Geomorphology of Landslides along Oak Ridge and South

Mountain, Southern California, with exploration of possible dating

techniques for land slide scarps.

Summer 1998

SCEC Intern:

Jacqueline G. Moccand - University Of Southern California.

Advisor:

Dr. A. Blythe - University Of Southern California.

ABSTRACT:

The aim of this project was to examine the geomorphology of the massive landslides that are prevalent on the northern slopes of Oak Ridge and South Mountain, Southern California. Complimentary to this was the investigation of different rock dating techniques currently available, including the relatively new methods of using cosmogenic isotopes to date rock exposures. Had it been possible to access the steep scarp slopes of these massive, (1000 ft in some cases) landslides, an approximation of the time of surface rupture would have been obtained from analysis of the mineral olivine using the method of 3-Helium geochronology. An age for the exposed rock surface would have been obtained thereby giving a window for the time of sliding. However this was not possible, and only relative ages of the mass movement events could be obtained. Cross sections of 4 of the major landslides were made using topographic maps of the area, as well as studying aerial photographs. A qualitative age was given to each slope failure event based on the gradients of the slopes.

What prompted this investigation is the hazard these types of catastrophic movements can present to human life and property, and the need to better

understand these movements and their frequency in order to help mitigate against potential future danger.

AIM:

The aim of this project was to examine the geomorphology of the massive landslides that are prevalent on the northern slopes of Oak Ridge and South Mountain, and also to investigate the different rock dating techniques currently available. This includes the use of cosmogenic isotopes to date rock surfaces, in this case the rock slide scarp slopes. If viable 3-He geochronology could be used to obtain an age for the exposed rock surface, and thus get a window for the time of catastrophic movement. In addition to using topographic maps and field investigation of the area, the skill of seeing relief in stereoscope vision was to be perfected and help identify features. The ultimate product desired was a digitized topographic map for Oak Ridge and part of South Mountain. If possible ages for the landslide events were to be obtained from 3-He geochronology that would be conducted at K. Farley's lab at CALTECH.

INTRODUCTION:

The study area is in Ventura county, approximately 50 miles northwest of the University of Southern California. It is a hilly, mountainous region primarily used for oil-well drilling and production, citrus and avocado agriculture, cattle ranches, sand and gravel production as well as being an area of suburban development. Large ancient landslides are clearly seen from the Santa Clara river basin, and the steep relief and seismically induced uplift provide the potential for future large-scale slope movements. The activity of humans in the way of road construction, mining, quarrying, drilling for oil and agriculture which necessitates irrigation can all contribute to reactivation of old landslides as well as instigating new slope movement.

This study concentrated on the 10 mile stretch of highland roughly 2 to 3 miles south of the towns of Fillmore and Piru . This area consisted of the north facing slopes of Oak Ridge and South Mountain, which are composed primarily of interbedded sandstone and claystone of the Sespe Formation and interfingered with the marine sedimentary strata comprising the Vaqueros Formation (Irvine, 1995). Other formations in the region include the Topanga Group which contains the Conejo volcanics, the Modelo Formation and an andesite sill which can be seen in the form of steep cliffs on the northern crest of South Mountain. Others include the Pico and Saugus Formations, the latter of which is the most widely exposed unit of rock in the area. The Saugus strata varies between 900-1800 feet (275 to 550m) thick (Brown, 1959). The anti-dip slopes of Oak Ridge and South Mountain create an east-west trending belt of high relief that marks the southern boundary of the Ventura Basin and Santa Clara river Basin. The highlands were created by the north-south compression of the basin and continue to undergo uplift today.

Oak Ridge Fault is a south dipping thrust fault (Dolan et al., 1995) that underlies the mountain belt and is responsible for their uplift. It originates out in the Santa Barbara channel and runs for more than 100 km through Ventura county, towards the eastern end of the Santa Clara river basin (Figure 1). The fault has a broad s-shape, it is convex to south offshore, and concave to north on shore. The general strike of the fault is north-east, and it splits into two strands at Wiley Canyon , which has some dramatic land and rock slide scars. The northern strand goes east-north-east along the southern side of the Santa Clara River, whilst the southern strand goes east-south-east into the Santa Susana Mountains, where it is over-ridden by the Santa Susana fault. (Dunne et al., 1987). The fault is believed to have been active during the Pliocene and Pleistocene, when the majority of the larger landslides are thought to have occurred (Irvine, 1995). However at present the main faults displacement is not considered to be a serious ground rupture hazard, with an estimated time period of 1010 years between earthquakes on the order of M subW 7.3. However, speculation exists that a blind eastern extension of the system was responsible for the 1994 Northridge earthquake (Dolan et al., 1995).

