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VULNERABILITY AND SEISMIC RISK ANALYSIS FOR ZONDA DEPARTMENT AREA, SAN JUAN PROVINCE, ARGENTINA

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SUMMARY

This paper, performed for the Zonda Department area in San Juan Province- Argentina, aims at assessing geological hazards in general, seismic hazards in particular and other subsequent risks that may result from earthquakes. Consequently, seismic risk mapping is elaborated based on seismic vulnerability and probable physical- spatial damages derived from high- intensity earthquakes. This will ease soil- use planning for a greater exploitation of natural resources, with a minimum impact on valley resources and a maximum expansion of future activities.

Methodologically, a detailed geological mapping of areas of great interest is carried out based on the interpretation of satellite images, aerial photographs and ground examination. This aims at identifying and categorizing main potential seismic sources and related peril.

Seismic vulnerability is studied from the analysis of functional and direct vulnerability coefficient. Damage calculus is a probability study, which requires seismic risk mapping that show probable site effects placing for different seismic intensities. These maps are tools for designing and planning regional urban areas concerning human settlement, infrastructure and productive activities, such as territorial organization measures in seismic emergencies.

Geographic Information System (GIS) technology has been employed. This research attempts to know Zonda's seismic risk in order to start mitigation work, determine key projects, advise private and public sectors when developing special programs of vulnerability reduction, and support every day actions in governmental scope.

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INTRODUCTION

The seism, as a natural determining factor apart from causing the loss of lives and goods, it may alter the normal development of the community's activities. In turn, the constructed environment may have a positive or negative influence on a natural determining factor.

Within this frame, the investigation is methodologically developed taking into account aspects of particular significance.

The first one consists of the elaboration of geological studies and later mapping of regional urban areas. According to this study, the vulnerability coefficient with respect to the parameters and indicators of the geological risk are analysed in detail, and seismic risk maps that graphically make up the spatial location of probable seismic effects, IX, VIII and VII intensity Mercalli Modified Scale, are elaborated.

Finally intervention strategies are proposed, in order to plan regional urban areas which are shaped according to the previous stages and which represent a valuable contribution considering that seismic prevention should constitute a never ending project in order to preserve the citizens´ urban life.

PROJECT DEVELOPMENT

The Zonda Valley – Seismotectonic Configuration of San Juan Province

San Juan province is situated in the central west region of Argentina. This is the zone of major seismic activity in this country. This area was shaken with several earthquakes in the last hundred years damaging the whole area and causing the loss of human lives and assets. Some of these quakes have produced superficial rupture and they are located near area considered here.

San Juan city is located approximately 350 km to the east of the South American plate and the Nazca plate boundary. Along this trench, the Nazca plate eastward movement is subdued beneath the South American plate westward movement. The subdued plate is about 100 km deep beneath San Juan province. This zone of subduction presents high concentration of earthquakes principally in the area that corresponds to the flatten subduction (from 28º to 32º of south latitude).This incident coincides with a gap in active volcanism. Barazangiand.[1]

The seismologic characteristics are the following ones:

- intraplate seismic activity or shallow earthquakes, including the events with possible superficial displacement, which are the ones of major seismic hazard.
- interplate events which are at depths from 100 – 150 km at the interface to plates. Pérez.[2]

The Zonda valley is part of the Andean foothills where the deformation is represented by a fold and thrust belt with eastern vergence (thin-skinned tectonics). Here quaternary faults are distributed.

Considering these antecedents it can be observed that the Zonda valley is situated in a region where there are evidences of quaternary rupture and registers of high magnitude destructive earthquakes. This area presents features associated to modern deformation which are some segments of superficial rupture. All these factors are essential to evaluate and prevent seismic hazards from the regional and local aspects. This work aims at preliminary studying all the aspects mentioned.

