Seismic Hazard Assessment of the San Joaquin Hills Using GIS

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Abstract

The San Joaquin Hills region of Orange County is undergoing rapid commercial and residential development. The anticlinal structure of the area is likely due to a combination of tectonic uplift and seismic activity on local fault systems. The goal of this project was to determine the hazards of the fault zones in the area while there may still be time to translate these findings into sound planning practices for the area.

Geotechnical and fault investigation reports were collected for as many sites as possible in the San Joaquin Hills region. The findings from these reports were then collected and transferred to a GIS-based map. This map was designed in such a way to allow a convenient regional view of report coverage and findings and was linked to a more complete bibliography displaying report titles, conclusions, and relevant trench logs. Because little conclusive or comprehensive information was found during this study, a strong case can be made for the need for further fault investigations in the San Joaquin Hills region.

Introduction

The San Joaquin Hills region in southern Orange County is an area that is undergoing tremendous growth. Recent studies suggest that the anticlinal structure of the San Joaquin Hills is due to a combination of folding and faulting in the area. The tectonic and seismic hazard significance of the faults is not understood. Considering the rapid

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development of the region, it is imperative that the seismic hazard of these faults be assessed so regional planning can proceed in an informed manner.

The goal of this research project was to create a GIS-based map and database to compile information on these faults from geotechnical development reports and fault investigation studies. This information may be used to assess seismic hazards in the San Joaquin Hills region. This project involved contacting and collecting fault data from geologic consulting firms and local and regional governments. The data is the basis for a regional GIS map which displays important seismic hazard information such as recency of fault rupture, fault location and exposure, sense of motion (if known), and a bibliography of published and unpublished sources. The goal was to make this map as useful as possible for the sound planning of the region. If the faulting and neotectonic structures can be considered and incorporated into mitigation measures for the area, the risk of property damage and loss of life may be significantly reduced in the future.

Methods

The first stage of this project involved collecting and recording data from local agencies. Originally it was assumed that this information would be reasonably accessible at the city government level. It was soon apparent that the necessary geotechnical reports would not be available from the cities in question and that an alternative was needed. The necessary reports were eventually found with the help of consultants who were originally involved in the writing of the reports and who were kind enough to lend out their work. Once the reports were obtained, they were cataloged and the results were summarized. Where possible, the report's conclusions and any important diagrams were copied and filed with my own summary sheets.

To keep track of progress and plan for new acquisitions, the California Division of Mines and Geology's "Geology and Engineering Geologic Aspects of the South Half Tustin Quadrangle, Orange County, California, 1976 (Special Report 126)" and "Geology and Engineering Geologic Aspects of the Laguna Beach Quadrangle, Orange County, California, 1976 (Special Report 127)" reports were studied. The reports provided insights into the potential activity of fault zones and the terrain and lithologic features of map units that were referred to by subsequent geotechnical reports. The plates provided with these reports were also duplicated and became a valuable medium for tracking the regions covered by each geotechnical report received as well as the areas where more coverage was needed.

As geotechnical and fault investigation reports were collected, an intake form was created and used to summarize the results. This form included the names of the reports and their authors, their reference numbers and dates, the areas covered, their methods for investigation, and a summary of their findings. The ages of the oldest unfaulted unit and youngest faulted unit were also collected, along with the strike, dip, and sense of motion of the fault, where known. The reports were then divided into two rough preliminary categories: reports with fault information and reports without. The reports without fault information of any kind were cataloged and set aside. The geotechnical and fault investigation reports that included fault information were then organized to streamline their transfer into a GIS-based map.

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The GIS-based map was created using a topographic base map of the Laguna Beach Quadrangle and the South Half of the Tustin Quadrangle. Shapefiles were created to match the fault traces, both substantiated and estimated, from the California Division of Mines and Geology's Special Reports 126 and 127. Several shapefiles were needed to accurately represent fault traces that were known, estimated, concealed, and intruded with diabase. These separate themes can be easily displayed and categorized according to any criteria listed.

