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Planothidium Species in Rivers and Lakes of the United States

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In 1996, Round and Bukhtiyarova created the genus *Planothidium* from the *Achnanthes lanceolata* group. The genus is distinguished by having a flatter valve than *Achnanthidium*, multiseriate striae, continuous in the *delicatula* sub-group, interrupted centrally on the raphe valve, with a horseshoe-like depression on one side of the rapheless valve, in the *lanceolata* sub-group. The *lanceolata* sub-group are found in alkaline waters and are epipelic or epiphytic inhabit. Members of the *delicatula* sub-group are found in marine and freshwater habitats with high electrolytes.

Planothidium species have been identified and imaged from samples collected during 1993-1995 field seasons for the USGS National Water Quality Assessment (NAWQA) Program and samples collected in Grand Traverse Bay, Michigan by J.C. Kingston and others during 1977-1978. Taxa include *P. lanceolata*, *P. dubium*, *P. ellipticum*, *P. rostatum*, *P. peragallii*, *P. calcar*, *P. hauckianum*, as well as several related taxa that haven't been properly transferred yet, *A. delicatulum* var. *robusta*, *A. hauckiana* var. *rostrata*, *A. grana*, *A. dispar*, *A. lanceolata* var. *abbreviata*, *A. lanceolata* var. *apiculata*, *A. lanceolata* var. *bimaculata*, *A. lanceolata* var. *frequentissima*, *A. lanceolata* var. *haynaldii*, *A. lanceolata* var. *omissa*, *A. peragallii* var. *fossilis*, *A. peragallii* var. *parvula*. Also included are several undescribed species: *Achnanthes* sp. 2 (ANSWRC), *Achnanthes* sp. 7 GLRD, and *Achnanthes* sp. 24 GLRD.

Program, 14th North American Diatom Symposium, University of Michigan Biological Station, September 24-27, 1997, p. 17.

Quantitative Techniques for the Processing of Periphyton Samples Containing Sediments

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Quantitative analyses of algae from freshwater benthic environments require some special methods and precautions. Technique for collection of episammic or epipelic periphyton necessarily includes some sediment in the sample. Aside from the usual problem of how to separate fine sediment from diatoms, quantitative analysis also requires a careful inclusion of adnate species. Their numbers could be selectively reduced if the sediment wasn't proportionally included in the processing of the sample. To obtain an accurate count of cells, those attached to grains of sediment must be included in the count. There are two problems to overcome to obtain accurate counts. Firstly, a proportional fraction of sediment must be included in all subsamples taken for digestion and soft algae counts. Sediments that fall from suspension too quickly to be included proportionally in the subsampling or that are too large to fit through a pipette tip used for subsampling are sieved with ~210 micrometer mesh. The collected sediment can then be proportionally sampled by percentage of mass and subsequently added to the same proportion of the liquid fraction. Secondly, as much algae as possible must be detached from the sediment to produce a sample to be counted in a Palmer/Maloney cell or other counting device so that the sediment doesn't interfere with viewing. A rinse, stir and pour method can be used to remove a large proportion of cells from the sediment without destroying the cells. Testing the efficacy of processing procedures requires careful examination of all discarded fractions to ensure that cell losses are very low.

Program, 14th North American Diatom Symposium, University of Michigan Biological Station, September 24-27, 1997, p. 39.

Notes on Some Commonly Misidentified and Problematic Diatom Taxa of the Genus *Cymbella* in U.S. Rivers

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In the light microscopical analysis of diatom samples collected for the USGS National Water Quality Assessment (NAWQA) Program, several species of the genus *Cymbella* were found to be somewhat difficult to positively identify due to likeness in form and ambiguity in key features. These taxa include the following species: *Cymbella affinis*, *C. cistula*, *C. cymbiformis*, *C.* species 1 JCK, *C. tumidula*, and *C. turgidula*. Many of these taxa have similar features, such as placement and number of stigma(s), raphe structure, and valve shape. Light micrograph images are included to illustrate key features.

Program, 14th North American Diatom Symposium, University of Michigan Biological Station, September 24-27, 1997, p. 40.

