THE VAIONT SLIDE: USING MODERN TECHNOLOGY TO RE-EVALUATE THE SLOPE FAILURE MECHANISM

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Cycle: XXIV

Abstract

On October 9th 1963 a catastrophic landslide suddenly occurred on the southern slope of the Vaiont dam reservoir. A mass of approximately 270 million m$^3$ collapsed into the reservoir generating a wave which overtopped the dam and hit the town of Longarone and other villages nearby. Several investigations and interpretations of the slope collapse have been carried out during the last 45 years, however a comprehensive explanation of both the triggering and the dynamics of the phenomenon has not been yet provided. Much of the data on the Vaiont slide are available in non-electronic hard copy format. However, in order to allow a re-evaluation of the currently existing information on the slide, during the first year of the research, a bibliographic electronic database in MS-Acces format and an ESRI-geodatabase have been developed. The reasoning, the structure and the contents of the e-bibliography and Geodatabase are indicated and analyzed herein below.

INTRODUCTION

The Vaiont landslide is considered since ever as a natural laboratory to investigate the failure mechanisms and the evolution of large rock masses. Several interpretations of the event have been attempted during the last 45 years, e.g.: Muller, 1964; 1987; Selli et al.,1964; Hendron & Patton, 1985; Semenza, 2000; Semenza & Ghirotti, 2000. The rapid collapse was attributed to unusual mechanisms, in order to explain the sudden acceleration of the mass (Tika & Hutchinson, 1999; Kilburn & Petley, 2003). Nevertheless, a comprehensive explanation of both the triggering and dynamics of the phenomenon still remains elusive. The most comprehensive work may be considered the one by Hendron and Patton (1985), nevertheless they underlined the need for further researches. The main goal of this research project is the evaluation of the failure mechanism of the Vaiont slide through the re-evaluation and integration of the available geomorphological, geological structural, geomechanical and hydrogeological data. To this purpose, new methods and techniques, such as GIS technology, photogrammetric analyses, terrestrial and aerial laser scanning data acquisition and interpretation, topographic analyses (COLTOP 3D analyses; Jaboyedoff, 2005), laboratory tests, and numerical 3D modeling, will be carried out (Fig. 1).

In the first year of the research activity, a bibliographic electronic database in MS-Acces format and an ESRI-geodatabase have been developed. The creation of an alphanumeric and spatial database as a support to scientific studies on Vaiont landslide, and generally speaking on large rock landslide, represents a necessary requirement for a proper re-evaluation and integration of all existing data. Since the geomechanical data collected to date may not be considered sufficient nor properly distributed in space, in situ geomechanical investigations are being carried out.

THE ELECTRONIC BIBLIOGRAPHIC DATABASE

The Catastrophic Vaiont landslide generated a large number of researches, but most of the documentation is in non-electronic hard copy format. Hence, the first step was to scan this documentation. Then, all the references to published papers, theses and unpublished technical reports on landslide have been organized and stored in a database using MS Access software.

The database currently contains 80 journal articles, 5 book articles, 52 monographs, 5 thematic maps, 30 proceedings, 6 unpublished reports, and 13 documents classified as “Other” (newspaper articles, conference presentations and divulgement material). It can be noted that most of the documentation, in particular journal article and monographs, was produced in the last decade testifying the possibility of re-evaluate the landslide phenomenon using new knowledges and modern technologies.
STRUCTURE AND CONTENTS OF THE GEODATABASE

A geodatabase is a database designed to store, query, and manipulate geographic information and spatial data. Different types of spatial data, such as vector and raster dataset, and their attributes and location can be stored. In addition tables and relationships between data can be included. So the geodatabase is the first step to implement a Geographic Information System (GIS) finalized to the study of landslides and related factors. Vector dataset consist of geometrical primitives such as points, lines, curves, and shapes or polygon(s), which are all based on mathematical equations, to represent territorial data (geomechanical stations, faults, lithology and so on). Raster dataset is a data structure representing a generally rectangular grid of pixels, or points of color. In the GIS raster datasets with varying formats are usually used to represent continuous territorial data (DEM, slope, etc.) and to perform simple to complex analyses. Currently the Vaiont geodatabase was implemented using ESRI ArcGIS Desktop 9.3 software and contains the following data.

