Central Region
Earth Surface Processes Team
2008 Rocky Mountain Area
Science Center Review

Team Chief Scientist	Eugene (Buddy) Schweig
Associate Team Chief Scientist	Gene Ellis
Administrative Officer	Brenda Williams

http://esp.cr.usgs.gov/

I. Introduction

Brief Team Overview

The Central Region Earth Surface Processes Team serves the Nation by providing integrated geologic, climatic, and environmental data and by conducting research that can be used by governments, the private sector, and individuals to make decisions about natural resources and our climate that will impact our economy and our future.

The ESP Team's offices and laboratories are located primarily in Building 25 of the Denver Federal Center (DFC), but we also occupy offices and laboratories in Buildings 15, 21, and 56 of the DFC. One employee and one Emeritus scientist are co-located with EPA offices in Corvallis, OR, and one employee is located at Oklahoma State University in Stillwater, OK.

The ESP Team has 64 Federal employees (57 permanent full-time, 2 permanent part-time, and 5 term), 5 contract employees, and 12 Emeritus scientists, for a grand total of 81 people.

The ESP Team budget for Fiscal Year 2008 is expected to be $11,516,426, which includes all funding. This is an 11 percent increase over Fiscal Year 2007, which was $10,361,890.

Overview of Client Base

The ESP Team is funded primarily from two USGS base programs. The Earth Surface Dynamics Program (ESD) funds climate change-related activities, and the National Cooperative Geologic Mapping Program (NCGMP) funds geologic mapping activities. Sources of reimbursable funding include the National Park Service, U.S. Department of Energy, Bureau of Land Management, National Science Foundation, USAID, and other federal, state, and local government agencies. In FY2007, the ESP Team received $4.03M and $4.07M, respectively, from the ESD and NCGMP funded programs. Other USGS programs contributed $525,000. The team also received $170,000 in reimbursable funds from outside the Bureau.

The ESP Team works with the following agencies and organizations:

Within the USGS: Other Disciplines

- Biology
- Geography
- Water

Other Federal Agencies

- Department of Interior: NPS, BLM, FWS, BOR, BIA
- Department of Agriculture: USFS, NRCS
- Department of Energy: YMP, NTS, National Labs
- Department of State: USAID
- Department of Commerce: NOAA
- Department of Defense: Army, Navy, Air Force
- Centers for Disease Control
- EPA
- NASA

- NSF funded: NCAR
- Smithsonian Institution: National Museum of Natural History
- Geological Survey of Canada
- Environment Canada

Native American Tribal Entities

Universities
- Too many to list, in the U.S. and internationally

State Agencies
- State geological surveys, primarily in the central and western states
- State Departments of Parks and Recreation
- State Departments of Fish and Game
- State Departments of Natural Resources
- State Departments of Health
- State Departments of Transportation
- State Engineers, State Water Resources Boards, Water Conservation Districts
- Canadian provincial geological surveys

Other Organizations
- The Nature Conservancy
- City and County governments
- Local planning and conservation groups
- Intercultural Center for the Study of Deserts and Oceans
- Center for Mountain Archeology
- Calico Early Man Archaeological Site
- California Desert Studies Consortium
- International Geosphere-Biosphere Programme
- U.S. Climate Change Science Program

II. Science Mission and Capability

Mission of the Science Center
Our world is being transformed as population increases, the climate and environment change, and the needs for water, agricultural, energy, and mineral resources increase. To address societal issues related to this transformation, the Central Region Earth Surface Processes (ESP) Team conducts research on past climatic and environmental changes, the geologic framework of natural resources and hazards, and the interactions among geologic, biologic, and hydrologic systems at and near the Earth's surface. This work supports land and resource management decisions, the search for new sources of key materials, and the assessment of the environmental effects of climate change and human activities.

Priority Science Issues for the Center

In order to achieve our team mission, our primary research priorities and directions in the ESP Team currently include:

- Subsurface framework geology for application to ground-water flow modeling, water availability, and contamination potential studies;
- Structural geologic studies, particularly fault kinematics and fracture characterization for use in ground-water studies and geologic hazard prediction and mitigation;
- Multi-purpose bedrock and surficial geologic mapping for research, resource availability, land-use planning, geologic hazards, and many other uses;
- Climate modeling – past, present, and future;
- Climate variability;
- Paleoclimate and paleoecological modeling and reconstruction via proxies such as vegetation, lake sediments, microfossils (pollen, ostracodes), rock and sediment magnetic properties, and tree-ring data;
- Eolian and dust studies;
- Human impacts of climate change;
- Landscape dynamics.

Core Capabilities for the Center

The ESP team has a broad range of capabilities that allow us to address our research activities, which are commonly integrative in nature. These include:

- Surficial geologic mapping;
- Bedrock geologic mapping;
- Quaternary geology;
- Structural geology;
- Stratigraphy;
- Geochemistry;
- Photogrammetry;
- Climate modeling from global to regional scales;
- Paleoclimate and paleoecological modeling and reconstruction;
- Paleohydrology
- Paleosea-level reconstruction;
- Geomorphology;
- Paleo- and environmental magnetism;
- Palynology

Our research laboratories and analytical facilities are a particular strength of our Team. The following laboratories (shown with the primary projects that use them) provide uncommon and, in some cases, unique capabilities:

- Environmental- and Paleo-Geomagnetism Laboratory – American Drylands, Rio Grande Basins, and CLUES2 projects.
- Soil Geochemistry and Physical Properties Laboratory – American Drylands, Eolian History of North America, Mojave Basins, and CLUES2 projects.
- Palynology Laboratory – Quaternary History of Alaska and CLUES2 projects.

- X-Ray Diffraction and Coulometer Laboratory – American Drylands, Eolian History of North America, and CLUES2 projects.
- Lacustrine Sedimentology and Geochemistry Laboratory – CLUES2 project.
- Radiogenic Isotope Laboratory – multiple projects.
- Geophotogrammetry Facility – multiple projects.
- GIS Laboratory – multiple projects.

Overview of Research Activities

The research activities of the ESP Team may be summarized as geologic mapping, paleoclimate studies, and research on climate variability; however, in detail, the Team's research activities are highly diverse and cover a wide range of science themes. Major project activities include the projects shown in the following table, followed by summaries of each project.

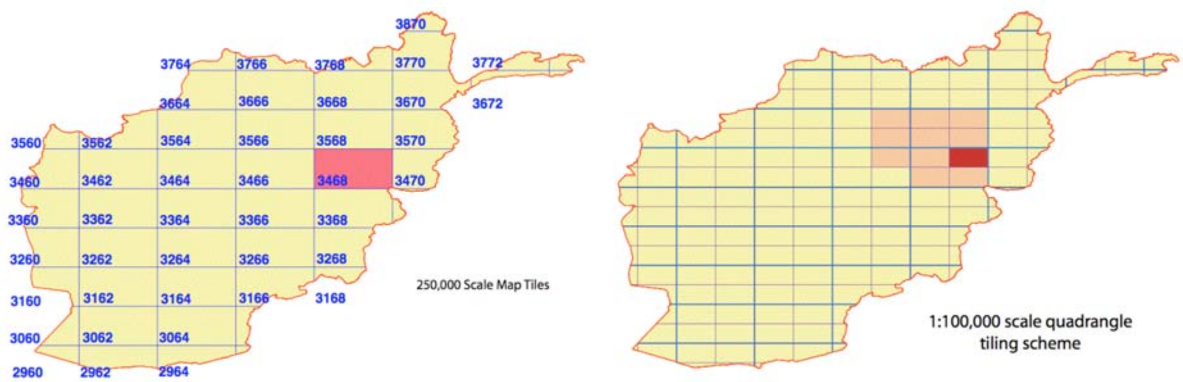
Number	Project Title	Project Chief
7910CH2	Afghanistan Reconstruction Project (Geologic Mapping Task)	Bohannon, Robert G.
8172BEF	Environmental Health in the U.S. - Mexico Border Region	Page, William R.
8929CP0	U.S. Mexico Border Geologic Mapping	Page, William R.
89280DX	CR MRT Central Colorado Assessment (Geologic Mapping Task)	Klein / Kellogg
89280FJ	CR MRT Integrated Studies of Big Bend National Park (Geologic Mapping Task)	Gray / Bohannon / Page
89290EX	Geologic Framework of Rio Grande Basins	Hudson, Mark R.
89290G7	Eolian History of North America	Muhs, Daniel R.
89290HK	Cryospheric Studies	Clow, Gary D.
89290I5	Alaska Quaternary climate history	Ager, Thomas A.
89290J6	Regional Surficial Geologic Mapping, Western Plains and Rocky Mountains	Fullerton, David S.
89290JW	Effects of climatic variability and land use on American drylands	Reynolds, Richard L.
89290K1	Climate Change, Land Use, and Environmental Sensitivity -- Phase 2 (CLUES2)	Thompson, Robert S.
8929C3A	Missouri River Geologic Framework	Lundstrom, Scott C.
8929C44	Exploring Future Flora, Environments, and Climates Through Simulations (EFFECTS)	Shafer, Sarah
8929CM4	Paleohydrologic History of the Mojave Desert Region	Reheis, Marith
8929CNR	Framework Geology of Mid-Continent Carbonate Aquifers	Blome, Charles D.
89320GP	Radiogenic Isotope Laboratory (part of Core Labs Operations project)	Simmons, Kathleen R.
9937C5R	Geology of Parks and Federal Lands of the Southwest (Mesa Verde Task)	Carrara, Paul E.

Brief Summaries of Individual Projects:

(1) Afghanistan Reconstruction Project – Geologic Mapping

Bob Bohannon, Task Leader
Funding: USAID, through USGS International Programs
http://afghanistan.cr.usgs.gov/

To support USAID's Afghanistan Economic restructuring and Rural Development, the USGS is providing technical assistance to work with appropriate Afghanistan government organizations to assist with the development and implementation of a national plan for natural resources assessment. USGS activities fall under six components: 1) capacity and institutional building, 2) geospatial infrastructure development, 3) coal resources, 4) mineral resources, 5) water resources, and 6) earthquake hazards. Accurate, up-to-date geologic maps provide an underpinning for all of these components. Phase 1 of the geologic mapping effort involved digitizing and updating geologic mapping originally produced by Russian geologists in the 1970s at a scale of 1:250,000. The digital data were overlain on satellite images and shaded relief bases generated from Digital Elevation Models. A national-scale geologic map of Afghanistan was also compiled from the Phase 1 data. In Phase 2, maps will be compiled at a scale of 1:100,000 from the best available existing geologic information, relying heavily on satellite and remote sensing data, and incorporating field observations when possible, involving both USGS and Afghan geologists. Each Phase 2 quadrangle will be produced as a PDF map set that includes a geologic and a topographic map, a description of map units, cross sections, and a summary report.



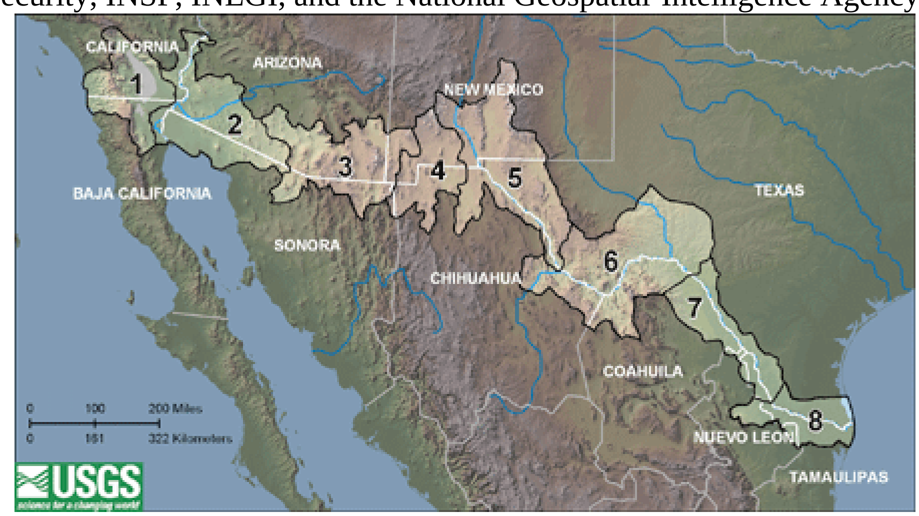
Phase 1 at 1:250,000-scale shown on the left, and Phase 2 at 1:100,000 scale shown on the right.

In addition to mapping tasks, project members are heavily involved in training Afghan geologists and support personnel in the intricacies of both geologic fieldwork and GIS procedures.

(2) Environmental Health in the U.S. - Mexico Border Region
Ric Page, Task Leader
Funding: SIR Border Health Initiative

The major issues surrounding the U.S.-Mexico border involve economics, population growth, and border security that present challenges to environmental management and natural resource planning. To monitor trends and analyze the stresses to the environment, bi-nationally integrated baseline datasets that portray the status of the landscape are needed. Issues of particular concern include: (1) contaminants in ground water, surface water, rock, soil, and biota from agricultural, municipal, and industrial activities; (2) airborne pollutants from fossil-fuel combustion and other activities; (3) contaminants from past and present mining activities and mineral deposits; and (4) pathogens, pharmaceuticals, hormones, and other contaminants released in treated and untreated human and animal wastewaters.

The primary objective of this project is to develop an integrated, Web-based, environmental resource database for display and further analysis within a geographic information system (GIS) framework. This information system, available to the public through an Internet Mapping Service (IMS), provides the data and tools needed to examine the occurrence and distribution of disease-causing agents in the environment and their specific exposure pathways in water, air, biota, rock, and soil. A desired outcome of this project will be an enhancement of opportunities for collaborative research with public health agencies and biomedical researchers as a result of the identification of information gaps. Project development efforts and outreach activities focus on U.S. and Mexican federal agencies, such as EPA, SEMARNAT, PEMEX, Department of Homeland Security, INSP, INEGI, and the National Geospatial-Intelligence Agency.



Border Health Initiative study areas, which are delineated by watershed boundaries.

The Lower Rio Grande Valley, subarea 8, was the pilot project area for the initial effort; consequently it contains the most comprehensive datasets. In 2006 the project began to encompass the entire U.S.-Mexico border region, an area over 157,000 mi^2 and home to more than 12 million people. Efforts will establish a border-wide base map on the Internet Map Service using a medium-resolution basic geospatial framework including satellite imagery, land use and land cover, major transportation networks and digital elevation models with the locations of the major population centers over all eight study areas. The Geologic Discipline efforts are focused on developing the geologic and geophysical framework for each of the eight study areas in an integrated manner, with an aim towards providing seamless geology across the entire U.S. – Mexico border region. Of particular note is the effort to reconcile geologic information across the international border.

(3) U.S.-Mexico Border Geologic Mapping
Ric Page, Project Chief
Funding: NCGMP

The overall objective of this project is to establish the geologic framework of the border region to support border-wide earth science investigations. This main objective will be met by compiling detailed (1:100,000 to 1:24,000-scale) geologic map datasets and integrating geophysical and geochemical data in defined study areas. The objectives for FY 2007 include:

- Assessment of all existing geologic mapping and geophysical and geochemical data;
- Continue program development by identifying and prioritizing issues to be addressed, and identifying areas of common scientific interest with other USGS programs as well as needs of other government agencies with borderland responsibilities;
- Define and prioritize project study areas;
- Develop a 5-year workplan for carrying out geologic studies beginning in FY 2008.