Results of the First Western Coal Availability Study--
Hilight Quadrangle, Powder River Basin, Wyoming

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The U.S. Geological Survey, in cooperation with the Bureau of Land Management, Geological Survey of Wyoming, and U.S. Bureau of Mines, has produced an estimate of the amount of available coal in an area about 35 miles south of Gillette, Wyoming, where the Wyodak coal bed is, in places, more than 100 ft thick. Available coal is coal that actually is accessible for development under current regulatory, land-use, and technologic conditions. This first western coal availability study, in the Hilight quadrangle, has shown that approximately 60% (2.7 billion short tons) of the total 4.4 billion tons of original coal resources in the quadrangle is available for development. Of this total 4.4 billion tons, 2.9 billion tons are contained in the Main Wyodak coal bed; 67% (1.9 billion tons) of this coal bed is considered available.

Local coal-development considerations include dwellings, railroads, pipelines, power lines, wildlife habitat (eagles), alluvial valley floors, cemeteries, the Hilight oil and gas field, and the Hilight gas plant. Some of these considerations would be mitigated so that surface mining could proceed; others presently preclude mining in their vicinity.

[Molnia, C.L., Biewick, L.R.H., Blake, D., Tewalt, S.J., Carter, M.D., and Gaskill, C., 1996, Results of the first western coal availability study -- Hilight quadrangle, Powder River Basin, Wyoming: in Chiang, Shiao-Hung, ed., Coal -- Energy and the Environment, 1996; Thirteenth Annual International Pittsburgh Coal Conference Proceedings, pg. 798-803.]

Determining the Endowment of Federal Coal in the U.S. -- A Digital Data Base of Coal Ownership Status

L.N.R. Roberts, L.R.H. Biewick, and C.L. Molnia, USGS, Denver, CO

Coal produced from Federal leases has tripled from about 12 percent of the total U.S. production in 1976 to almost 34 percent in 1995. The reason for this increase is demand for low-sulfur coal for use in power plants and the fact that large reserves of this low-sulfur coal are in the western interior U.S., where the Federal government owns the rights to the majority of the coal reserves.

The U.S. Government does not have a library of standardized digital files which show status of energy mineral (oil and gas as well as coal) ownership; thus, it is difficult to determine how much Federal coal exists in any particular area. Digital files of coal ownership are needed because they can be combined with coal tonnage estimates from the U.S. Geological Survey (USGS) National Coal Assessment and with other spatial data. Combining such files in geographic information systems can aid in answering complex questions related to coal ownership, quantity, quality, depth, distance from power plants and transportation systems, and proximity to restricted areas such as National Parks. The digital ownership data are also used by the Bureau of Land Management (BLM) in their evaluation of Federal coal properties for development.

The USGS, in cooperation with BLM, is collecting all ownership data and compiling them in ARC/INFO coverages, to form a standardized library of these files. The original ownership data are presently scattered, residing in several district and state offices of the BLM, in different formats, at varying scales, and only for particular areas of interest. Some areas have no digital ownership coverage; in such cases, we are creating the files.

To date, we have completed and standardized the digital energy mineral ownership data for high priority coal areas: the Powder River Basin, Wyoming and Montana; the Piceance Basin, Colorado; the Wasatch and Kaiparowits Plateaus, Utah; the San Juan Basin, New Mexico and Colorado; and parts of southern Wyoming. The digital ownership data will be made available to the public through the BLM.

Roberts, L.N.R., Biewick, L.R.H., and Molnia, C.L., 1997, Determining the endowment of Federal coal in the U.S. -- A digital data base of coal ownership status: Geological Society of America Abstracts with Program, 1997 Annual Meeting Salt Lake City, UT, p. A289.

A New Approach to Digital Map Production

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Authors prepare their geologic maps in various formats prior to submitting them to the Central Publications Group of the USGS. The maps are mostly digital (mainly ARC/INFO and GSMCAD), but we still receive inked greenlines which we in turn have digitized in AutoCad. Our current approach to production is to save the maps in a common file format (DXF or ArcView shapefile), import the file into Adobe Illustrator via MAPublisher, and then compose the rest of the map sheet in a high-end graphics environment rather than a GIS. The advantages of this technique in comparison with conventional map preparation are numerous—much faster production time, ease of making revisions, reduced costs. Since the entire map sheet is in digital form, it can be distributed in a variety of ways: (1) conventional printing on paper at a printing plant, (2) plot on demand, (3) online release of a PDF file. [Use of trade names is for description only, not endorsement by the USGS.]

