ГЕОФІЗИКА

UDK 550.34

R. Altez[1] and J. Laffaille[2]

THE SEISMIC-HISTORIC MICROZONING AS A FUNDAMENTAL COMPLEMENT TO SEISMIC HAZARD EVALUATION

This paper discusses the needs to start a review process about the historical seismicity in Venezuela, from a different perspective to that used for compilation of already existent catalogues, with an interpretation intended to be more precise than exhibited by isoseismic curves assigned to most important earthquakes.

Key words: earthquakes; seismic microzoning; seismic hazard evaluation.

Introduction

The seismic hazard with which towns and populations cohabit is appreciated, generally, from a perspective that favours the physical investigation starting from observations made in present time. However, earthquakes effects are not the same along time, and this owing not only to the differences between materials and constructions used by the different societies at each of the regions affected by earthquakes along their history, but also to the environmental and morphological change of areas where those towns are located and to the cultural effect following the occurrence of an important seismic event in a region to be studied. In good measure, many of those changes have been produced by great magnitude earthquakes, which leads to highlight the importance of studying the geomorphological effects associated to these events, using historical information as interpretative tool. In some extreme cases, those big earthquakes (like other disasters of severe impacts) have generated "attractiveness" spaces for urbanism development, which have been occupied later without taking in consideration their origin. The systematic revision of historical data regarding the geographical distribution of macroseismic intensities, leads to the conclusion that the effects of an earthquake in particular can be differential in a certain locality. These effects would be related to, among other variables, the soil response in front the seismic waves. From this perspective, *the analysis of historical data can generate important information in a first approach to the seismic microzoning of a place of interest.*

Likewise it should be noted, methodologically, that what is realized as *data* is not necessarily an identical fact or phenomenon from the different disciplinary or investigative perspectives of the sciences. It is clear that "data" do not exist as such in the reality being observed, but rather is the result of what the investigator builds about the information to which approaches, from his knowledge platform (hence the different perspectives with which a given reality is approached). In this sense, what it comes to be named "historical data" arises from the revision and interpretation of information accounting for the past, and this information possesses multiple ways to manifests itself or to become "source": manuscripts, cartography (contemporary and up-dated), images (photograph, arts), aerial photographs, bibliography (from specialized writings to literature), building materials, oral tradition and up-to topographical or stratigraphic area transformations.

Equally, when understanding that *the answer offered by the populations in front to earthquakes is historical and socially heterogeneous*, it is (in the same way) pertinent to investigate the characteristics that have shaped the structures and infrastructures of those towns affected by earthquakes and that, consequently, they even cohabit with this hazard. In consequence, the different types of building supplies that are manifested in the urbanisation should be studied punctual and systematically, to evaluate (and to re-evaluate, in many cases), the effects of historical earthquakes. This attention leads to know not only the physical characteristics of materials used in the constructions (wood, stone, adobe, bahareque, bricks, cement, tiles, masonry, etc.), but also the differential social access to this materials and the constructive techniques used in each case (the same materials, worked with different techniques, offers diverse solutions), which determines in most cases the behaviour and resistance of the same ones.

Studies with methodological attention to these variables, will contribute at the present time to a better evaluation of the seismic hazard, when relating these conditions with the morphology and the physical structure of the environment where these populations are located, projecting those results on the present and the future of the hazarded towns. This type of works could be contributing to new methodological strategies of investigation to the seismology, and they can be identified as "historical-seismic microzoning". Under this optics, *the re-evaluation of the big historical earthquakes it's*

proposed, in search of useful information in the sense of establishing a first approach to the response of each place in face to a new seismic eventuality.

What is sought to notice in this work, also and in general, points towards an epistemological suggestion that could enriches the seismological microzoning analysis of places and cities, since methodological proposal by itself, doesn't lies on technical or systematic application aspects, but on the necessity of linking theoretical and interpretive resources from different scientific disciplines. The implementation of multiple analytic resources, such as here is proposed, allows to achieve more certain results in the knowledge search. Owing to which the work doesn't brings quantitative results, but the signalling towards the necessity of a sum of methodological perspectives accounting analytically of the physical, natural, and material conditions, *realized as decisive historical variables*, and not only as aspects observed exclusively from the present. This is the point of view that allows us to understand in a dynamic way the hazards, just as they actually are.