- Vector datasets representing the attitude of strata (points), faults (lines), lithology (polygons), and sections (lines), digitized from pre and post landslide geological maps (Giudici and Semenza, 1963; 1965). Within these have been stored.
- Vector datasets representing geognostic boreholes (point) from Broili (1959) and geophysical investigation (lines) from Caloi (1960), and their attributes (type, depth, stratigraphy).
- Vector dataset representing geomechanical stations (points) from past and recent surveys. Related attributes consist of rock test results and properties (attitude, Schmidt Hammer test, GSI, JRC, Point Load Test, JRC, etc.).
- Vectors datasets representing elevation points and contour lines digitized from pre and post landslide geological maps, official regional maps (CTR, Regione Friuli Venezia Giulia) and LIDAR survey (in acquisition).
- Raster datasets representing the Digital Elevation Model (DEM) of the area before and after the landslide. DEMs were calculated using the above mentioned topographic data.
- Raster datasets representing the aerial photos of the area before the landslide (1960). These data are organized in a ESRI-Geodatabase structure named Raster Catalog that allow an efficient storing and management for multiple datasets.

In addition, the geodatabase contains tables with the geotechnical an geomechanical properties of the material involved in the sliding, and rules to join and relate the attributes tables.

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<th>Goals</th>
<th>Methodologies</th>
<th>Expected results</th>
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<td>• Definition of triggering mechanisms and propagation in large rock slides&lt;br&gt;• Definition of fractures propagation mechanisms in rock masses&lt;br&gt;• Study on fragmentation mechanisms and propagation of velocities</td>
<td>• Published and unpublished data computerization&lt;br&gt;• GIS and WebGIS&lt;br&gt;• Analysis and integration of exiting geomechanical and structural data&lt;br&gt;• Re-evaluation of geological and hydrogeological aspects&lt;br&gt;• Pre and post slide DEM based structural analysis COLTOP 3D&lt;br&gt;• Laser Scanner e Terrestrial Photogrammetry&lt;br&gt;• Rock triaxial tests&lt;br&gt;• 2D/3D numerical modelling using FEM, DEM and hybrid codes</td>
<td>• Creation of an alphanumeric and spatial database as a support to scientific studies on Vaiont landslide, and generally speaking on large rock landslides&lt;br&gt;• Creation of a tool for sharing and disseminating the results&lt;br&gt;• In depth studies of geomorphological, geomechanical and structural characteristics&lt;br&gt;• In depth knowledges of geometry and structure of landslide body&lt;br&gt;• Evaluation of shear strength and deformation behaviour of rock masses&lt;br&gt;• Triggering simulation and propagation of large rock landslides</td>
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Figure 1. Main goals, methodologies and expected results of the research.
FUTURE STEPS OF THE RESEARCH
In the next future vector data on the geological and geomechanical features will be analyzed and updated to implement a geological and geomechanical model for the numerical 2/3D modeling. 2/3D continuum and discontinuum codes and key-block analysis will be used to investigate the importance of structures and kinematics of the failure and its spatial/temporal development. Surface analyses comparing DEMs before and after the phenomenon will allow in defining the displaced masses and, thus, the directions of the different parts of the landslide body. Moreover, a DEM-based structural analysis performed by COLTOP 3D software (Jaboyedoff, 2005) on available data before the landslide, will help in identifying the structural setting that led to the failure and drove the direction of the movement.

The 3D modeling will be initially approached with professor Doug Stead at the Simon Fraser University, Vancouver, Canada.

References
SUMMARY LAST YEAR’S ACTIVITY

Courses:
M. FLORIS: “Introduction to GIS techniques” Dipartimento di Geoscienze, Università di Padova.
A. NATALE, G. CIOTOLI “Analisi geo-spaziale in ambiente GIS”, Centro di Ricerca CERI -Valmontone (RM)

Posters:

Publication:

Fieldworks on the Vaiont study area:
- September-October: Geomechanical survey around the Vaiont landslide area and around Erto and Casso for the validation of the remote data and the acquisition of new geomechanical data.

Seminars:
- SUPERCHI L., 20-10-2009 - Implementation of a Geodatabase of Published and non-Published data on the Catastrophic Vaiont Landslide - Dipartimento di Geoscienze, Università di Padova.