GEOLOGICAL RISK COUNTERMEASURES IN COLOMBIA: NOW AND TOMORROW

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1.- ABSTRACT.

This paper is the summary of the procedures in disaster situations analysis that include geologic components in Colombia and introduce proposals to improve them, taking into acount both some original ideas of the writer and outlines based on the Japanese organization.

2.- GENERAL FEATURES OF THE COUNTRY.

The most remarkable features of the country related with location, topography, climate, rivers and geology are sumarized in the table 1 (next page) and in the figures 1 and 2. In agreement with the plate tectonics concept (see fig. 3) the country is located in the interaction zone of the Nazca Plate with West to East movement, South American Plate with East to West motion, and Caribbean Plate with West to North East slow movement. The west coast of the country is part of the called Pacific Fire Belt and the definition of the best theory about the mechanism of energy transmission of Earthquakes to this area is still a matter of discussion (see fig. 4), the real fact is that its consequences are affecting the Colombian people.

On the other hand, inland there are a lot of geological faults many of them with activity, wich generate Earthquakes of several magnitudes. The figure 5 shows the location of the main geological faults, including the Romeral Failure and the Frontal Failure of the East mountains (N-NE direction) wich are a big hazard to the human live and possessions on the Andean Zone where most of the people of the country is settled; this two failures had been the source of destroyer Earthquakes. The figure 5 also shows the seismicity of the country with the location of the Earthquakes epicenters. In the figure 6 the actual seismic risk zonation of the country is showed.

3.- DISASTER SITUATIONS.

Colombia is a country wich has multiple potential hazards: Big mass movements, active volcanoes, the majority of his population facing high or intermediate seismic risk, tsunamis, many flood prone areas and several technological risks.

In the last years tragic events such as the landslide of Quebrada Blanca (1.974), landslide of El Guavio (1.983), landslide of Villatina (1.987), Utica debris flow avalanche (1.988), eruption

LOCATION: North Western side of South America.
EXTREM LATITUDES: 4^0 13' 30'' (South), 12^0 30' 40'' (North).
EXTREM LONGITUDES: 66^0 54'' (East), 79^0 01' 23'' (West).
FRONTIERS. NORTH: Caribbean Sea, **EAST:** Venezuela and Brasil, **SOUTH:** Brasil,Ecuador and Peru, **WEST:** Pacific Ocean and Panama.
AREA: 1'138.914 Km2. **POPULATION:** 30'000.000 (Estimated).
TOPOGRAPHY: Three chain of mountains (N-E direction)forming the Andean zone in the Western and Central regions,with altitudes up to 5.775 m.asl.
CLIMATE: From ever-snow-covered mountains to hot and humid jungle.Two rainy seasons.Precipitations from 500 to 5.000 mm/y,in some parts of the Pacific Region up to 9.000 mm/y.
RIVERS: Four discharge systems: Atlantic Ocean (N), Pacific Ocean (W), Orinoco River (E), and Amazonas River (S). Some of the rivers are: Magdalena(257.438 Km^2, 7.003 m^3/s), Caqueta(199.137 Km^2, 12.380 m^3/s), Atrato(35.702 Km^2, 4.557 m^3/s).
GEOLOGY: Active geological faults (N-S direction).Western and Central mountains include igneous and metamorphicus rocks. Eastern mountains have sedimentary deposits. Colluvial and Alluvial deposits and residual and transported soils are found.

TABLE 1. GENERAL INFORMATION OF COLOMBIA.

of the Nevado del Ruiz Volcanoe (1.985), the earthquake in Old Caldas (1.979), the Popayan earthquake (1.983), the Tumaco tidal wave (1.979), the Joan hurricane (1.988), floods of 1.988 and similar ones every year are disasters evidencing the high risk wich the country faces.

4.- FRAMEWORK OF DISASTER PREVENTION.

Only after painful disaster situations, the Colombian Government understood the socio-economic importance of the study of the natural hazards. Whit the enactment of Law 49 of 1.988 and its regulatory Decree 919 of 1.989, the National System for Disaster Prevention and Assistance was established. (see fig. 7).The system includes a National Committee, Descentralizerd Committees at Regional and Local level in the whole country, a National Office (ONAD), a National Technical Committee, a National Operative Committee, related Ministers and Administrative Departments, other national and regional entities, Red Cross and some private organizations.