Precedent Investigations Linked to Cases of Study

The first great earthquake in the Venezuelan Andes seismic history is emblematic in the central context of this work. Referring to this event, well-known as La Grita earthquake of 1610 [1], that on February 3 a big earthquake ruining all for the epoch existent populations and villages between Mérida and La Grita cities occurred. A very great mass movement (seismic avalanche) affected the Bailadores valley (trans-forming the topography of the area and generating a wide space where the town named from the resulting place-name of that fact, “La Playa” -The Beach-, was subsequently developed), to about 30 km from La Grita town.

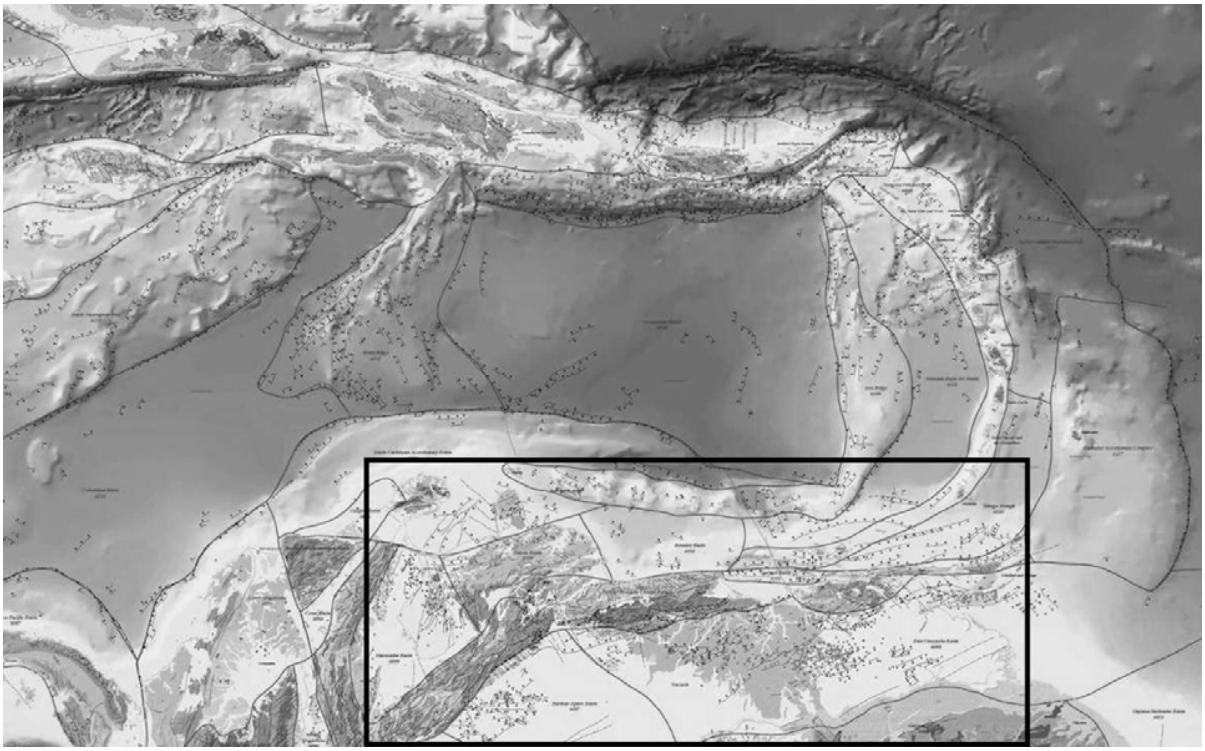

Fig. 1: Into the Caribbean geological context, Venezuela area is remarked on a Fragment of “Map Showing Geology, Oil and Gas Fields, and Geological Provinces of the Caribbean Region” [3]

Analytically and methodologically, this information was useful to produce an indirect estimate of the event magnitude and to define its macroseismic epicentre [2], but has not had inferences on the urban design of the affected region (see Fig. 1and 2 for the Venezuelan physical context).

