Factors Influencing Occurrence, Scale, Mobility, Runout, And Morphology Of Mass Movements On The Continental Slope

Homa J. Lee
U.S. Geological Survey, M/S999, 345 Middlefield Road
Menlo Park, CA 94025
650-329-5485 (phone) 650-329-5411 (fax) homa@octopus.wr.usgs.gov
Award Number: N00014-97-F-0035

LONG-TERM GOAL

Achieve an improved understanding of the relationships between sedimentation, environment, and the morphology of continental slopes. This goal will be accomplished primarily through investigations within the northern California (Eel River) study area and incorporation of data from around the World. An underlying assumption of our work is that the occurrence and morphology of mass movement features on the continental slope depend upon a combination of characteristics, each of which varies over the region in a consistent manner. The various components of this project are part of a concerted effort between the geotechnical groups at the USGS and Laval University. Their activities are very much interwoven but, for administrative reasons, their respective budgets are identified separately as are the annual reports.

OBJECTIVES

Identify factors that can be mapped regionally and that determine where and how slope failures occur; derive a basis for producing regional maps that indicate relative landslide susceptibility. Model shear strength development with depth and incorporate this model into continental slope stability, post-failure behavior, and bedform processes. Observe and model pore pressure development in continental slopes. Analyze the relationship between seismic intensity, sediment instability and slope processes.

APPROACH

Our research focuses on the factors that lead to variations in the sedimentological and environmental conditions determining slope failure. We develop improved correlations between engineering classifications and strength factors. We measure excess pore water pressures in situ. We simulate sediment accumulation in specially designed cells. Geotechnical properties are related to sediment density state, obtained from detailed logs of downcore variability of sediment density and sound velocity. Using available bathymetry, we construct slope maps. Seismic shaking variations are evaluated probabilistically by seismologists. Driving stresses are balanced against strength variations in a geographic Information System (GIS) to obtain a regional estimate of relative slope stability.

Key individuals, at USGS: Homa Lee, Kevin Orzech, Diane Minasian, Peter Dartnell, and Florence Wong: physical property logs of sediment cores and relations between geotechnical and classification properties, algorithms relating sediment properties, environmental factors, and slope stability within the framework of a GIS; at Laval: Jacques Locat, Jean-Marie Konrad, Éric Boulanger, Priscilla Desgagnés, Francis Martin and Frederic Laurent: detailed geotechnical property measurement, SEM studies, and assessment of compressibility, rheology, and shear strength development.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1999		**00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Factors Influencing Occurrence, Scale, Mobility, Runout, And Morphology Of Mass Movements On The Continental Slope	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U. S. Geological Survey,345 Middlefield Rd,Menlo Park,CA,94025**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

WORK COMPLETED

In FY99, we continued our development of a GIS-based approach toward regional assessment of offshore landslides. To expand the applicability of our results, we are conducting a comparative study of the Los Angeles Margin using data obtained by Lee as part of a sediment pollutant transport study. We have prepared maps of the Los Angeles margin that show the distribution of relative slope stability. These studies are valuable because the Los Angeles margin shows a much broader distribution of slope failure features and the set of available data is as extensive as that from the Eel Margin. A paper comparing our methodology as applied to both the Eel and Los Angeles margins was prepared for the International Symposium on Landslides to be held in 2000. We are also developing a more fundamental relationship between landslide occurrence and sediment lithology. In the past we have relied upon surficial sediment density as a measure of lithology. We are expanding our correlations to include engineering classifications that are not impacted by consolidation state.

During FY 99, our field work was concentrated on the East Coast, within the New Jersey Margin area in conjunction with the Marion Dufresne OCEANOGRAPHIC cruise. One USGS scientist (Dianne Minasian) joined a group of three scientists from Laval (P. Desgagnés, P. Côté, and M.-C. Héroux) and a research team led by C. Alexander. The main purpose of the Marion Dufresne cruise was to take Calypso cores (20 to 50m long) in a landslide area within the Hudson Apron. A total of 3 long cores were collected (MD9922-11, 12, and 13), of which one is kept at Laval and is to being shared with the USGS group for various geotechnical tests. All cores were logged, onboard the ship, at 1-cm resolution for density, sound velocity, and magnetic susceptibility.

We are collaborating with Syvitski, Parker, Garcia, Orange, and Locat in recognizing and interpreting migrating sediment waves. We feel that these features are common along continental margins and that they are frequently misinterpreted as submarine landslides. We are developing criteria for recognizing these features and applying numerical and physical models to understand the mechanics of their development.