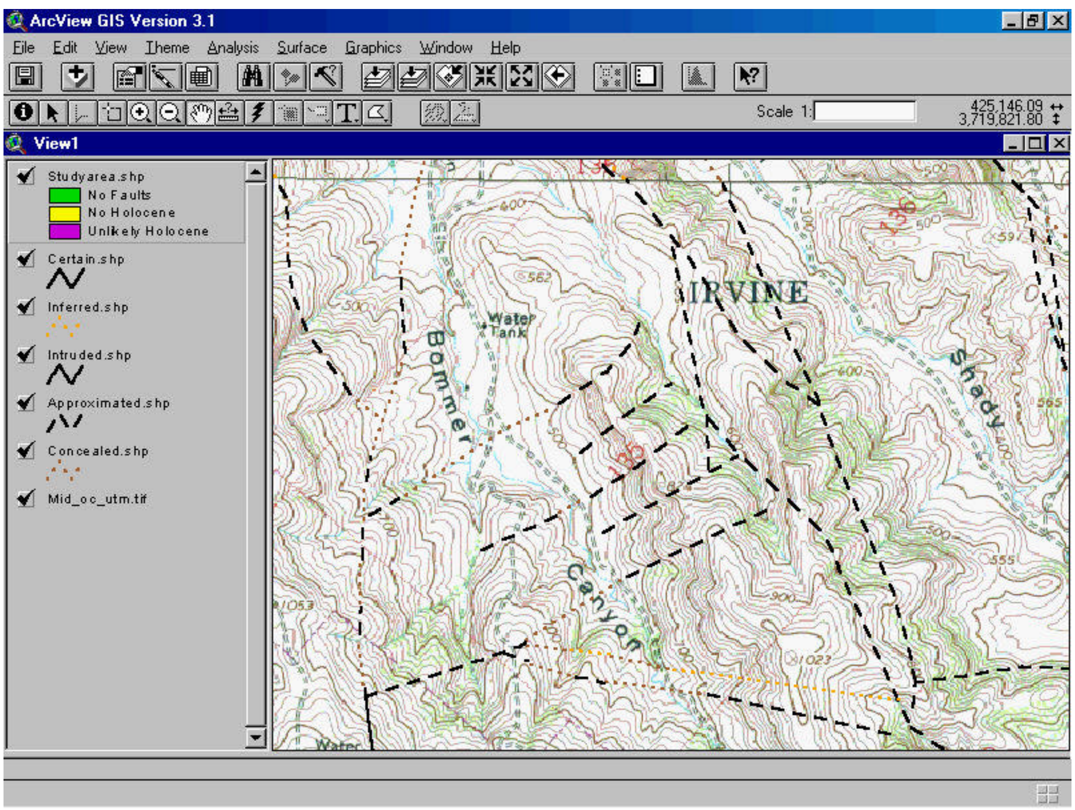

Figure 1: *Screenshot from the GIS map showing the fault themes, which were based on information from CDMG Special Reports 126 and 127. The different fault themes represent known fault information such as estimated or concealed traces, or diabase intrusions.*

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After the fault traces had been drawn, more shapefiles were created to represent areas studied by the geotechnical and fault investigation reports. Each study area in the theme was then linked to a table entry specifying the relevant report information. Among the information included in the theme table were report titles, authors, dates and reference numbers, stated recency, and an abbreviated summary of findings. This information serves as an expandable dynamic bibliography of reports relevant to the San Joaquin Hills region. This bibliography will serve well as a foundation as research continues to assess regional seismic hazards.