On the other hand, the Great Earthquake of Venezuelan Andes occurred in the year 1894 (in which numerous damages being related apparently to induced effects rather than to the event direct action were reported), also emerge as an interesting example to illustrate this work objectives. In that event, seven of the nine temples for the date existing in the Mérida city lost their roofs being partially destroyed [2]. At

least three of them were located very near to hillsides borders, meaning by this: the Milla and El Llano Churches (both less than 100 m from the North hillside of the city), and the Belén parish Church that was almost destroyed, located at dozens of meters from the South hillside (see Fig. 3).

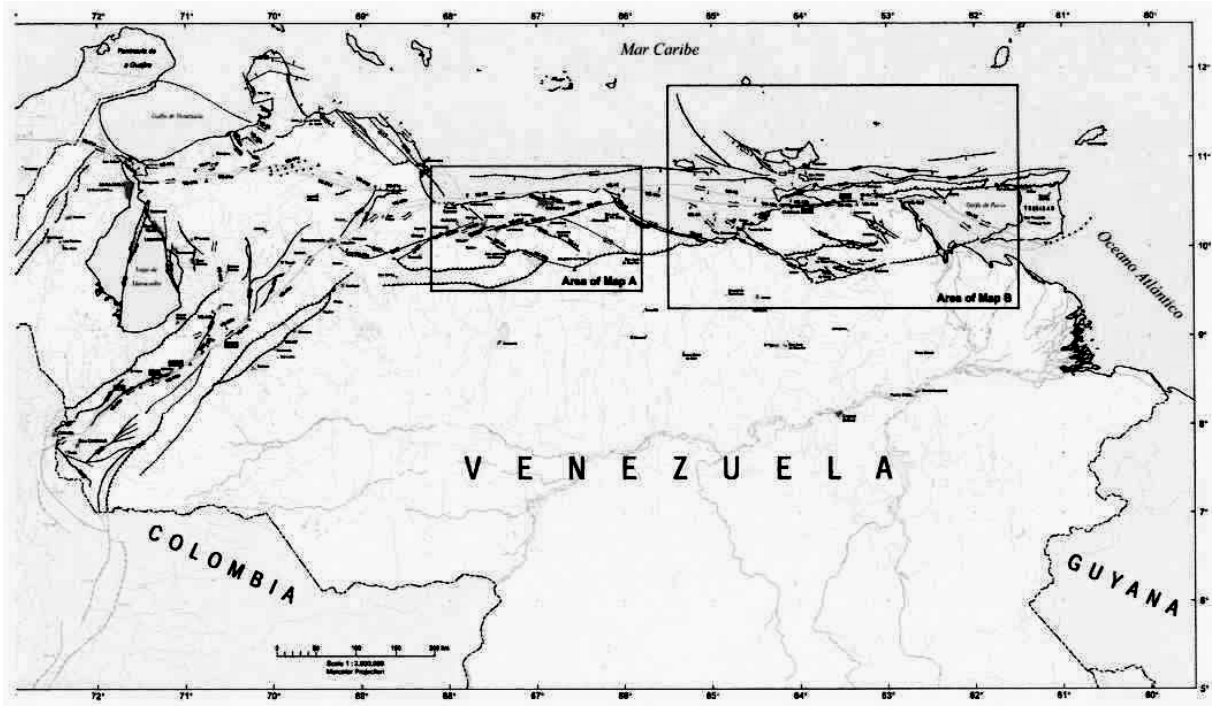

Fig. 2: Fault map of Venezuela; detail [4].