RESULTS

Classic slope failure features on the Eel Margin are rare even though our methodology shows a high vulnerability to slope failure during seismic loading, indicating either that mass wasting on the Eel Margin takes unexpected forms or that mass wasting is less significant than would be expected. Shallow-seated failures are more common on the Los Angeles Margin. Our methodology shows an even higher vulnerability to slope failure in Los Angeles Margin areas experiencing numerous shallow-seated failures. Our methodology shows promise in terms of delineating the environmental conditions that are conducive to shallow-seated submarine slope failure.

In collaboration with Laval, analyses of reconstituted specimens of Eel river sediment have been subjected to drained cyclic loading. Under conditions comparable to a long series of earthquakes, we have found that the undrained shear strength increases significantly. Although these conclusions are derived from tests on re-constituted sediments, we can now formulate a working hypothesis: seismic strengthening is a significant mechanism for explaining the paucity of shallow landslide features in the Eel Margin.

IMPACT/APPLICATION

Relationships developed in this project show the importance of sediment liquidity index and seabed density profiles in representing the behavior of marine sediment. These values can be used to predict regional slope stability and the rheological behavior of debris flows. This project shows the value of GIS techniques in combining the impact of a variety of marine sediment and environmental factors to yield information about a predicted outcome, in this case, susceptibility to slope failure. General strength-density relations can be used for modeling sediment accumulation and stability.

TRANSITIONS

Geoacoustic properties are being used by mappers and acousticians to identify lithologies acoustically. Rheological properties are being used by modelers to represent debris flows. Landslide generation models are being used by landscape evolution modelers.

RELATED PROJECTS

Lee has developed a USGS project to investigate sediment and pollutant transport on the Los Angeles margin using many of the same techniques produced by STRATAFORM. Locat is investigating the behavior of a newly formed sediment layer acting as a natural cap over contaminated sediment in Canada. The development of this project benefited from approaches developed within STRATAFORM.

PUBLICATIONS

Boulanger, É., Locat, J., Desgagnés, P. Martin, F., and Lee, H., 1998. Geotechnical testing of Eel River sediments collected as part of the R/V Wecoma Cruise # W9807A (July 14 – 25th 1998). Department of Geology and Geological Engineering, Laval University, Québec, CANADA, GREGI Report 98-02, 45 p.

Boulanger, É., Konrad, J.-M., Locat, J., and Lee, H.J., 1998. Cyclic behavior of Eel River sediments: a possible explanation for the paucity of submarine landslide features. AGU Fall meeting, San Francisco, Abstracts.

Lee, H.J., Dartnell, P., Israel, K., Wong, F., and Locat, J., 1998. Evaluating shallow-seated submarine slope stability: comparison between the Eel margin and the Los Angeles margin, California. In: STRATCON '98: "STRATA AND SEQUENCES ON SHELVES AND SLOPES", SEPM-IAS Research Conference, Sicily, September 14-19th 1998, Abstract.

Lee, H.J., , Dartnell, P., Minasian, D., Wong, F., Israel, K., and Locat, J., 1998. Shallow-Seated Slope Stability Contrasts: Eureka, CA vs. Santa Monica Bay, CA. AGU Fall meeting, San Francisco, Abstracts.

Lee, H.A., Locat, J., Dartnell, P., Israel, K., and Wong, F., 1999. Regional variability of slope stability: application to the Eel Margin, California. Marine Geology, 154: 305-322.

Lee, H.J., Locat, J., Dartnell, P., Minasian, D., and Wong, F., 2000. A GIS-based regional analysis of the potential for shallow-seated submarine slope failure. Accepted for publication, 8th International Symposium on Landslides, Cardiff, England, In press.

Locat, J., Lee, H.J., Boulanger, É., and Maurice, F., 1998. Rapid sedimentation, the role of bioturbation and shear strength development: comparison between the Eel River Margin (California) and Saguenay Fjord (Québec) sediments. . In: STRATCON '98: "STRATA AND SEQUENCES ON SHELVES AND SLOPES", SEPM-IAS Research Conference, Sicily, September 14-19th 1998, Abstract.

Locat, J., Lee, H.J., Kayen, R., Israel, K., Savoie, M.-C., and BOULANGER, É., 1999. Shear strength development with burial in recent Eel River Margin slope sediments: Marine Geotechnology and Resources, in review.

Locat, J., Mayer, L., Gardner, J., Lee, H., Kammerer, E., and Doucet, N., 1999. The use of multibeam surveys for submarine landslide investigations. Invited Article. International Symposium on: Slope Stability Engineering: Geotechnical and Geoenvironmental Aspects, Shikoku, Japan, 8 p., in press.