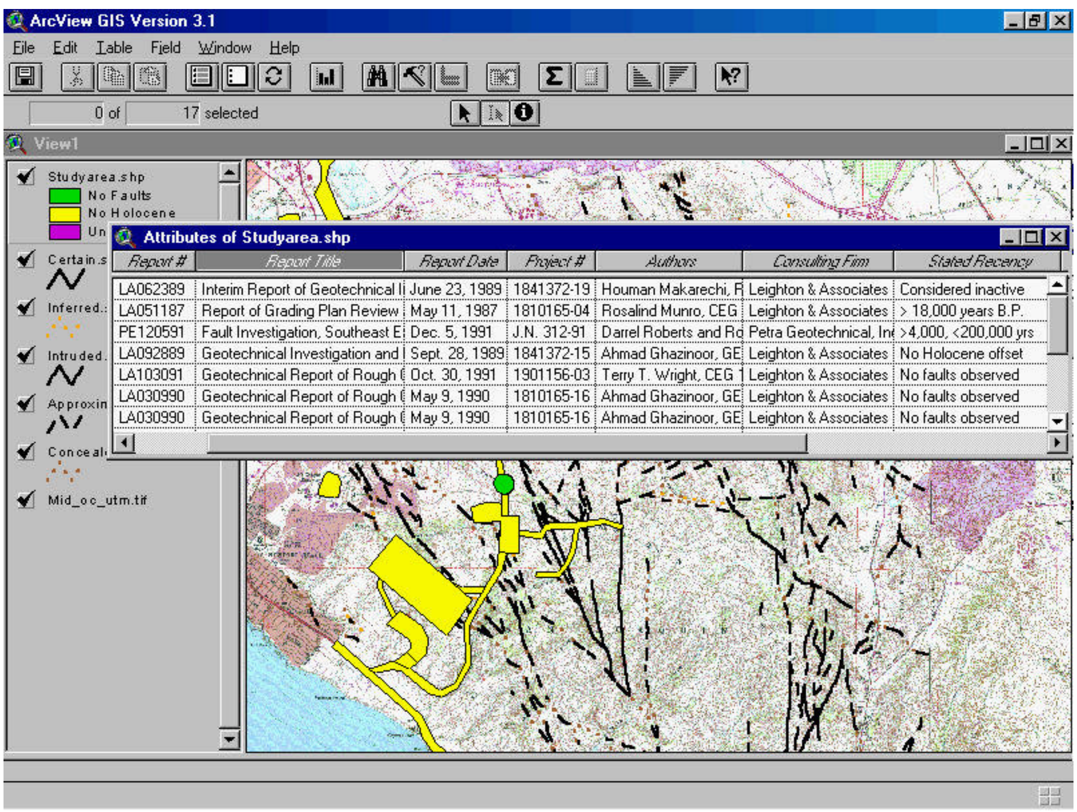

Figure 2: *Screenshot of the GIS map with the Study Area theme table open. This table forms the basis of the report bibliography and includes complete report titles, reference numbers, and author information.*

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The findings listed in the theme table were intentionally simplified to allow for color coding of the areas on the map. The categories chosen separated reports with no faults detected from areas with faults found to have no Holocene displacement and possible Holocene displacement. The areas with no faults would be color-coded green, while those with no Holocene displacement were yellow, and those with possible Holocene displacement were red.

