SCIENCE AND ART
ROYAL INSTITUTE OF TECHNOLOGY
INTERNATIONAL UNIT

Preface

This study has been carried out within the framework of the Minor Field Studies (MFS) scholarship programme, which is funded by the Swedish International Development Authority (SIDA).

The MFS scholarship programme offers Swedish undergraduate students or recent graduates an opportunity to carry out two months' field work in a third world country for their Masters theses or similar in-depth studies. The study should primarily be conducted in a country supported by the Swedish development aid programme.

The main purpose of the MFS programme is to create interest among Swedish university students to work in developing countries, providing them with initial experience of conditions in the third world. A further purpose is to attract students into professions suitable for this kind of work, thus supplying SIDA staff and widening the Swedish personnel resources for recruitment into international organisations.

The International Unit at the Royal Institute of Technology (KTH), Stockholm, administers the MFS programme for all faculties of engineering and natural sciences in Sweden.

Sigrun Santesson
Programme Officer
MFS Programme

Summary

Santiago de Puriscal is a town with 12 000 inhabitants, located approximately 40 km southwest of San José, the capital of Costa Rica. Santiago is the main town in the community of Puriscal. The town is situated on the top of an enormous landslide. The landslide has an average velocity of 5-15 cm annually towards the northwest. It has been shown that the landslide has increased in area. It is mainly during the rain period that the landslide moves. The landslide in combination with earthquakes has caused severe damages in the town. Many buildings have been destroyed by fractures. Some have been torn down and others are unusable, e.g. the church.

The aim of this master thesis is to investigate the ground movements in and around the town. This is useful for geotechnical purposes, e.g. where the movement is most rapid and where the tension is biggest. To do this, various observation epochs have been carried through. The observations are used to enable comparison between different epochs of the geometrical configuration of a network. The network was established in 1990 and consists of 24 points in the town and 3 external control points 1-2 km outside town. The observations have been done by traverse observations and levelling at 3 epochs.

The three external points were meant to be outside the borders of the landslide and to serve as stable points for the whole network. When observations of the external points were compared, it was found that they probably have moved with approximately 0.5 m. Therefore they can not serve as stable points. Thus the 24 points in town could only be used to detect internal displacements. This means that only internal movements can be found but not movement of the network as a whole.

When comparing the traverse observations of March 1991 and August 1992, horizontal displacements could be found in 7 points at a maximum of 1.4 cm. The other points did not have a statistically significant displacement. Comparing the level changes in the town, displacements were found in many points at a maximum of 2.40 cm between September 1990 and July 1992. Prior to the evaluation of the 1990-1992 observations the internal movements were estimated to at least 4-5 cm annually. This could not be proved by this analysis.

The conclusions of this thesis are in brief :

- The intervals between observations have to be longer than one year to obtain required significance for the movements.
- Only analysis of relative observations could be done due to lack of stable control points.
- The internal movements on top of the landslide are small compared to the expected absolute movement of the landslide.

Sammanfattning

Santiago de Puriscal är en stad med 12 000 invånare. Den är belägen c:a 40 km sydväst om Costa Ricas huvudstad San José. Santiago är den största staden i kommunen Puriscal. Staden ligger ovanpå ett enormt jordskred. Jordskredet har en medelhastighet om 5-15 cm per år i nordvästlig riktning. Det har bevisats att jordskredets areal har ökat. Det är särskilt under regnperioden som jordskredet rör sig.

Jordskredet i samband med jordbävningar har vållat allvarliga skador i staden. Många byggnader har blivit förstörda av sprickor. Några har rivits medan andra är oanvändbara, t.ex. stadens kyrka.

Syftet med detta examensarbete är att undersöka jordrörelserna i och runt staden. Detta är till nytta för geotekniska ändamål, t.ex. var rörelsen är snabbast och var spänningen är störst. För att göra detta har mätningar genomförts under flera epoker. Mätningarna används till att jämföra olika mätningsepoker av den geometriska konfigurationen hos ett punktnät. Det skapades 1990 och består av 24 punkter i staden och 3 kontrollpunkter 1-2 km utanför staden. Mätningarna har gjorts polygonalt och med avvägning i 3 epoker.

De tre punkter som är belägna utanför byn var ursprungligen menade att användas som stabila referenspunkter för hela nätet. När epokernas mätningar jämfördes upptäcktes att de troligen hade rört sig ungefär 0.5 m. Därför kan de inte användas som fixpunkter. Detta innebär att de 24 punkterna i staden enbart kan användas för att hitta interna rörelser, dvs enbart spänningar kan upptäckas men inte nätets absoluta rörelse.

