23	X
16	Pallatanga	Chimborazo	Landslides from the hills made the access road impassable	23	IX
17	Pallatanga	Chimborazo	The Church fell	23	VIII
18	Chillanes	Bolivar	Landslides in nearby hills	23	IX
19	Chillanes	Bolivar	The Church fell	23	VIII
20	Latacunga	Cotopaxi	Houses and temples with severe damage	23	VII
21	Latacunga	Cotopaxi	The gunpowder mill is close to collapse	23	VII
22	Latacunga	Cotopaxi	Major landslides of mountains and slopes, especially in the Pachanlica River , which was dammed.	24	X
23	Saquisilí	Cotopaxi	Cracks so large that they make construction difficult	24	IX
24	Saquisilí	Cotopaxi	Damage to the church tower	23	VI
25	Saquisilí	Cotopaxi	Cracks in the streets	23	VIII
26	Angamarca	Cotopaxi	Houses with cracks in the walls	23	VI
27	Angamarca	Cotopaxi	The earth opened up	23	VIII
28	Alausí	Chimborazo	Most of the houses are still standing but are of no use.	23	VI
29	Alausí	Chimborazo	Collapse of the hills	23	X
30	Alausí	Chimborazo	Part of the brandy factory collapsed	23	VII

31	Alausí	Chimborazo	Cracks in walls of Church and houses	23	VI
32	Tixán	Chimborazo	The greatest ruin and death toll it has ever had.	24	VIII
33	Tixán	Chimborazo	Completely destroyed	23	VIII
34	Chunchi	Chimborazo	Major landslides	23	X
35	Chunchi	Chimborazo	The Church fell	23	V

It is important to note that, in the analysis of historical earthquakes, it is found that cracks in the ground appear around intensities VIII and IX 22.

To define the Isoseist map, it is necessary to obtain the average intensities of each location, values that are summarized in the following table:

Table 3

Average intensities of the 1797 earthquake

Number	Locality	Province	Intensity Average
1	Quito	Pichincha	5.7
2	Ambato	Tungurahua	9.0
3	Riobamba (Sicalpa)	Chimborazo	9.0
4	Guaranda	Bolivar	8.5
5	Pallatanga	Chimborazo	8.5
6	Chillanes	Bolivar	8.5
7	Latacunga	Cotopaxi	8.0
8	Saquisilí	Cotopaxi	7.7
9	Angamarca	Cotopaxi	7.0
10	Alausí	Chimborazo	7.5
11	Tixán	Chimborazo	7.5
12	Chunchi	Chimborazo	7.5

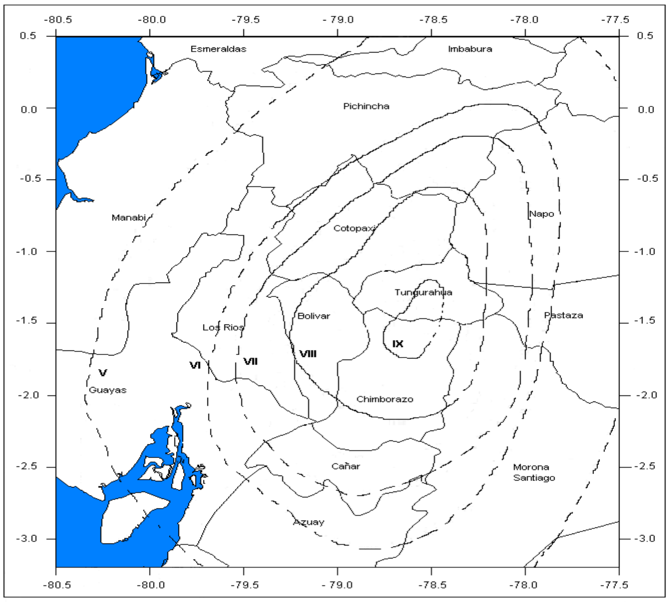
By joining the points of the same seismic intensity, the different isoseismic lines will be obtained , defined for each intensity value, it is remembered that for the interpretation of these lines, continuous lines are used in places where data is available, and cut lines in places where there is no data, the curves are defined as follows25 : “the shape of the curves is more or less elliptical with its major axis in a north-south direction, following the direction of the branches of the Andes mountain range, this tendency has been verified along the Inter-Andean Valley with earthquakes before and after that of 1797, which can be interpreted by assuming that this effect is a consequence of an attenuation of the seismic waves when crossing the mountain ranges, in the east and west directions” . Taking into account the above, we define the Isoseist Map of the Earthquake of February 4, 1797, which is indicated in figure 2.