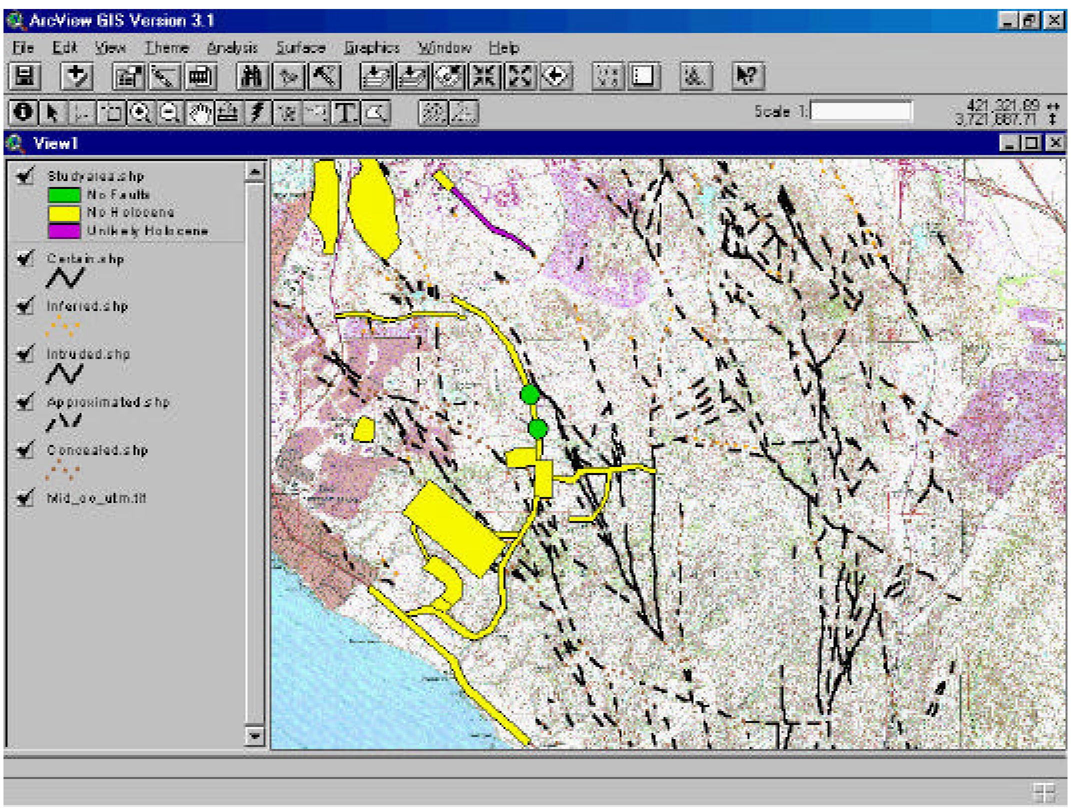

Figure 3: *Screenshot from the ARCView GIS Map showing the Study Area theme along with the topographic base map and fault themes. The topographic base includes portions of the South 1/2 Tustin Quad and the Laguna Beach Quad. The Study Areas are color coded to allow identification of report results at a glance.*

To increase the utility of the map, a special feature available with ARCView 3.1 was used. Small text files were created for each report and linked to the corresponding

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study area using ARCView's 'Hotlink' feature. These text files were comprised of report titles, authors, and dates along with excerpted summaries. This feature effectively allowed the reports to speak for themselves by including the authors' own statements. This also allows for an intuitive, 'clickable' map where information is immediately accessible.