Då polygonmätningarna mellan mars 1991 och augusti 1992 jämfördes hittades rörelser i 7 punkter, den största på 1.4 cm. Då avvägnings-mätningarna jämfördes hittades rörelser i många punkter, den största på 2.40 cm mellan september 1990 och juli 1992.

Innan utvärderingen av mätningarna 1990-1992 uppskattades de interna rörelserna till åtminstone 4-5 cm per år. Detta visade sig inte stämma enligt denna analys.

Slutsatserna är i korthet följande :

- Tiden mellan mätepokerna bör vara längre än ett år för att ge de uppmätta rörelserna önskad signifikans.
- Endast analys av relativa mätningar kunde göras eftersom stabila kontrollpunkter saknades.
- Interna rörelser i jordskredet är små jämfört med jordskredets uppskattade absoluta rörelse.

Resumen

Santiago de Puriscal es una ciudad de 12 000 habitantes situada a unos 40 kms al suroeste de San José, la capital de Costa Rica. La ciudad está ubicada sobre un sector de gran deslizamiento. Este tiene una velocidad de 5-15 centimetros por año en dirección noroeste. Hay evidencias de que el area del sector de deslizamiento aumenta cada año, especialmente en los periodos de lluvia. El deslizamiento conjuntamente con los terremotos han causado daños graves en la ciudad. Muchos edificios han sido dañados por grietas, algunos han debido ser demolidos y otros, como por ejemplo la vieja iglesia, declarados inhabitables por temor a derrumbes.

El objetivo de este exámen de grado es el de investigar los movimientos de tierra producidos en el centro de la ciudad y sus alrededores. Esto es de utilidad geotécnica, por ejemplo se trata de determinar donde se producen los movimientos mas rápidos y donde se encuentran las zonas de mas tensión. Para efectuar este análisis se ha hecho mediciones en épocas diferentes. Estas mediciones se han utilizado para comparar épocas diferentes de la configuración geométrica de 24 puntos de referencia en la ciudad misma y tres fuera de ella. Las observaciones se han hecho con métodos de poligonación y nivelaciones de precisión en tres épocas diferentes.

Los tres puntos externo fueron inicialmente elegidos para servir de control de toda la red. Luego del análisis de las mediciones en las diferentes épocas, se comprobo que probablemente estos se han movido alrededor de 0,5 m. Por lo cual no se pueden utilizar como puntos de referencia estables. Esto significa que solo los 24 puntos al interior de la ciudad pueden ser utilizados para el análisis de movimientos internos o sea el movimiento total de la red no puede ser estudiado.

Despues de comparar las mediciones poligonales de Marzo 1991 y Agosto de 1992 se descubrieron movimientos en 7 puntos, el mas grande es de 1,4 cm. Los otros puntos no tienen movimientos estadisticamente seguros. Luego de comparar los resultados de las nivelaciones de precisión hechas en Septiembre de 1990 y Julio de 1992, se descubrieron movimientos estadisticamente asegurados en 18 puntos, el mas grande 2,4 cm. La velocidad de desplazamiento del deslizamiento que se estimaba, hasta antes de nuestro analisis en 4-5 cm por año, no es confirmado en este análisis.

Las concluciones en general son:

- El tiempo entre las épocas de observación necesita estar más que un año para obtener movimientos significantes por algunos puntos.
- Solo análisis de movimientos relativos son obtenidos por que no hay puntos externos estables para medir movimientos absolutos.
- Los movimientos internos son pequeños en comparación con el estimado movimiento total.

Contents

1. Introduction

The village of Santiago de Puriscal, Costa Rica, is located about 40 km southwest of the capital San José. The village is the trade and population centre of the Puriscal community. Around 12.000 people live in Santiago, where agriculture and local merchandising is the main occupation. The village and its surrounding area is situated in a bowl-shaped mountain slope, where an enormous landslide is situated. It causes severe problems for the village, e.g. destruction of buildings and soil erosion. Despite of causing problems for the inhabitants by destructing walls, breaking pipelines etc., the landslide may decrease real estate values for the whole area, which may cause major economic problems.