Donatich, Alex, 1997, A new approach to digital map production: Association of Earth Science Editors Program and Abstracts, 31st Annual Meeting, Boulder, Colo., p. 13–14.

Environmental Geochemistry, Mercury Speciation, and Effects to Surrounding Ecosystems of a Belt of Mercury Deposits and Abandoned Mercury Mines in Southwestern Alaska, USA

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ABSTRACT: Mercury-rich deposits and abandoned mercury mines are scattered over several thousand square kilometers in southwestern Alaska, USA. Stream-sediment, stream-water, and fish collected downstream from mercury mines contain highly elevated mercury concentrations when compared to that in corresponding samples collected from background sites. Stream-sediment samples collected near mines contain abundant cinnabar and as much as 5,000 ppm mercury. Generally, mercury concentrations in collected stream-water samples are below the 2.0 ppb drinking-water standard recommended by the State of Alaska. Mercury concentrations are much higher in unfiltered stream-water samples than in filtered water samples, indicating that suspended particles transport most of the mercury. Speciation studies indicate that methylmercury in stream-sediment and stream-water samples is low, generally less than 1 percent of the total mercury. Greater than 90 percent of the total mercury in the fish is methylmercury, which is typical of freshwater fish. However, all mercury concentrations in fish are below the 1.0 ppm (wet weight) action level for edible fish recommended by the U.S. Food and Drug Administration (FDA).

1 GEOLOGY AND MINERALOGY

Numerous epithermal mercury-rich deposits and abandoned mercury mines are located throughout a large region covering several tens of thousands of square kilometers in and surrounding the Kuskokwim River basin in southwestern Alaska. The deposits are hosted in sedimentary rocks of the Cretaceous Kuskokwim Group, the Triassic to Cretaceous Gemuk Group, and the Paleozoic Holitna Group, as well as Late Cretaceous and early Tertiary mafic to felsic intrusive rocks (Sainsbury and MacKevett, 1965). Mineralized mercury-rich veins and vein-breccias are found in the sedimentary or igneous rocks, or at their contacts. Formation of these deposits is closely correlated with igneous activity of a Late Cretaceous and early Tertiary magmatic arc in southwestern Alaska (Gray et al., 1997).

The mineralogy of the deposits is dominated by cinnabar and stibnite with subordinate realgar, orpiment, native mercury, pyrite, gold, and solid and liquid hydrocarbons; quartz, calcite, limonite, dickite, and sericite are alteration gangue minerals. Several of the deposits were mined between the early 1900's and the 1980's, but they are not currently operating because of low prices and low demand for mercury. About 41,000 flasks of mercury (1 flask=76 lb or 34.5 kg) have been produced from the region, which is about 99 percent of the total mercury produced from Alaska. Red Devil is the largest mercury mine in Alaska and it produced about 36,000 flasks of mercury. Most of the southwestern Alaska mercury deposits consist of small, discontinuous veins that rarely exceed a few meters in width and a few tens of meters in strike length. The deposits generally contain about 1 to 5 percent mercury and less than 1 percent antimony and arsenic, but are base- and precious-metal poor. The presence of the abandoned mercury mines in southwestern Alaska is a potential hazard to residents and wildlife populations because drainage enters streams and rivers that are part of local ecosystems.

2 ENVIRONMENTAL CONCERNS

Mercury is a heavy metal of environmental concern because elevated concentrations can be toxic to living organisms. Mercury has no known metabolic purpose, and contaminations are regarded as undesirable and potentially hazardous (National Academy of Sciences, 1978). Most mercury toxicity problems are related to organic mercury compounds, of which methylmercury is the most toxic to humans (Eisler, 1987). Conversion of inorganic forms of mercury (for example, cinnabar) to methylmercury is generally a result of bacterial activity. Methylmercury is volatile, water soluble, and concentrates in tissues (bioaccumulation) of fish and other aquatic organisms. Once mercury is converted to water-soluble forms, like methylmercury, it becomes readily available to biota. Mercury can increase in concentration with increasing trophic position in the food chain

(biomagnification), such as fish. Concentration of mercury in fish provides an easy pathway for mercury to enter the food chain (Eisler, 1987).

To evaluate environmental concerns, concentrations of mercury were measured in stream-sediment, stream-water, and fish collected downstream from deposits and mines. Mercury concentrations in fish are used to address the levels of mercury in the food chain that could eventually affect human health. Samples were also collected throughout southwestern Alaska where there are no known mercury deposits to establish regional backgrounds.