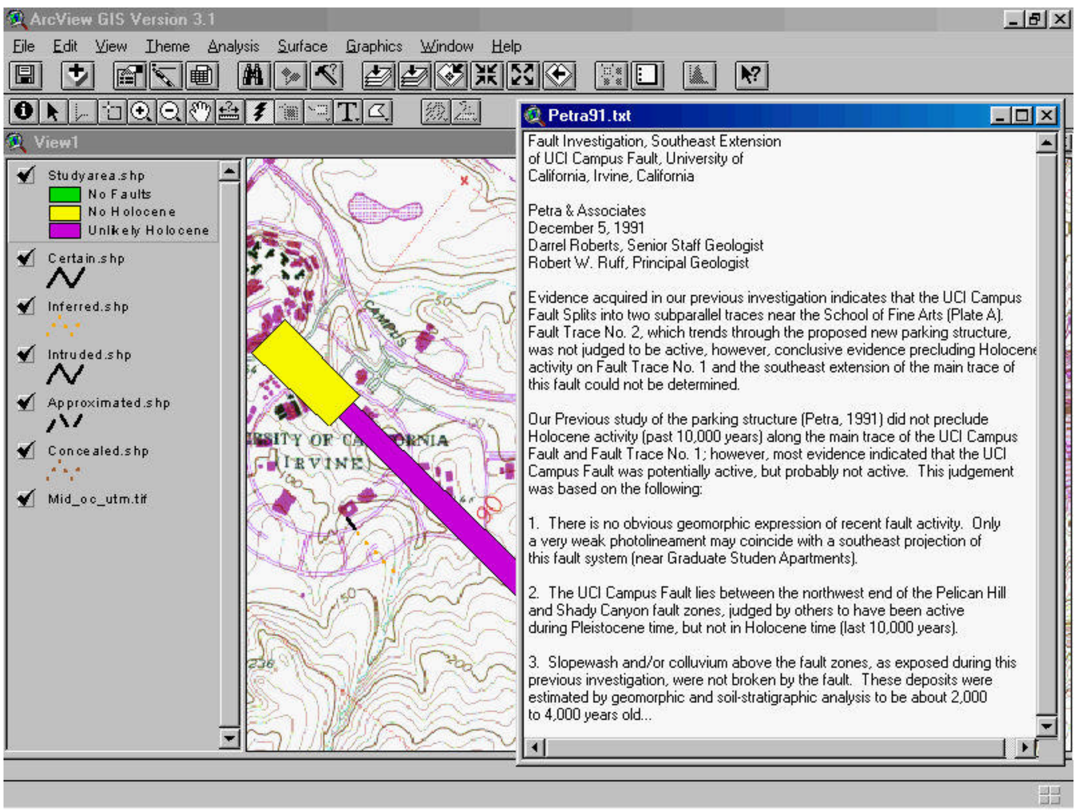

Figure 4: *Screenshot of the GIS map and an example of a hot link to an excerpted report summary, in this case Petra, 1991.*

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Discussion Section

The results of this research project show a need for further investigation in the San Joaquin Hills region. There were only two major fault investigations found: one for the 'North Ford' region off the Pelican Hill fault zone and the other for a large parcel in the center of the Pelican Hill fault zone.

The North Ford region was found to have ruptured no sooner than between 10 and 13,000 years Before Present, and the central region of the fault zone was dated at 18,000 years B.P. or older. The North Ford region derives it date from a pause and slight reversal in sea level rise that occurred between the Flandrian Transgression (after 18,000 years B.P.) and the Xerothermic Period (beginning between 8 and 10,000 years B.P.). The fault observed at North Ford ruptures alluvium from the period of sea level rise, but does not rupture the thin paleosol identified as belonging to the Xerothermic Period (Leighton and Associates, July 1985).

The fault investigation conducted on a large parcel in the middle of the Pelican Hill fault zone showed a minimum recency of 18,000 years B.P. This investigation found a distinct stone line that remained unbroken above a fault trace. The creation of this stone line was then associated with the end of the sea level rise associated with the Flandrian Transgression. Because the trace did not rupture the soil above the soil line, it was concluded that the fault has not been active since approximately 18,000 years B.P. (Leighton and Associates, November 1985)

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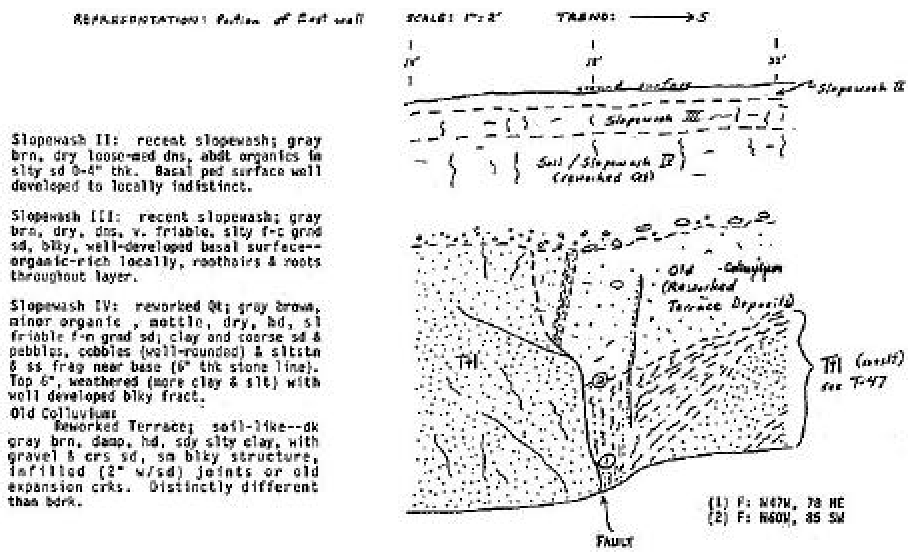