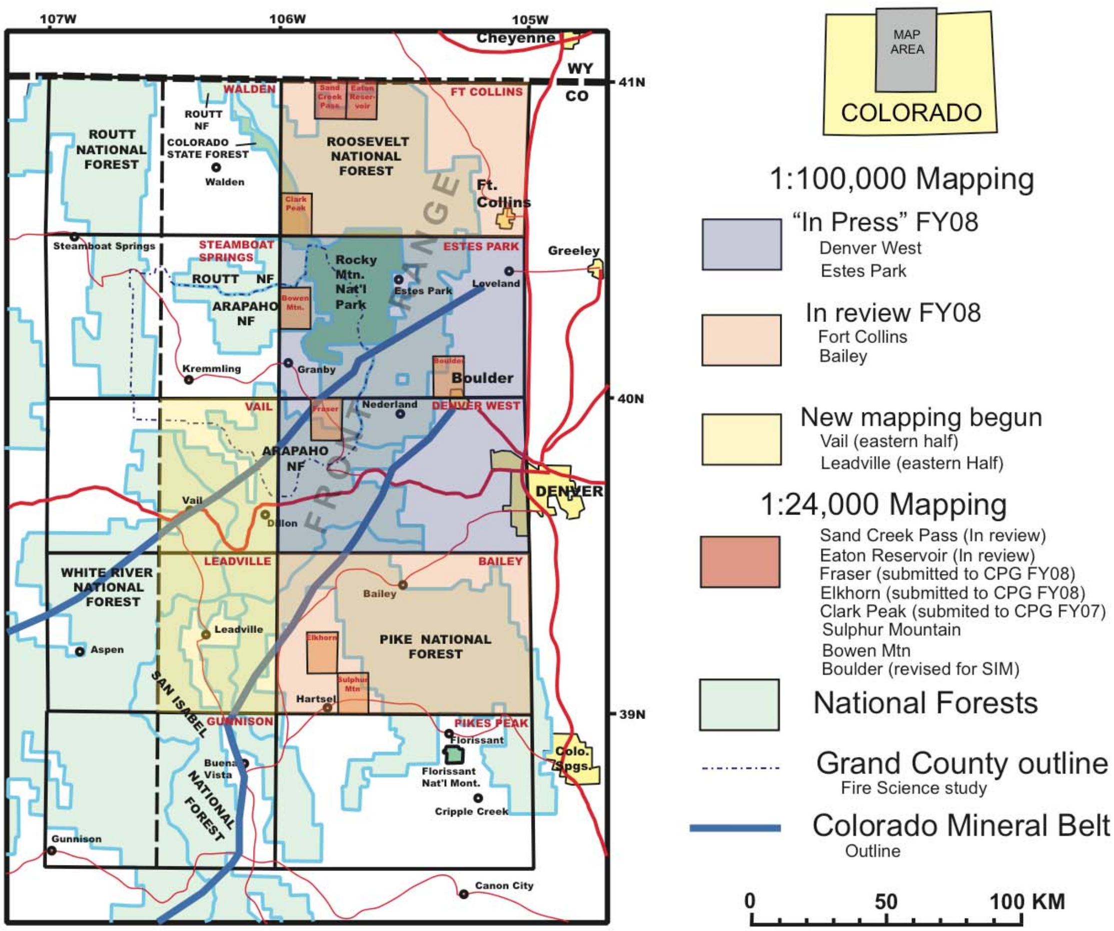
A pilot US-Mexico border geologic mapping project would provide a logical follow-up to existing border projects, including the Big Bend project, of which the geologic mapping task ends in 2008, and the US-Mexico Border Environmental Health Initiative, which may only have one additional year of funding. A pilot project to explore further border issues and assess the current state of relevant geologic data would provide a platform for expansion and development of a broader US-Mexico Border project needed to address other important issues including border security, trans-boundary aquifer modeling, mineral resource assessment and development, environmental geochemistry, water availability and quality, global change, and ecosystem studies. Addressing these issues requires bi-national geologic mapping, geophysics, and geochemical data as fundamental geospatial datasets. A FY 2007 pilot study helped to establish a core geologic mapping team that would assess current border mapping, identify potential funding sources, define and prioritize issues and related study focus areas, and carry out geologic mapping activities to help address the many important border-wide issues. Such a project might also attract OFA interest and funding from agencies including NORTHCOM, DHS, DOD, and DOI land management agencies with responsibilities along the border such as NPS, BLM, and FWS.

It is envisioned that the project will focus on site-specific geologic framework studies, such as producing detailed maps and conducting geophysical and geochemical surveys to support ground- and surface-water modeling, tunnel prediction, and geoenvironmental issues, but initiation of these tasks depends on the availability of future funding from potential project collaborators. Our studies would also contribute to, and participate in, investigations of geologic hazards, such as landslide, earthquake, wildfire, and flood hazards, and mineral resources assessment and environmental geochemistry.

(4) Central Colorado Assessment (Geologic Mapping Task)
Terry Klein and Karl Kellogg, Co-Task Leaders
Funding: jointly by MRP and NCGMP
http://esp.cr.usgs.gov/research/central_colorado/index.html

The mission of the Framework Mapping Task is to provide accurate geologic maps and topical studies of the Colorado Front Range region that help to sustain and improve the quality of life and economic vitality of the region and mitigate natural hazards. The Front Range urban corridor in north-central Colorado, with a population growth of more than 30 percent since 1990, stretches about 350 km from Pueblo in the south, through Denver, north to the Colorado-Wyoming border. Important resource and land-use management issues throughout central Colorado, especially in the mountainous region west of the urban corridor, include: (1) ongoing assessment of the quantity and quality of ground and surface waters, (2) accurate assessment of industrial and mineral resources, (3) environmental effects of abandoned mine lands on National Forest and private lands, (4) geologic hazards, such as landslides and stream flooding, and (5) long-term effects of forest fires on erosion and deposition, all exacerbated by a warming and drying climate. Of particular concern are hundreds of old mines and prospects within the northeast-trending Colorado mineral belt that, due to acid-water and trace-metal contamination, threaten the quality of both surface and ground water. Addressing these and other land-use issues requires accurate and up-to-date digital geologic maps and related topical data.

The project entails mapping and remapping poorly understood areas in order to create state-of-the-art, digital databases. These include 1:100,000-scale geologic maps of the Fort Collins, Estes Park, Denver West, Bailey, and eastern halves of the Vail and Leadville 1:100,000 quadrangles, in addition to several 1:24,000-scale geologic quadrangle maps.



CENTRAL COLORADO ASSESSMENT PROJECT - TASK 2
(Framework studies of the Colorado Front Range region - status of mapping, FY08)

Several topical studies being conducted concurrently with the mapping include (but are not limited to): (1U-Pb zircon dating and neodymium studies of Proterozoic basement rocks, using the SHRIMP facility in Menlo Park, California, to characterize and better understand the Proterozoic history of the Front Range region, (2) determining $^{39}Ar/^{40}Ar$ ages of Laramide and Tertiary plutons and hydrothermal alteration that accompanies many of these plutons, (3) fracture analysis related to groundwater flow in several areas in the Front Range, (4) characterization of the metamorphic history of the Front Range basement rocks, (5) a more detailed understanding of the Quaternary history of the Front Range region, and (6) geologic response to wide-spread destruction of lodgepole pines by pine-bark beetles in Grand County, and the possible catastrophic wild fires that may result (Fire-Science study).

The project in its present form will end September 30, 2009. Plans for a new project that will continue 1:100,000-scale to the south of the present mapping area are currently being discussed, and include mapping of the Pikes Peak 1:100,000 quadrangles and eastern halves of the

Gunnison and Canon City 1:100,000 quadrangles. This mapping is intended to integrate with future mapping in southern Colorado by the Rio Grande Basins Project (RGBP).

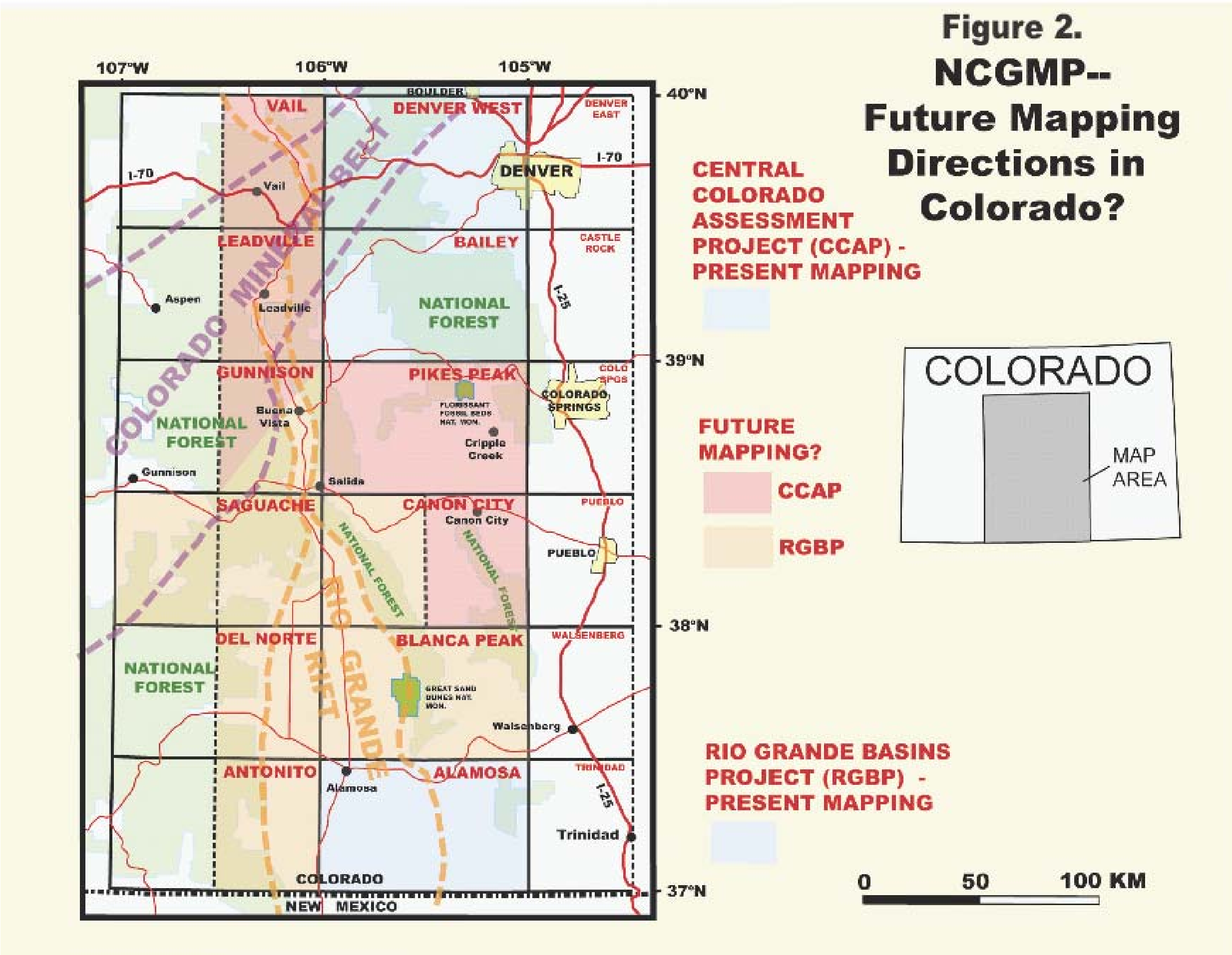


Figure 2. NCGMP-- Future Mapping Directions in Colorado?

(5) Integrated Studies of Big Bend National Park
John Gray and Bob Bohannon, Co-Project Chiefs
Funding: jointly by MRP and NCGMP
http://esp.cr.usgs.gov/info/bigbend/index.html

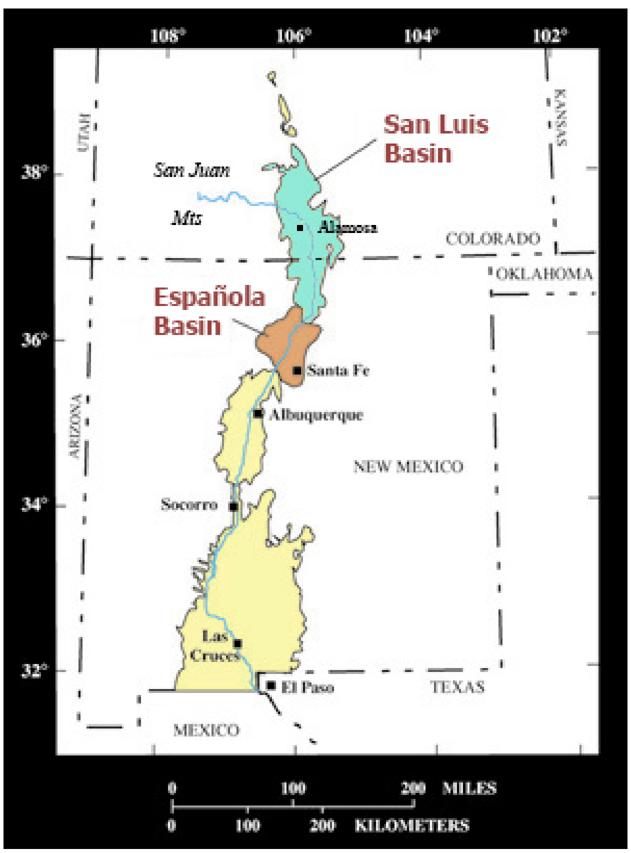
Big Bend National Park is the 8th largest national park in the contiguous United States and hosts about 350,000 visitors annually. The Park contains a variety of world-class volcanic, structural, geomorphological, and paleontological examples. Mapping by Maxwell (1966) synthesized earlier work, but updated mapping is required to investigate unresolved issues related to volcanic and surficial stratigraphy as well as the volcanic, plutonic, and tectonic evolution of the park. An updated map of the park will provide the National Park Service with a digital geologic map to address resource management issues, including land use planning, surface and groundwater quality and quantity, wildlife and plant inventories and monitoring, habitat sustainability, and ecosystem and antiquities preservation. The major objective of this task is to produce a

1:100,000-scale geologic map of the park. The final map products will be a printed map and pamphlet, and a GIS dataset.

Mapping of Big Bend National Park is a cooperative effort between federal, state and academic agencies, including the National Park Service, Texas Bureau of Economic Geology, Texas Tech University, University of Texas, Lamar University, Texas Christian University, Baylor University, and Sul Ross University, among other schools.

(6) Geologic Framework of Rio Grande Basins
Mark Hudson and Tien Grauch, Co-Project Chiefs
Funding: jointly by NCGMP and MRP

This project investigates the geologic framework of the Rio Grande region in different areas along the course of the river through the southwestern U.S. to provide information on critical ground-water aquifers, hazards (seismic, subsidence, landslide), and resources (minerals, energy). Project activities include geologic and geophysical mapping for important basins (e.g., Espanola, San Luis, Santo Domingo, Albuquerque) of the Rio Grande rift in parallel with mapping by the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) and the Colorado Geological Survey (CGS), supported by STATEMAP, and academic mapping, supported by EDMAP. Mapping is integrated with studies of stratigraphy, biostratigraphy, magnetostratigraphy, and hydrogeologic characteristics of basin-fill sequences, and structural geology with emphasis on major faults and their effects on groundwater. Geophysical mapping uses high-resolution aeromagnetic, gravity, and electromagnetic surveys to understand faulting and basin geometry. By exploring relations among rift tectonics, late Cenozoic climate, Santa Fe Group sedimentation, bimodal volcanism, and landscape evolution, the project forecasts subsurface hydrogeologic characteristics in areas where subsurface information is sparse.



Basins of the Rio Grande encompass the main metropolitan areas of northern New Mexico (e.g., Santa Fe and Albuquerque) and are home of half the population and a similar part of the economy. In Colorado, the San Luis basin is center of an extensive agricultural economy and host of the Great Sand Dunes National Park and Monte Vista Wildlife Refuge. Linked by the through-flowing Rio Grande along the tectonic trough of the Rio Grande rift, the vitality of basin communities and economies depends on a growing supply of water extracted from complex aquifers, mostly in Santa Fe Group rift-basin sediments. Water withdrawals are regulated by New Mexico and Colorado State Engineers Offices to maintain the long-term utility of the aquifers, to satisfy regulatory and treaty commitments for instream flow of the Rio Grande, to avoid subsidence due to pumping, and to avoid low-quality or contaminated ground water. Knowledge of the aquifer systems and the linkages between recharge, ground-water flow, lithologic and stratigraphic characteristics, fault displacements, alteration/cementation, and productivity/sustainability of the resource are poorly known outside areas of production wells.