2.1 Stream-sediment samples

Stream-sediment samples collected downstream from abandoned mines contain as much as 5,000 ppm mercury (Gray, 1994). Stream-sediment samples collected from streams in unmineralized areas typically contain less than 1.0 ppm mercury, indicating that the samples collected near the mines have highly elevated mercury concentrations. These high mercury concentrations are due to the presence of the ore-mineral cinnabar (HgS) that is resistant to physical and chemical weathering. Although total mercury concentrations in the stream-sediment samples are high, mercury speciation studies indicate that concentrations of the highly toxic methylmercury are low. Methylmercury concentrations rarely exceed 1.0 ppb in stream-sediment samples, and usually comprises less than 1 percent of the total mercury.

2.2 Stream-water samples

Stream waters below the mercury mines in southwestern Alaska are slightly alkaline, pH of 7.1-8.4 (Gray et al., 1996). Cinnabar is highly insoluble in water and does not easily form acid drainage during weathering. In addition, there is rarely enough pyrite in these deposits to generate any significant acid drainage. Thus, acid formation in streams below the mines is generally insignificant.

Unfiltered stream-water samples collected below mercury mines generally contain less than 1.0 ppb mercury, but may contain as much as 2.5 ppb mercury; whereas, corresponding stream-water samples, filtered through a 0.45μm membrane, contain less than 0.20 ppb mercury. These stream-water results indicate that suspended material transports most of the mercury downstream from the mines. Mercury speciation studies indicate that concentrations of methylmercury are low in stream-water samples. Methylmercury concentrations are typically less than 0.10 ppb in all stream-water samples, which is generally less than 1 percent of the total mercury in these waters. All background stream-water samples collected in the region contain less than 0.10 ppb mercury. Generally, mercury concentrations in these stream waters is below both the 2.0 ppb drinking-water standard recommended by the State of Alaska (Alaska Department of Environmental Conservation, 1994) and the 2.4 ppb maximum concentration recommended by the U.S. Environmental Protection Agency (EPA), but exceeds the 0.012 ppb concentration that the EPA indicates may result in chronic effects to aquatic life (Environmental Protection Agency, 1992). When stream water exceeds 0.012 ppb, edible portions of fish are analyzed to determine if they exceed the FDA action level of 1 ppm wet weight (Federal Register, 1979).

2.3 Fish

Muscle samples (edible fillets) of freshwater fish collected downstream from mines contain as much as 0.62 ppm mercury (wet weight). Mercury concentrations for these fish are considered elevated because similar fish collected from background streams contain only about 0.10 ppm mercury (Gray et al., 1996). Generally, methylmercury comprises more than 90 percent of the total mercury in fish muscle, which is typical for freshwater fish. Although fish collected downstream from the mines contain mercury concentrations higher than background samples, the mercury contents in the fish are below the 1.0 ppm FDA action level for edible fish, at this concentration, advisories are posted and the sale of fish is restricted.

Mercury concentrations were also measured in northern pike and salmon collected from large rivers in the region because these fish are often consumed by local residents and sportsmen. Mercury concentrations in muscle samples of the pike and salmon are low, less than 0.10 ppm, and are also below the FDA action level.

3 CONCLUSIONS

Stream-sediment, stream-water, and fish samples collected downstream from the abandoned mercury mines contain high concentrations of mercury in comparison to regional background concentrations in corresponding samples. The mercury-rich mineral cinnabar, derived from mercury deposits upstream, is the dominant source of mercury in the stream environment. The low concentrations of methylmercury in stream-sediment and stream-water samples indicates only minor conversion of inorganic mercury in cinnabar to the highly-toxic methylmercury. The elevated mercury concentrations in fish collected near the mines indicate that some biologically available mercury is taken-up by the fish. The fish probably accumulate the mercury through their gills from suspended particulates in stream water or from food sources. When mercury enters the food chain it can be hazardous because mercury tends to concentrate in the highest predators through biomagnification. Mercury concentrations in fish are useful for addressing the levels of mercury in the food chain that can eventually affect human health. However, all of the fish analyzed contain mercury concentrations below 1.0 ppm action level for edible fish recommended by the FDA. These results represent a case study of the environmental effects of mercury mines that has application to similar mercury-rich mineral deposits worldwide.