Figure 5: *Trench 47A from Leighton and Associates 1985 (right) shows the stone line used to date the most recent displacement. The line is approximately 18,000 years old, and shows no offset.*

If the region being studied was small, then these two investigations might be sufficient to accurately gauge the Pelican Hill fault zone's activity. In truth, the area of the fault zone dwarfs the area detailed in these two fault investigations. Despite this, dozens of subsequent geotechnical reports have been based on the findings of these fault investigations. The geotechnical reports typically catalog the faults found, then conclude that the recency of rupture is the same as recency for the fault strands described in the fault investigations.

This method is appropriate when the fault found in the trench is obviously very old. Some trench logs detail faults found with Miocene-aged diabase intrusions. These fault strands must then be between 5 and 23 million years old, and Holocene rupture can be easily ruled out. Most of the trench logs contain less certain results. The stratigraphy suggests that the ruptures are old, but they are covered with alluvium or colluvium of uncertain age. If the colluvium could be dated with some certainty, Holocene ruptures could be concluded against. One such trench log can be found in Petra and Associates'

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1991 report. The trench log shows a fault rupture that terminates quite close to the surface. Just above the fault rupture lies a buried animal burrow, or krotovina. This burrow may have been created along a now obscured extension of the trace because the animal was likely to have follow the path of least resistance, that of fractured rock and soil. This type of trench is not indicative of error or conspiracy, but rather a need for further study and more careful investigation.

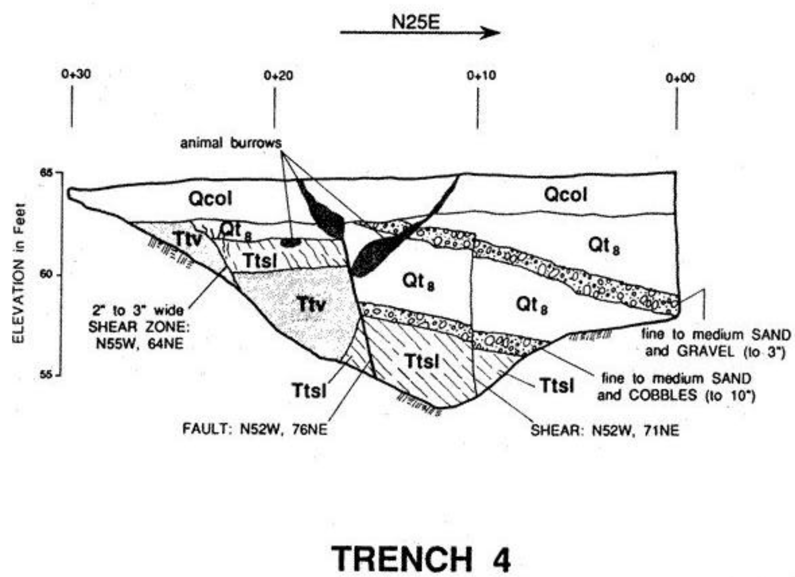

Figure 6: *Trench 4 from Petra Geotechnical 1991 (above) shows an interesting correlation between krotovina and fault traces.*

It is also possible that fault rupture has been obscured by the sandy soils overlaying the bedrock units. These soils may have been ruptured and weathered but lack distinct bedding, which would help to detect small displacements. These soils might also have dissipated the fault's displacement. Such anomalous displacement was seen on Montague Island after the 1964 Alaska earthquake. On the island, the fault slip was

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expressed by fractures at the foot of a 150-meter high fractured rock cliff. No fault slip was found on the top of the cliff, the rock evidently dissipated the slip with its numerous fractures (Bray et. al., 1994).   This pattern of diminished displacement might be evidenced in a trench log from a Leighton and Associates report from 1989. A minor surface disruption can be seen above a fault trace in Trench Log 49. There is a slight possibility that the trace that extends to the surface has been obscured by the sandy soil and the surface offset is due to the displacement of a reverse fault.