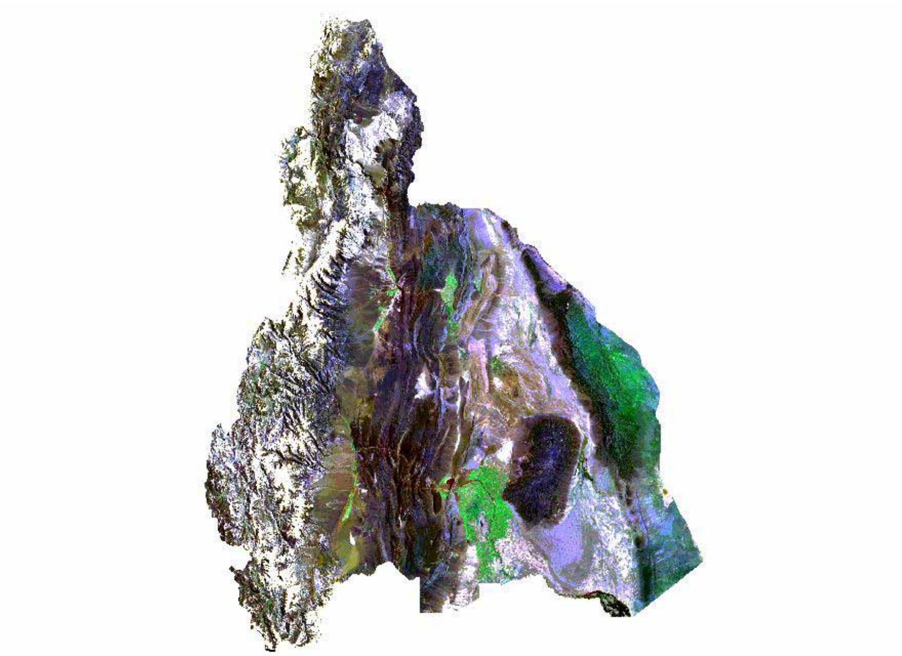

Figure No 1: San Juan Province Satellite Image

General Geology

Ullum – Zonda valley is a tectonic depression. The eastern front is conformed by Loma de Las Tapias, Sierra de Marquesado, Chica de Zonda. They are constituted by conglomerates, sandstones, and limestones.

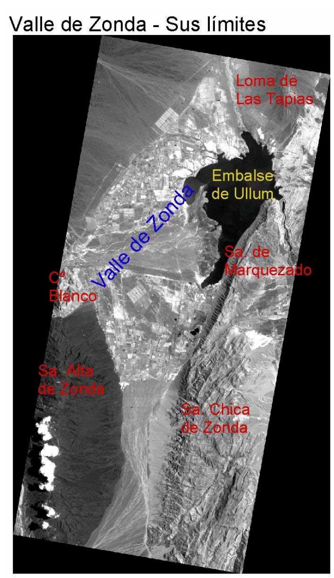

Figure No 2: The Zonda Valley Limits

The eastern margin shows quaternary movements. Then, the San Juan river was endicated producing great lacustrine sediments diffusion in the eastern valley. Uliarte.[3]

At the west it can be observed the intrusive rocks of Cerro Blanco and Cerro La Sal and sedimentary sequences in Sierra La Dehesa and Alta de Zonda.

Quaternary sediments are represented by lacustrine material on the east side of the valley, conglomerated material from colluvial processes in the mountain fronts and fluvial sediments.

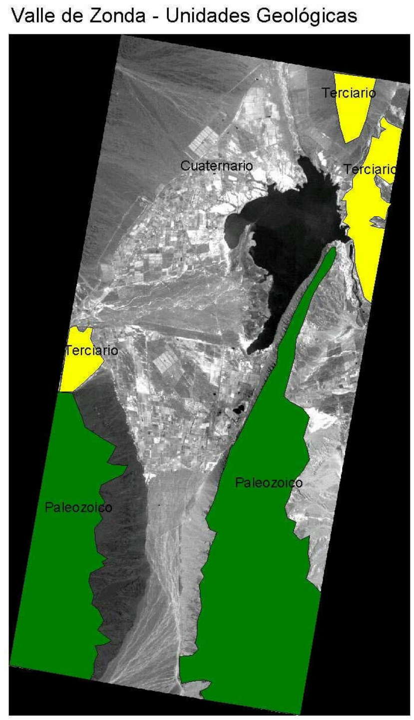

Figure No 3: The Zonda Valley Geological Configuration

Tectonic Configuration

The Andean eastern foothills fault system is located in the central area of San Juan province, between 31º to 32º30’ of south latitude, and it is 150 km long. It is part of the mountain front of Sierra de Villicum, Sierra de Marquesado, Sierra Chica de Zonda, Cordón La Flecha and Pedernal. Bastias.[4]