REFERENCES

Alaska Department of Environmental Conservation, 1994, Drinking water regulations: State of Alaska, Department of Environmental Conservation report 18-ACC-80, 195 p.

Eisler, Ronald, 1987, Mercury hazards to fish, wildlife, and invertebrates: a synoptic review: Fish and Wildlife Service Biological Report 85(1.10), 90 p.

Environmental Protection Agency, 1992, Water quality standards; establishment of numeric criteria for priority toxic pollutants; states' compliance; final rule: Federal Register, 40 CFR Part 131, v. 57, no. 246, p. 60,847-60,916.

Federal Register, 1979, Action level for mercury in fish, shellfish, crustaceans, and other aquatic animals: comment from the Department of Health, Education, and Welfare, Food and Drug Administration, v. 44, no. 14, p. 3990-3993.

Gray, J.E., 1994, Environmental geochemistry of mercury deposits in Alaska: U.S. Geological Survey Fact Sheet 94-072.

Gray, J.E., Gent, C.A., Snee, L.W., and Wilson, F.H., 1997, Epithermal mercury-antimony and gold-bearing vein lodes of southwestern Alaska: Economic Geology Monograph 9, p. 287-305.

Gray, J.E., Meier, A.L., O'Leary, R.M., Outwater, C., and Theodorakos, P.M., 1996, Environmental geochemistry of mercury deposits in southwestern Alaska: mercury contents in fish, stream-sediment, and stream-water samples, *in* Moore, T.E., and Dumoulin, J.A., eds., Geologic Studies in Alaska by the U.S. Geological Survey, 1994: U.S. Geological Survey Bulletin 2152, p. 17-29.

National Academy of Sciences, 1978, An assessment of mercury in the environment: National Academy of Sciences, Washington, D.C., 185 p.

Sainsbury, C.L., and MacKevett, E.M., Jr., 1965, Quicksilver deposits of southwestern Alaska: U.S. Geological Survey Bulletin 1187, 89 p.

The reference for this abstract is:

Gray, J.E., 1997, Environmental geochemistry, mercury speciation, and effects to surrounding ecosystems of a belt of mercury deposits and abandoned mercury mines in southwestern Alaska, USA [abs.], *in* 4th International Conference for the Society for Geology Applied to Mineral Deposits, Turku, Finland, August 11-13, 1997: Papunen, Heikki, ed., Mineral Deposits: Research and Exploration, Where do they Meet?, p. 899-902.

Uranium and uranium isotopes as tracers of nutrient addition: a case study in South Florida

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Drainage water from agricultural areas south of Lake Okeechobee is the suspected carrier of excess phosphorous (P) to portions of the Everglades of South Florida. The addition of fertilizer-derived P to Everglades peat can be assessed through the monitoring of fertilizer-derived uranium (U). Phosphate fertilizer typically contains 20-200 $mgkg^{-1}$ U that correlates with P content and that originates from the mined phosphate rock. Fertilizer U also retains a distinctive, rock-like $^{234}U/^{238}U$ alpha activity ratio (AR) of 1.00 ±0.05. These characteristics provide a distinctive U-based signature of fertilizer that is potentially traceable in low- U environments such as Everglades peat. Six peat cores from areas variably impacted by excess P were sampled to determine the depth-wise distribution and the apparent lateral dispersion of fertilizer-derived U. Peat closest to canals carrying agricultural runoff sorbs enough U to produce anomalous bulk uranium concentrations of >1.0 $mgkg^{-1}$ in shallow horizons. In these horizons the easily-exchangeable U that is soluble in 0.1 M $NaHCO_3$ has an isotopic composition that is consistent with a fertilizer origin (AR= 0.97 to 1.03). In contrast, peat samples from unimpacted sites contain <0.2 $mgkg^{-1}$ U and have AR values of 1.05 to 1.22 in the exchangeable fraction. Some peat horizons of intermediate depth and U content have exchangeable U with AR values that suggest a mixture of natural and fertilizer-derived U. Isotopic evidence for fertilizer addition to a cultivated field was equivocal because of poor contrast with background AR values of the local soil (AR =1.03 to 1.05). Measurements of AR in agricultural runoff are pending.