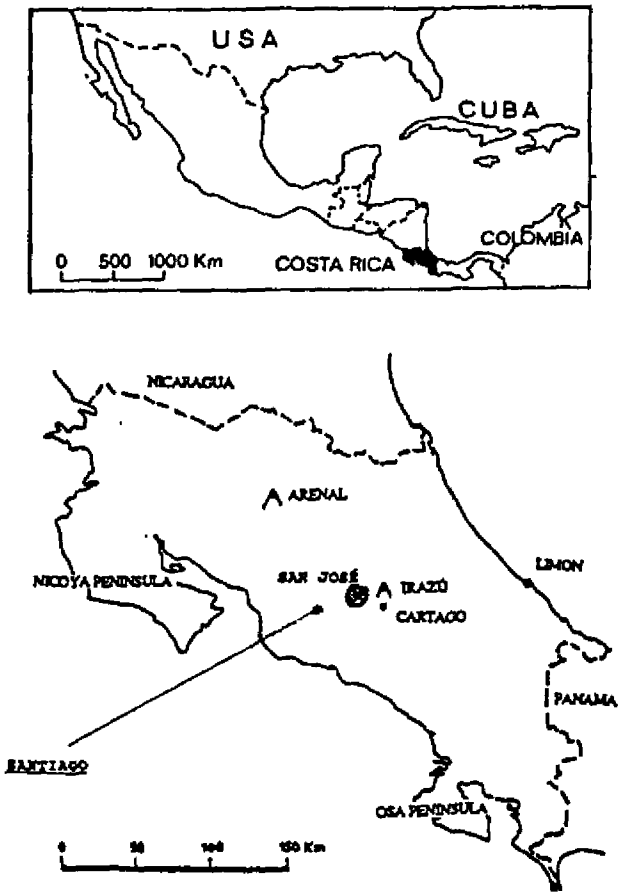
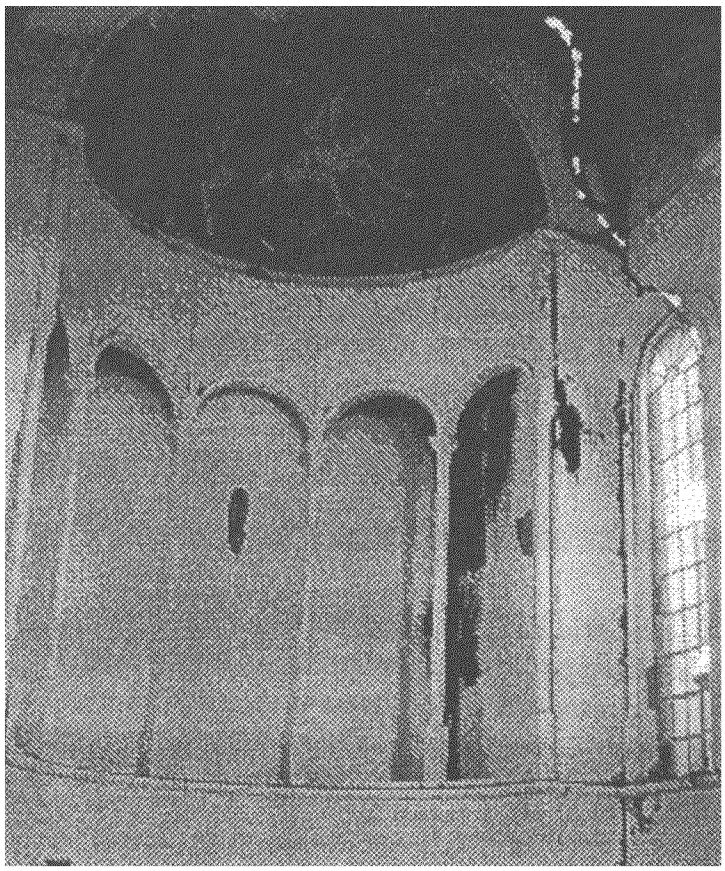


Figure 1.1. Location of Costa Rica and Santiago de Puriscal.

1.1. Short project description

In order to prevent or at least minimise the damages, it is helpful to get an idea of the size and direction of the ground movements in different parts of the village. The information can then be used to determine whether it is safe to construct new buildings in a certain part of the studied area or not.

Since the area contains such an extraordinary geological event, it has been the subject of geological studies, e.g. by Dr Sergio Mora from ICE[1]. A report concerning ground movements and deformations may therefore be useful for further geological research.



Picture 1.1. Cracks in the walls of the old church in Santiago.

[1]Instituto Costarricence de Electricidad.

Reconstruction of weak buildings has to be done in areas with large movements and strains in the ground. To determine these movements, geodetic observations have been done in two epochs by OVSICORI[2] personnel (see chapter 5).

Since no calculations or further observations have taken place, the main task within this project was to measure a third epoch with conventional geodetic methods, and afterwards calculate the deformations. With the results in hand, a brief evaluation in geodetic perspective was done.

1.2. Development of the thesis

This work originated through a contact between Dipl. Ing. Erick Asenjo (Royal Inst. of Technology, Stockholm, Sweden) and Ing. Tomás Marino Herrera (OVSICORI). After a request for any form of geodetic diploma work from the authors in March 1991, Ing. Marino responded with several proposals, of which this one was chosen.