METHOD:

The very first steps taken incorporated a lot of background reading and investigation into the different dating techniques available to the earth science community. Special emphasis was given to 3-He cosmogenic dating, a relatively new dating method. Other radioactive and cosmogenics were looked into as well, for example 10-Be, along with the more traditional method of carbon dating. Dendrochronology as well as lichenology were touched upon also. Then the less precise, more subjective methods for dating were looked at, including the use of aerial photos, carrying out geomorphic interpretation from topographic maps and the use of landslide slope cross sections. Once the background research was done, the more physical field geology was started.

The preliminary steps involved going out into the field and doing reconnaissance of the area. Possible investigation sites were identified and the basic topography was observed until it became familiar and interpretations were attempted as to how certain features were formed, what information they could provide about the area, and basically a hands on feel for the project area was initiated (Figure 2).

Back in the lab, the multiple topographic maps of the area were aligned and set up on a drafting table. They were studied carefully and finally a Mylar overlay was produced, tracing the contour lines at 500 ft intervals. Once this was done, the information was electronically scanned into a computer and the tedious process of digitizing the map took place. Upon completion the aerial photos that had been ordered from the Fairchild Aerial Photograph Collection (housed at

Whittier College) were picked up and carefully studied. Hours were spent becoming familiar with the area, and trying to correlate what was seen in the field with what was on the topographic maps, and then matching those observations with the aerial photos. Surface mapping and the aerial photo interpretation allowed the typical characteristics of landslides to be identified. These tell-tale features included scarps, hummocky topography, topographic depressions, stream channel alteration and the distortion of slope contours. New and unusual landslide and offset features that may not have been observed in previous studies (Irvine, 1995; Knott, 1992) were also looked for.

During this time a meeting with geologist J. Treiman, at the downtown office of the CA Division of Mines and Geology, Department of Conservation, was set up. This was most informative and helpful, with several questions being answered as well as some new thoughts, questions and concerns being raised, especially about the viability of such an investigation in an area prone to recent increased erosion (special thanks to El Nino). Further input was made by geologists P. Irvine, and useful documents on landslide hazards were procured.

In order to look at relative ages, cross sections of a selection of the largest and most dramatic landslides were made. Four locations were selected (Figure 3) as they provided the clearest slopes, most unaffected by erosion. Also they had relatively sparse vegetation cover, which is a factor that could potentially interfere with the 3-He dating process. If the rock surface is not exposed to the incoming energy from the atmosphere, conducting the cosmogenic analysis would be of limited value. The cross-sections were digitized and given relative ages based on a qualitative scale which based age on gradient, the steeper the gradient the younger the landslide, at least this was the assumption made.

A final trip back to the field, the object of which was to try and collect rock samples from the hanging walls of the huge landslides, as well as look for samples that had potential for dendrochronology, lichenology and weathering surfaces, for which the coronas could be used to give relative ages of the rock.

If good rock samples with sufficient olivine content were found, approximately
5 lbs. from each site were to be obtained, going in to a rock depth of no more than 30 cm. If no basalts were found, a back-up was to collect about 10 lbs. of quartz-rich rock which could be analyzed for other cosmogenics.

CHALLENGES:

Access, access, access! A good learning experience. It is not enough in geology to simply come up with a good idea and desire to study the problem. If access is not possible whether due to no roads, closed roads, private roads or impassable roads (all of which were challenges faced), the study is not going to be a success. Linked to this is also the physical arduous task that can be involved in collecting a rock sample, and this is not even mentioning the fact of hiking four hours with a 7 pound rock sledge, and multiple 5-10 lb. rock samples. For example this project needed samples from steep, high elevation scarp slopes. However the localities which could be partially accessed by road still left a long and difficult climb to reach the landslide scarps. There were no routes to the top, even by means of trying to traverse longer, but gentler ridges. Compounding the problem was the dense and thorny vegetation that created a thick, and difficult barrier to get through. Even if, for example, the Caulmet Canyon Scarp had been reached (after 4 hours of hiking there was still a third of even steeper relief to cover) it would probably have been necessary to use a climbing harness to get suitable rock samples. The other landslide surfaces held the same access problems. It is also possible that after all the effort and physical energy expended in reaching the exposure surface, either the desired rock type was not present or it was still impossible to reach the desired mineral bearing rock outcrop, unless aided by a system of ropes and rock climbing equipment. Samples from the sides of the slopes were available but they were highly eroded, weathered scree and debris, which was of no scientific value.