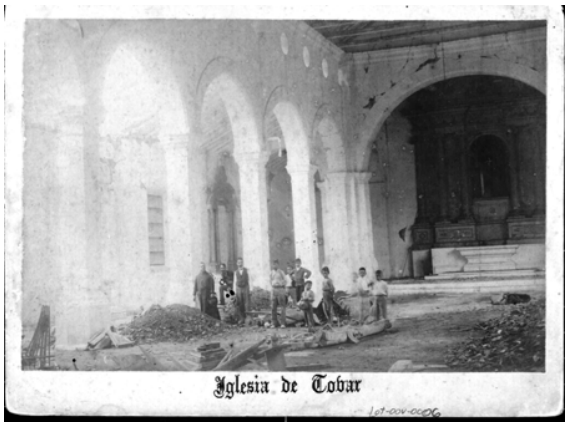

Fig. 3: Damages in Tovar's church after the Andes Great Earthquake occurred on 1894. (Picture by Romero González; courtesy of the FUNVISIS Documentation and Information Centre).

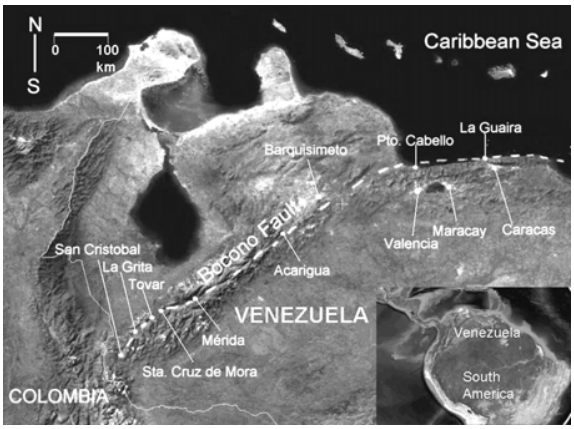

Fig. 4: Relative location of some towns and cities over the Bocono System Fault, on a satellite image from http:worldwind.arc.nasa.gov

Likewise, field visits performed to the town of Santa Cruz de Mora in the frame of this work elaboration, allowed to corroborate that damages experienced in this city on the occasion of the earthquake of 1894, were more intense in some sectors than in others. For example, in the North sector of the city (nearest area to mountain hillsides, located toward the apical area of the alluvial cones where the noticed constructions for the case were located), the damages were minor and even many houses were almost undamaged. It is possible that this effect is associated with the smallest sediments

thickness (which is expected in this kind of areas), aspect that suggests this fact should be taken into account for the future planning of territorial regulation of the town (for an explanation about the towns and cities named here, see Fig. 4).

In general, the historical seismic information has been reviewed and processed in terms of characterizing the occurred event (epicentre localization, seismic magnitude, etc.), and neither thinking on the possibility of learning something about the characteristics of the affected sites by these events, nor on the damages relationship to the "site reply" to the seismic waves action. We advise a different way to analyzing the existing information, in search of data rendering *information more related to the site and their context (natural, historical and social) than to the event*.

Just as it was pointed out previously, *because answers offered by the populations in front of the earthquakes are historical and socially heterogeneous, it is pertinent, in consequence, to investigate with more care to those differential variables*. This implies that, from all perspectives, it is equally necessary analytically to consider the natural, as much as the historical, and the social contexts; this is: *to consider them in relationship*. The decisive link existing among all these aspects is indivisible and the scientific observation should enlarge and to deepen its look in this sense. From the building materials until the constructive techniques, as well as the place in which it's rise and builds the towns and cities, *all those characteristics possess a social and historical determinant, that deserves to be taken methodologically into account*. The re-evaluation of the effects of destructive historical earthquakes, as well as the microzoning in particular, they should pay attention to this problem.

Methodological Examples

The case of 1812 (maybe the most emblematic of the Venezuelan seismology), there is an investigation antecedent in this perspective [5], which offers a detailed study of the damages suffered in the city of Caracas with the aforementioned earthquake (see Figure 5). With this work it was possible to trace feasible scenarios, in case of repeating an earthquake of the same characteristics presently. This was put into practice in YAMAZAKI *et al.* [6] and in [7].