The following can be deduced from similar earthquakes that have occurred in the same epicentral zone: "the greatest effects are expected to occur to the north and south of the epicenter, and to a lesser extent in directions perpendicular to the former, which is equivalent to saying that the destruction will occur on a larger scale in the inter-Andean alley, with lesser effects in the coastal and eastern regions from the foothills of the Andean mountain ranges that delimit them. Subsequent earthquakes have confirmed the previous deductions."

The Isoseist Map is based on the work of Jose Egred , from the Geophysical Institute of the National Polytechnic School, as regards the shape and direction of the isoseismic lines , the intensities on the Modified Mercalli scale (I MM) are evaluated in table 3 and 4 indicated above.

Figure 1

Isoseist Map of the Earthquake of February 4, 1797



RESULTED

Summary of seismic activity in the province of Chimborazo

Table 4 indicates the year, location, and intensity of each seismic event. It is important to clarify that most historical earthquakes occurred in "Antigua Riobamba" (Old Riobamba), and that the town is designated by its current name, Sicalpa. Furthermore, the earthquakes indicated are those known for the damage they caused to the populations, since these are the ones recorded in historical documents. Only the main events of maximum intensity are included, leaving aside premonitors and aftershocks. The Modified Mercalli scale, indicated in section 1.2, is used to assess intensity.

The seismic events indicated in Table 2 have been illustrated in Figure 1 to better appreciate the location of the epicenters with their respective intensities. It is worth clarifying that if the epicenter of an event coincides with another, the one with the greatest intensity has been graphed.

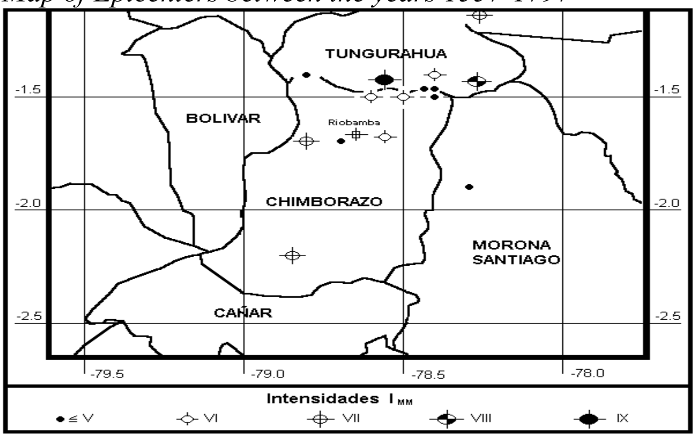
Table 4

Historical Seismicity of the Province of Chimborazo

DATE				EPICENTER		REF.	1 MM
YEAR	MONTH	DAY	HOUR	LAT.	LON.		
1557	FEB	--	--	1.50S	78.5 W	21	VI
1640	- -	--	--	1.43 S	78.55 W	21	III
1645	SEA	15	--	1.68 S	78.55W	i	VI
1674	AUG	29	--	2.20 S	78.83W	ii	VII
1687	NOV	22	--	1.10 S	78.25 W	21	VII
1698	JUN	20	06:00	1.45 S	78.25W	21	VIII
1738	SEP	29	--	1.4 S	78.80 W	21	III
1739	APR	10	--	1.9 S	78.30 W	21	IV
1744	--	--	--	1.5 S	78.60 W	21	VI
1745	--	--	--	1.4 S	78.40W	21	VI
1773	APR	23	--	1.5 S	78.40 W	21	III
1776	JAN	03	--	1.47 S	78.44 W	21	IV
1777	JUN	17	--	1.47 S	78.40 W	21	III
1786	MAY	10	3:00 PM	1.70 S	78.70W	21	VII
1786	JUN	23	02:30	1.70 S	78.70W	21	IV
1797	FEB	04	07:45	1.43 S	78.55W	21	IX

