Project Aims and Objectives

Environmental degradation is often associated with modern population growth and the development of intensive, industrial agriculture and large-scale clearing of forests. Archaeological research shows that ancient cultures also adversely affected their environments. Ancient environmental degradation has been closely associated with the Mediterranean basin and the Middle East. More recent research, including the author's, has shown that severe soil erosion and environmental degradation also occurred in Latin America. However, there is still controversy and disagreement over the timing and causes of environmental degradation in Latin America. This is especially true in the highlands of southern Mexico where archaeologists assume the landscape to be more static than it really is. Episodes of erosion are often attributed to Spanish introduction of grazing animals and European agricultural systems. Research by the author and his colleagues, which includes the radiocarbon dating of buried soils, shows that this is incorrect. We associate much of the major erosion to two pre-Hispanic time periods. One, around 1500 BC, is associated with population growth and agricultural intensification. Another, around AD 200 was the result of urbanization into city-states, population growth and the movement of people into upland settings susceptible to erosion. Recent research indicates that the decline of extensive civilizations in the highlands of Oaxaca, (e.g. Zapotecs of Monte Alban, Mixtecs of Yucuita and Cerro Negro) resulted from environmental degradation rather than warfare. In addition to highland erosion we have documented environmental changes in the lowland, coastal area of the Rio Verde drainage basin (see references in CV). Because of an extremely steep gradient, sediment eroded from the highlands was not deposited until it reached the low, coastal region. Sediment deposition then altered the river's location and affected settlement patterns in the lower valley.

Sedimentary deposits in upland valleys record regional environmental changes. Valley fill consists of many layers of organic-rich soils, separated from one another by low organic-matter channel deposits. Buried soils represent periods of landscape stability separated by deposits from hillside erosion. These buried soils are also important because their high organic-carbon content allows them to be radiocarbon dated, thereby providing a chronology of stable land surfaces. Radiocarbon dates have been determined for 31 paleosols. While sedimentary deposits of valleys have provided a great deal of information, they are open systems and we have no control, or idea, of what has been lost to downstream erosion. Given the mountainous terrain of the region closed basins are difficult to form. While working on maps of the region with my Geomorphology class I noticed distinctive closed depression lines indicative of sinkholes or closed depressions into which intermittent streams flow but from which there is no outlet. They occur in small isolated areas of limestone bedrock that somehow were preserved during mountain uplift. These depressions act as sediment traps and will record a complete environmental history of the surrounding area. They are found in a portion of the Rio Verde drainage basin that I have not previously explored.

Research conducted during this sabbatical will focus on three objectives.

First, there will be a detailed examination of the soils and sediments of the closed depressions. This will provide a more complete environmental record of landuse changes in the surrounding hills (e.g., deforestation for agriculture). It will also expand my research into a new region of the drainage basin and allow for correlation with previously examined areas.

Second, collaboration with an interdisciplinary team will strengthen my research conclusions. While we feel that anthropogenic changes (e.g. deforestation) led to many environmental changes we still must investigate other potential explanations. These include geologic uplift and climate change. This research requires an interdisciplinary team to investigate these other possible explanations. My colleague for almost 20 years, Dr. Arthur Joyce of the University of Colorado, has received an internal seed grant for new research that includes several scholars with different specialities. My research will be an essential portion of this grant and will supplement their research. Dr. Goman (palynology), from Cornell University, will investigate pollen trapped in the depressions to determine possible landuse and vegetation changes. Pollen recovered from cores will record changes in vegetation that can be correlated with climate change over the last few millennia and will also provide a record of the introduction of

cultivated crops and the intensity of cultivation. Dr. Manning (dendro-chronology and dendro-climatology), also of Cornell University, will collect cores from trees to determine possible climate change. He will also examine isotopes of oxygen and carbon as proxies of climate change. Dr. Middleton (bioarchaeology), of the Rochester Institute of Technology, will be examining phytoliths (silica accumulation in plant cells that have distinctive shapes unique to individual species) to provide evidence of vegetation and correlated climate change. Naomi Levin (environmental geochemist) will examine isotopic differences in soil carbonates and exposed sediments. Ratios of different isotopes in soil carbonates are used to determine paleo-climates. Isotopic changes resulting from exposure to cosmic radiation will allow us to more closely determine the rate and timing of soil erosion.

My role on the research team will be to provide the geomorphic and soil genesis setting for these other experts. While they are looking at specific aspects (e.g. pollen, etc.) I will be looking at the landscape level, i.e. what earth-surface processes were operating and how did they form, or modify, the soils within which the vegetation grows and from which the samples were obtained. For example the higher elevations are covered with dense forest which at first seems due to the higher elevation, However the higher elevations are capped by an ancient lava flow, forming a soil that is less susceptible to erosion than soils of the lower slopes. Vegetation differences are related to bedrock, not elevation.

