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EXPERIENCES FROM THE PAEZ EARTHQUAKE, COLOMBIA

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ABSTRACT

The 6.4 Richter Magnitude surface earthquake that hit the Paez river basin, southwestern part of Colombia, serves as example of the complex task of accomplishing both a reasonable stability emergency evaluation following geoscientific procedures, and to get a quick - positive response from a heterogeneous group of scared people, mostly of them indians without our same vision of the world. Right after the event, a group of experts of Ingeominas, the Colombian National Institution in charge of the geological hazards applied a novel methodology of hazardous zoning, assessing in short time, as the circumstances demanded, the main factors which appeared to control the stability of the area. The technical reports allowed to produce a zoning of the Paez river basin, in 1:10000 and 1:25000 scales, and summarize the overall state of the epicentral area, in a 1:100000 scale map. The event experiences are used to make remarks about the respect and consideration of the indian beliefs, as the main local culture found, and also about hazard and vulnerability and our role as geoscientifics towards the lowering of the components of risk in developing countries.

KEYWORDS

Ecological Geosciences; emergency zonation; ethnic; pre-disaster vulnerability; post-disaster vulnerability; model basins; paez; prediction.

INTRODUCTION

On june 6th, 1994, at 20h 47' Greenwich time, an 6,4 Richter magnitude earthquake with a focal depth of less than 10 km., hit the Paez river basin, in the Cauca Department. The National Colombian Seismological Network, NSN, managed by Ingeominas, the National Institute of Geosciences, Mining and Chemistry, located the earthquake at 2.9 degrees north latitude and 76.08 degrees west longitude; the epicenter was located about 10 Km. southwest of the Nevado

del Huila volcano.

The earthquake effects included a combination of damaging events, starting with direct structural failures of houses and infrastructure, following with all sorts of mass movements, and ending with a huge debris flow which causes most of the about 1100 casualties.

The geoscientific emergency evaluation, done by teams of geologists and geotechnical engineers, allowed to make a zonation of the main damaged area in sectors with less or most suitability for living (Ingeominas, Forero-Dueñas,edit. 1994), being a technical base-layer over which decisions regarding understanding the nature of the hazard situation, identification of critical points, shelters location, evacuation procedures and so on were taken by the Colombian National Office for Disaster Attention and Prevention, NODAP.

The difficulties about the technical evaluation were great both because of the nature of the task itself, in a short period of time, and for the access problems, being only possible arrive by using helicopters. But having done this step, the geoscientistics found a different culture living in the epicentral area, the indians.

They have a different authority organization, and see the world under different parameters, being bonded to the so called mother earth; these conditions put an additional, and perhaps at the end quite useful, ingredient in the immediate task of control the disaster situation and perform the disaster management under the most efficient, less arguable, parameters.

THE EARTHQUAKE AND ITS GEOENVIRONMENT

The main shock was located by nine of the stations of the NSN, which is a modern 14 seismometer satellite system; the network also received around 800 aftershocks from the 6th to the 30th. of june, ranging in magnitude from 1,8 to 4.8 in the Richter scale (Ingeominas, 1994, Dimaté *et al.*, in Forero-Dueñas, edit.).

The location of the epicenter was done with the seismological stations of the NSN, reinforced with data coming from other stations belonging to the Southwest Seismological Observatory, a regional Colombian network, and the National Seismological Network of Ecuador. In the Mercalli Modified intensity scale, the event had an epicentral grade of VIII.

The field activities identified the Moras Fault, of high angle and with a general N40°E direction, as the most possible source of the energy liberation. In general was evident the lack of detailed knowledge about neotectonics in the region, having as a working base only regional maps but without including the ideal necessary information and not oriented to the specific problem. This is a common matter in many areas of our country.

Ingeominas (París and Romero, 1994) has developed an updated simplified version of the neotectonic situation of Colombia, including the Moras Fault; this is a purpose-built map towards the understanding of a basic layer in any seismic hazard assessment for the country. The Andean zone , where was located the epicenter of the Paez earthquake, is covered by a cluster of faults,

all of which have more or less possibility of being an earthquake-generator.

The materials found around the epicentral area includes many sorts of rocks and soils, ranging in age from paleozoic up to quaternary. The genesis includes magmatic processes, metamorphism and sedimentary sequences (Ingeominas, 1994, Orrego *et al.*, in Forero-Dueñas, edit.).