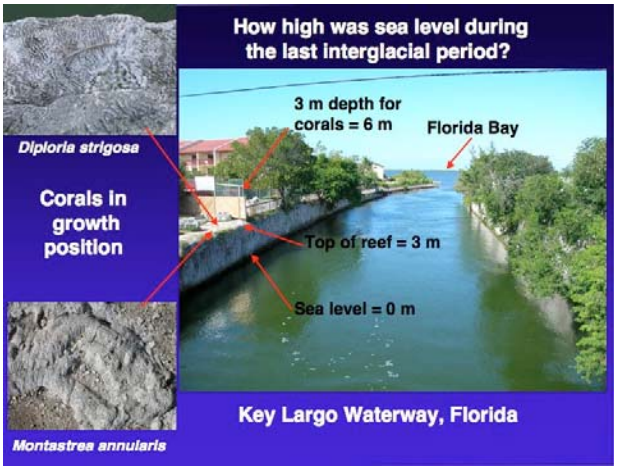
Gravity, magnetic, and electromagnetic geophysical methods are used in the northern and central Rio Grande rift in New Mexico and Colorado, including the Albuquerque, Santo Domingo, Espanola, and San Luis basins, to determine (1) thickness and facies of basin-fill aquifer system, (2) locations of basin-bounding and intrabasin faults, and (3) the lateral and vertical extents of buried igneous rocks. Geologic and geophysical constraints are integrated to build three-dimensional geologic models that illustrate important aspects of not only the hydrogeology of Rio Grande basins, but also their structural framework, rift development, and sedimentation history. Future project activities will continue to be focused on the San Luis basin of both

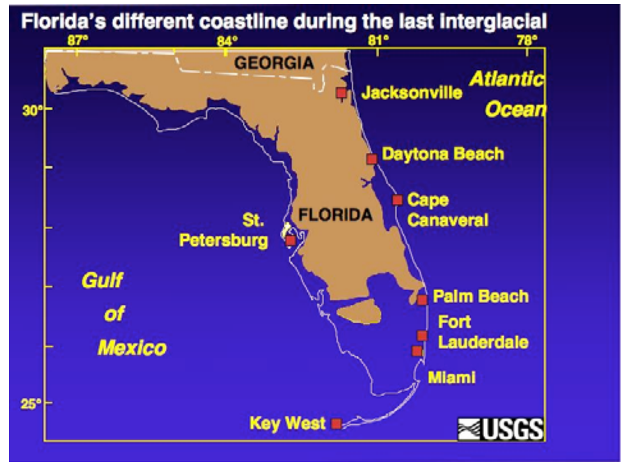
(7) Impacts of Climate Change on Coastal and Eolian Landscapes
Dan Muhs, Project Chief
Funding: ESDP
http://esp.cr.usgs.gov/info/eolian/

The objectives of this project are:

Task 1: to understand the impacts of climate change on coastlines of the USA by examining evidence of past high sea stands. Such past high stands may be analogs for the future, both for the magnitude and extent of sea level rise and the reorganization of ocean currents and effects on marine organisms.

Our current efforts are to understand the timing and paleoenvironments of high sea stands in the past four most recent interglacial periods, about 120,000 yr BP; ~200,000 yr BP; ~300,000 yr BP; and ~400,000 yr BP. These interglacials were very distinct from one another, but all were characterized by being exceptionally warm periods of the past 2.6 million years. Two of them, the ~120,000 and ~400,000 yr BP high sea stands, are known or suspected to have had sea levels higher than present. Thus, these periods provide crucial evidence of what could happen on coastlines in a warmer Earth. For example, we know that tectonically stable southern Florida has emergent coral reefs that indicate a sea level several meters higher than present (below, right). A similar high sea stand in the future would submerge most of southern Florida's largest cities (below, right).





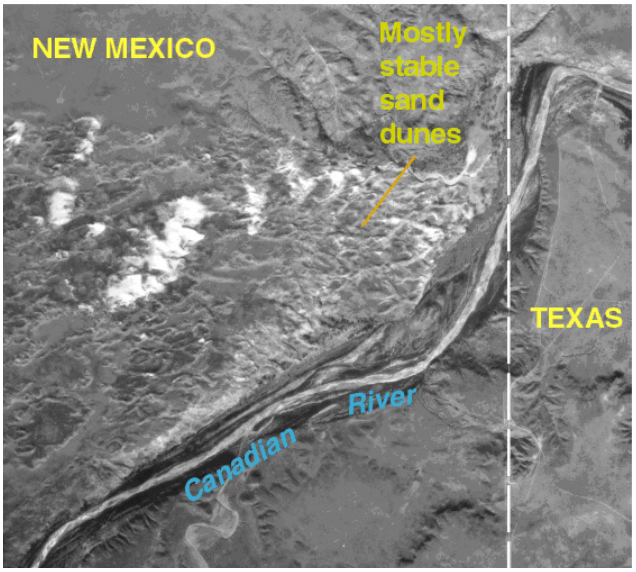
Task 2: to understand the impacts of climate change on arid and semiarid landscapes where wind: (1) plays an important role in landform development, such as dune fields; (2) leaves crucial records of past climate change, such as dune fields; and (3) where wind-blown dust additions play a significant role in soil genesis. There are three subtasks:

- ***Subtask 1, Eolian sand:*** to understand the processes responsible for sand dune activity in the U.S. and to assess the potential for reactivation of stabilized sand dunes in the U.S. under changing conditions of climate and land use;
- ***Subtask 2, Loess***: to investigate records of natural climate variability recorded in loess deposits;
- ***Subtask 3, Airborne dust:*** to test hypotheses about the role of dust in climate change and to assess the importance of far-traveled, airborne dust in soil formation.

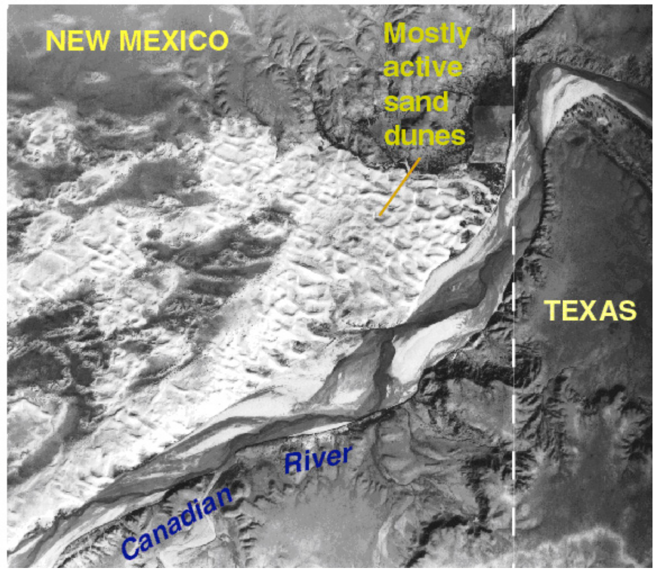
Subtask 1: Eolian sand

During the last glacial period, there were large areas of active dunes in the Great Plains, some even large enough to dam major rivers, such as the Platte River in Nebraska. Many areas of the Great Plains have had active sand dunes in the very recent past (the past thousand years or so), where dunes are presently stable. This means that these dunes can be potentially reactivated under a climate not very different from the present one. We now think that moisture balance and degree of vegetation cover are more important than wind in determining whether dunes are active or not. Actively moving dunes have been identified on 1936 and 1938 aerial photographs in North Dakota, Colorado, Kansas, Oklahoma, Texas, and New Mexico. Results of aerial photograph interpretation and analysis of historic climate data suggest that the most likely cause of activation in the 1930s was loss of vegetation cover due to increased temperatures and decreased rainfall (comparative photos below).

QUAY COUNTY, NEW MEXICO, 1991:

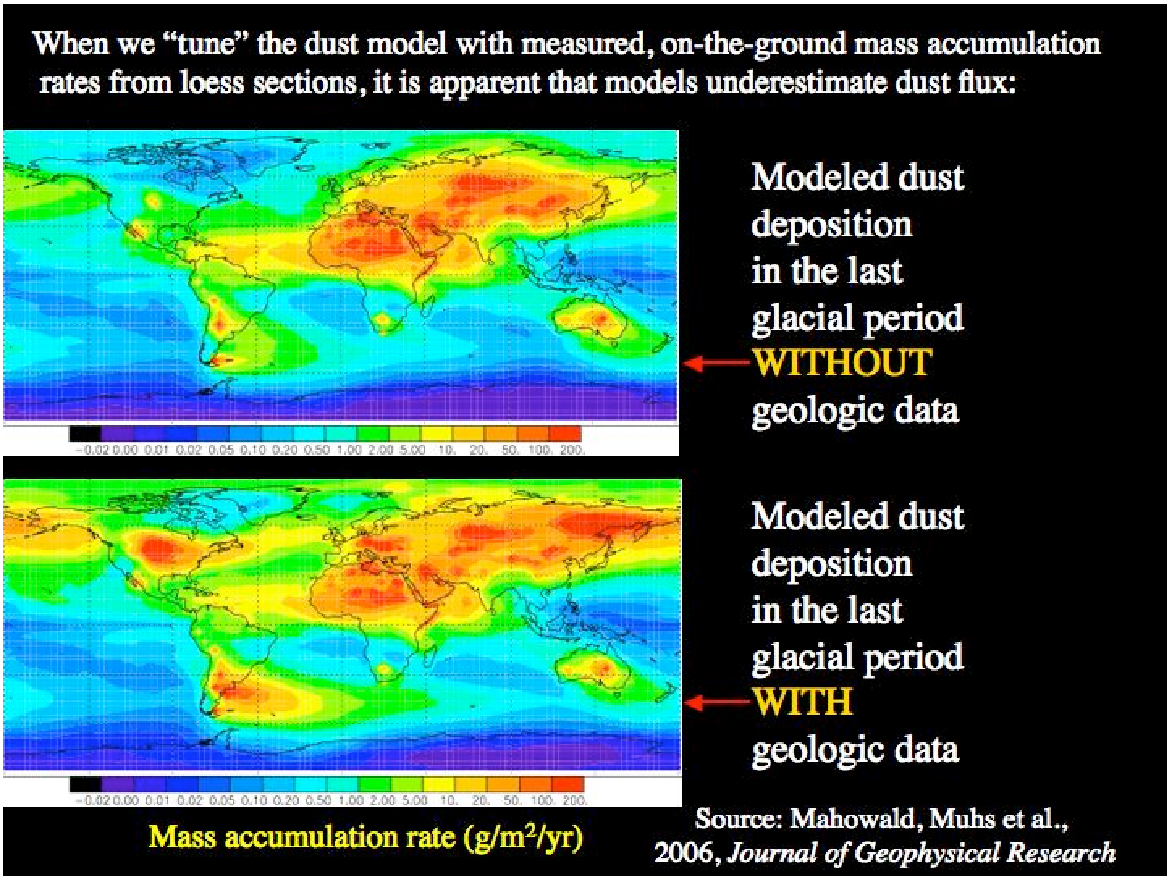


QUAY COUNTY, NEW MEXICO, 1936:



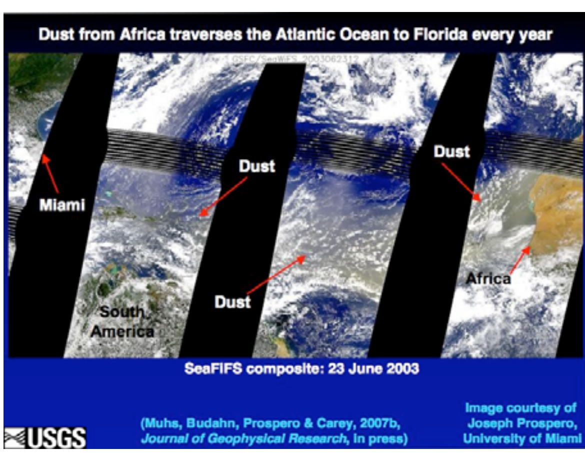
Subtask 2: Loess

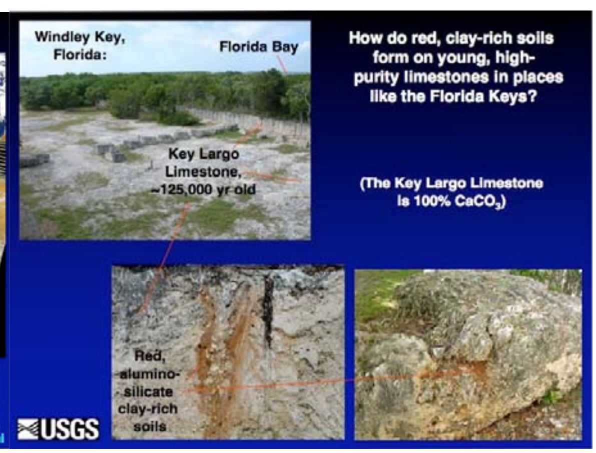
Atmospheric scientists are now recognizing that dust is an important record of climate, but also that dust itself may alter climate through its effects on planetary radiation balance and iron fertilization of phytoplankton in the ocean. Loess deposits in the Great Plains and Midwest record the highest known dust fluxes on the planet during the last glacial period. However, climate models have had difficulty in generating the tremendous dust flux during this period (map below, upper), consistently underestimating loess deposition rates. Much of our work has been on documenting (a) the rates of dust flux during the last glacial period through stratigraphic and geochronologic studies and (b) identifying sources of loess. Isotopic and geochemical studies show that much of the loess in the Great Plains region of Nebraska, Colorado, and Kansas is not derived from glacial flour, but rather from the silt-rich, but poorly consolidated bedrock of the White River Formation. This finding is important because it means that during the last glacial period, conditions on the northern Great Plains were very dry and windy, with even less vegetation cover than is the case today. We have partnered with climate modelers to compare dust models done both with and without geologic data. When geologic data are incorporated into climate models, dust transport during the last glacial period was more dramatic (map below, lower). The fine-grained portion of this loess, while still in transit, may have altered the overall solar radiation balance in the region and after deposition it may have provided much more iron to the ocean’s primary producers (phytoplankton) than previously thought.



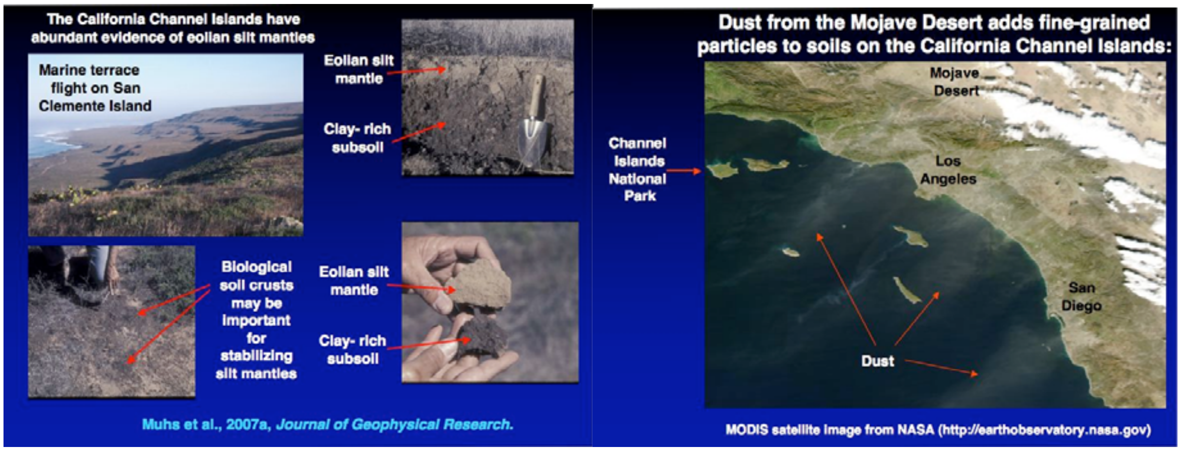
Subtask 3: Airborne dust

We now know that airborne dust reaches far greater distances over the globe than was ever appreciated by geologists before the advent of Earth-observing satellites. African dust is transported west all the way across the Atlantic Ocean to the eastern seaboard of the USA and Caribbean islands (below left). We have confirmed that African dust comprises a significant component of soils from Florida (below right) and south to at least Barbados.





