MAPENCO PROJECT: general results and future perspectives

CASTRO JUNIOR, R. M.[1], SOUZA, J. M.[2], GOMES, E. S.[3]

[1]*Cartographic Engeneering, Universidade Federal do Espírito Santo, Vitória, Espírito Santo, Brasil, (e-mail: rodolfo@npd.ufes.br)*
[2]*Geology, Fundação Ceciliano Abel de Almeida, Vitória, Espírito Santo, Brasil, (e-mail: jaimesouza@ltc.ufes.br)*
[3]*Civil Engeneering, Prefeitura Municipal de Vitória, Vitória, Espírito Santo, Brasil, (e-mail: etango@ig.com.br)*

Abstract: The city of Vitória-ES, capital of the State of Espírito Santo, Brazil, has an area about 104 km², including the Islands of Vitória, Lameirão, Trindade, other islands located in Vitória's bay and the Martinz Vaz Archipelago. The Island of Vitória, where were developed the studies described in this paper, has a relief consisting of a Central Massif and many isolated hills.

Geologically, the granitic massifs stand out, appearing almost always zoned, with a range of lithologies, such as granite, granodiorite and gabbro. Two fracture patterns with directions NE-SW and NW-SE are responsible for the relief framework, which when associated with weathering, generates the oval shape denominated "Pães de Açúcar". The process of disaggregation of the massif borders forms a source of colluvial material, that consists of blocks, and buried and semi-buried boulders, characterizing the geotechnical unit of Talus deposit.

The urban development of the Central Massif's slopes and of the isolated hills occurred in a progressive and disordered way in the 1960's and 70's, with habitations of low and medium size. The need to systematically evaluate, record and map the conditions of the city slopes allowed the creation of a convention between workers from the District of Vitória (PMV) and the Espírito Santo's Federal University (UFES) and Ceciliano Abel de Almeida Foundation (FCAA), through the Topography and Cartography Laboratory (LTC) from the UFES's Technological Center. The MAPENCO PROJECT - Slope Mapping of Vitória City, addresses the recognition of the geological-geotechnical conditions of the city's slopes, to allow the analysis of the many risk situations, generating technical data to assist the public administration in urban planning.

Résumé: La ville d'Vitória-Es, capital de l'état d'Espírito Santo, Brésil, a un secteur environ le km² 104, y compris les îles de Vitória, Lameirão, Trindade, d'autres îles situées dans le compartiment de Vitória et l'archipel de Martinz Vaz. L'île de Vitória, où ont été développés les études décrites en cet article, a un soulagement se composer d'un massif central et de beaucoup de collines d'isolement.

Géologiquement, les massifs granitiques se tiennent dehors, semblant presque toujours répartis en zones, avec une gamme des lithologies telles que le granit, la granodiorite et le gabbro. Deux modèles de rupture avec les directions NE-SW et NW-SE sont responsables du cadre de soulagement, qui, une fois lié à survivre à, produit de "Pães de Açúcar" dénommé par forme ovale. Le processus de la désagrégation du massif encadre des formes une source de matériel colluvial, cela se compose des blocs et enterre, et de semi-finale-buried, rochers, caractérisant l'unité géotechnique du dépôt de Talus.

Le développement urbain des pentes du massif de central et des collines d'isolement s'est produit d'une manière progressive et désordonnée dans les années 60 et les années 70, avec des habitations de basse et moyenne taille. La nécessité systématiquement d'évaluer, enregistrer et tracer les conditions des pentes de ville a permis la création d'une convention entre les ouvriers de la zone de Vitória (PMV) et l'université fédérale d'Espírito le Santo (UFES) et le Ceciliano Abel de Almeida Foundation (FCAA), par le laboratoire de topographie et de cartographie (LTC) du centre technologique de l'UFES. Le PROJET de MAPENCO - tracer de pente de ville de Vitória, adresses l'identification des conditions géologique-géotechniques des pentes de la ville, pour permettre l'analyse des nombreuses situations de risque, produisant des données techniques pour aider l'administration publique dans la planification urbaine.

Keywords: slope stability, preventive methods, mass movements, geographic information systems, engineering geology maps, geology of cities

INTRODUCTION

Area characterization

The city of Vitória, ES has an area of about 104km², including the islands of Vitória, Lameirão, Trindade, other islands located along the bay of Vitória and the Martins Vaz archipelago. Vitória Island, the focus of this study, has a rugged relief consisting of a Central Massif and many isolated hills. The Central Massif reaches an elevation of 290 m, with steep rectilinear slopes that in some areas expose rocky outcrops and in others, weathered material which supports a cover of vegetation.