The mentioned work linked quantitative and qualitative investigation methods, allowing thus to conclude more thoroughly over the earthquake effects in the city of Caracas. The death number review (associated to the historical context conditions, the construction typology, and the differential social

Fig. 5. Caracas with the damages microzoning by the earthquake of 1812 (modified by Altez [5]). Scale used: European Macroseismic Scale 1998 (EMS-98), especially the damage grades (grades between I and V). The marks correspond to the following grades: Grade V (black circle), Grade IV (grey circle), Grade III (black cross).

access to the materials and techniques of construction), assumed in discussion with the studies that

didn't take into account the primary historical sources, allowed *to reconsider the intensities and associate them to the site effects in relation to the social and historical aspects as decisive variables*. Also, a detailed evaluation of the reported damages in the constructions, concluded that most of the damages were related with the age of these constructions, its maintenance state, the materials type used and the constructive techniques, taking in consideration these techniques in its social context. These aspects showed intensities associated to these conditions, rather to the violence of the seismic waves.

The heterogeneous distribution, in consequence, of the damages observed in this work, doesn't allow us to assume in conclusive way that the same ones demonstrate a unique association with the site conditions, but, precisely, *with the historical and social conditions of the constructions in relation with the site conditions*. Nevertheless, such heterogeneity neither should be understood exclusively by these social conditions of the materials and construction techniques used, because this perspective doesn't result absolutely optimum to understand the case.

Based on this investigation, YAMAZAKI's *et al.* work [6] outlined possible scenarios linked to the repetition of an earthquake such as that of 1812. The review of the primary sources elaborated in ALTEZ [5], allowed the systematizing of the information recollected and the validation of the simulation in this respect. The analytic consideration of the historical information, in the work of YAMAZAKI *et al.*, and not the simple adhesion of the same for the work, led to conclude over the distribution of the damages and its link with the possible fault rupture, as well as its association to the site conditions. From these efforts, this work estimated results that facilitated the construction of possible scenarios in case of the repetition of an event such as that of 1812, as well as to reason in relation to the rupture of the fault segment associated to the event.

Proposal

In the conclusions of the works previously mentioned, the authors called attention of the effectiveness that implies to relate in this type of studies the earth sciences with the social sciences. In this relationship, with evident methodological implications that transform the approaches of the object in study, it is possible to find the key of a new analytic perspective, which must not suppose the simple addition of investigation techniques, but the epistemological relation pointed out above in the introduction. In this work those concerns are recaptured and it is advised about the necessity of building new methodological strategies that arise in the linking of complementary analytic proposals. In this way the strategic relationship between seismological, geologic, architectural, historical, anthropological theoretical perspectives, among others, will result as bigger and better investigation resources in these cases. If the scientific investtigations have understood that the historical contextualization is a decisive tool in the interpretation of the impacts caused by destructive natural phenomena (which is valid not only for the study of past disasters, but for those that happen currently also), obviously, such a perspective should contribute to a better understanding in the case of the evaluation of the seismic hazard.

It is proposed, therefore, the inclusion in the studies of seismic microzoning of the attention to the dynamic condition of the variables considered in these studies, which not only implies to notice that the materials response in front of earthquakes change along the time (because it changes the technology historically and socially, as well as the resources used in this respect), but also the nature (and the relationship of the society with the nature) transforms in the same way. This is why that the microzoning studies could be more successful if their variables are observed from a historical perspective of analysis.

A dynamic consideration on the site conditions, the construction typology and their differential relationship with society, will allow that the conclusions on possible scenarios where destructive historical events repeat, offer nearer probabilities to the reality. It is therefore that the variables that must be analyzed in this respect, should be, in fact, considered in their dynamic nature, and not from a perspective that privileges the present conditions of those variables. There exists a mention to the "dynamics of the seismic source" in AMPUERO [8], although the author makes reference in this case to the "disciplines that study the relationship between cinematic parameters and the parameters of mechanical behavior of the fault" (p. 11), referring, obviously, to exclusive physical aspects from that perspective of the investigation, because it is not their goal to mention to other dynamic conditions in this respect.

The combination of quantitative and qualitative resources of reality approach and the objects in study, will allow the emergence of new methodological strategies. That is to say, it is not about outlining "a new methodology" for the seismic microzoning, but to understand that the methodological strategies that are put into practice in investigations that take into account these interpretive perspectives, will be more effective. This is why, for example, besides appreciating the variables in their dynamic condition, the review of the intensities of destructive historical earthquakes, will lead to the reconsideration of the

data and the setting in practice of that reconsideration in relation with the site conditions or with the reasoning aimed to the elaboration of scenarios studies. If all the destructive historical earthquakes were re-evaluated systematically, surely those results would allow to reason more precisely on the present seismic hazard.