The **third** focus of this research will be an examination of buried stream channels along the lower Rio Verde. My previous research showed that, because of intensive sediment influxes from highland erosion, this river has shifted repeatedly across the floodplain. However, modern floodplain deposits totally obscured these old, now buried, channel patterns. Previous research depended on deep archaeological excavations and many deep auger cores. These provide point and transect data but obviously have limited geographic extent. Dr Sarah Barber, (U of Central Florida), will be working in the lower Rio Verde examining archaeological sites with Ground Penetrating Radar (GPR) Reflections of the radar pulses reveal the underlying stratigraphy. In return for helping her with soils and sediments of the sites, I can use her GPR equipment for my own research. This will allow me to examine a much greater area of the floodplain and gain a more accurate picture of buried stream channel changes and how the drainage system evolved relative to the archaeology.

Background Work

I've conducted ten field seasons in Oaxaca. I have experience in the region and know how to function in its culture. During the 2006 field research I established an excellent working relationship with the officials of Yanhuitlan, centered in our main research area. On a few occasions they actually drove me and my students to our research areas in the municipal police car. Also, I have the support of Dr Marcus Winter (co-author on publications) of the Mexican INAH (Instituto de National Antropologia e Historia) who will secure the necessary permits and provide a letter of introduction for the field work . Most of the equipment I need is stored in Oaxaca City and available for my use as part of the team working in Oaxaca. The remainder I will take with me. Laboratory analysis will be done using standard lab equipment and supplies already at hand. I have a Soil Import Permit from the USDA that allows me to bring soil samples back into the country. My colleague, Dr Arthur Joyce, will be in Oaxaca, along with the other faculty and their graduate students working on the larger project. During the coastal portion of the work we will stay in a house rented by Dr. Sarah Barber. During the highland portion of the research we will stay in hotels I've used in the past.

Procedures and Methodology

Previous research was limited by needing to use public transportation, taking you only gets you from town to town. Then you must walk. This greatly limits the area covered. With that in mind I recently bought a 4WD pickup which I plan to drive to Oaxaca, Mexico. This will greatly enhance my ability to cover larger areas and get to remote locations. Because of the large number of people involved in this research the field component has been broken into three time intervals. In addition to transportation logistics this has the advantage of using the main dry season for a portion of the field research and the ability for additional sampling should questions develop from the initial sampling.

Summer, 2008: Three months of early summer will be spent conducting field work. Because the rainy season forms later and is less intense in the highland area, field work will begin in the lowlands with coring of coastal lagoons and abandoned stream channels along with a GPR survey of the floodplain. Sampling will also be done in support of Dr Barber's use of Ground Penetrating Radar (GPR) in the vicinity of known archaeological sites. After several weeks we will move to the Oaxacan highlands. Reconnaissance of the closed depression areas in the western part of the Rio Verde drainage will be done in coordination with Dr Manning, who will collect tree cores and vegetation samples in the same area. Then field work will proceed to the Nochixtlan valley where I will collect soil samples for my research which will support additional research being done by Dr Middleton (phytoliths) and Naomi Levin (isotope geochemistry).

Fall, 2008: This time will be spent doing laboratory analysis of soil samples along with preliminary data and statistical analysis. I will also use this time to prepare presentations on the preliminary research.

Winter, 2009: This is the height of the dry season. The main field research for this time period will be coring the closed depressions along with Dr. Goman. I will be looking at the stratigraphy of the cores (evidence of severe flooding or gentle accumulation) while Dr. Goman is collecting samples for pollen analysis. If access to the areas of closed depressions is not possible during the previous summer, Dr. Manning's tree coring would also be done at this time.

Spring, 2009: The winter field season will be extended into the spring as needed. Examination of field and laboratory data almost always brings up questions that can only be answered by additional field work. This time would also be spent doing laboratory and statistical analysis of samples collected during the winter. In late spring I will be doing soils and geomorphic field work in support of new excavations by Dr Joyce and his graduate students.

Summer, 2009: Completion of laboratory and statistical analysis. Write up results for presentation an national conferences. Share data with collaborators and begin writing journal articles.

Importance/Value

Sustainability of agriculture and food production will become increasingly more important as fossil fuel-based fertilizer costs increase and water becomes a more limiting factor. Climate change also is a factor related to food production and obviously a major environmental issue. I plan to use the knowledge from this research in my Environmental Sciences classes. In particular, I'm teaching two new courses this coming spring semester, "Water Resources Seminar" and "Sustainability: Food and Agriculture" both of which will benefit from this research.

I've been successful in the past in including Stockton students on my research. They have worked with, and done very well with, graduate students from major research universities. I've been talking with Gorica Majstorovic of the LACS program about developing a program that integrates LACS and environmental concerns. She has several students who have expressed an interest in this research. I plan to include them in the project if at all possible.

Further Research

The objective of Dr Joyce's grant is to provide seed money to investigate new research directions related to human-induced environmental change in Mesoamerica . Preliminary results from this study will be used in support of grant proposals of further, more intensive research by the various collaborators on this project. This will lead to grant applications to organizations such as NSF, National Geographic, and other archaeological funding groups. I will continue to use Stockton students in this research.

Outcome

I plan to present immediately the results in talks at professional meetings. Some of the talks, based on field observations will be given during the sabbatical. Other talks will take a little longer as they will be based on data from laboratory analysis. I plan to submit rapidly the results of this research for publication in scientific journals. Results of this research will also be important updates to chapters in two books that I'm working on. I enjoy relating my lectures to real world events and personal research. I fully expect this research to enhance lectures in many, if not all, of my classes.