ray bombardment of rock materials exposed at the earth's surface may enable us to estimate long-term erosion rates directly. Although still experimental, we believe these techniques to be sufficiently developed and many of the potential pitfalls well enough known (or at least identified) that they may be applied carefully to geomorphic problems. To date these techniques have been applied mainly to bedrock surfaces and to cobbles or boulders on depositional surfaces such as glacial moraines or stream terraces. However, because much of a landscape's history is contained within soils and regolith, it would be advantageous to attempt to apply these techniques directly to those portions of the landscape, as well as to cobbles, boulders, or bedrock where appropriate. We believe that although these rates would likely be subject to some error, they would be preferable for analyses of landform evolution to estimates based primarily on short-term sediment yields.

As a first step in applying these techniques to terrestrial sediments, we present preliminary analytical results of in situ-produced cosmogenic ^{14}C extracted from pebbles and coarse sands collected from three trenches at the Walnut Gulch Experimental Watershed, southern Arizona. The trenches were dug in interfluve, mid-slope and footslope environments, respectively, and sampled at depths ranging from the ground surface to approximately 3 m. Ages of the sampled deposits or surfaces are not known. Coarse-grained sediments collected from unchannelized areas should minimize uncertainties in exposure history arising from potential erosion and redeposition by eolian or slope wash processes. Also, because fine sediments have been shown to concentrate atmospheric ^{10}Be washed into the soil profile, coarse sediments should minimize the potential for similar contamination by atmospheric ^{14}C.

Because a sedimentary deposit is usually derived from bedrock or sediment which has been exposed at the earth's surface for some generally undetermined time period, the inherited component of the in situ cosmogenic isotope concentration in soils is perhaps the largest source of error in this method. In situ-produced ^{10}Be and ^{26}Al have been used most frequently to study bedrock erosion rates; however, it is advantageous to use a relatively short half-life isotope such as ^{14}C in sediments, since the inherited component should decay away in older deposits. To evaluate the effectiveness of the technique in eliminating a detectable inherited ^{14}C component, the depth distribution of in situ-produced ^{14}C will be compared to the theoretical exponential attenuation of in situ ^{14}C production with depth. Results will be compared between the three sampled environments.

09:30 a.m. Bierman, Paul R.

USING COSMOGENIC ISOTOPES TO MEASURE BASIN-SCALE RATES OF EROSION
BIERMAN, Paul R., and Steig, E., Department of Geology, University of Washington, Seattle, WA 98195

We present a new and different approach to interpreting the abundance of in situ-produced cosmogenic nuclides such as ^{36}Cl, ^{26}Al, and ^{10}Be. Unlike most existing models, which are appropriate for evaluating isotope concentrations on bedrock surfaces, our model can be used to interpret isotope concentration in fluvial sediment. Because sediment is a mixture of material derived from the entire drainage basin, measured isotope abundances can be used to estimate spatially-averaged rates of erosion and sediment transport. Our approach has the potential to provide geomorphologists with a relatively simple but powerful means by which to constrain rates of landscape evolution.

The model considers the flux of cosmogenic isotopes into and out of various reservoirs. Implicit in model development are the assumptions that a geomorphic steady-state has been reached and that sampled sediment is spatially and temporally representative of all sediment leaving the basin. Each year, the impinging cosmic-ray flux produces a certain quantity of cosmogenic isotopes in the rock and soil of a drainage basin. For a basin in steady state, the outgoing isotope flux is also constant. We solve for the rate of mass loss (m) as a function of isotope abundance in the sediment (C), the cosmic ray attenuation length (Λ), the isotope half life, and the effective isotope production rate (P):

$$m = \Lambda(P - C\lambda)C^{-1}$$

There are only a few published measurements of cosmogenic isotope abundance in sediment. We calculated model denudation rates for sediment samples from Zaire [1] and central Texas (^{21}Ne analyses by B. Hudson, Lawrence Livermore). The denudation rates we calculate appear reasonable and are similar to those we have measured directly on granite landforms in Georgia and southeastern California and those calculated for the Appalachian Piedmont [2].