Program with Abstracts, 4th International Symposium on Environmental Geochemistry, October 5-10, 1997, Vail, Colorado. U.S. Geological Survey Open-File Report 97-496, p 99.

Preliminary Geophysical Results from the Rio Rancho Area, New Mexico.

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A combined airborne time domain electromagnetic pulse (TDEM) and magnetic survey was conducted in March 1997 in the Middle Rio Grande Basin in the vicinity of Rio Rancho, New Mexico. The area covered by the survey generally coincides with a high-resolution magnetic survey conducted in 1996 (see Grauch et al., this vol.). In addition to the airborne surveys, ground electrical resistivity (DC) and audiomagnetotelluric (AMT) studies were performed in the summer of 1997. The primary objective of the geophysical surveys was to delineate geological structures and facies changes within the Santa Fe Group aquifer system important to the local and regional hydrogeology. The surveys were based on the assumption that the axial channel gravel deposits, which are the main aquifers in the Middle Rio Grande Basin, will have a higher electrical resistivity than surrounding finer-grained materials.

The choice of the airborne TDEM method for this investigation was dictated by several factors. First, airborne methods efficiently provide significant amount of information over a wide area. Second, airborne TDEM can be used to infer the general distribution of the electrical resistivity up to a depth of several hundred meters from the surface, a greater depth penetration than available from other airborne electromagnetic (EM) methods. However, even though the method has been used for many years in mining geophysics to find massive sulfides, its use in the area of hydrogeological mapping is new. Interpretative techniques aimed at mapping the subtle resistivity variations due to the lithologic facies changes are not yet fully developed.

In the GEOTEM* TDEM system (operated by Geoterrex*), a burst of EM signal is generated by an antenna mounted on the airplane. In the receiver, the arriving EM signal is recorded as a voltage at specific times after each pulse (TDEM response). The received signal is affected by many factors, but, ideally, the shape and strength of the signal depends on the resistivity distribution in the subsurface. Therefore, using appropriate algorithms, one can convert the measured voltages to the electrical resistivity distribution with depth. In general, stronger signals indicate lower resistivities and weaker signals indicate higher resistivities. Earlier arrival times provide information on the shallower depths, and later arrival times provide information on the deeper depths.

The Rio Rancho survey covered an area about 25 km x 40 km. It was flown using 400 m flight spacing at a 120 m height above ground level (AGL). Over urban areas the flight height reached about 250 m AGL. A data point was recorded every 15 m along the flight direction.

The response of the TDEM system is affected by cultural features on the ground. Fences, pipelines, communication lines, railways and other man-made conductors can contaminate the responses. The areas affected by such cultural noise can not be used for interpretation. The majority of cultural anomalies can be easily identified, but sometimes the cultural noise response is very subtle and can be mistaken for the earth response. The Rio Rancho area is severely affected by the cultural noise, especially in the central and eastern part of the survey.

In order to obtain resistivity information in areas affected by cultural noise and to provide an independent check on the interpretation of TDEM models, we collected ground-based DC and AMT data in the study area. Preliminary resistivity values interpreted at few points from AMT, DC and TDEM models are in the range of 100 to 5 ohm-m, which is also a range of resistivities measured by induction logs in wells scattered over the area.

Our preliminary results, in the form of maps of voltages recorded at different times, show a good agreement between the TDEM response and other subsurface information. Clear changes in the TDEM response occur at several mapped faults and at faults inferred from the high-resolution magnetic survey. Voltage maps for most times show a similar geographic pattern that can be divided into five areas of distinct voltage responses. On the east we observe a very low voltage area that can be related to thick axial gravel deposits of the Ancestral Rio Grande inferred from well logs. The western boundary of this low voltage area is roughly 2 km to the east of the inferred western boundary of the thick axial river deposits. To the northwest an area of higher voltages coincides with the Zia Horst, in which uplifted silty units of the lowest Santa Fe are near the surface. To the south of the Zia Horst, at a center of the map, lower voltages correspond in part to channel-rich middle Santa Fe units. The voltage pattern suggests this unit does not extend as far north as expected. On the other hand, exposed basalt in the southern part of this area, which is prominent on the magnetic map, is not observed on the voltage maps. Either the basalt is too thin to be detected or its electrical properties are similar to the underlying deposits. On the west we observe an area displaying the highest voltages, the eastern boundary of which coincides with the Sandhill Fault. Mesozoic Mancos shale is the likely cause of the highest voltage responses. Between the highest voltages on the west and the lower voltages in the center of the map is an area of moderate voltages, which is bounded on the east by two faults clearly observed on the magnetic data.