The Nevado del Huila volcano (5365 masl) is one of the 15 active volcanoes of Colombia. The location of this right in the upper basin of the Paez river made at the beginning of the hazard evaluation think in an obvious relation between an avalanche and the volcano. As a matter of fact there was already a preliminary hazard map modelling this event (Ingeominas, 1986, Cepeda *et al.*,). However no relation was found, and only an slight effect was observed in the glaciers. The volcano did not show any main seismologic abnormal behaviour by comparing the activity pre and post earthquake.

THE EMERGENCY EVALUATION AND ITS APPLICATION

When a couple of days after the earthquake the first news of the magnitude of its consequences arrive to the Ingeominas central office in Bogotá, a group of engineers and geologists were sent to act as the technical mission supporting the NODAP. The initial group was composed by senior environmental-engineering geologists, Mr. P. Caro and Mr. M. Moreno, and by a couple of geotechnical engineers, with specializations also in hazards and seismic matters, myself and Mr. J. Martínez, who was the general coordinator of the mission given his position as Subdirector of the Geoenvironmental Area. The group had a strong geoscientific formation and experience in engineering projects and hazard evaluation, of several years of practice and study. The group was reinforced by Dr. A. González-García, President of the Colombian Geotechnical Society, as an advisor.

The former background is quite important, when is intended to gain lessons from our experience in the earthquake. When the group arrived and started flying the area, was shocked by founding hundreds and hundreds of landslides, a huge mark of a high energy event in the Paez river channel, the debris flow, and a general damage situation in the basin of the Paez river. The complicated part was that immediate pressure was put to get the stability concept of the Ingeominas team. The technical formation and good sense of Mr. O. Cardona, head of NODAP, a seismologic engineer himself, was useful to explain to everybody the difficulties of the task in a short period of time, and that we were ready to do the best possible job.

After the first aerial impression of the situation, the team had a meeting and from the exchange of ideas and to cope with the situation, the next zonation strategy was agreed :

- Select targets of evaluation, according to the reports of people in danger sent to NODAP by the local emergency committees.
- At the same time additional targets were chosen to carry out the understanding of the physical phenomena and prevent possible new events.
- Groups of two, geologist-engineer, were spread over each selected target by helicopter. In many cases the landing was not possible, and was necessary to jump to reach the ground. After a time of observation-assessment-evaluation, the geologic-geotechnic setting of each place was defined;

this time of walking-sampling ranged from 1 to 3 hours in each place.
- The local community, Paez indians mostly, were amiable in general. As part of each mission, the geoscientifics also include an explanation of the situation to everybody, and to respect the local cultural-hierarchical organizations, we try to speak and make the walking with the head of the community which at the end was the one who understood more our explanations, spreading them afterwards.
- Sketches of the targets were done, in plain and profile, also taking helicopter pictures to help in the zoning, later on. In most of the cases we had topographic bases in 1:25000 to 1:10000 scale to help in the drawing. The sketches were jointed in a 1:100000 scale map, summarizing the overall stability situation.
- To improve the usefulness and the quick understanding of our geoanalysis for everybody, all the collected data of geology, geomechanical indexes, failure mechanisms, ground-water levels, stability assessments, slopes, and all the hard technical information was simplified. Three summary zone were shown, including the expected ground-structures response to all the possible hazards in a given target.
- The three zones were presented with emphasis in the aptitude for living, as it was one of the most common questions in every place. The zones were: Most suitable zones for living (in red color), Non suitable zone for living (in red color), and Non clear-stability zones (in yellow color) in which either the complexity of the situation or the lack of proper observations (in some cases the landing was not possible) did not permitted to make a clear definition; in these later zones temporal activities were allowed.
- Nightly meetings were done with all the institutions involved in the emergency, with the coordination of NODAP, and the active participation of the indian organization representatives. Questions were solved, and the final deceptions about the location of possible shelters and evacuation points were taken in common agreement.
- The official concepts by Ingeominas, after each day of work, only were communicated directly to NODAP, institution that was in charge of spreading the results to the people and the media. That was very important, concentrating our team in the technical assessments.

The difficulties of the hazard assessment were very big, and not were few the cases in which our group had to walk alone in between the failed slopes, and the destroyed roads and houses, given the fact that neither the locals nor the red-cross people liked to walk in extremely risky and unstable ground. However, at the end this fact was also valuable to gain the respect of everybody, having a general feeling that the central government sent people really interested in helping traditionally forgotten areas. In some of those cases, we had to do it, because it was the only way to draw profiles and sketches and assess the stability; it is also necessary to say that for one reason or the other, we could not obtain proper post-disaster aerial photographies to help us in evaluating the emergency.