SAMPLE	LOCATION	P (atom $g^{-1}y^{-1}$)	ABUNDANCE (atoms g^{-1})	ISOTOPE	LOWERING RATE* (m My^{-1})
EMB-1#	Zaire	16	$2.5*10^6$	^{10}Be	3.6
LUI-33&	Llano Uplift	24	$3.7*10^6$	^{21}Ne	4

Isotopic data and production rate from [1]
* Assumes bedrock density of 2.7 g cm^{-3}
& Corrected for $^{18}O(\alpha,n)^{21}Ne$ with shielded samples

[1] D. Lal, et al. Nature, 328, 139-141, 1987; [2] M.J. Pavich, Geomorphology, 2, 181-196, 1989.

09:45 a.m. Bennett, Steven W.

EOLIAN SAND TRANSPORT AT THREE STATIONS ON A DUNE BACKED COASTLINE IN NORTHERN INDIANA AND THEIR RELATIONSHIPS TO WEATHER-RELATED AND SITE-SPECIFIC CONTROLS
BENNETT, Steven, W., Department of Geological Sciences, Indiana University, Bloomington, IN 47405; OLYPHANT, Greg A., Department of Geological Sciences, Indiana University, Bloomington, IN 47405.

Continuous measurements of eolian sand transport (using Automated Sand Traps) and wind speed/direction at 1.5 m above the surface were achieved on a dune backed coastline near Gary, Indiana. Data were collected on an hourly basis for a 6 month period during which 55 major sand movement events were observed. The sandstorms lasted from 1 to 16 hours with an average length of 4 hours and produced total transport quantities of up to 227 kg m^{-1}. The largest sand movement totals occurred when the wind was northerly; indeed 75 percent of the total sand captured at our station in a small blowout occurred during periods when the wind was from north. Northerly winds also dominated overall sand movement at our station on the crest of a vegetated foredune, but the total amount of transported sand was only 6.5 percent of that in the blowout. Hourly sand transport efficiency, expressed as the ratio of measured transport to theoretical transport (based on Bagnold's equation), averaged 0.34 at the blowout station during the spring of 1992, whereas averages for the dune crest station and a station on the backshore were 0.04 and 0.15, respectively, during the same period. Efficiencies were highly variable, even during individual storms, and exhibited no obvious systematic trend. However, storm-wind direction, topography, and sand surface character (e.g. vegetation and surface moisture conditions) were all observed to have an influence on the efficiency of sand transport at the study site.

10:00 a.m. Grant, John A.

GRADATIONAL MODIFICATION OF THE RIO CUARTO CRATERS, ARGENTINA.
GRANT, John A. and SCHULTZ, Peter H., Geological Sciences, Box 1846, Brown Univ., Providence, RI 02912.

The Rio Cuarto Crater Field in Argentina (64°15'W, 32°45'S) is comprised of ten elongate NNE-SSW oriented depressions. Individual craters are up to 4.5 km long and decrease in size southward over a ~30 km distance. All the craters possess a 4:1 length-to-width ratio and are presently <10 m deep. Preserved rim relief is highest on the south or downrange end of the craters. Formation occurred during a low angle impact (as reported elsewhere) into the well-sorted sandy loessoid Pampean Formation (mode +4 phi), a pedocomplex locally >15 m thick. Stratigraphy at Rio Cuarto is capped by a ~1.5 m thick late Holocene sandy loess sheet. This overlies a truncated paleosoil B-horizon of probable hypsithermal age that is exposed in some crater walls. Hence, the craters are likely less than 3.5-5 ka old.

Rapid, mostly eolian modification at Rio Cuarto reflects substrate and climate effects on gradational history. Current prevailing winds approximately parallel long axes of the craters and produces a net downrange transport of sediment. Loess stripped from the crater floors forms longitudinal and more distal transverse dunes extending up to 1 km downrange of the rims. Redistribution of sediment stripped from the walls creates transverse dunes: exposed and oversteepened intradune walls backwaste and widen the craters. Lateral eolian transport of loessoid sediment out of the craters forms near-rim dunes that mantle exterior sides. Exposure of more resistant, calcic horizons on crater floors eventually slows deflation.