The components of the system make plans, programs, projects and specific actions to reach the following objectives:

- To Define both responsabilities and functions of his components in situations related with disasters.
- To Garantee the eficient management of the resources in the prevention and atention of disaster situations based in a Nation-

al Plan.

The National Technical Committee is an adviser organism that make both scientistic prevention programs and attention-recuperation measures in case of disaster situation; as part of this committee the National Institute of Investigations in Geosciences Mining and Chemistry, INGEOMINAS, is in charge of the geological risk analysis and makes the hazard and risk maps of the country. INGEOMINAS also makes the volcanic vigilance with the development of Volcanoes Observatories and the deploying of the National Seismic and Volcanic Monitoring Network, oriented towards the improvement of the warning and forecasting capabilities concerning volcanic eruptions and earthquakes.

5.- PRESENT METHODOLOGIES IN THE TECHNICAL ANALYSIS.

The methodologies followed for INGEOMINAS as part of the National Technical Committee are still changing, looking to improve them day by day. As an example, in the figs. 8, 9 and 10 are showed the specific methodologies of the last thre big projects of the Enviromental Geology Division and the new Engineering and Geological Risk Area of INGEOMINAS. Even if each project has different specific objectives, there are several common features and the evolution of the methodologies is evident.

The first project "Geotechnical Zonation of Bogota City", was finished in 1.989, the second project "Mass Movement and Stabilization Study of Cundinamarca Department, 1st. Phase", was finished in 1.992 and the third project "Avalanche Risk in Utica town", was completed in 1.992. As common features we can find:

- Phase of compilation of the related information.
- Use of Remote Sensing with the interpretation of aereal photographies in scales varing from 1:20.000 to 1:40.000.
- Use of direct and indirect field surveys, appling conventional in situ sampling and the electrical resistivity Geophysical method to define both geological composition and underground water behavior.
- Field checking of the interpretation of aereal photographies.
- Stress-strain-time and classification tests in the soils and rocks laboratory to the better understanding of the response of the field materials to the applied loads, performing stability analysis.
- Production of Geological, Morphodynamic, and Slopes maps.
- Finally, each project shows a final map in accord with the particular objective: Geotechnical Zonation of Bogota in 1: 25.000 scale, Mass Movement Zonation and stabilization of Cundinamarca 1st. phase, in 1:100 to 1:1.000 scales, and Avalanche Risk zonation of Utica town in 1:5.000 and 1:25.000 scales. The bigest scales are related with detailed zonations because of their utilization in the design of stabilization works.

As evolution we can find:

- The incorporation of the Engineering Design phase, that because

of the particular conditions of the country, is a big jump to avoid the accumulation of many technical reports and the loss of valuable time without a real or practical solution. That is the new approach of INGEOMINAS, looking for the so called "Applied Science".
- The addition of novelty analysis, as the evaluation of Risk in Utica, going for new methodologies that allow to find some reasonable numerical values of Risk. So, besides the hazard maps we start the development of risk maps taking into account the vulnerability factor, very important topic to perfcrm economic analysis.

Natural hazards as earthquakes and volcanic eruptions are in the stage of observation with the development of specific projects in colaboration with other countries as Japan and Canada. We hope to enter in the forecasting stage with the continuity and the improvement of the observations.

6.- PROPOLSALS TO IMPROVE OUR COUNTERMEASURES.

6.1. GENERAL PLANS.

In a natural disasters vulnerable country this factor contributes to disrupt our social and economic development, so in first term is necessary the proper budgetary appropiation for disaster prevention by the Government; for example in Japan this appropiation is about 5% of the total amount of the budget for general accounts and is classified into 4 categories:

- Research and development.
- Disaster preparedness.
- Conservation of national land.
- Disaster emergency and recovery measures.

This classification could be the base of a better organization against disasters in my country. Fitting Plans in each subject must be formulated with more than 5 years of extent.

With regard to Mass Movements a "General Plan for Mass Movement Disaster Countermeasures" could be formulated by INGEOMINAS encompassing national land conservation projects, development of warning system and promotion of alarm and evacuation system, and observation and investigation concerning the forecast of mass movements. The national land conservation projects could include slope collapse countermeasures, Sabo project for prevention of sediment runoff and debris flow, seashore erosion, river shore protection and land subsidence projects.