Geochemical studies show that silt mantles that overlie soils on andesite or basalt bedrock in Channel Islands National Park and the southern Channel Islands of California are probably derived from mainland fluxes of dust, rather than weathering of the local bedrock (photo below left). Such dust additions are possible under easterly "Santa Ana" winds (photo below right). The silt mantles form the soil A horizons (topsoils) that are the medium of growth for many of Channel Island National Park's endangered plants.



(8) Cryospheric Studies
Gary Clow, Project Chief
Funding: ESDP

This project focuses on: a) *monitoring* climate and environmental change on federal lands in arctic Alaska, b) *modeling* climate and environmental change in arctic Alaska through the end of this century, and c) reconstructing past climate changes in the polar regions using borehole paleothermometry.

Monitoring: Climate projections by the latest global coupled Atmosphere-Ocean General Circulation Models (AOGCMs) suggest significant environmental changes will occur in the Arctic during the next 40-100 years (ACIA, IPCC). According to these models, climate change will be Arctic-wide with a pronounced enhancement over the Arctic Ocean and adjacent coastal plains. Projected changes include: a near-total loss of summer sea ice on the Arctic Ocean by mid-century, a 90% loss of shallow permafrost in the Northern Hemisphere by 2100, significant changes in wildlife habitat and ecosystems, large impacts on native peoples, enhanced CO_2/methane releases from warming permafrost exacerbating global climate change, amplified coastal erosion, and increased vulnerability of high northern infrastructure to permafrost instability. Given the large potential impacts and the uncertainty in the model projections, a comprehensive monitoring effort is warranted.

USGS (in cooperation with BLM and FWS) is developing a long-term permafrost- and climate-monitoring network (DOI/GTN-P) on federal lands in northern Alaska as part of the Global Terrestrial Network for Permafrost and the Global Climate Observing System (GCOS).

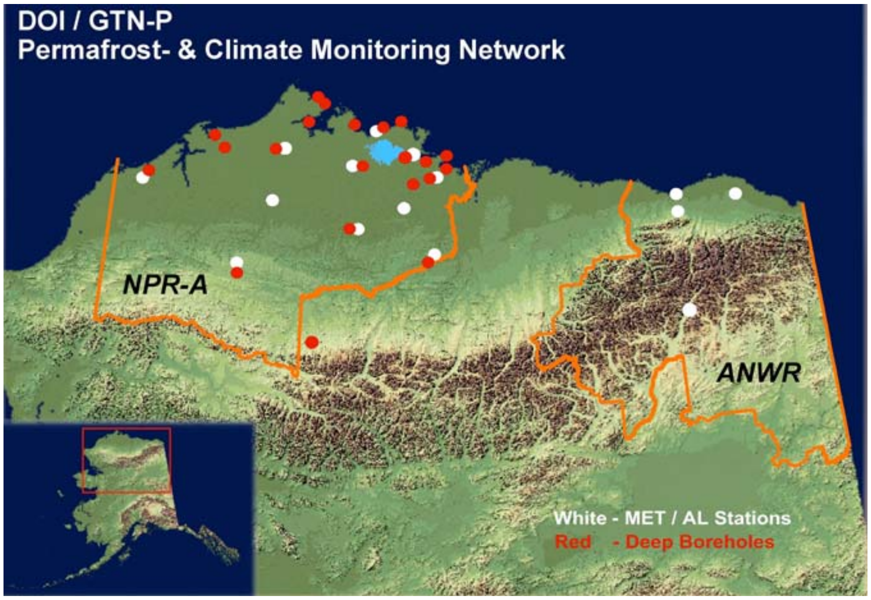


Figure 1. DOI/GTN-P permafrost- & climate-monitoring network in arctic Alaska. The deep borehole array spans the National Petroleum Reserve Alaska while the automated surface stations span both the NPR-A and the Arctic National Wildlife Refuge (ANWR).

DOI/GTN-P consists of two subnetworks: 1) An array of 15 automated meteorological/active-layer stations, and 2) a 21-element deep borehole array. Many of the automated surface stations are co-located with deep boreholes, forming Permafrost Observatories. The automated MET/AL stations continuously monitor temperature and moisture conditions in the permafrost active-layer as well as several other essential climate variables (air temperature, wind speed and direction, shortwave radiation, albedo, snow depth). These data are providing a wealth of information regarding current environmental conditions across arctic Alaska and will be invaluable inputs for predictive landscape- and ecosystem-change models. Data from part of the automated network is available through real-time telemetry to assist DOI land managers with their day-to-day operational decisions. Periodic temperature measurements in the DOI/GTN-P borehole array are used to monitor the *thermal state of permafrost* deeper than a few meters. Data obtained thus far from the borehole array show that shallow permafrost temperatures on the Arctic Coastal Plain changed little during the late-1970s and 1980s but have warmed about 3.5°C across the array since 1989. This warming is large enough that many sites are approaching or have already passed the -5°C mean-annual ground-temperature threshold traditionally used to estimate the location of the continuous/discontinuous permafrost boundary. This observation suggests that if climate were to remain fixed at where it is today with no further warming, the continuous/discontinuous permafrost boundary would eventually jump from its current location south of the Brooks Range to a new location on the Arctic Coastal Plain.

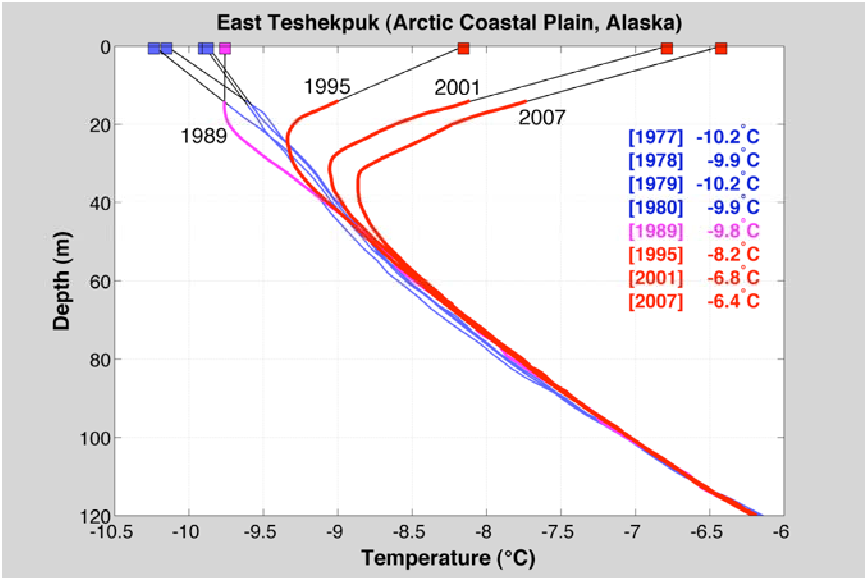


Figure 2. Permafrost temperatures measured in the East Teshekpuk borehole on the Arctic Coastal Plain. Mean-annual surface temperatures have increased about 3.6 K at this site since the late 1970s.

Modeling: Climate change is projected to have a significant impact on federal lands during the next few decades, particularly in Alaska. However, the severity and spatial distribution of these impacts are poorly known at this time. To develop optimal strategies for managing DOI lands in the face of climate change: 1) Coarse-scale AOGCM climate projections for the next few decades need to be "downscaled" to the local and regional scales most relevant to DOI land managers. 2) The downscaled climate projections will need to be used to drive local/regional scale landscape-change and ecosystem-change models.

To satisfy these needs, the Cryospheric Studies project is developing a high-resolution *dynamical* downscaling capability within DOI that will complement statistical downscaling methods already in use by other USGS projects. The dynamical method we are pursuing is the next-generation regional climate model (WRF) developed under the sponsorship of the National Center for Atmospheric Research (NCAR). This model is expected to be suitable for a wide range of applications of interest to DOI. WRF is now running on our climate-modeling computer in Denver. Preliminary test simulations in northern Alaska and elsewhere look very encouraging. Once NCAR completes the AOGCM-to-WRF interface (should be done within a year), we will be able to use WRF to downscale AOGCM future climate projections to about 1-km resolution. Over the next few years we plan to couple WRF to landscape-change and ecosystem-change

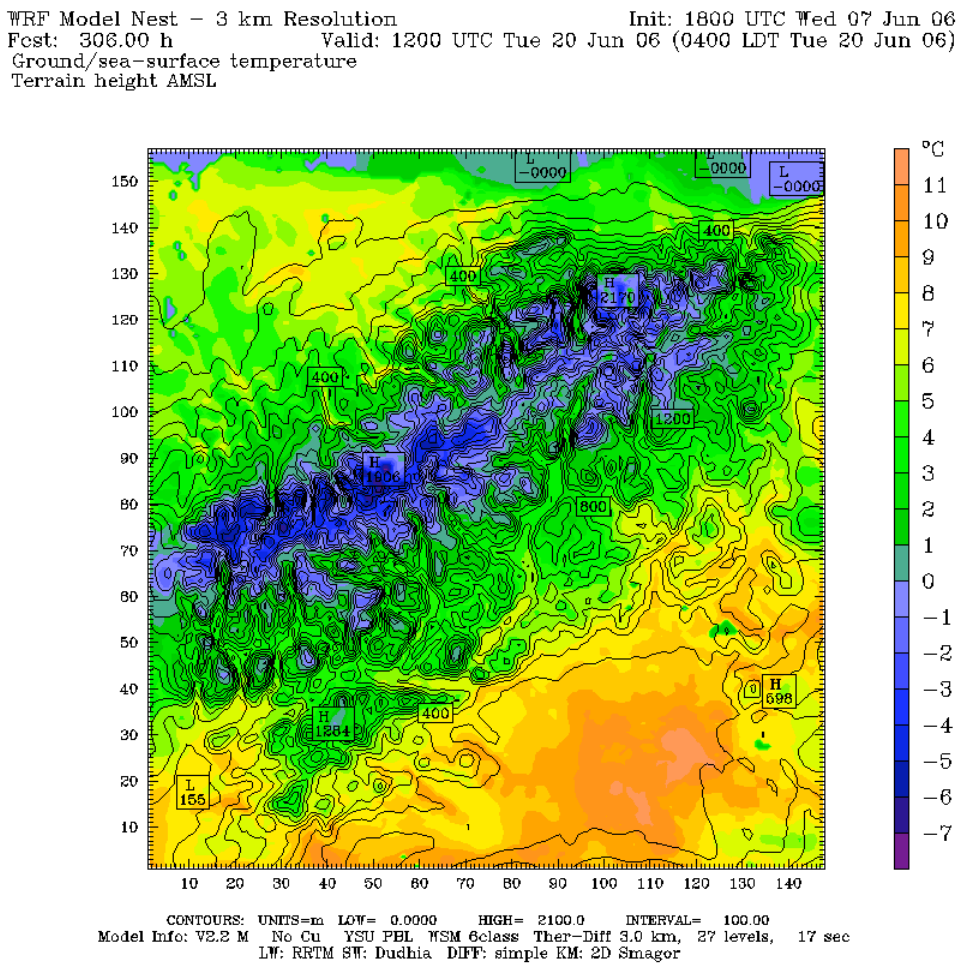


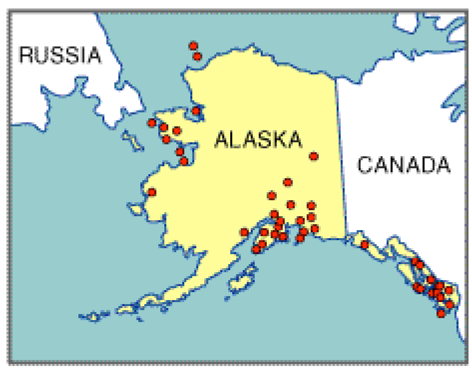
Figure 3. Surface temperatures calculated by the WRF regional climate model running at 3-km resolution for the Arctic and Yukon Flats NWRs at 0400 ADT on 20 June 2006. WRF accounts for numerous effects including: atmospheric dynamics, radiation, cloud shadowing, topography, vegetation, and soil conditions.

models. In this way, WRF would act as the bridge, enabling the cascade of processes from global-to-local to be linked. The severity and spatial distribution of climate impacts in northern Alaska will then be explored.

<u>Reconstructing Past Climate Changes</u>: The final aspect of the Cryospheric Studies project is the reconstruction of past climate changes in the polar regions using *borehole paleothermometry*. Surface-temperature reconstructions based on this method are derived through geophysical inversion of precise borehole temperature measurements. Climate changes derived in this way are generally much more accurate than those based on proxy methods. Our primary objective under this task is to help improve our understanding of the Earth's climate system and its capacity for change by producing *accurate* temperature reconstructions of the polar regions during the last 40 ky. This will: a) help document the range of natural climate variability in the polar regions, b) improve our understanding of the response of the climate system to changes in external forcings, and c) better establish the magnitude of the tropics-to-poles meridional temperature gradient during glacial and interglacial times; it is this gradient that fundamentally drives the dynamics of the Earth's atmosphere and oceans.

(9) Alaska Quaternary Climate History
Tom Ager, Project Chief
Funding: ESDP
http://esp.cr.usgs.gov/research/alaska/index.html

This project involves reconstruction of the late Pleistocene and Holocene history of environmental change in Alaska, focusing primarily upon the past 30,000 years, using the geological evidence (especially pollen records) from the late Quaternary as a means of examining past climate changes and the ecosystem responses to those changes. The methods employed in this study involve sampling of deposits (bogs, lakes, and natural exposures) that contain fossil pollen, plant macrofossils, and sometimes ostracodes and diatoms. The project has focused mostly upon the late Pleistocene and Holocene history of (1) Tongass National Forest in southeastern Alaska; (2) south-central Alaska, including Chugach National Forest; and (3) western Alaska, Bering Sea and Chukchi Sea (locations of some of the study areas are shown as red dots on the map at right). Some additional research has been done recently in interior Alaska.



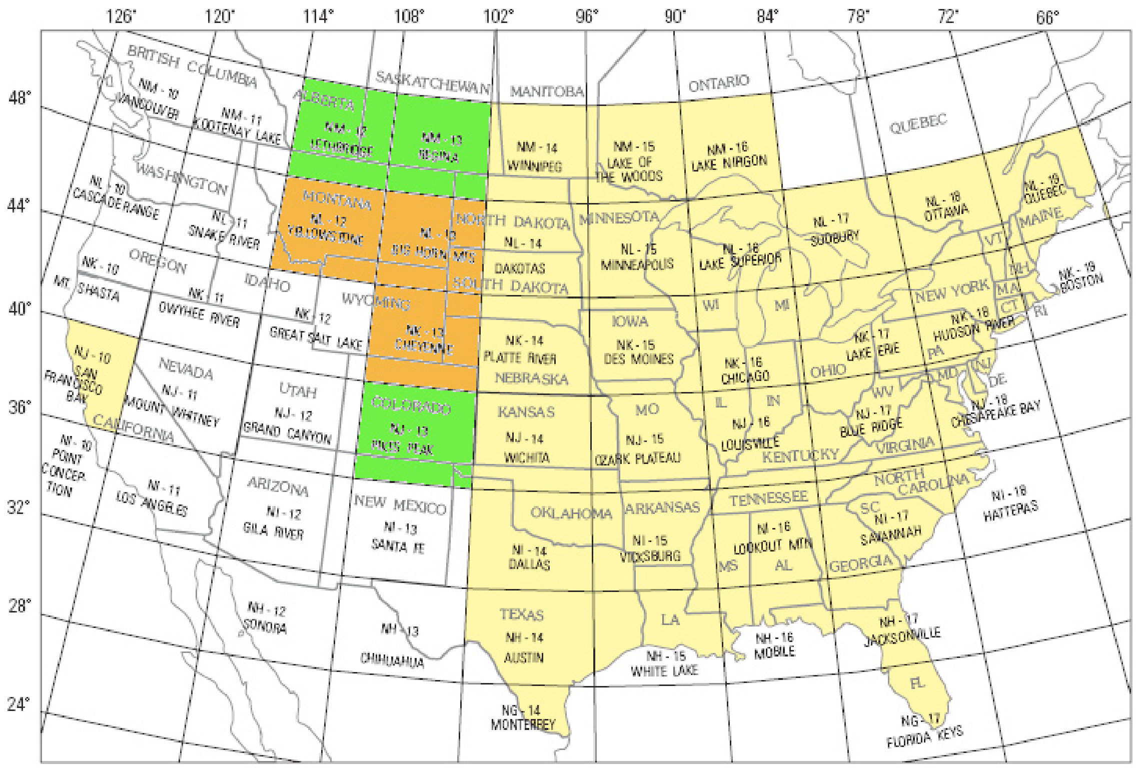
High latitude ecosystems are highly sensitive to climatic change. Today Alaska is undergoing rapid environmental changes (e.g., rapid glacial retreat, thinning sea ice, vegetation changes, permafrost degradation, lengthening of snow free season, coastal erosion, massive outbreaks of pathogenic insects in forests, increasing frequency and severity of fires). Similar events have happened in the past, and therefore studies of the geological record may provide important insights into the likely consequences of ongoing and future climate changes. Studies are aimed primarily at reconstructing the late Quaternary histories of each of the three major vegetation types in Alaska: coastal rainforest, boreal forest, and arctic and alpine tundra.