We have not yet determined the electrical resistivity values that correspond to particular geological units. We had hoped to use the contractor-provided electrical conductivity-depth-thickness (CDT) profiles to identify the zones of different resistivities, but preliminary comparison of the profiles with induction logs was disappointing in the Rio Rancho area (in the Cochiti area, the few logs and AMT models roughly agreed). Another algorithm, developed and owned by BHP* geophysical company provided resistivity sections that closely correlated with well logs and available geological sections. We must develop an algorithm that will invert the data to reliable resistivity-depth information.

* The use of trade names is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Proceedings from the 2nd Middle Rio Grande Basin Study Workshop, Albuquerque, New Mexico, February 10-11, 1998.

Isotopic Ages, Cooling Histories, and Magmatic Origins for Mesozoic Tonalitic Plutons from the northern Peninsular Ranges Batholith, s. California

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$^{206}Pb/^{238}U$ ages on zircon, determined using either or both the high-resolution ion microprobe (SHRIMP) and conventional isotope dilution methods, are interpreted as ages of emplacement for a suite of twenty-three Mesozoic plutonic samples collected along a roughly E-W-trending traverse through the northern Peninsular Ranges batholith (PRB). These ages are compared to U-Pb sphene ages, and ^{40}Ar-^{39}Ar hornblende, biotite, and K-feldspar ages as well as apatite fission-track ages for the same sample suite to help delineate apparent cooling histories. The sampling spans the width of the batholith and includes mainly tonalitic units from all three major tectonic blocks of the PRB.

Zircon ages span from 118-125 Ma for shallow plutons from the NE Santa Ana and NW Perris Blocks, to 108-114 Ma for shallowly emplaced plutons in the Monument-Steele-Gavilan Peaks area, to 100-106 Ma for intermediate-depth, Bonsall-type plutons of the north-central Perris Block, to 94-97 Ma for central Perris - NE San Jacinto Block plutons, and finally to 83-84 Ma for deeper level plutons east of the San Jacinto Mylonite Zone. With the possible exception of the latter event, magmatism appears to progress eastward at a relatively steady pace for approximately 30 m.y. The apparent cooling rates for these different areas vary from rapid in the west (~200°C/m.y.), to moderate in the central areas (50-130°C/m.y), to slow in the very eastern area (25-40°C/m.y.). The slow rates in the east suggest either reheating to temperatures up to 300-500°C about 65-70 Ma, or prolonged residence at depth (~15 m.y.). An exception in the eastern block, the massive San Jacinto pluton appears to have cooled very rapidly (>350°C/m.y). Apatite fission-track ages, which record cooling below ~110°C, and apatite track lengths have been determined for six samples across the traverse. Apatite ages range from ~93 Ma in the westernmost Perris Block to ~36 Ma in the extreme eastern part of the San Jacinto Block and indicate a progressive eastward age decrease similar to the trend in $^{206}Pb/^{238}U$ zircon ages.

Our interpretation of these age data differs slightly from previous ones for similar rocks in the middle and southern portions of the PRB, in that our data define a relatively smooth progression of magmatism from west to east, and that the transition from western-type plutonism to eastern (La Posta-type) is interpreted to have occurred at 99 Ma. The involvement of older crustal components to the progressive enrichment of eastern-type magma sources is also highlighted with the documentation of Proterozoic inheritance within zircon populations from samples of the northeastern part of the batholith as well as progressively-enriched initial Pb, Sr, and Nd values.

Geological Society of America, Abstracts with Programs, 1998 Cordilleran Section Meeting, v. 30, no. 5 , p. 59-60.

Real-time Monitoring of Bluff Stability at Woodway, Washington

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Damaging landslides occur almost every year on steep bluffs near Puget Sound. Most occur during or after periods of heavy rainfall. Previous workers have attributed such slides, particularly the deep ones, to ground-water seepage within the bluffs. Few actual measurements have been made, however, to study the relationships between rainfall, seepage, and bluff stability. During the summer of 1997, the U.S. Geological Survey began a project to monitor rainfall, ground-water pressures, and slope movement at an unstable bluff adjacent to the head of a slide that derailed a freight train during January 1997. The site is in Woodway, Washington, about 10 km north of Seattle.