The sequence of the hazards was modelled, starting with the earthquake (first order hazard) damaging structures and producing mass movements (second order hazard); part of the shook soils, rocks and debris reached the streams, without any important damming, and shaped almost instantly a debris flow (high order hazard) centralized in the Paez river channel. The violence and speed of the flow, around 50 kph close to the epicentre, added to the surprise of having something else just following the earthquake, were the cause of most of the casualties in the towns and villages located in the flow route.

CULTURAL CONSIDERATIONS

The area affected by the earthquake is populated by a mixture of ethnic groups, and cultures. This lack of uniformity among the population makes very difficult to reach every one with a single technical speech.

In that area is located the Tierradentro region, mainly composed by Paeces indians, being a world-recognized centre of anthropologic value. Also in the Silvia region Guambianos indians are settled. We found a mixture of world conceptions, including a diversity of religious centres with catholics and evangelical churches, among others. There are also people of mixed race as half-castes (mestizos) and mulattos; also we found whites and some black populations.

The indian inhabitants speak their original language, and many of them also speak or understand spanish as well. Most the area is divided in indigenous Resguardos as a way of land property; the indigenous are ruled by Cabildos as the traditional authority.

We found some crops of poppy (amapola) in the lands cultivated near the border of the debris flow in Paez river basin. As a matter of fact, natives told us that some of them saw the disaster as a punishment of God for being cultivating illicit crops. These illegal activities had been detected by the police, and before the disaster the helicopters, the same that were serving us as transport media, were used in antidrugs missions; that fact did not help us very much in some cases, and some distrust was felt when we, the white government, arrived to help them, the hunted and in some extent the traditionally abandoned.

The Paeces had the avalanche among their ancient events, linking similar phenomenon with life signals of the earth, the mother. And any such event is related to their particular conception of the world, calling for a truthful bonding with the earth. Histories about the birth of Juan Tama, the mythical Paez ruler, associated to an avalanche were told to us. These facts put new pressures over our group: how to move them with evacuation procedures supported with a three color sketches and some geoscientific ideas about friction angles, recurrence periods and undrained shear strength, if they took the event as an expression towards the reinforcement of their believes, and the attachment to their lands and sacred places?.

The only way was to understand their vision of the world, agree that some, even dangerous places, might be used for temporary uses only under their own responsibility and that the evacuation places were selected by them among a set of choices identified with our maps. In some cases many meetings were done, to try to clarify to the governors of the Cabildos that we were not taking advantage of the situation to help to destroy their culture, and that after more formal-detailed studies were done, starting right after coping with the emergency, the return or at least the preservation of their lands will be guaranteed.

The reconstruction phase have to consider all these complexity, and as a fact the Government created a special Institution, with indian name, called Corporation Nasa-Kiwe with an open and what seems to be following truly multicultural bases.

RISK SITUATION AND PROPOSALS

Considering the risk as the product between hazard and vulnerability, and remembering the lack of input parameters found to make a precise hazard assessment, is also worth commenting about it.

The risk is only assessed properly when its two components are defined. It is worth remembering the overall location of our country in a region where interacts the South American, Caribbean and Nazca plates, in a tropical mountainous environment with all sorts of associated geodynamic events (Forero-Dueñas, 1992), and having in mind the scenario coming from the inland active faults (Paris and Romero, 1994), the situation seemed to be complicated. And it is worst, given the fact that we did not have identified yet all the input parameters that requires a proper seismic hazard assessment. Of course that we already started doing it, and projects as the NSN, the National Acelerographs Network, NAN, and the Seismic Zonation of Bogotá, lead by Ingeominas are going to give us a clue about our real state of hazards and the right design spectra to ensure the physical stability of the structures.

However, today we have a vulnerable situation by definition in most of our Andean zone, because if we do not know who is the enemy (hazard) how could we might be able to fight properly against him (vulnerability reduction). And in our Andean region is settled most of the population and infrastructure of the country.