The objectives of this study are (1) to reconstruct detailed histories of terrestrial ecosystem changes during the late Quaternary across Alaska from geologic evidence preserved in lakes and peat deposits; (2) to interpret wherever possible apparent linkages between past ecosystem changes and known climatic events in Alaska; (3) to apply the new knowledge of ecosystem history and ecosystem responses to climate change to problems of land use management, archeology, vertebrate paleontology and climate modeling through our own research as well as collaborative research with scientists from other agencies and academic institutions; (4) conduct studies of pollen records from marine cores obtained on the continental shelf and slope of Gulf of Alaska during an NSF-funded oceanographic cruise in 2004 (Ager was a participant), to evaluate the potential for offshore-onshore correlation of pollen zones and for combining paleoclimatic reconstructions from terrestrial and marine climate proxies.

Ager's past research in Alaska has shown that very dramatic changes in Alaska's climates have occurred that radically altered the ecology of the region. During the middle Miocene, for example, a major global warming event (ca. 17-15 Ma B.P.) allowed the development of temperate broadleaf-conifer forests that covered much of interior and south-central Alaska. Forests at that time included many tree types that now grow in places like Pennsylvania and Virginia: oak, basswood, chestnut, beech, maple, sweetgum, ash, hickory, walnut, and redwood.

(10) Regional Surficial Geologic Mapping, Western Plains and Rocky Mountains
David Fullerton, Project Chief
Funding: NCGMP

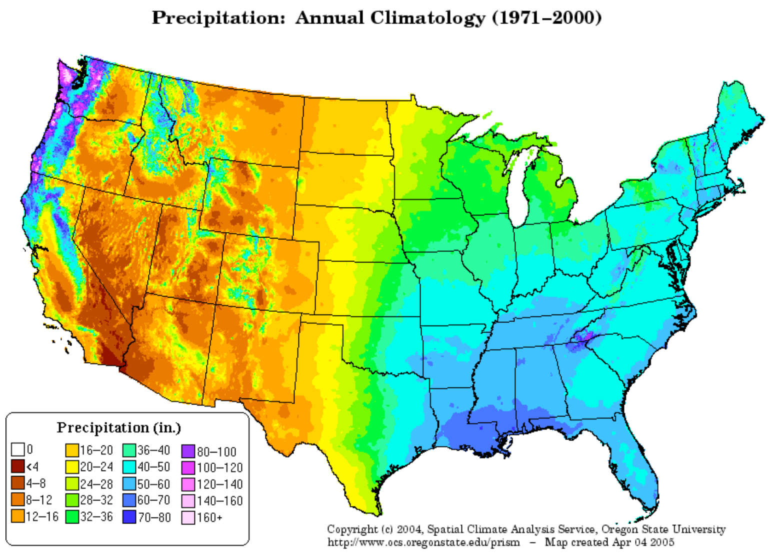
The project is producing 4° x 6° quadrangle maps and quadrangle maps at larger scales showing surficial deposits and materials and rocks of Quaternary age in the western Great Plains and Rocky Mountains in the U.S. and adjacent Canada. The 4° x 6° quadrangle maps are basic sources of regional overview information related to surficial deposits and materials and rocks of Quaternary age in the U.S. and adjacent Canada. They are used by the Environmental Protection Agency, The Nature Conservancy, and other agencies and organizations in ecological classification mapping programs. The small-scale surficial geologic maps depict the areal distribution of surficial deposits and materials and rocks of Quaternary age, and emphasize their physical, chemical, and engineering properties. They facilitate regional, national, and international overviews of geologic hazards (e.g., flood-prone areas; landslide deposits and landslide-prone deposits and materials; areas of expansive clay), natural resources (e.g., sources of aggregate, peat, clay; potential sources of shallow ground water), and areas of environmental concern (e.g., wetlands; areas of intense erosion; surface mines, tailings, and spoil; areas of potential soil and ground-water contamination). The maps, texts, and supplemental illustrations relate to regional land use, management, and policy. They provide a database to reconstruct geologic history, climatic changes, changes in major river systems through time, and to establish the stratigraphic and chronologic frameworks of surface and subsurface deposits and materials and rocks of Quaternary age.



INDEX TO INTERNATIONAL MAP OF THE WORLD 1:1,000,000 TOPOGRAPHIC SERIES
Published maps in the "Quaternary Geologic Atlas of the United States" (U.S. Geological Survey Miscellaneous Investigations Series I–1420) shown in yellow. Green indicates quadrangles in preparation; orange are planned.

(11) Effects of Climate Variability and Land Use on American Drylands
Rich Reynolds, Project Chief
Funding: ESDP
http://esp.cr.usgs.gov/info/sw/

Arid and semi-arid lands and are among the Nation's most sensitive regions to climatic change and land-use practices. Combinations of natural factors (such as short-term climatic change) and vastly expanding population, especially in the Southwest, place unprecedented pressures on our dry landscapes and their ecological resources. The existing and potential impacts make American drylands a national priority for understanding environmental change and its effects on both human-dominated and natural systems. In particular, interactions among scientific understanding, land management, societal adjustment, and local to regional planning require contributions and collaborations across many arenas of natural and social sciences. Examples of key problems include physical impacts of drought and wet periods, ecosystem health (e.g., invasive plant species), human health, water quality and quantity, carbon cycling, as well as fire frequency and impacts.



Arid and semi-arid lands compose about one half of the Lower 48 states. Arid lands have less than 250 millimeters (about 10 inches) of annual rainfall, and semiarid lands have a mean annual precipitation of between 250 and 500 millimeters (between about 10 and 20 inches).

This project addresses the need to understand, monitor, and predict changes in physical and ecological landscapes of American drylands and how these changes can and will influence landscape stability, ecosystem dynamics, and human communities. With new understanding of interactions among physical, biogeochemical, and human systems, and of the responses of these systems to forcing from climate and demographic change, we provide information as well as forecasts of near-term changes in physical and ecologic landscapes to federal, state, local, and Native American agencies and communities, for their land-use planning, management of resources, and protection of human health.

During FY09, the Project will focus on integration of interacting climate, surface processes and deposits, vegetation, and dust across regions, partly enabled by new capability on climate modeling. Aims will include (1) understanding the process-scale controls on biological invasions of drylands and (2) forecasting future dust sources, loads, and compositions, with bearing on human health.

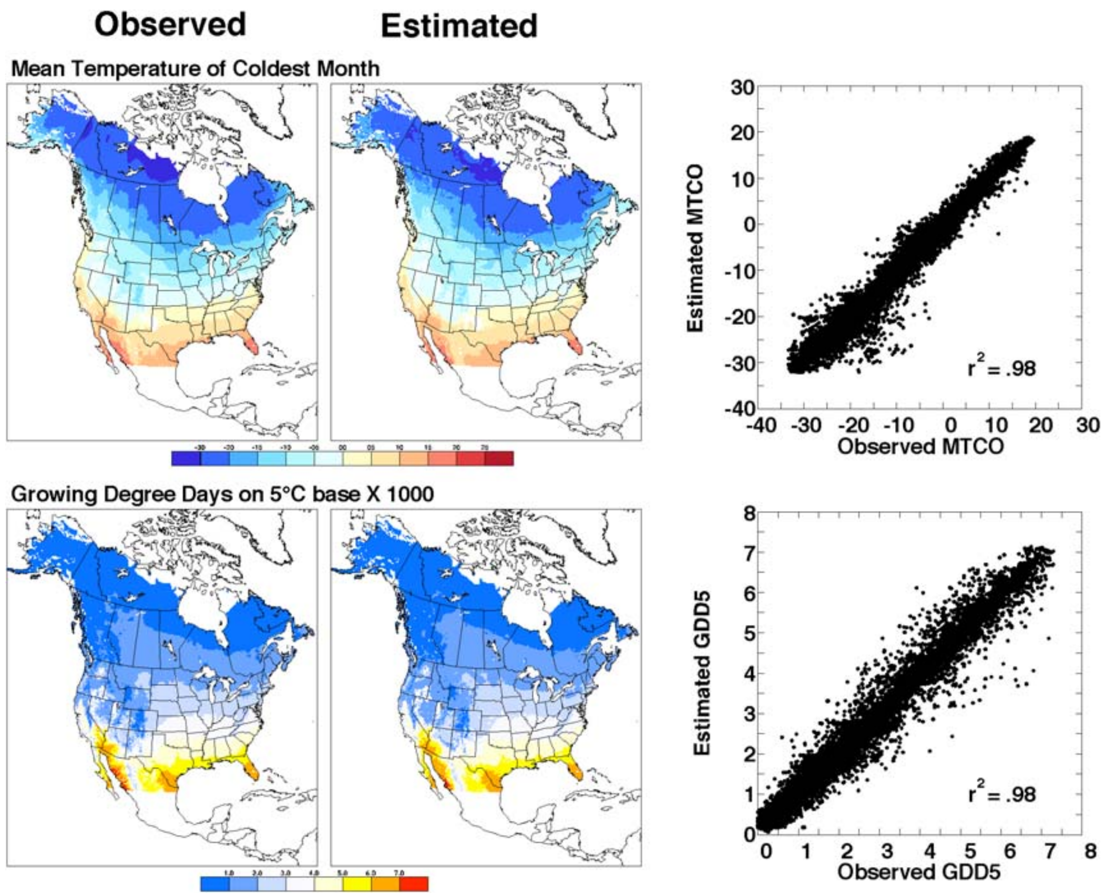
(12) CLUES -- Climate Change, Land Use, and Environmental Sensitivity
Bob Thompson, Project Chief
Funding: ESDP
http://esp.cr.usgs.gov/info/clues/

The past is the laboratory for understanding the complex interactions among, and the effects of, changes in climate, atmospheric chemistry, ecosystems, hydrology, surficial-geologic processes, and human activities. CLUES develops data sets and methods to reconstruct past climates, evaluate uncertainty, and work with modelers to assess how well numerical models can simulate climates different from the present day. In collaboration with other federal agencies and the international academic community, the project compares synoptic-scale paleoenvironmental reconstructions over the past 20,000 years with numeric model simulations of past climate and vegetation to evaluate uncertainties in both reconstructions and simulations. Key aspects of CLUES2 include:

Elucidation of modern relations between climate and vegetation. The project has assembled datasets of climate, vegetation, landcover, and ecoregions for North America on equal-area 25 km and 10km grids. These data are used to examine the relations between present-day climatic parameters and the distributions of important woody species and of ecoregions. These results that are published as an atlas for North America (USGS Prof. Pap. 1650 – five volumes now published) and provide the basis for the development of quantitative methods for estimating climate from vegetation assemblages.

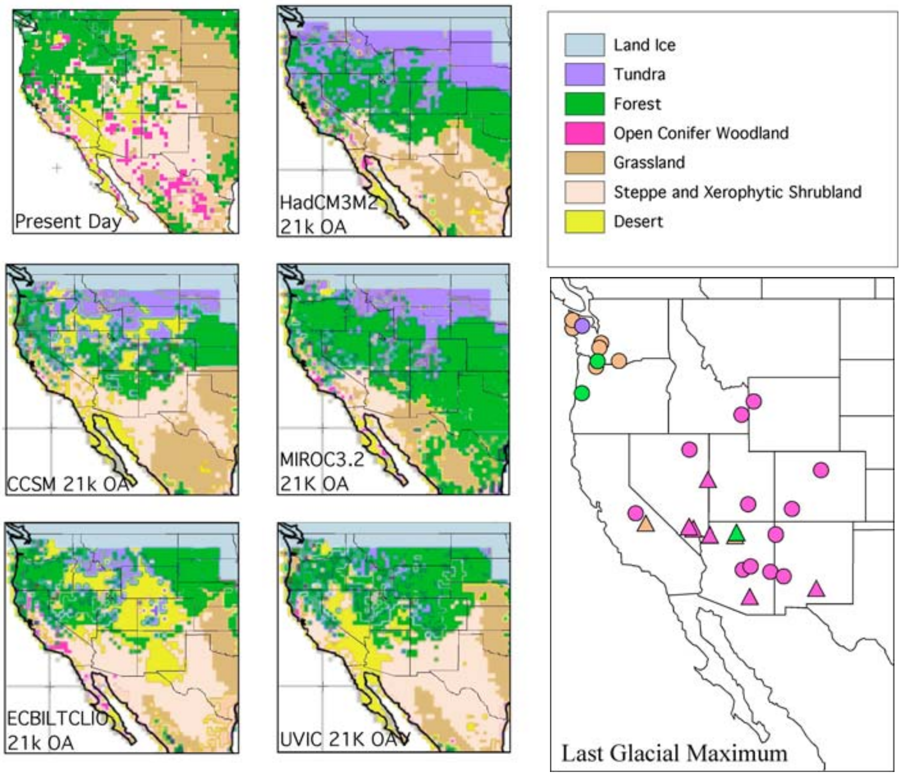
Paleoenvironmental studies. Project members compile databases of paleobiological (packrat middens, pollen) and paleohydrological data. These data are used with the quantitative relations developed from the modern climate and vegetation data to provide synoptic-scale reconstructions of past environmental and climatic conditions for key time periods. In association with the IGBP BIOME6000 project, these fossil pollen and plant remains are also used to reconstruct past changes in biomes within a standard framework that facilitates data-model comparisons.

Simulation of past climates and environments. Research over the past two decades has revealed that changes in atmospheric carbon dioxide concentrations can modify how plant species respond to climatic changes. Accordingly, the present-day relations between climate and plant distributions may not apply to past (and future) time periods with carbon dioxide levels that are significantly different from modern levels. To circumvent this problem, the project uses the BIOME4 model to simulate past vegetation from key past climate episodes.



The CLUES project is developing quantitative methods for estimating climate from presence-data plant distribution data. This figure shows modern tests of these methods from the modern gridded data.