Only limited overall denudation is accomplished by fluvial and groundwater activity as indicated by low drainage densities in and around the craters (~0.4-2.5 km/km² and 0.3-0.5 km/km², respectively) and the lack of well-defined gullies at wall seeps. Occurrences of rim and wall incisement are rare and generally correlate with the location of pre-crater drainages that sometimes introduce alluvial fill.

Gradational styles at Rio Cuarto contrast with those in and around Meteor Crater, Arizona, where fluvial denudation is relatively more important. In contrast to Rio Cuarto, minimal denudation of ejected lithologies at Meteor Crater forms surface armoring lag deposits. As a result, gradation rates at Rio Cuarto are considerably higher than at Meteor Crater, and indicates that oblique impact features in surficial deposits represent geologically transient signatures relative to more common, deeper craters formed by higher angle impacts.

10:15 a.m. Gustavson, T. C.

PLAYA BASIN DEVELOPMENT, SOUTHERN HIGH PLAINS, TEXAS AND NEW MEXICO
GUSTAVSON, T. C., Bureau of Economic Geology, The University of Texas at Austin, Austin, TX 78713, and HOLLIDAY, V. T., Department of Geography, The University of Wisconsin at Madison, Madison, WI 53706

More than 20,000 playa basins have formed on fine-grained eolian sediments of the Quaternary Blackwater Draw and Tertiary Ogallala Formations on the High Plains of Texas and New Mexico. These basins are typically subcircular to oval and as much as 3 km in diameter and 15 m deep. Numerous hypotheses have been proposed for the development of playa basins: (1) subsidence due to dissolution of underlying Permian bedded salt, (2) dissolution of soil carbonate and piping of clastic sediment into the subsurface, (3) animal activity, and (4) deflation. All of these processes may contribute to playa basin growth, but playa basins developed mostly as a result of the interaction of eolian and fluvial processes.

Evidence of eolian processes includes lee dunes and straightened shorelines on the eastern and southern margins of many playas. Lee dunes, which occur on the eastern side of ~15% of playa basins and contain sediment deflated from adjacent playas, are crescentic to oval in plan view and typically account for 15 to 40% of the volume of the playa basin. Quaternary fossil biotas and buried calcic soils indicate that grasslands and semi-arid to arid climatic conditions prevailed as these basins formed. Evidence of fluviolacustrine processes in playa basins includes centripetal drainage leading to fan deltas at playa margins and preserved deltaic and lacustrine (playa) sediments. The roughly circular shape of these basins is due primarily to centripetal drainage and sheet flow on basin slopes. Through time playas have undergone numerous cycles of flooding and desiccation, which minimized vegetative cover and made playa sediments available for deflation. Playa basins expanded as fluvial processes eroded basin slopes and carried sediment to the basin floor where, during periods of minimal vegetation cover, loose sediment was removed by deflation.

Other processes that played secondary roles in the development of certain playa basins include subsidence induced by dissolution of deeply buried Permian salt, dissolution of soil carbonate and piping, and animal activity. Two small lake basins in Gray County, Texas, occur above strata affected by dissolution-induced subsidence. Dissolution of soil carbonate was observed in exposures and cores of strata underlying playa basins. However, dissolution is incomplete, and the missing soil carbonate is insufficient to account for the volume of the overlying playa basin. Cattle, and in the past vast numbers of migrating buffalo, destroy soil crusts in dry playas, making these sediments more susceptible to deflation, and carry sediment out of flooded playas on their hooves.

10:30 a.m. Terpstra, Paul D.

1987-1991 BEACH AND NEARSHORE MONITORING AT A MAJOR COASTAL ENGINEERING PROJECT ON THE ILLINOIS SHORE OF LAKE MICHIGAN
TERPSTRA, Paul D. and CHRZASTOWSKI, Michael J., Illinois State Geological Survey, 615 E. Peabody Drive, Champaign, Illinois 61820

Five years of monitoring geomorphic changes in the vicinity of a major coastal engineering project on the Illinois shore of Lake Michigan have shown that a disruption of natural dynamic equilibrium can cause rapid adjustments to the