Figure 2

Map of Epicenters between the years 1557-1797



The analysis of the historical seismicity of the province of Chimborazo reveals a significant record of seismic events over the last four centuries, emphasizing the importance of this region in the tectonic dynamics of Ecuador. Through the review of historical sources and previous seismic catalogs, it was possible to document and organize information on several major earthquakes that affected this territory, particularly in the cities of Riobamba, Guano, and Colta.

One of the most notable events is the earthquake of February 4, 1797, considered one of the most destructive in Ecuadorian history. It caused widespread devastation in Riobamba and surrounding areas, with an estimated intensity of XI on the Modified Mercalli Scale. Subsequent earthquakes recorded in 1868, 1926, 1949, and 2001 also contributed to shaping the seismic profile of the province.

The isoseismal maps and collected testimonies confirm that the intensity and impact of these events varied according to proximity to the epicenter and the geological characteristics of the terrain. The earthquakes were particularly destructive in areas with poor construction and high population density.

The review highlights a pattern of recurring seismic activity in Chimborazo approximately every 50–70 years, emphasizing the importance of integrating historical data with modern monitoring systems. The lack of instrumental records for many of these events underscores the need to preserve and analyze documentary sources to better understand the seismic risk in the region.

DISCUSSION

The historical seismicity of the province of Chimborazo reveals a complex and recurrent pattern of seismic activity that underscores the region's vulnerability to strong earthquakes. The documentation of past events, especially those preceding the era of instrumental seismology, provides invaluable insight into the long-term behavior of seismic sources in the central region of Ecuador.

The 1797 Riobamba earthquake stands out not only for its catastrophic impact—resulting in massive destruction and a high number of casualties—but also for its role in shaping the scientific and societal understanding of seismic risk in the region. The reevaluation of its intensity from XI to IX in recent seismic catalogues demonstrates the evolution of methodologies and the importance of consistent criteria in seismic classification.

This historical perspective allows for a better calibration of hazard models, especially in areas where instrumental data is limited or spans a short period. In Chimborazo, where tectonic forces are driven by the interaction of the Nazca and South American plates, understanding the recurrence intervals, affected areas, and magnitudes of past events becomes crucial for developing accurate seismic hazard maps.

Moreover, the study reveals the necessity of integrating historical accounts, isoseismal mapping, and local narratives to capture the full impact of seismic events, particularly in rural or poorly instrumented zones. Such integration supports more resilient urban planning, the establishment of efficient early warning systems, and a heightened public awareness of seismic risk.

CONCLUSIONS

Historical seismicity remains a critical reference for the assessment of seismic hazard, particularly in regions like the province of Chimborazo where instrumented records are relatively recent. The information gathered from centuries-old earthquakes has been fundamental in shaping Ecuador's seismic regulations, including the INEN CPE 5:2001 and the NEC-SE-DS of 2015, which incorporate historical data into seismic hazard maps.

The 1797 Riobamba earthquake, one of the most significant seismic events in the country's history, serves as a stark reminder of the potential destruction that can occur in central Ecuador. Its enduring relevance is reflected in numerous scientific studies and its inclusion in seismic catalogues, where its intensity has been revised based on improved methodologies and broader datasets.

In light of the findings, it is recommended that:

- Historical seismic records be systematically preserved and digitized to facilitate their integration into modern hazard assessments.
- Further interdisciplinary research be encouraged, combining geology, history, and social sciences to enhance the understanding of past events.
- Education and preparedness programs in high-risk areas like Chimborazo be strengthened, incorporating historical examples to raise public awareness.

Understanding and valuing historical seismicity not only enriches our comprehension of past events but also plays a pivotal role in preparing for future seismic scenarios in Ecuador and across similar tectonic regions.

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