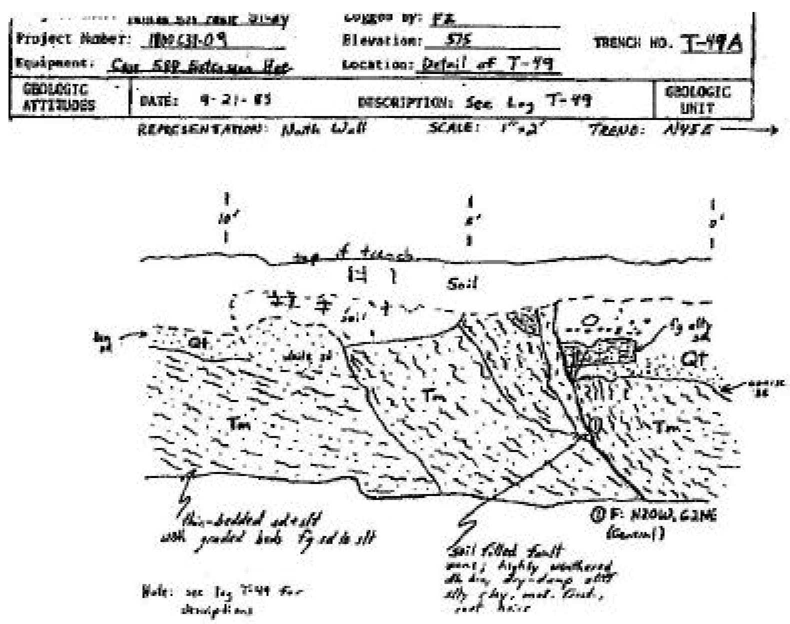

Figure 7: *Trench 49 from Leighton and Associates 1989 (top right) shows a potential slight surface displacement, which may be related to the fault system.*

It is important to note that neither of the above examples presents conclusive evidence contradicting the findings of the geotechnical reports. The examples merely show curious features that would benefit from further study. That is why it is so unfortunate that the trenches exposed were excavated and studied in such ways that further study is difficult. Geotechnical consulting firms studied the areas on behalf of

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their clients with the express purpose of excluding the possibility of Holocene rupture to comply with the Alquist-Priolo Act and allow development. This act requires detailed study in any area where a critical structure is to be placed near the fault trace of an active fault. These firms usually operate on a tight schedule and aren't able or encouraged to study the area in great detail. The San Joaquin Hills would benefit from a comprehensive fault investigation.

On a more positive note, the bibliography and database created by this study should be a useful stepping-stone to create a comprehensive catalog of area studies and demonstrate the need for detailed investigations. The bibliography's access via the GIS-based map will provide added convenience by visually displaying the relative frequency of investigations in any given area. This bibliography wasn't the intended focus of this project, but has stepped into the forefront by necessity. It is hoped that it will be of use in numerous future projects.

Conclusion

This project was successful in collecting fault information for the San Joaquin Hills region of Orange County and condensing it into a user-friendly GIS-based map. This map should prove useful in assessing regional seismic hazards and highlights areas in need of further study. One of the challenges in completing this project was the relative inaccessibility of geotechnical and fault investigation reports. These reports are difficult to obtain at the county and city levels and were more readily available through the involved consulting firms. The second difficulty of this project was the poorly constrained dates of the possible Quaternary fault ruptures. If late Quaternary or Holocene fault rupture could clearly be determined or ruled out, then hazard mitigation in the San Joaquin Hills could proceed in an informed and organized manner. This recency data is critical not only to comply with the Alquist-Priolo Act but also to assure sound planning practices. The bibliography compiled by the project should prove particularly useful and would benefit by future expansion. One possible product would be a GIS-based map created to index relevant geotechnical reports by region, street address, and tract number. This map may successfully bridge the gap between the tract numbers and street address indexes used by the city and county and the topographic bases used by geologists and seismologists.

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* *This bibliography represents works cited in this report. A complete bibliography of geotechnical reports examined during this project is available with the GIS-based map.*

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