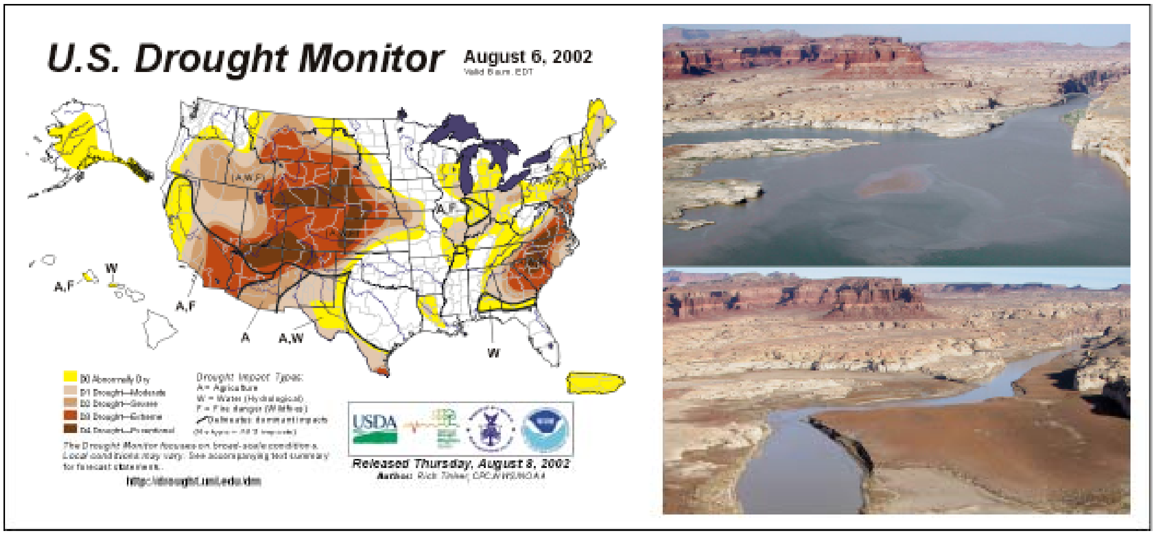
<u>Comparisons of reconstructions and simulations.</u> In association with the international Palaeoclimate Modelling Intercomparison Project, Phase 2 (PMIP2), the CLUES project uses compares observed patterns in paleoenvironmental data (and associated quantitative estimates of past climatic conditions) with simulations of past climate and biomes produced by an array of coupled ocean-atmosphere-vegetation models. These comparisons permit the identification of plausible causes and mechanisms of past climate changes and assessment of uncertainties in both reconstructions and simulations.



Comparison of Last Glacial Maximum biomes observed in the paleobotanical data (lower right) with biomes simulated by BIOME4 for the present day (upper left) and from the output of five PMIP2 models. This comparison indicates that all of the models simulate more forest vegetation (and probably moisture levels) than actually occurred.

Upper Colorado Basin (UCB) Studies.

The Colorado River supplies water for rapidly increasing populations in seven western states and Mexico. Its waters support cities and agriculture, generate electrical power, harbor endangered species of fish, and provide recreation for millions of Americans. The climate of the Colorado River basin varies greatly from year to year, and thus the flow of the river is highly variable. The Colorado River Compact, a 1922 agreement among the seven states, allocated the river's waters based on an assumption that its annual flow would be 16.4 million acre feet per year (the average flow in the early 20th Century). However, this turned out to be a poor assumption – since then the river's flow has frequently been below this amount, and tree-ring studies suggest that the long-term mean flow may have been nearly 2 million acre feet per year less than the assumed average flow. Severe drought has visited the Colorado River Basin over much of the last decade, with the conditions in 2002 worse than anything seen in much of this region during the historic period.



Left side: An example of the amplitude of the 2002 drought. Right side: The effects of this drought on the Colorado River (Replicate photographs of Lake Powell at the confluence with the Dirty Devil River, Utah (entering from left). A. June 29, 2002. B. December 23, 2003. Photographs by John C. Dohrenwend; USGS Fact Sheet 2004-3062 v. 2)

CLUES studies UCB seek to provide detailed reconstructions of past changes in hydrology and ecosystems in the UCB. In collaboration with researchers from NOAA and the university community, we will integrate instrumental, paleolimnologic, dendrochronlogic, and paleoecologic data to provide a unified view of past climatic changes and variability over the Holocene. Tree-ring, instrumental, and isotopic studies will provide detailed records of climatic variability over the past 1500 years, the period that encompasses the Medieval Warm period, the Little Ice Age, and the warming of the past 150 years. We will overlap these studies with paleoecologic and isotopic studies of changes and variations during older time periods, such as the warmer-than-present climate in the Northern Hemisphere during the early and middle Holocene. These studies will reconstruct past climatic variability; elucidate interactions among changes in climate, ecosystems, and hydrology; and provide the basis for evaluating how well numeric models can simulate climates different from that of today.

(13) Missouri River Geologic Framework
Scott Lundstrom, Project Chief
Funding: NCGMP

In FY2006 a new NCGMP project was initiated within the Central ESP team on the geologic framework of the Missouri River. In cooperation with the National Park Service, South Dakota Geological Survey, Nebraska Conservation and Survey Division, and university partners, the initial new geologic mapping is focused in a task on the Missouri River corridor region along the Missouri National Recreational River (MNRR) of southeast South Dakota and northeast Nebraska. The geologic framework of the river corridor, especially the glacial and postglacial geology emphasized in our work, dominates the geomorphic and hydrogeologic bases of the physical habitat and ecology. The area of the corridor spanned by the MNRR includes several geologically significant terrains. The river valley, with a width of 3-6 km throughout most of the Dakotas and eastern Montana, expands markedly in the study area to a width of 10-16 km, which is one of the widest parts of the river valley. The expanded reach coincides with the southernmost extent of the James River lobe of the late Wisconsinan Laurentide Ice sheet. In the uplands south of the river valley in eastern Nebraska, a much older and morphologically distinctive pre-Illinoian glacial terrain is partially mantled by loess. Both terrains include extensive glacial-buried-valley aquifers, which are contiguous with the alluvial-outwash aquifer that underlies the river and its valley.

The geomorphology of the river valley is dominated by post-glacial Holocene deposits and by the presently active fluvial system. Before the dam system was built during the mid 1900s, the river episodically transported large but variable fluxes of sediment from the extensive drylands upstream of the study area. [Numerous crosscutting packages of meander-scroll morphology provide a record of changing fluvial processes that reflect response of basin hydrology and sediment yield that we are testing with mapping and chronology studies. Exposures enhanced by incision of the sediment-poor post-dam river commonly show well-sorted sand of point bars and channels overlain by overbank sediments and well-bedded channel fills dominated by silt, clay, and mud. In contrast, sparse exposures of glacial outwash have much coarser gravel dominated by crystalline lithology. Though Pleistocene glacial gravel is widespread in the subsurface of the valley, it is largely buried by postglacial fluvial sediments.]

Geologic mapping of the Missouri River corridor is directly relevant to adaptive management and ecology of the modern river by documenting the spatial distribution, properties, and variability of the local geologic environment and its controls on river ecosystem processes. The geologic framework, as defined by appropriately detailed mapping, provides major controls on the nature and distribution of erosion, sediment supply, substrate characteristics of channels, banks, and floodplain, ground-water/surface-water interactions, and water quality. Each of these aspects is a potentially significant influence on distributions and vigor of riverine species. For example, glacial geology of the area may be particularly relevant in supplying stable, hard spawning substrate (such as coarse gravel) for native fish species, including the endangered pallid sturgeon. In addition, geologic mapping provides a long-term record of the range of river environments in response to historic and pre-historic millennia of climate change to which modern ecosystems have adapted.

(14) EFFECTS: Exploring Future Flora, Environments, and Climates Through Simulations
Sarah L. Shafer, Project Chief
Funding: ESDP
http://esp.cr.usgs.gov/info/effects/

Future climate change will significantly affect the Earth's physical and biological systems. In order to accurately forecast environmental responses to future climate change, we must improve our understanding of the physical controls and dynamics of environmental systems. The EFFECTS Project uses a variety of numerical models to investigate the interactions of climate, ecosystems, and land surface characteristics on multiple temporal and spatial scales, with particular attention to the potential changes that may occur under future climate change. This project has three main objectives:

- Improve our understanding of the processes mediating the interactions of climate, ecosystems, and land surface characteristics.
- Investigate the potential effects of future climate change on ecosystems and land surface processes.
- Develop model simulations and analyses of future environmental change impacts specifically for use by conservation and natural resource managers, with a particular focus on federal lands in the western United States.

The EFFECTS Project uses a variety of physically-based process models (e.g., vegetation models, water-balance models) and empirical datasets (e.g., observed climate data) to investigate the dynamics and controls of the physical processes that are important for understanding both present and future environmental change (e.g., drought variability). In order to simulate the potential future environmental impacts of climate change, we rely heavily on future climate simulations generated by coupled atmosphere-ocean general circulation models (AOGCMs) run under a variety of future greenhouse gas emissions scenarios.

An important part of our future climate change research is assessing the potential future impacts of climate change on physical and biological systems, including the distributions of species. We have used future climate simulations from 10 AOGCMs to create downscaled future climate data for the western hemisphere. In collaboration with colleagues, we have used these data to simulate future distribution changes for 2,954 bird, mammal, and amphibian species in the western hemisphere, such as the Northern Goshawk (right) whose range changes simulated using data from the HadCM3 AOGCM indicate potential future range contraction in the western United States.

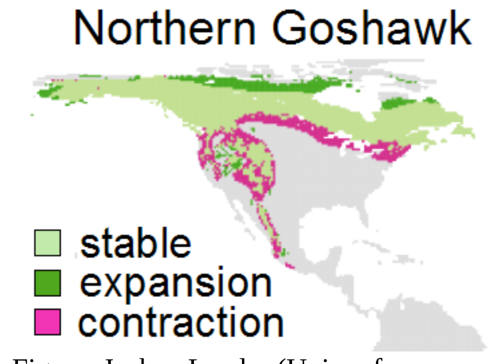


Figure: Joshua Lawler (Univ. of Washington)

Conservation and natural resource managers are particularly interested in learning more about the potential impacts of future climate change on the ecosystems they manage. A focus of the EFFECTS Project is to work with conservation and natural resource scientists and managers to develop simulations and analyses of climate change that can be used for conservation and natural resource management. We are currently involved in collaborative projects with the National Park Service's Klamath Network (Crater Lake National Park, Lassen Volcanic National Park, Lava Beds National Monument, Oregon Caves National Monument, Redwood National Park, and Whiskeytown National Recreation Area) and with the Washington State office of The Nature Conservancy. Other stakeholders, including other federal land management agencies and private landowners, may also find the results of this research useful.

(15) Paleohydrologic History of the Mojave Desert Region
Marith Reheis, Project Chief
Funding: ESDP, NCGMP
http://esp.cr.usgs.gov/info/mojave/

The Mojave Desert (Fig. 2) occupies a transition zone between western California, which dominantly receives westerly Pacific moisture, and areas to the east that dominantly receive southerly summer monsoon moisture. Climate records from the Mojave may potentially contain a sensitive history of the changing influence of these two moisture sources. Comparison of western North American paleolake records shows both local and regional differences in the timing of lake level change interpreted from paleolimnologic indicators such as lake level, TDS, stable isotope values, and paleontologic content. Local differences are commonly related to issues such as dating, physiography, and hydrology (including surface area to volume ratio), sources of water, and factors such as tectonics, which affect the basin morphometry. Regional differences are mainly related to climate and, in particular, to resident air masses whose characteristics are determined by continental ice sheets, sea surface temperature, seasonal and annual position of the polar front, solar variability on short (output) and long (orbital) time scales, and other factors. Changes in the geometry of the continental ice sheet, sea surface temperature in the equatorial Pacific, and likely solar output yield strong regional differences in climate and thus in paleolake characteristics. However, few detailed paleolake studies have been published for the Mojave Desert region, and none for periods prior to the latest Pleistocene.

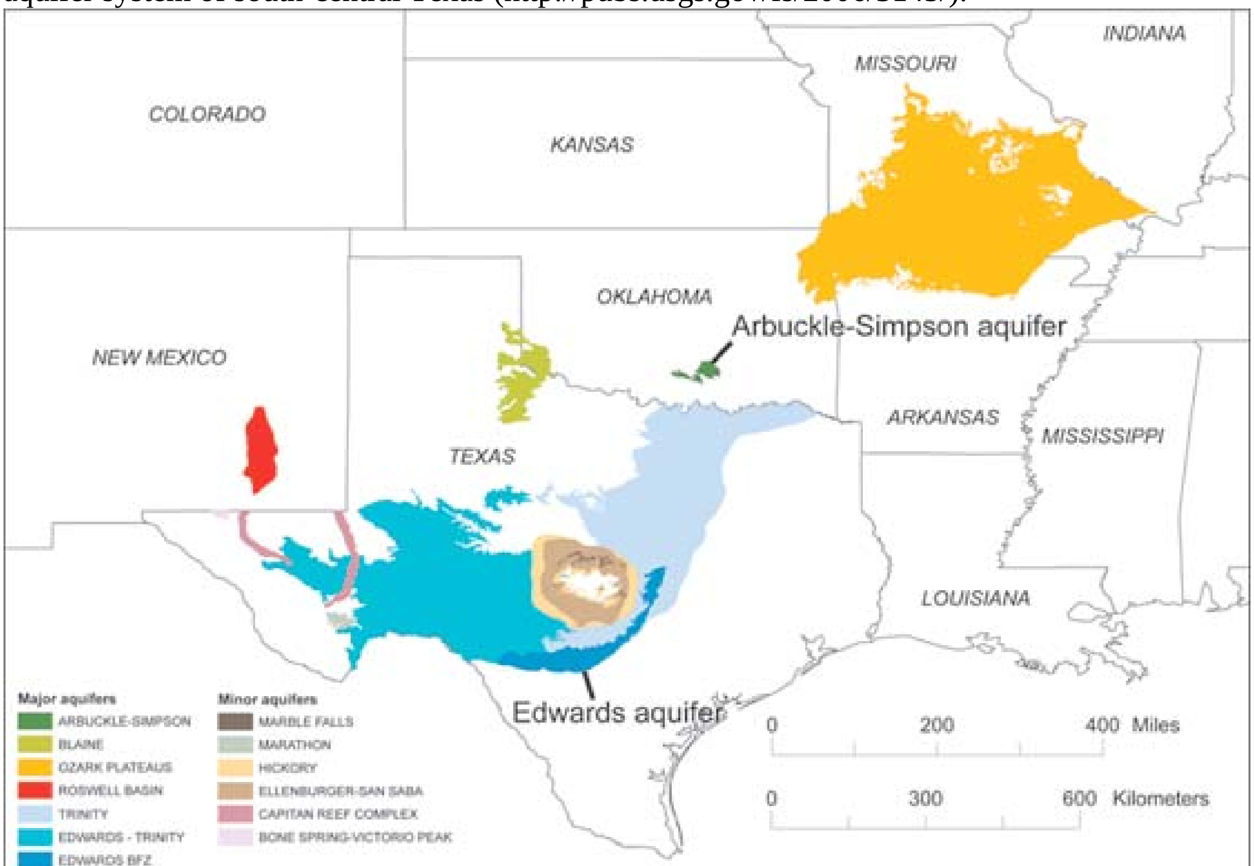
Previous studies of Lake Mojave (by Wells and others, 2003) suggest that it, much like Lake Estancia in New Mexico, reached high levels before and after more northerly lakes, indicating climate controlled behavior. Unfortunately, Lake Mojave and its upstream precursor, Lake Manix, have not received the detailed study that is needed to understand their response to both local factors, such as changing inputs from the Mojave River due to basin integration events, nor to regional factors such as climate change. Recent studies of cores in the Gulf of California (by Barron and others, 2004) suggest well-defined time-series changes (last 16 ky) in seasonal wind directions that should have a direct impact on Mojave Basin air temperature and moisture regime, including seasonality. Our preliminary study of ostracodes from Lake Mojave and Lake Manix cores show strong time series shifts from a summer-rain-sourced lake to a winter-precipitation-sourced lake that should be related to changes in proxies from the nearby marine records, thus linking oceanographic and land based climates.