The massifs are of granitic composition, and include granodiorite and gabbro components. Compositional zoning gives rise to distinct textural variations. The intrusives range from light to dark gray in color and from fine- to coarse-grained. Cross-cutting dykes of altered diabase are present locally.

Two fracture patterns with directions trending NE-SW and NW-SE are responsible for the relief framework which, when associated with weathering, generates the oval shape denominated "Pães de Açúcar".

The process of disaggregation of the exposed rocks yields colluvial material that is preserved as a talus deposit. Within this deposit, partly or wholly buried blocks and boulders are a dominant constituent.

The population of the island, estimated at 300 000 inhabitants, is concentrated in the city of Vitória, which is built on the slopes of the Central Massif and extends onto the surrounding isolated hills. Rapid expansion of the city occurred in the 1960s and 70s when the island's rural economy, dominated by coffee growing, was replaced by new industries located in the capital. To cope with the influx of migrant workers, the city expanded outwards without proper planning controls and the housing stock now includes many homes of poor standard.

General background

In many cities throughout the country, mass movement failures involve loss of life, incur high remediation costs, and are of concern to the population at large. In urban areas such as Vitória where the natural forest has been removed, the physical and climatic conditions combine to increase the risk of ground failure (Castro Junior et al. 1995).

The need to systematically evaluate, record and map the conditions of the city slopes led to the creation of a consortium comprising researchers from the District of Vitória (PMV), the Espírito Santo's Federal University (UFES) and Ceciliano Abel de Almeida Foundation (FCAA), working through the Topography and Cartography Laboratory (LTC) from the UFES's Technological Center. The MAPENCO PROJECT - Slope Mapping of Vitória City set out to map the geological and geotechnical conditions of the city's slopes, to allow analysis of localities at risk and to generate technical data to assist the public administration in urban planning. This work has culminated in a risk ranking system that takes account of landuse, slope, the geotechnical properties of the local bedrock and the local hydrological and climatic conditions.

METHODOLOGY

The MAPENCO Project commenced in February, 1995, since then 25 hills have been mapped and evaluated. Recommendations have been presented in technical reports delivered to the municipal administration.

The first phase of the project involved a major data collection exercise (Temoteo et al. 1996). Geological, hydrogeological and climatological data were acquired, along with geomorphological and landuse information, and technical reports

Fieldwork to identify and delineate areas at risk was carried out with the aid of 1:2000 and 1:5000 scale colour aerial photographs and involved compass traverses with information recorded on a 1:2000 scale cartographic base.

Areas affected by, or susceptible to, instability were identified and site conditions noted. This preliminary evaluation involved detailing for each site, the geology, geomorphology and landuse. In areas of instability, the likely impacts were assessed and recommendations proposed for stabilization. Where stabilization had already been carried out, this was also recorded. Following this physiographic characterization, areas were classified according to the perceived level of risk (low, average and high) following the methodology proposed by IPT (1980) and shown in Table 1, below. Areas of high risk requiring intervention were notified to the local administration.

The Municipality of Vitória is currently developing the TERRA Project, in which the aim is to provide an integrated approach to public, social and environmental issues in the most needy areas of the city. The MAPENCO Project supplies information to aid the TERRA Project, particularly in relation to land improvement schemes.

Table 1. Risk Classification

CLASS OF RISK I Thematic Representation (color): green	Areas which present few signs of erosion, with low possibility of accidents or home destruction.
CLASS OF RISK II Thematic Representation (color): yellow	Areas with moderate to high possibility of accidents involving block failure in low occupation terrains
CLASS OF RISK III Thematic Representation (color): red	Slopes intensely eroded, deforested, with unstable blocks and with high possibility of failure causing accidents.

FACTORS AFFECTING RISK

The risk rating scheme developed for the 25 hills mapped to date is dependent on both natural and anthropogenic factors, which may change with time. The risk rating can be reduced by remedial work, reforestation or relocation of homes away from highly susceptible areas. Conversely, the rating can rise, where urban pressures lead to development in unsuitable locations, for example, on higher, steeper slopes. The ground available for development in lower risk classes (I and II) is also strongly influenced by the development of new transport corridors. In the case of Vitória, the introduction of bus line services between the hills Romão and Forte São João has polarized development in these areas leading to a reduction in the area of low risk development land. Where housing relocation is the only option, proper site investigation should be a prerequisite and should include proper studies of the likely impact on the local groundwater.