In the Andean eastern foothills fault system, Bastias (1985) includes quaternary faults located in the weastern front of Sierra Chica de Zonda and the eastern margin of Sierra Alta de Zonda. These margins conform the lateral limits of Zonda basin.

The Blanquito – Cerro Bayo fault system (Bastias, 1985) is located in the west border of the Andean eastern foothills. This shows evidences of quaternary displacement especially in the eastern margin of Sierra Alta de Zonda, from the north of Cerro Blanco to Blanquitos zone trough a discontinuous segment.

At Sierra Chica de Zonda and Marquesado eastern borders, La Rinconada - Las Tapias segment is delineated. This segment presents quaternary rupture evidences. At Lomas de Las Tapias latitude is evident that the segment bifurcates in two different sections at two sides of Sierra de Villicum. This system is related to La Laja earthquake (1944), La Rinconada earthquake (1952) and both show morphologic evidences of quaternary mobility. These epicentres are located 35 and 25 km from the Zonda valley.

In the Andean central foothills near the Zonda valley there are modern evidences of Maradona - La Dehesa fault segment.

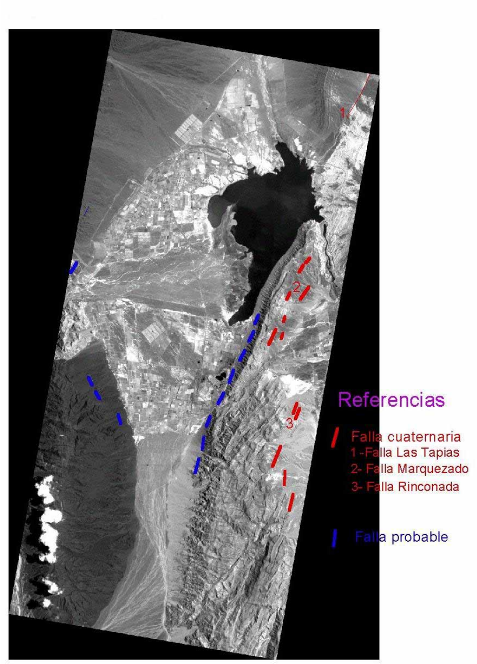

Figure No 4: The Zonda Valley: Geological Analysis

The Seismic Vulnerability Study

Vulnerability is the tendency of people, activities carried out and goods to suffer from damage or modifications when high magnitude earthquakes take place. Considering this definition, the following concepts can be observed:

Direct Vulnerability expresses the possible physical performance of the elements analysed. In order to construct the direct vulnerability coefficient, it was taken into account the population size, the constructive state of the respective superstructure and infrastructure elements according to geological risk indicators.

Functional Vulnerability expresses the performance of the elements analysed. In order to construct the functional vulnerability coefficient the number of people, the activities carried out and the number of hours of use from the adapted spaces where these activities take place, are interrelated.

Total Vulnerability whose coefficient is conformed considering the two previous ones.

It is necessary to point out that the concept of vulnerability is eminently a concept of interrelations:
Direct vulnerability relates the population to physical elements from the city internal structure and the soil geological characteristics. On the other hand, the concept of functional vulnerability relates the population to its structure of activities.

Vulnerability Matrix-Diagram

It is based on the methodology used in previous studies. The matrix vulnerability will be elaborated for Zonda, San Juan Province, Argentina.

This matrix orders and systematises the analysis of each urban sector with relation to direct vulnerability, in order to analyse each coefficient component element. It will be useful to solve detected problems, so as to get acceptable levels of vulnerability.