Conclussions

This paper didn't approach in any moment the issue of a quantitative evaluation (neither of the mentioned cases, nor as a methodological proposal), because, just as it has been stated clear in the Proposal, what is sought is linking theoretical and analytic perspectives that account in a deeper and better way of the analysis of seismic hazards. This is why, the work as such does not "studies cases", but rather it uses the cases like examples. The intention has been to draw attention about the necessity of taking analytically into account the historical information inside the microzoning studies, in connection with the dynamics of the response (materials, technologies, social, environmental) and the site conditions.

It is clear that the historical information is not enough as to advance a zonification map. But it is possible that it allows to guide upgraded investigations in the sense of making them more efficient, and even to advance some important forecasts in the context of the urban growth in some of the cities that have been affected by big earthquakes. The examples used in this work account on that possibility.

The works mentioned previously in relation to the impact of the earthquake of 1812 in Caracas, offer another example to consider. The review and systematizing of the historical sources allowed validating the information obtained for the calculation of possible scenarios. In this case it could appreciate that, inside the heterogeneous distribution of the damages, the association of the same ones to site conditions, neighboring to the fault and social and historical relationship of the materials and constructive technology, was the decisive factor. The most outstanding constructions and of more span, as the churches, didn't suffer the same damages, but was associated to the age and to the maintenance of the same ones. In the same way, the attention to the historical context allowed to understand that the death number was magnified by later narrations and that it deteriorated the analyses of the case from all the points of view. Equally, it could be observed that most of the deaths were caused by the constructive typology (very heavy roofs supported by inadequate propping-ups or expired by age), and they affected the population differentially (when most of the adults were at the celebration of Holy Thursday, the elder men, children and maids, were the most numerous victims). These conclusions led to reconsider the intensities of this earthquake and the use of a scale (EMS-98), more appropriate for the case, in relation to the one more generally used (Modified Mercalli), which is not always precise in these details.

It is suggested, then, to recapture the investigation of the big historical seismic events that have effected in cities and towns, directing the results towards the construction of scenarios that pay attention to the contexts (historical, social, cultural, materials, structural, natural), proper of each time and each place, based in the descriptions and existent documentation, in the own characteristics of the constructions at the time of the event, and the analysis of the physical conditions of each site.

What is suggested is the elaboration of *multidisciplinary works* in which historians, architects, engineers, seismologists, geomorphologists, anthropologists and other specialists participate. It is about investigations that require of a notable effort (technical, methodological and theoretical), to complement and to validate the information reported in the seismic catalogs and historical sources, as well as field works destined to visit the places described in documents already processed with the purpose of verifying the conditions of the sites. For this, also, it is necessary to continue and deepen the searches in primary documentation, turning to qualitative methods in the capture of historical information.

These cross-sectional methodological strategies, as those that are suggested in this work, include (for example), to interview people that in one way or another, could have some relationship with what happened at the time of the studied event (for the cases of remote past, the testimonies are found in other sources, evidently). Maybe to be able to access these narrations can seem a complicated matter (or to awaken the suspicion that it is not a systematic and formal method of capture of data); however, the authors of this work can give faith of interviews carried out with witnesses of what happened in the earthquakes of 1932 and 1933 in the Andes area (for example), of children and grandsons of the 1894 Great Earthquake of the Venezuela Andes and of other important events where decisive information was obtained about their effects. It is not unknown, likewise, also that the seismology uses this resource in field observation after a destructive earthquakes; however, the methodological destination of the information doesn't always contribute to transverse analytic reasoning, as those here proposed. Seismologists are strongly concentrates on the structural damages, as well in the impact lived, in the testimony of effects over nature, among others,

without linking this information with the historical data for understanding all the behaviors and replies in general, in relation with previous events.