Against Earthquake disasters a "Coordination Committee for Earthquake Prediction" could be established, and make a plan according with the location of our seimogenic sources and seismic nests, this Committee can designate some areas of specified observation in the whole country and areas for intensified observation in the most critical places, and in these areas establish or reinforce a proper observation system. This committee also could study the upgrading of a seismatic standards for buildings and life line facilities.

With regard to volcanic disasters, the Volcanologic Observatory Project of INGEOMINAS must be reinforced. Is well know that virtually every eruption has measurable precursors, so volcanoes that erupt frequently offer many chances for testing predictions and must be observed; those which erupt infrequently are the subject of the greatest uncertanties and are the most challenging, so in any case the intensive monitoring is indispensable. In this point the international colaboration with multidisciplinary hazard-mitigation research projects can enlarge the world wide knowledge about volcanoes.The Vulcanologic Observatory Project could include the next elements: Eruption prediction, volcanic hazard assessment, research in volcanic processes, practical communication of the scientific information, and international projects.

6.2. SPECIFIC METHODOLOGIES.

Is clear that natural disasters occur in the whole world, however the developing countries are more prone to suffer their consequences because of both absence of budget to build suitable countermeasures and sometimes low technical knowledge; so, the international cooperation and the interchange of technical procedures and proper methodologies is a very important aspect to reduce the impact of natural disasters over the earth.

With regards to Geological Risks there are specific points to improve, some of this points are up till now common uncertainties in the whole world:

- In the called Geotechnical Zonations of cities, there are many components involved. The first step must be the Geological Map, showing not only surface aspects but vertical sections also at least up to the common construction levels of both shallow and deep foundations systems of houses and buildings. Each described formation must include the time scale of the materials, and general behavior with regards to engineering as underground water behavior, elements of secundary permeability, posible consecuences of cuts and so one. In situ sampling and geophysical methods must be used.

Specific Geotechnical Hazard Maps are the next step, the Geotechnical Engineering is an ample science that includes: static and dynamic stress-strength-time relationships and index properties, landslides, foundations, and so one and also specific maps including for example liquefaction analysis,the so called quick clays and expansive soils studies. In each case, quantitative evaluations taken into consideration typical cases must be done. Moreover we can jump from Hazard maps to Risk maps studing specific areas in detail including puntual information of vulnerability, studing the exposition and the resistance of the elements under danger. In this point is very important remark the great importance of laboratory facilities as the large scale slope failure simulator of big models and the shaking table, we need to study our so called tropical soils using this techniques to develop regional models of soils and rocks behavior.

With the information of the Geotechnical Zonation, that is the starting study, other analysis can be worked properly, that includes flood analysis, earthquake zonations, tsunami prone areas, urban development plans, location of shelters, and so one.

The final goal of some of this maps must be to open the public awareness, so, in the future each family will want to know the location of his home in the risk areas, and the use of big scales will be necessary. As an example, in Japan the Fukushima Prefecture is producing hazard maps in 1:10.000 scale.

- With regards to zonation analysis of river basins, the improvement of indirect quantitative analysis is very important. Of coarse before enter in the numerical calculations, the physical chemical process of each area must be properly understood.

As was pointed out by the author in the podium-discussion of the International Space Year Conference (Tokyo, November 16-20, 1.992) the newly remote sensing space technology can be used to study the natural disasters as well as global environmental topics such as climatic change, greenhouse gases, ozone layer holes, deforestation and desertification. The combination of the Remote Sensing with the Geographycal Information Systems provides a big tool that must be improved and used as soon as possible to the study and the forecasting of the natural disasters; the IDNDR programme could help in the worldwide dissemination of this techniques.

7.- CONCLUSIONS.

- The great impact of natural disasters in Colombia obligate the national institutions to the daily improvement of the methodologies and strategies to ensure better results.

- The International cooperation is indispensable to develop many projects and ideas to fight against the natural disasters. The programme designated as IDNDR must be used for a deeper understanding of this problems; the Japan can share the accumulated expertise to enhance the global capability in disaster prevention.