Since 1997 Vitória city has completed 65 major slope stabilization schemes. Other corrective measures include improved drainage and slope stabilization using buttresses.

DATA MANAGEMENT

Data were captured and stored electronically, initially in Visual Fox-Pro, and latterly in Geographic Information Systems. Currently, information is made available either through written reports, through the World Wide Web and multimedia. High risk areas, detected as a result of the field survey, are immediately communicated to the public authorities and only then are they registered in the database.

Geographic Information Systems (GIS) were used in the MAPENCO Project to manage the geological and geotechnical information (Castro Junior et al.1997a; Temoteo et al. 1996). The location, nature and extent of the geotechnical risk were assessed using the GIS SPRING, from the National Institute of Spatial Researches, INPE (1996). In this preliminary stage, the GIS was used to display the spatial relationships between risk areas and points, slope, and landuse. Other data related to the physiographic characterization, including the geotechnical analyses and recommendations from site works were managed separately in a Visual Fox-Pro database (Castro Junior et al. 1997b).

In a second stage of work, the geographic data from SPRING and the tabular information from VISUAL FOXPRO were migrated to ArcView 3.x GIS from ESRI (1996) and attributes applied to each of the geographic objects. Customised interfaces were developed in AVENUE language to allow data input and retrieval, and to facilitate automated querying and reporting.

In a third stage, a customized module was designed for the management of geological and geotechnical data within a GIS known as SPID – Digital Information Processing System, developed by the Topography and Cartography Laboratory (LTC) of the Federal University of Espírito Santo. This was configured to manage data originating from Multipurpose Technical Cadastres. The module SPID-MAPENCO was developed from the GIS SPID and customized to support the functionality needed for geological-geotechnical mapping of urban slopes. In addition to the standard GIS functionality, a list of reports and forms was added to the module to facilitate geographic and tabular querying of risk areas and points.

FUTURE PERSPECTIVES

The MAPENCO Project is considering additional preventative measures to mitigate mass movement risk. Two proposals to support the decision-making process have been put forward: one involves development of a rainfall monitoring network; the other is to increase public awareness of instability features. The link between rainfall and mass movement incidents is well established through information made available by research institutions to the Civil Defense and Fire Department of the city. A rainfall monitoring network, consisting of digital weather stations, capable of transmitting data directly to the Civil Defense and/or Fire Department, would assist in developing a more reliable early warning system.

Information provided by members of the public is likely to form an important part of any monitoring plan. A significant number of slides are caused by anthropogenic activities. They include badly compacted earthworks, sub-vertical or vertical cuts, and leakage from water services. Creating public awareness of the nature of the problem in high risk areas and urging a cautionary approach to ground modification are likely to be important elements of a mitigation strategy (Souza 2003).

CONCLUSIONS

The MAPENCO Project provides support and advice to the city of Vitória on all aspects of slope stability. It has also contributed to the TERRA Project, by making geotechnical information available as part of the urban development process. The MAPENCO Project has given teachers, students and professionals involved in stability studies an opportunity for scientific development within a multidisciplinary project.

The information recorded by the MAPENCO Project is contained in reports and plans, available on-line at http://www.ltc.ufes.br/mapenco/ (access by password). It is also available in digital format (CD-ROM) which incorporates a system of geographical information called SPID-MAPENCO®.

Initiatives of this type must continue to be supported by public administrations and are highly relevant in cities prone to mass movement failures, for example, Rio de Janeiro, São Paulo, Porto Alegre and Recife.

The implementation of the geoprocessing techniques developed within the MAPENCO Project ensures a prompt and accurate response in matters relating to urban planning including housing relocation, conservation, reforestation, and the impact of public works. The public authorities have responded positively to the project, accepting the technical aspects and implementing appropriate measures to resolve the problems of slope instability in the city. The ten years of study of the MAPENCO Project have provided the city of Vitória-ES with a broader perspective of the geological and geotechnical issues that need to be addressed if the city it is to develop in a way that minimizes risk to the population at large.

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