It seems to be clear that, if the expectations of the investigations in microzoning aim to a optimum and effective result in the seismic prevention, it is unavoidable the attention to all the variables that play a decisive role in the effects and damages of the earthquakes from a perspective that takes into account the historical behavior of the same. In this way, as much as the structural and infrastructural aspects of the construction and their techniques put in practice for it, as well as the geomorphologic variable conditions, need to be understood historically before seismologically. In this sense, it is pertinent to conclude that *the historical understanding of seismological variables must be assumed as the methodological sense of the microzoning*.

References

1. Simón F.P. Noticias Historiales de Venezuela, Tomo II. Fundación Biblioteca Ayacucho, Caracas, 1992 (original from 1627).
2. Ferrer C. y Laffaille J. El alud sísmico de La Playa: causas y efectos. Revista Geográfica Venezolana (ULA, Mérida) 39 (1 y 2); 1998, pp. 23–86.
3. French C.D. and Schenk C. Map Showing Geology, Oil and Gas Fields, and Geological Provinces of the Caribbean Region, USGS Open-File Report, 97-470-K, 2004.
4. Audemard F. (Comp.) Quaternary Faults Map, 1:2.000.000, USGS-FUNVISIS-PDVSA-LPII, 2000.
5. Altez R. El terremoto de 1812 en la ciudad de Caracas: un intento de microzonificación histórica. Revista Geográfica Venezolana (ULA, Mérida) Special Issue, 2005, pp. 171-198.
6. Yamazaki Y., Audemard F., Altez R., Hernández J., Orihuela N., Safina S., Schmitz M., Tanaka I, Kagawa H., and JICA Study Team – Earthquake Disaster Group, Estimation of the seismic intensity in Caracas during the 1812 earthquake using seismic microzonation methodology. Revista Geográfica Venezolana (ULA, Mérida), Special Issue; 2005, pp. 199–216.
7. JICA (Japanese International Cooperation Agegency), Study on Disaster Basic Prevention Plan in the Metropolitan District of Caracas, Pacific Consultant International in association with OYO International Corporation, Final Report, March, Caracas, 2005.
8. Ampuero, J-P., Dinámica de la fuente sísmica: nuevos paradigmas. IV Coloquio sobre Microzonificación Sísmica, Memorias. Serie Técnica (FUNVISIS) (1); 2005, pp. 11-14.

СЕЙСМО-ІСТОРИЧНЕ МІКРОЗОНУВАННЯ ЯК ФУНДАМЕНТАЛЬНЕ ДОПОВНЕННЯ ДО ОЦІНКИ СЕЙСМІЧНОГО РИЗИКУ

Р. Альтез і Х. Лаффайль

У статті обговорюється необхідність початку процесу перегляду даних про історичну сейсмічність Венесуели з використанням вже існуючих сейсмічних каталогів і різних підходів з метою точнішого визначення сейсмічного ризику, ніж те, що задається ізосейстами, які належать найсильнішим землетрусам.

Ключові слова: землетрус; сейсмічне мікрорайонування; оцінка сейсмічного ризику.

СЕЙСМО-ИСТОРИЧЕСКОЕ МИКРОЗОНИРОВАНИЕ КАК ФУНДАМЕНТАЛЬНОЕ ДОПОЛНЕНИЕ К ОЦЕНКЕ СЕЙСМИЧЕСКОГО РИСКА

Р. Альтез и Х. Лаффайль

В статье обсуждается необходимость начала процесса пересмотра данных об исторической сейсмичности Венесуэлы с использованием уже существующих сейсмических каталогов и разных подходов с целью более точного определения сейсмического риска, чем представляемое изосейстами, принадлежащими сильнейшим землетрясениям.

Ключевые слова: землетрясение; сейсмическое микрорайонирование; оценка сейсмического риска.

[1] ***Universidad Central de Venezuela, School of Anthropology, and Venezuelan Society of History of Geosciences, Caracas, Venezuela***
[2] ***Universidad de Los Andes, Geophysics Laboratory, and Foundation for Seismic Risk Prevention (FUNDAPRIS), Caracas, Venezuela***

Надійшла 08.10.2008