After communicating several times through faxes, a preliminary project proposal was presented. The school of geodesy ETCG[3] was also involved when Dipl. Ing. Luis Aguilar accepted to be Supervisor for the field project. The project was funded by SIDA / ASDI[4] through CITEC[5]. Further preparations were done, and finally the Authors initialised the field work in Costa Rica the 7th of July, 1992.

1.3. Realisation of the field work

After arriving in Costa Rica, the first two weeks were used for preparations and solving of some problems concerning instrument availability. Traverse observations were also done on three external points surrounding the village. Precision levelling was then carried through during two weeks.

[2]Observatorio Vulcanológico y Sismológico de Costa Rica.

[3]Escuela de Topografía, Catastro y Geodesía.

[4]Swedish International Development Authority, in Spanish ASDI.

[5]Centre for International, Technical and Educational Cooperation (formerly International Unit), Royal Institute of Technology.

After some more preparations, the traverse observations in Santiago de Puriscal took place during two more weeks. The last three weeks were used for calculations and re-observations of gross errors from the field work of the project. GPS[6] calculations from costarrican GPS campaigns with the program TOPAS were also done. New traverse observations of the presumed fixed points were finally performed.

The field work part of the project was terminated the 7th of September, 1992. Since then the authors have been back in Sweden processing the observations and completing the thesis.

1.4. Involved institutions

1.4.1. OVSICORI-UNA

OVSICORI (**O**bservatorio **V**ulcanológico y **S**ismológico de **C**osta **R**ica) has its origin when Universidad Nacional in Heredia was founded. The main objective of OVSICORI is to study the natural processes that affect the economic, social and spatial relations of the country. Thus OVSICORI observes volcanoes, earthquakes and other related phenomena. To do this, a network of seismographs covering the country has been established. Several volcanoes are observed, by physical and chemical means, for eruption prognosis.

1.4.2. ETCG-UNA

ETCG (**E**scuela de **T**opografía, **C**atastro y **G**eodesía) at the Universidad Nacional in Heredia, Costa Rica was founded in 1974 in co-operation between the Central American countries and the Federal Republic of Germany. Its objectives are to educate personnel to take care of all surveying related subjects. Therefore ETCG offers a Bachelor of science degree in surveying. Courses in all main subjects are given, e.g. geodesy, photogrammetry and catastral surveying. For the time being,ETCG is for example involved in projects on tectonic movements in Costa Rica and Central America.

[6]Global Positioning System.

1.4.3. Department of Geodesy, KTH Stockholm

The Department of Geodesy[7] is a part of the School of Surveying at KTH (Royal Institute of Technology). At the department various projects in Geodesy and Surveying have been brought through.

[7]From January 1993: Department of Geodesy and Photogrammetry.

1.5. Acknowledgements

During our work we have received valuable help from many persons. We wish to express our gratitude for their indispensable aid.

First of all we thank our supervisors; Dipl. Ing Erick Asenjo and Prof. Lars E. Sjöberg in Sweden and Ing. Tomás Marino and Dipl. Ing. Luis Aguilar in Costa Rica. Without their guidance this thesis would not exist.

The following persons earn a special gratitude for all their help at work and during spare times.

Dr. Eduardo Malavassi, Director OVSICORI
Dipl. Ing. Julio Roldán, Director ETCG
Dr. Sergio Mora, Chief geologist at ICE, San José
Dr. Tomas Nord, Dept. of Geodesy, for making the computers work
Prof. Wolfgang Niemeyer, University of Braunschweig, Germany
Dipl. Ing Dieter Tengen, GeoTec GmbH, Laatzen, Germany
Civ. Ing. Helena Wolgé, who was there before
Dr. Anders Bodare, Department of Soil and Rock Mechanics, KTH
Dipl. Ing. Holger Zielenski, Department of Photogrammetry, KTH
Staff at OVSICORI-Universidad Nacional, Heredia
Staff at ETCG-Universidad Nacional, Heredia
Staff at ICE, San José
Staff at Department of Geodesy, KTH
Staff at CITEC, KTH
Staff at KORDAB, Sweden
Staff at Leica AB, Sweden
Staff at SAB, Quetzaltenango, Guatemala, for the patience while learning Spanish
Our teachers at KTH
Our classmates
Gido Montero Tang and family in Santiago de Puriscal, for letting us stay
Inhabitants of Santiago de Puriscal for the patience
Amable, Taxi driver, Santiago de Puriscal
Roberto, for the drumming
Sotomayor, for splendid poetry
Maarit Seppälä, who just listened during hard times
Margan Haghighat, who could stand waiting
Our families