- Projects as the Volcanologic Observatory, and the National Seismic and Volcanic Monitoring Network must be preserved and continued. Also, new possible projects as the large scale slope failure simulator of big models and the shaking table laboratory facilities could be developed to the study of the so called tropical soils on my country.

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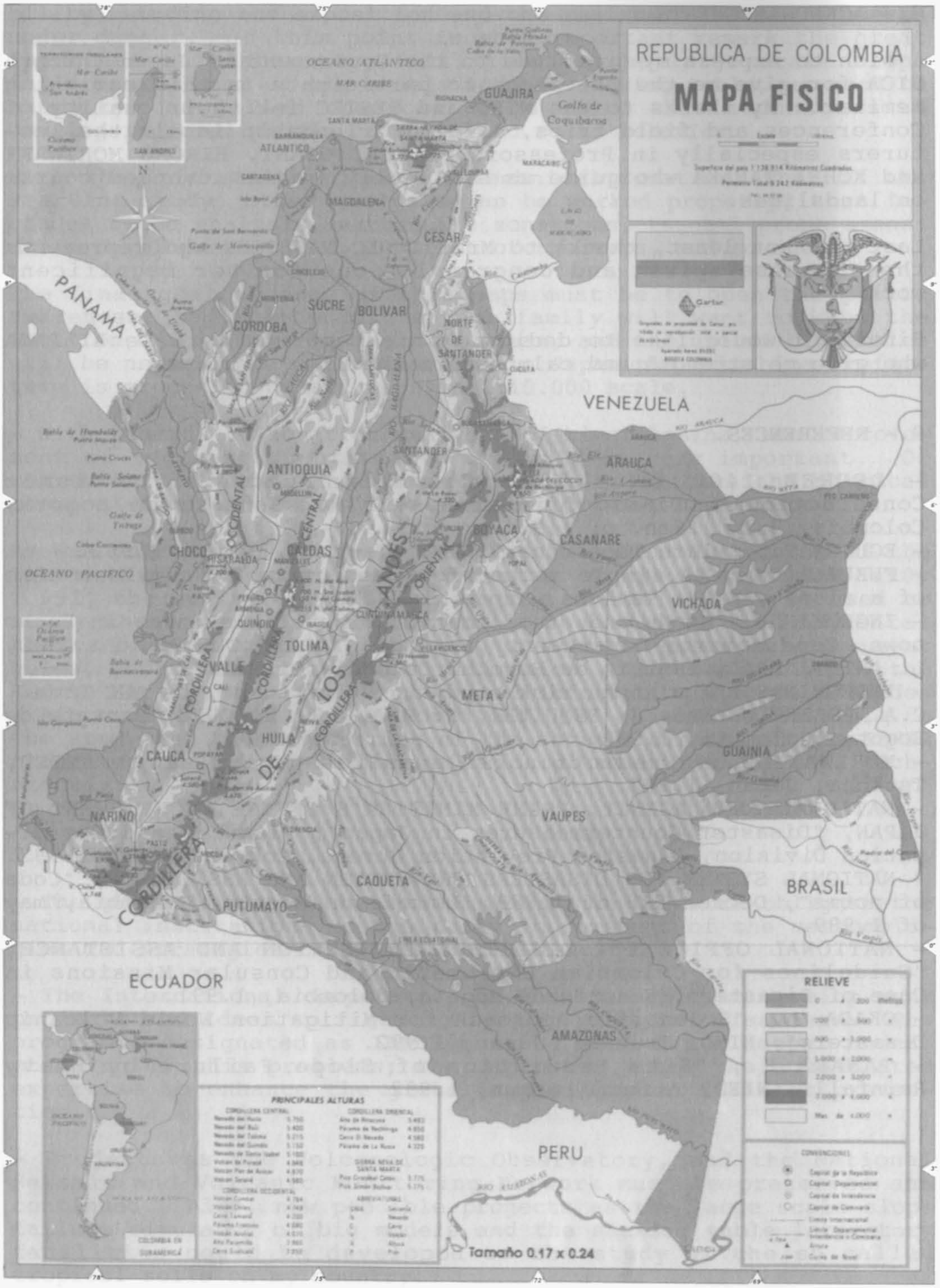

FIG # 1. PHYSICAL MAP OF COLOMBIA.