RESULTS:

My original proposal for this study was to map the geomorphology of Oak Ridge and look at the rock slide scarps on the hanging wall of the Oak Ridge and South Mountain complex. It was also to try and establish the chronology of the scarps using 3-He technique on exposed interbedded basalts. The first part of the study was completed, and calumniated in the production of a digitized topographic map for the area; unfortunately the second part was not possible. From past studies though it has been concluded that landsliding was most prevalent in southern California during the periods of 11-17 ka and 30-34 ka. It has also been noted that the landslides also frequently occurred between 9-14 ka likely due to increased levels of precipitation during a glacial maxima (Knott, 1992). The sliding was likely induced by the rapid uplift the area was experiencing and also the wetter climate of the Pleistocene.

From the comparison of gradients it is estimated that the Wiley and Caulmet Canyon landslides occurred after those in Balcom Canyon, and also the one found within Lododo Incorporated's property (Figure 4). In past studies Californian landslides have been assigned ages by the use of observed geomorphic characteristics which is another way to give a qualitative age estimation (Table 1).

Although the geochronology aspect of this project was not successful, my personal and academic goals were definitely met! I wanted to gain hands on experience in the field of geology and also to obtain a better understanding of how real research and geological investigation is conducted. I achieved these goals, and now have a much better appreciation of what goes into the whole process. Topics I had never even considered before, as simple as they are, proved to be major problems. Things such as access roads, permission to use these roads, entry onto private property, access to rock exposures, finding the desired rock type in the exposure, battling thorny vegetation and unfriendly farm dogs and so on! Basic things, but crucial to overcome if the study is to be a success.

The overall experience however, was extremely rewarding. I learned a lot about dating techniques, the morphology of landslides, aerial photo interpretation - my ability to see in stereoscope has vastly improved, and my computer skills have definitely been added to. But perhaps the best thing about the SCEC internship was the insight it gave me to real geology. I met and talked with many geologists both in academia and in the work force, and I learned about co-operation and how everyone relies on someone's past work or current research in order to advance their own personal investigation, even if it is simply using a topographic map that a cartographer made sometime in the past. Co-operation is not restricted to just the scientific community, but also the public at large. A geologist needs to be succinct at interpersonal skills, dealing with legal issues, management aspects and basically being able to approach people and make them understand or at least appreciate the science being conducted, and how it will benefit the community.

Science is all about co-operation, without it research will definitely encounter stumbling blocks and therefore never reach its full potential.

CONCLUSION:

The ages of the landslides along Oak Ridge and South Mountain were not possible to obtain using 3-He geochronology, although relative ages were found from gradient comparison. However the usefulness of these qualitative ages is debatable. What prompted this study was the hazard that landslides present to humans, and the need to better understand them in order to improve mitigation against them. The hope was that if concrete dates had been obtained for the catastrophic events, the study could be continued and an investigation as to whether or not the ages of slope failure correlated with past seismic activity along the fault.

One solid observation from this project is that there exists a mistake on one of the topographic maps of the area. The American topographic map: Simi Valley West, 34118-C7-TF-024 has a mistake in the vicinity of Wiley Canyon. A contour line is marked as 1600 ft when in fact it is actually 1800 ft.

APPLICATION:

What originally prompted this research is the concern for human life and property that can be threatened by seismic activity and mass movement events. Earthquakes can induce landslides, rock falls and similar catastrophic activity that are potentially life threatening. Therefore these areas of geology should be intensively studied and mitigation constantly improved if possible. Landslides can occur as a result of many factors being put together, including changes in water content, pore pressure, angle of repose and so forth. But whether slope failure is a result of regular processes or seismically induced slip, the end result ultimately pose the same threat to humans. Therefore it is beneficial to study such phenomena in order to better prepare and mitigate for such situations. The importance of earthquake-induced landslides to long-term slope erosion and slope failure hazards in seismically active regions is an area that can benefit from further study as it is of relevance to human safety and development. Methods currently exist that allow the amount of earthquake-induced landsliding in a seismically active region to be calculated (Keefer, 1994). This information can be used in the mitigation process.