The Paez earthquake is the evidence that the seismic risk is a hand grenade that is able to exploit at any time in any place. The huge costs associated with the recovery actions are the testimony of how vulnerable we are. However, with the creation of the new Ministry of the Environment and the associated Regional Autonomous Corporations, RAC, and the economic reinforcement of the local governments, is not worth carrying out steps such as:

- Establish a definite educational campaign, starting with children, to try to have a basic knowledge of the earth activity and the geodynamic events among the population. If our present generation of adults is not able to be educated, the coming ones will. This single geoscientific layer might be a key to undertake properly any disaster-related action (prevention, emergency, recovery), having a common language to talk about.
- Establish-reinforce local seismological networks, as complement of the NSN and NAN, which are more interested in high magnitude events. To do that properly, it is possible to agree between one or more RAC, and the involved towns, the definition of Areas of Intensified Seismic Observation, AISO. Criterion to define them might be: areas that have had a large earthquake in the past, areas with active faults, areas with permanent seismicity, strategic areas with socioeconomic- ecological great relevance, and so on.
- When necessary, with the same institutional actors-sponsors, in the most populated or valuable areas, to define at least few model basins, MB, to prevent them against possible effects associated with earthquakes. That includes the aseismic structural designs, and the generation of high-order hazards such as landslides, dams and avalanches. In this MB might be applied model techniques of land-use and a general high level of countermeasures and cultural understanding against hazards, as a mean to lower the vulnerability. The example of the MB might be contagious, serving as a guide to adjacent ones. The initial costs will be compensated at the end; the control of our disaster situations have been found to be extremely expensive being worth

putting money in preventive stages.

At the National Level, Ingeominas can carry out the reinforcement of the NSN, NAN, neotectonic and microzoning projects, instructing and assessing regional technical groups, and act as an overall manager of all the data compiled at regional levels. The strategy intended to help in reducing the national seismic risk, as a primary goal, by :

- Proper quantification of seismic hazard, producing a suitable seismotectonic model of the country, considering elements as anisotropy in the seismic waves propagation, and the role and relative influence of regional and local faulting systems in our seismicity.
- Helping in lowering the Vulnerability with suggesting right acceleration design spectra, giving appropriate acceleration attenuation equations, studying local effects associated with topography and soils. Also with educational campaigns to regional bodies is possible to spread the knowledge and lower the uncertainty on the subject.
- To have as a secondary product of all the seismologic and field work, an strategy to earthquake prediction. Given the associated uncertainties it is not worth having it as a very primary flag, but with the use of all the collected data, we might be able to start some prediction stages in the future. As example, a programme of geophysical measurements might be a good complement to the instrumental data, as a well as a regular study of ground deformations. The analysis of seismological precursors such as : foreshocks, anomalous activity, seismic gap of the second kind, source analysis, and migration of microearthquakes, are among the parameters to study to our own seismic setting with all the collected information at regional and national levels.
- To carry on the researching on the geotechnical static and dynamic behaviour of our own soils. We have cases of unusual response in materials with very particular structure-fabric, originated in the climatic-environmental conditions of the Equatorial zone. Joint projects can be carried out with Universities and the RAC.
- To be aware of our role as conductors in great extent of the Vulnerability conditions of the population. Besides the emergency vulnerability, that might be understood more as a physical one, we as geoscientistics also are capable in reducing the pre-disaster and post-disaster vulnerability. That may be done spreading a sense of presence among the population, explaining what is all about geohazards, suggesting countermeasures and drawing scenarios of action in case of a disaster.
- Include in an explicit way the cultural analysis of the regions where we are going to develop our applied projects. This is valid not only to the disaster situations but for common studies. In that way, the geoscientifics might be giving a positive impulse to the social sciences, with a continuous research that will not be restricted to study behavioural changes during crisis. All this broad vision of the geosciences, are part of the Ecological Geosciences (Forero-Dueñas and Booth, 1995).

CONCLUSIONS

Among the main elements coming from this experience are :

- The physical and cultural complexity of the Paez basin help us to remind: complex emergency situations are better solved by well trained experienced teams; the methodology of zoning have been found to be useful and easy to catch up by the final users and the people; the way of understanding nature might affect evacuation procedures, being necessary to reach common decisions involving the affected population.

- The Paez earthquake hit in a violent way a basin with low population density, but if the same happened in a well populated one, the generated disaster might reach huge proportions. We are vulnerable in the Andean region.
- Cultural elements are part of any applied geoscientific evaluation, not only in disaster situations, if is intended to use it with the maximum benefit for the population.
- Among the suggested steps to reduce the seismic risk and its associated events, a combination of hazard understanding, reduction of vulnerability and preventive countermeasures are the strategy to follow. Neotectonic and geological studies, geomechanical modeling of our soils and rocks in static and dynamic conditions, effects associated with topography and local deposits, local seismic networks, areas of intensified observation, model basins of special management, and the beginning of prediction stages are suggested.
- To reduce the vulnerability, is possible to work in the traditional physical aspects, but playing also a educational , preventive and supporting role in pre and post-crisis scenarios.

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