In addition to external forcing by climate, a better understanding of the history of drainage integration along the Mojave River is needed to interpret the sediment record properly. Mojave lakes are supported by long-distance river systems, each of which was integrated through time in imperfectly understood ways; as a result, there is potential to compare environmental histories in different parts of the desert with the environmental record from the Death Valley core (Forester and others, 2005) if the integration events for those rivers are understood. Previous studies of exposed sediments of Lake Manix, the terminus of the Mojave River before its integration downstream to form Lake Mojave, suggest a long middle to late Pleistocene paleolake sediment record is preserved; these sediments potentially contain a detailed record of the previous glacial-interglacial transition from marine oxygen-isotope (OIS) 6 to 5. Segmentation of the Mojave River drainage can be used to separate local from regional climate effects at various times once the overflow history is known. Similarly, understanding the integration history of the Amargosa River system can yield climate response data. New interpretations of the integration history of the Mojave and Amargosa Rivers have the potential to revise the biogeographic history of aquatic species in the Desert Southwest.

Our approach to studying the late Quaternary paleoenvironment of the Mojave Desert focuses on the depositional records of drainages and pluvial lakes, as well as related settings and materials such as groundwater-discharge deposits and packrat middens. Task 1 employs physical, chemical, isotopic, and magnetic-properties analysis of sediment cores and stratigraphic sections to construct detailed paleohydrologic records. Task 2 employs geologic mapping and stratigraphic analysis of sediments, soils, and geomorphic features exposed in outcrop along the drainage pathways. Stratigraphic sections and soils in critical outcrops show environmental changes and interactions between lakes, rivers, and dune sands. Results from these studies will be integrated and compared with those of nearby marine records from the Gulf of California and from the southern California Pacific margin to determine how on-land paleoenvironmental conditions respond to changes in marine circulation as well as positions of continental glaciers. These reconstructions will enable better forecasting of future effects of global climate change on a marginal desert region under increasing population pressure.

(16) Framework Geology of Mid-Continent Carbonate Aquifers
Chuck Blome and David V. Smith, Co-Project Chiefs
Funding: NCGMP

The subsurface geologic framework and ground-water reservoir capacities of fractured and karstic carbonate aquifers in the south-central United States are largely unknown. Carbonate aquifers can be extremely susceptible to contamination through dissolution features that can range from small, straw-like conduits and widened joints to large caverns. These uncertainties make it difficult to assess the total response of the aquifer systems to significant withdrawals or to characterize the quantity of renewable groundwater. The states of Arkansas, Missouri, New Mexico, Oklahoma, and Texas all contain productive aquifers defined by water-bearing Paleozoic carbonate sequences. This new project builds on the expertise gained in the National Cooperative Geologic Mapping-funded project on the framework geology of the Edwards aquifer system of south-central Texas (http://pubs.usgs.gov/fs/2006/3145/).



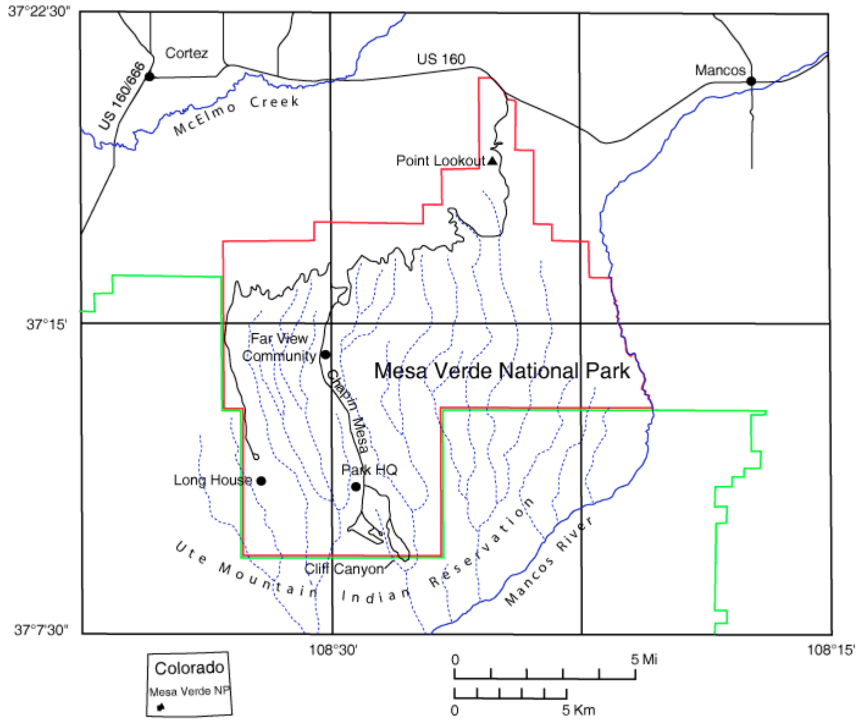
The Arbuckle-Simpson aquifer of south-central Oklahoma encompasses more than 500 square miles and is the primary water source for the towns of Ada and Sulphur as well as the Chickasaw National Recreation Area which hosts more than 3.4 million visitors annually. The aquifer is also the main source of springs in the area. Much of the discharge from these springs and seeps becomes the base flow of streams and it is estimated that this base flow represents about 60 percent of the total annual runoff in the Arbuckle- Simpson outcrop area. The U.S. Environmental Protection Agency (EPA) has designated the aquifer’s eastern ground-water basin as a sole-source aquifer.

The State of Oklahoma, the National Park Service, as well as local residents and citizens' groups, are extremely concerned that large-scale withdrawals from the Arbuckle-Simpson aquifer will result in declining flows in both springs and streams and grossly diminish the only ground-water resource in the region. To protect the aquifer, State Senate Bill 288 was passed on May of 2003 which imposed a moratorium on the issuance of any temporary ground-water permit for municipal, public water supply use. A comprehensive, 5-year state-federal project, aptly called the Arbuckle-Simpson Hydrology Study, was authorized by the Oklahoma Water Resources Board (OWRB) and includes staff and resources from the OWRB, Bureau of Reclamation, the USGS, Oklahoma Geological Survey (OGS), Oklahoma State University (OSU), and the EPA. Project activities involve extensive fieldwork and geologic mapping, with a focus on defining the Arbuckle-Simpson hydrostratigraphy using fault/fracture mapping, permeability/porosity analyses, three-dimensional (3-D) EarthVision™ geologic modeling, and airborne/ground geophysical surveys for critical parts of the Hunton anticline area, eastern Arbuckle Mountains.

Project accomplishments within the project's first year include a preliminary 3-D EarthVision™ model and helicopter electromagnetic (HEM) and ground geophysical surveys in and around the Hunton anticline area. The 3-D model is providing the framework for a multilayer ground-water MODFLOW model of the Arbuckle-Simpson aquifer. This 3-layer MODFLOW model is being constructed by the WRD Oklahoma City Science Center and is a critical product of the ongoing state-funded Arbuckle-Simpson Hydrology Study. Both the HEM and ground geophysics have already helped to more accurately characterize the aquifer's hydrologic properties, the locations and displacements of faults, and the degree of karst development. Additional objectives of the geophysical surveys are to identify and map: (1) major and minor faults that displace significant water-bearing units, (2) outcrops and subcrops of the major hydrostratigraphic units and determine their significance for ground-water flow and recharge, and (3) surface features, such as epikarst, that influence recharge potential. Other geophysical methods, including time-domain electromagnetic (TDEM), magnetic, gravity, audiomagnetotelluric (AMT), and borehole surveys, are also being explored in cooperation with the Boone Pickens School of Geology at Oklahoma State University - Stillwater.

(17) Surficial geology of Mesa Verde National Park
Paul Carrara, Task Leader
Funding: NCGMP
http://esp.cr.usgs.gov/info/meve/

The purpose of this task is to provide surficial geologic map coverage of the Mesa Verde National Park area in southwestern Colorado, at a 1:24,000 scale. This task will focus on identifying, mapping, and developing unit descriptions and a chronology for surficial deposits over an area of approximately 140 sq mi. The surficial map will focus on the various physical properties of the map units and associated geologic hazards, which include landslides, flash floods, and swelling soils. The map will provide the National Park Service with a digital geologic map of Mesa Verde National Park, a highly visible (500,000 visitors/year) park unit and one of the crown jewels of the National Park system. This task is one part of a larger project focusing on the geology of various National Parks and Federal lands in the southwestern United States.



Geology is an important concern within Mesa Verde National Park because the Park is plagued by various forms of mass movement (landslides, debris flows, rock falls), swelling soils, and flash floods that affect the Park's archeological sites as well as it's infrastructure (roads, septic systems, utilities, and building sites). Because the Park has only one entrance road, a major slump or erosion during an intense thunderstorm has the potential to trap thousands of visitors in the Park. Over the years, millions of dollars have been spent keeping the Park's road system open. Hence, the surficial mapping will also include a hazard assessment of the Park's road system. Although there are several existing geologic maps that encompass or contain parts of the Mesa Verde National Park area, these maps are either (1) at a small scale (1:250,000), (2) under represent the surficial geology, or (3) both. Hence, there is a lack of adequate surficial information for the Park at a scale more appropriate for planning (1:24,000). Geologic information, including surficial geology with a careful consideration of the engineering characteristics of surficial deposits and associated hazards, is needed in order to help the Park better manage its resources. Because the distribution of surficial deposits is strongly related to archaeological sites, plant communities, animal habitats, and soils, the information produced by this task will lead to an increased understanding of the Park's ecosystem and prehistoric land-use patterns. The task will also benefit visitors by providing information to update or expand current interpretive materials related to the Park's geology and ecology.

Although work on this task began only recently, preliminary analysis of aerial photographs has revealed numerous landslides within the Park's canyons. Many of these landslides head in the Menefee Formation; future studies will focus on the age of these landslides. Other possible studies related to the surficial mapping may focus on the (1) age and origin of the loess capping the upland mesas, (2) alluvial stratigraphy in the canyons, and (3) age of igneous dikes present in the southern area of the Park.

(18) Radiogenic Isotope Laboratory
Kathleen Simmons and Wayne Premo
Funding: multiple programs (primarily NCGMP, ESD, MRP)
http://esp.cr.usgs.gov/info/isotope_geochron_lab/

The Radiogenic Isotope Laboratory, located in Denver, Colorado, is a multi-user, multi-funded research laboratory that utilizes state-of-the-art isotopic techniques to solve geologic problems. Isotopic techniques are exceptionally powerful tools for baseline regional and local mapping studies as well as resource, hazard, environmental, biological, surficial processes, and global change studies. Radiogenic isotopes (Pb, U, Th, Rb, Sr, Nd, and Sm) can be utilized in both geochronological and isotopic tracer investigations within natural and artificial systems.

Examples of isotopic tracer applications:

- degree of anthropogenic contamination of natural systems
- eolian studies - origin of windblown dust, aerosol particles
- diet and grazing patterns of birds, animals, etc
- identifying isotopic signatures of mass extinction events
- forensic analysis of biological material (blood, feathers, etc.)
- groundwater flow conditions, circulation and mixing patterns, contamination
- mineral weathering reactions
- chemical modeling of carbonate diagenesis
- sources of metals in ore deposits
- delineation and origin of tectonostratigraphic terranes
- magma evolution and sources; petrogenetic studies of igneous rocks

Examples of geochronologic applications are:

U-series dating
- of corals and speleothems to provide a timescale for geologic record of climate variability
- of fracture fillings to determine frequency of earthquakes in an area
- rock-water chemical interactions in groundwater and geothermal systems
- coastline uplift rates; rates of valley downcutting; rates of areal denudation

Sr-isotope stratigraphy
- relative and absolute ages of Quaternary marine terraces; sea level history
- glacial-interglacial timing
- correlating and dating of marine carbonates, evaporites and phosphorites

U-Th-Pb and Sm-Nd dating
- age of emplacement of igneous rocks, metamorphism, ore deposits
- thermochronology/P-T-t paths (in conjunction with other geochronometry)

- sources of sedimentary and metasedimentary rocks (tectonic studies)
- age of deposition, mineralization of paleosols
- dating of diagenesis of shales

III. Emerging Science Opportunities and Issues

Near-Term and Long-Term science Opportunities, Issues, and Challenges

OPPORTUNITIES

Human Health: An exciting aspect of the Drylands project has been the effects of dust-borne contaminants on human health and building awareness of this issue. Similarly, the Mid-Continent Aquifers project is looking at the contamination of groundwater reservoirs with 3-D modeling in Texas and Oklahoma. Through collaboration with other teams and outside experts, many ESP Team projects have the potential to expand into the human health arena more directly, possibly opening up new funding opportunities.

Water Availability and Quality: The ESP Team increasingly has been working with the Water Resources Discipline of the USGS, state and local water agencies and organizations, and universities on the framework geology of aquifers watersheds. Virtually all of our mapping projects have water as one of their drivers, if not the primary driver. There is increasing interest in having better 3-D geologic input into modeling applications such as MODFLOW, which we can supply. We have been asked to take some of our techniques and expertise garnered in carbonate systems and apply them to clastic ones such as the high-plains aquifer. We are limited, however, by time and personnel.

International Cooperation: As evidenced by our very successful and productive cooperative program with the Afghanistan Geological Survey, we stand poised to provide consultation, guidance, and training to governmental agencies of developing nations around the world. In particular, we assist in bringing the personnel of such agencies up to speed with the latest digital and Internet-based techniques in a cost-effective and professional manner. Our Team personnel have experience with government agencies of such countries as Afghanistan, Bangladesh, Madagascar, Pakistan, etc. In our recent meetings with the Nigerian Geological Survey Agency there was great interest in our relatively low cost, easy to use mapping platforms developed our work with the Afghanistan Geological Survey.

Climate Change and Paleoclimate issues: Although the bureau plans for climate change research are not yet clear, the team is already extremely well positioned to contribute on a number of fronts in this area of increasing national and international concern. Team members have been performing exceptional modeling of past and future climate changes at a scale of individual wildlife refuges, rather than at the regional or continental scale of previous models. This has attracted much interest from the USGS Director, refuge managers, etc. Team work on dust sources and deposits and their effects on human health and ecosystems has attracted worldwide attention. Other team members studies have set the stage for groundbreaking modeling of the potential effects of future climate changes on fauna and flora. All of these and more combined with our laboratory capabilities put the ESP team in a unique position to take advantage of emerging opportunities.

DOI land managers are desperate to know what changes will affect the lands they manage in 40-50 years in response to climate change. Presently the Department's need for climate impact assessments for DOI lands greatly outstrips our team's resources in this area. Bolstering the team's ability to project climate and environmental change at local to regional scales would improve our ability to respond to DOI’s needs. This will require additional computer resources (e.g., supercomputer time) and staff (e.g., a quantitative landscape change modeler, ecosystem change modeler, etc.).

Homeland Security issues: Ric Page and his US-Mexico Borderlands initiative could be expanded to focus more heavily on the geologic characterization of rock and surficial materials along the border. The properties of such materials contribute to or, in some cases, prohibit the construction of cross-border tunnels and other types of illegal access.

ISSUES AND CHALLENGES

Retirements: As is always the case, retirements represent both a challenge and an opportunity. 33% of our workforce is eligible for retirement now and 58% will be within 5 years. In terms of research grade scientists fully 42% are currently eligible and 76% will be in 5 years. The loss of corporate knowledge and techniques has the potential to do tremendous harm to the team. This is also an opportunity, however, to fill positions with scientists well versed in new and emerging skills in modeling, GIS, field techniques, dating etc. An unexpected consequence of the economy and plunging real estate prices is that some researchers that were planning on retiring and moving are finding themselves unable to sell their homes and therefore unable to retire. This is delaying retirements that were anticipated under our current budget plans. On the other hand, we now must continue to fund these scientists, some of whom had been written out of future projects as they had informed us of their impending retirements.

Geologic Mapping: Framework geologic mapping is critical to so many activities of the USGS. Many schools are no longer producing geologists with the field skills or the kind of integrated thinking necessary for field mapping, but we have found that fine field mappers can be created with the mentoring of existing experienced mappers. It is therefore of major importance that we hire the next generation of geologists before the existing staff retires.