The reason Oak Ridge was focused on is because it provides impressive landslides to study, it is also relatively close to Los Angeles and is currently undergoing suburban development. The fact it overlies, and is being uplifted by a fault prompted the idea too that the study could be extended with time, to looking at past seismic activity and tying to find a correlation between the seismicity of the fault and the landslide events. It could potentially bring together geomorphology and paleoseismicity, two areas of geology currently enjoying special interest.

References

Brown, R.S.; The geology of the Grimes Canyon area, Moorpark and Fillmore quadrangles, Ventura county, California: unpublished M.S. thesis, University of California, Los Angeles. 1959

Dolan, J.F.; Sieh, K.; Rockwell, T.K.; Yeats, R.S.; et al, Prospects for larger or more frequent earthquakes in the Los Angeles metropolitan region, Science,, v.267, p.199-205. 1995

Gardner, D.A.; Stall; Dunne, Oakridge fault, Ventura Basin, California: Slip rates and late quaternary history, Phase II, Proposal to USGS in response to announcement No. 7234. 1988

Irvine, P.J., Landslide Hazards In the Moorpark and Santa Paula quadrangles, Ventura county, California. Department of Conservation, Division of Mines and Geology, open-file report 95-07. 1995

Keefer, D.K., The importance of earthquake-induced landslides to long-term slope erosion and slope-failure hazards in seismically active regions, Geomorphology, v.10n.1- 4, p.265-284. 1994

Knott, J. R., Engineering Geology and Geomorphology of the Grimes Canyon Area, Ventura County, California: unpublished M.S. thesis, California State University, Los Angeles, p35-43. 1992

Treiman, J.A., Oak Ridge and related faults, vicinity of Fillmore and Santa Paula, Ventura county, California, AEG Field Guide. 1991

Yeats, R.S.; Gardner, D.A., Oak Ridge Fault, Ventura Basin, California: Slip Rates and Late Quaternary History: in Jacobson, M.L., and Rodriquez, T.R., compilers, National Earthquake Hazards reduction Program, Summaries of Technical Reports, v.XXII, USGS Open File Report 86-383, p.196-201. 1986

Yeats, R.S.; Gardner, D.A.; Rockwell, T.K., Oak Ridge Fault, Ventura Basin, California: Slip Rates and Late Quaternary History, in Jacobson, M.L., and Rodriquez, T.R., compliers, National Earthquake Hazards reduction

Program, Summaries of Technical Reports, v.XXIII, USGS Open-File Report 87-63, p.179-182, 1986

Yeats, R.S.; Huftile, G.J., Convergence Rates Across Western Transverse Ranges, National Earthquake Hazards reduction Program, Summaries of Technical Reports, v.XXII, USGS Open File Report 86,383, p.194-195. 1986

Figure 1: Location Map Showing Oak Ridge Fault, Ventura County.

(Taken from Treiman, 1991)

Figure 2: Longitudinal Profile Along Oak Ridge and South Mountain From Coastline East to East End of Oak Ridge. (Taken from Yeats, Gardner & Rockwell, 1987)

Figure 3 - Photographs of Selected Landslide Sites:

1. Wiley Canyon - Concordia Resources Inc. Property (Oak Ridge)
2. Caulmet Canyon - Oil Field (Oak Ridge)
3. West Of Shiells Canyon - Lododo Inc. Property (Oak Ridge)
4. Balcom Canyon (South Mountain)

Figure 4a: Cross sections for the selected landslide sites, showing true elevation and gradient. (Note: For each location two cross sections were made, so as to give an average gradient.)

Figure 4b: Cross sections for the selected landslide sites, assuming same basement elevation. (This gives a clearer perspective of the sizes of the landslides. Depending on where the cross section was made - either nearer the middle of the rupture surface or towards the side, it can affect the eventual conclusion as to the age of the landslide. The results are therefore open to wide interpretation.)

Table 1: Geomorphic Characteristics and Ages of Landslides in the Southern California area. (Taken from Knott, 1992; Varnes, 1978)