Definition of Acceptable Levels of Vulnerability
It does not mean to cancel the vulnerability.
It does not only mean to reduce the coefficient value.
It is foreseen to achieve an equilibrium of the element conditions which conform the coefficient.
It means a search for the equilibrium of such elements' interrelations.
It contributes with elements for the definition of rules that constitute a previous stage to the determination of urban intervention strategies.
The value of acceptable vulnerability cannot be defined as a general and only value, but it must be determined according to the characteristics of the analysed radius.
The acceptable vulnerability must also involve:
The compatibility with the maps of risk.
Acceptable Risk for people and goods.

The criteria for the proposal of adequacy of the vulnerability levels will be:
To maintain the vulnerability coefficient in low to middle levels.
To maintain the percentage of non-seismic resistant housing in low to middle rank.
To increase the housing number of the area, as long as that does not raise the vulnerability level.
To maintain the existent population number in the area. However, this number will be a consequence of the raising, or not, of the proposed housing in the area.
When only the Non-S.R. housing percentage is modified, it means a replacing housing proposal in the same portion.

From the analysis of the direct vulnerability diagram, the proposal types which represents rules for the intervention strategies layout are inferred.

Maps of Seismic Risk
To design the maps, the following concepts of reference are used

"Seismic Risk is the probability of occurrence and the relative grade of severity at a particular period of time, from the group of possible effects produced by an earthquake". Roitman.[5].
It can also be interpreted as "the probability of losses caused by the seismic action".

Seismic events do not have an impact in the whole extension of the area uniformly. For that reason, it is supposed that any type of building may suffer four states of damages (Table 1). Grases. [6]

Table 1: State of Damages

Designation	State of Damages Description
D0	Without damage; slight damage on walls
D1	Damage in elements of partitions and others non-structural ones. Slight damage, reparable in structural elements
D2	Total loss of building, even when there is no collapse
D3	Total or partial ruin

The addition of damages D2 and D3 constitutes what is called irreparable damages.

To measure the risk that the population of the different sectors of the area could suffer, the group of effects which would be produced by a seismic event of intensity IX, VIII and VII Mercalli Modified Scale is quantitatively and qualitatively considered.

Maps for serious or irreparable damages in the constructions will be designed, for earthquakes of intensity

IX, VIII and VII Mercalli Modified Scale.

The seismic risk maps are tools to plan seismic areas. These maps allow to handle the physical space, that is to say, the location of human settling, infrastructure, productive activities, measures for people organisation before the seismic emergency. They constitute the graphic mould of the spatial location of probable risk effects for different seismic intensities. These risk maps will be built for Zonda, San Juan Province, Argentina.

Priority Areas for the Intervention Strategies Implementation

The strategies should be part of a plan with politics and strategic programs to be applied according to an environmental measures program, conceived as a strategic measures process.

The Seismic Prevention must constitute a Continuous Process. This should consider two priority actions: the gradual eradication of sectors whose constructive quality represents a serious danger for the involved population in case of destructive earthquakes, and secondly, the foreseen equipped spaces to give shelter to the victims.

Selection of Priority Areas

For the areas selection, from the seismic risk maps it is taken into account the sectors with the highest percentage of irreparable damage probability.

In order to define the strategy to be used in each of the sectors (Table 2), the diagram from the direct vulnerability matrix and the seismic risk maps will be considered.

Table 2: Strategies Classification

Rehabilitation	Recovery by recycling the housing with any grade of precariousness to cover qualitative deficit.
Renovation	Action that replaces housing whose grade of damage makes its recovery impossible.
Densification	Occupation for the construction of new housing to raise levels of construction and population density.
Retention of the urban limit	Control of the limits of the urban area
Urbanisation and occupation of free areas	Action which consolidates the urban sector through the occupation of interstitial spaces.

In conclusion, this study, which is based on Geographic Information System (GIS) technology, attempts to know Zonda's seismic risk in order to start mitigation work, determine key projects, advise private and public sectors when developing special programs of vulnerability reduction, and support every day actions in governmental scope.

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