Surficial Mapping: This is a subset of geologic mapping, but it is of particular importance to our team because people skilled at surficial geologic mapping are usually Quaternary geologists and work at the interface between the two research emphases of our team: global change and geologic mapping. Our current surficial geologic mappers are stretched thinly, and we may lose as many as five in the next few years. We are particularly interested in recruiting surficial mappers who are capable of integrating the techniques of GIS, data analysis, and system process studies.

Global Change Research: In the past few years the ESP Team has lost some of the giants of global change research to retirements. This has particularly affected our studies on reconstruction of past climates with the loss of Quaternary geologists. Many others may be retiring soon. We are struggling with the need to replace or augment specialists in the subfields of paleolimnology and related lacustrine studies.

EPN: This has been discussed often, but the new EPN cost structure is disproportionately affecting geologic mapping products. The ESP team has been proactive in putting funds aside for a large Working Capital Fund, but this is being reduced very rapidly. Both the NCGM program and the Geologic Discipline have come forward with funding to help, but the team will need to rethink what we promise in terms of products and to plan more efficiently for publication costs.

Future Capabilities Necessary to Meet Emerging Science Issues

Potential growth areas in the Earth Surface Dynamics Program include climate modeling, cold climate (Arctic-Antarctic) research, research related to climate variability, and the impacts of climate change on the landscape. New or expanding research directions in the National Cooperative Geologic Mapping Program include three-dimensional subsurface framework geology/stratigraphy, hydrogeology, and fault/fracture studies. Potential staffing needs to address these program directions include:

- Climate modeling: a research scientist with some combination of expertise in numerical modeling, statistics, or paleoclimate proxies. If this research activity expands significantly, requiring major computer hardware acquisition, additional computer support may be needed.
- Cold climate studies: a first priority in this area is likely to be an expansion of USGS’s permafrost monitoring network, which would require additional operational staff to build, deploy, and maintain monitoring stations, and to process incoming data. Skills required would include electronics, statistics, and computer programming. Additional research staff may also be required. The ESD Program Coordinator has expressed desire to expand our participation in this research area, particularly in the Yukon Basin and on the North Slope of Alaska, and we are exploring avenues for funding an expanded effort.
- Climate variability: this is a research component to be integrated into existing efforts, which cannot, at this time, be translated directly into specific staffing needs. As new and ongoing projects are refined and redirected, additional needs for skills and expertise may be identified.
- Three-dimensional subsurface framework geology: a research scientist with the ability to integrate stratigraphy, structural geology, hydrogeology, and airborne geophysics is needed. The scientist would need to be comfortable with modern techniques of scientific visualization, GIS, and related fields. Inasmuch as many technical aspects of hydrogeologic framework modeling are similar or overlap with those of petroleum geology, there may be opportunities to partner with the Central Region Energy Resources Team in this area.
- Fault and fractured rock mass studies: new advances in modeling and characterization of faults and fracture systems are contributing to more advanced hydrogeologic models and

to better geologic hazard predictions. Although ESP has no near-term staffing plans in this area, as a critical part of multipurpose framework geology and hydrogeology-related research activities, we must ensure that expertise in this area is maintained.

- Surficial geology and geomorphology: this critical need, which crosscuts the NCGM and ESD programs as well as several Bureau and Regional science priorities, must be maintained at a level appropriate for research needs and available funding. We need not only to be able to map surficial deposits, but to conduct process-oriented research in geomorphic processes and landscape dynamics.
- GIS support: at present, ESP has two full-time permanent GIS technicians. Additional staffing needs are filled with student or contract help as required. This arrangement has worked well and allows the ESP Team the flexibility to expand temporarily when required, but keep a small core staff for continuity. Additional growth in mapping and modeling activities (and/or international geology activities in areas such as Afghanistan or Pakistan) may require the addition of one additional, highly skilled and experienced GIS technician to the permanent staff. ESP has no firm plans to staff such a position, but should the need and opportunity present itself, an opportunistic hire may be explored.

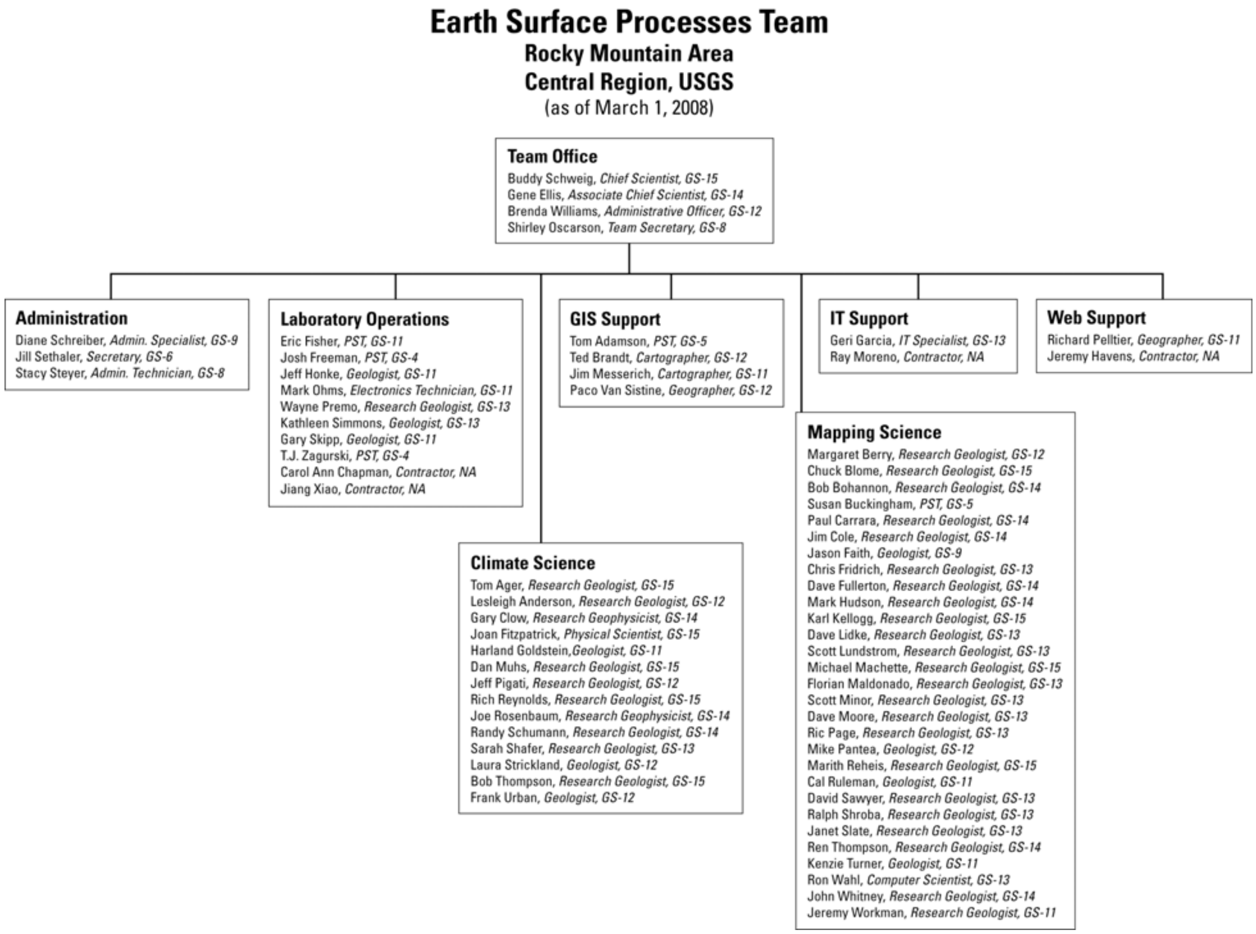
Anticipated Changes Necessary to Meet Future Challenges

There are no significant issues with research functions that we have but do not need. Rather the issues are with lack of staffing to meet the opportunities that may present themselves and those are discussed above. Also as discussed above, the ESP Team working with EPN and NCGMP must come up with a reasonable long-term solution to funding and producing map products.

The ESP Team has a great core of research talent. With a few notable exceptions, however, the mapping and climate change people overlap very little. There are opportunities to change this, which should make the team more flexible and better able to take advantage of interdisciplinary opportunities.

IV. Human Resources

Shown below is an organizational chart of the Earth Surface Processes Team, as of March 1, 2008. Various aspects of the workforce, both present and future, are shown in more detail in Tables 1-5 and discussed in this section.



As can be seen from the Tables 1-3 below, the Earth Surface Processes team comprises about 64 FTE and 5 contract employees. The Federal employees are almost all located at the Denver Federal Center and dominantly permanent. Over half of the non-contract employees consists of research grade scientists, which would be expected as the team mission is research oriented.

Table 1. Summary of the Federal Workforce of the ESP Team.

Professional/Technical Staff	FTE	Grade Range	Percent of Staff
Research grade scientists	33	GS 12-15	52
Operational scientists	13	GS 11-15	20
Science support technicians	7	GS 4-11	11
IT Specialists	1	GS 13	2
GIS support	3	GS 5-12	5
Center administrative staff and support	5	GS 6-12	8
Center supervisors and managers	2	GS 14-15	3
Total	64	GS 4-15	100

Table 2. Summary of the Contract Workforce of the ESP Team.

Function/Skill	Number	Branch/Section/Research Group
GIS support		
Laboratory technicians	3	ATA Services, Inc.
IT support	1	ATA Services, Inc.
Web graphics support	1	ATA Services, Inc.

Table 3. Summary of the Total Workforce of the ESP Team.

Type	Permanent full-time Federal Employees	Permanent part-time Federal Employees	Term Employees	Student Employees	Total Federal Employees	Total Contract Employees	Emeritus Scientists
Number	57	2	5	0	64	5	12

Workforce Management Considerations

Table 4 below shows retirement eligibility now and five years in the future. As mentioned above, 33% of our workforce is eligible for retirement now and 58% will be within 5 years. The problem (and opportunity) is greatest among research grade scientists, among which 42% are currently eligible for retirement and 76% will be so in 5 years. Thus a major concern for the ESP Team over the next 5-10 years is the loss of knowledge and experience through retirement of long-established senior scientists with expertise in fields critical to the ESP Team as well as to the ESD and NCGMP program missions. Many of these researchers are national or world leaders in their fields. Within five years, it is likely that the ESP team will lose at least three project leaders, and four or more senior scientists with skills that are critical to addressing program missions.

Table 4. Summary of Anticipated Retirements for the ESP Team.

Professional/Technical Staff	Total Number	Eligible FTE now (percent)	Eligible FTE in 5 years (percent)
Research grade scientists	33	42	76
Operational scientists	13	15	31
Science support technicians	7	14	43
IT Specialists	1	100	100
GIS support	3	0	0
Team administration and support	7	43	57
Total	64	33	58

It is imperative that the ESP Team pursue a proactive hiring strategy in order to bring in new staff that can be mentored by senior scientists before their expertise is lost. We have successfully used the SCEP and Mendenhall programs to bring in promising graduate students and postdoctoral students for mentoring and evaluation as potential permanent hires, and will try to make continued and better use of these avenues in the future. Over the next 2-3 years, the ESP Team should add or replace expertise in paleoclimate reconstruction, climate modeling, lacustrine sedimentology/geochemistry, and lacustrine microfaunal paleontology. Although most of the positions listed in Table 5 are permanent, we anticipate making increasing use of term hires with the intention of converting to permanent if the employees and there skills are acceptable.

Table 5. Anticipated Future Hiring Needs for the ESP Team.

Title	Number	Technical Area of Expertise	Grade	Permanent/Term/Contract
Research Geologist	1	Lacustrine sedimentology	GS-12	Permanent
Research Geologist	1	Surficial geology (analytical/computer)	GS-12	Permanent
Research Geologist	1	Geology of ecosystems	GS-12	Permanent
Research Geologist	5	Surficial geologic mapping (sedimentology, geomorphology)	GS-12	Permanent
Research Geologist	4	Bedrock geologic mapping (structure, petrology, sedimentology)	GS-12	Permanent
Research Geologist	1	Quaternary biogeochemist	GS-12	Permanent
Research Geologist	1	Quaternary geologist-process	GS-12	Permanent
Research Geologist	1	Quaternary geologist-eolian processes	GS-12	Permanent
Geologist	1	Isotope geochemist	GS-9/11	Permanent
Physical Science Technician	2	GIS support	GS-7/9	Term
IT Specialist	1	Computer infrastructure	GS-12	Permanent

V. Science Center Funding

The ESP Team is funded primarily from two base programs. The Earth Surface Dynamics Program (ESD) funds the climate change-related activities, whereas the National Cooperative Geologic Mapping Program (NCGMP) funds the geologic mapping activities. Sources of reimbursable funding of ESP included the National Park Service, U.S. Department of Energy, Bureau of Land Management, National Science Foundation, USAID, and other federal, state, and local government agencies.

Except for the Cryospheric Studies project, which has higher travel and equipment costs than most projects in the ESP Team due to its monitoring focus and Alaska location, none of the projects in the ESP Team have 20 percent or more OE, and several have less than 10 percent OE. We have observed that projects generally need 15-20% OE to function productively. Although the projects in the ESP Team remain highly productive, in many cases it is only because project personnel have been extremely creative, frugal, and expedient in finding and using resources. For example, the Alaska Quaternary History and Cryospheric Studies projects have made excellent use of cooperative agreements with BLM and USFS, who provide helicopter time and other expensive logistical support on an in-kind basis. Frequent-filer miles are used by several personnel to acquire bonus airline tickets for travel to fieldwork or meetings. Camping is often used to minimize lodging costs and stretch out field seasons by a few more days, or to exchange lodging for analytical costs so that more samples can be collected and analyzed.

Table 6. Geology Science Center gross funding for fiscal years 2004-2008.

Fiscal Year	SIR Program Amount	OFA Amount (total)	Regional Director's Office (CRISP/DOI)	Other	TOTAL	Annual Changes
2008 (estimated)	9,947,067	353,652	208,993	1,006,714	11,516,426	+11%
2007	9,151,071	359,613	190,122	661,084	10,361,890	+3%
2006	8,908,739	360,078	130,508	641,428	10,040,753	+1%
2005	8,758,770	958,724	128,712	80,000	9,926.206	+4%

As shown in Table 6, the ESP Team's funding has risen only slightly in recent years, with the possible exception of Fiscal Year 2008, where we expect to see an 11 percent increase. Taking into account the level of inflation in recent years, our funding has actually stayed flat at best and decreased in some years. Inflation and "salary creep" have cut into the funds we have available for operating expenses and thereby reduced the amount of project work we can perform. This is an example of the classic case of "losing ground by standing still". It is an issue of great concern to both the project scientists and the management of the ESP Team. We are aware that many, if not all, cost centers in the Rocky Mountain Area are experiencing the same situation; however, shared misery is small comfort to us.

Table 7. Geology Science Center funding table of reimbursable funding source from the major cooperators (>$50-100k/year) for fiscal years 2004-2008 (estimated).

Agency	FY2004	FY 2005	FY2006	FY2007	FY2008	Agency Total
Buffalo Nat. Park					50,000	50,000
Big Bend Nat. Park					94,000	94,000
Yucca Mtn.			87,876	120,000	100,000	307,876
Inyo Co., CA	56,571			50,000	50,000	156,571
Bangladesh	292,000	290,000	89,500			671,500
Afghanistan	151,000	498,000				649,000
Annual Total	499,571	788,000	177,376	170,000	294,000	

Table 7 shows that reimbursable funding follows no clear trend; it is highly variable year to year and is dependent on very large projects that come and go. On the other hand, we have built a very strong relationship with the National Park Service, which has provided us with reliable funding and we have, in turn, provided them with well-received topical studies.

Table 8. Summary of Report Production, FY 2007.

Fiscal Year	Interpretive USGS Reports	Non-Interpretive / Data Reports	Abstracts	Fact Sheets	Journal Articles	Map Products (Formal Publications)	TOTAL
2007	14	32	68		16	3	133
2006	6	33	38		24	5	106
2005	7	32	52	1	24	33	149
2004	7		62	1	21	1	92
2003	23		35		16	6	80