The monitoring project will help clarify the time lag between rainfall events and resultant water-pressure changes, the magnitude of seasonal and short-term water-pressure variations, and the effects of water pressure changes on bluff stability. Field data are collected every 15 minutes and relayed by phone to a computer network where they are processed and then presented on the World-Wide-Web. Near-real-time monitoring of the site will also allow us to test and refine technology that might be used for landslide forecasting, emergency notification, or mitigation.

Baum, R.L., Harp, E.L., Lahusen, R.G., Likos, W.J., and Powers, P.S., 1998, Real-time monitoring of bluff stability at Woodway, Washington [abs.] *in* Abstracts and Biographies--Puget Sound Research '98 , Seattle, Washington, March 11-12, 1998: [Olympia, Washington] Puget Sound Water Quality Action Team, (poster abstracts) p. 2

Meteorite Impact Generated Shock Remnant Magnetization in the Earth's Lithosphere

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Evidence is presented that MAGSAT data contains Shock Remnant Magnetization (SRM) signatures due to meteorite impacts. The global distribution of these impact-related magnetic signatures is not entirely random due to plate tectonic effects. Comparison with known impact sites indicates that many SRM signatures are the result of multiple impacts, while others are associated with isolated events. The distribution of SRM signatures can be used as a guide for locating undiscovered impact sites, both on land and in the oceans. The center of an SRM signature is generally offset from the impact site by several hundred kilometers. The offset distance depends on the meteorite's incident angle of trajectory with respect tot the vertical. The smaller the angle, the less is the offset.

At least three Shoemaker-Levy type meteorite string events can be identified. One passes just west of the Australian coast, extending from the southern Indian Ocean to the equator. A second stretches across Africa from Madagascar to Morocco. A third string stretches from just northeast of Luscon in the Philippines to the southern edge of the Central Siberian Plateau..

A specially designed scalar invariant derived from the crustal portion of a degree and order 29 magnetic field model has been used to isolate these SRM signatures. This scalar invariant peaks sharply over magnetized bodies and falls to zero at the lateral limits of the source body, thus yielding far better resolution of these source bodies than one gets by just examining total intensity residuals. This scalar invariant is quite sensitive, and is capable of isolating SRM signatures generated by meteorite impacts leaving craters as small as 1 Km . The Barringer, Arizona meteorite impact is one example.

International Association of Geomagnetism and Aeronomy 1997 Abstract Book for the 8'th Scientific Assembly, Uppsala, Sweden

ONGOING WORK ON MATERIALS FLOW IN THE MINERALS INFORMATION TEAM (MIT), MINERAL RESOURCES PROGRAM (MRP)

MATERIALS FLOW -- A NEW USGS RESEARCH AREA

Materials extracted from the earth are necessary to produce our most fundamental needs—food, clothing, and shelter. Materials are also needed to maintain and improve our standard of living. Materials flow, in the most literal sense, is a systems approach to understanding what happens to materials we use from the time a material is extracted through the processing, manufacturing, and to its ultimate disposition. Traditionally, the USGS has focused on material sources. In this new research area, the USGS has expanded its materials focus to the whole cycle; from source to ultimate disposition. The purpose of this work is to understand how and why we use our resources, and to help identify policies and practices to make resource use more efficient and protect the environment.

Research Products, USGS Minerals Information Team, Mineral and Materials Analysis Section

Reports are planned for the following studies in 1998: ***"Overview of Materials Consumption and Their Trends," "Estimating Total Raw Materials Consumption: A Methodology and Example Using Lead," "Crushed Cement Concrete Substitution for Construction Aggregates: A Materials Flow Analysis," "Aggregates from Natural and Recycled Sources,"*** and **"Energy Consumption for Recycled and Natural Aggregates."**

Consumption of Materials in the United States, 1900 to 1995

The flows of materials generated in the economy have significant impact on our lives and the world around us. Growing populations and economies demand more food, goods, services and space. Since the beginning of this century, the types, amounts, and properties of materials consumed in the United States have significantly changed. In 1900, almost half of the materials consumed domestically (on a weight basis) were from renewable resources, such as wood, fibers, and agricultural products. The rest was derived from non-renewable resources, such as minerals. By 1995, however, the consumption of non-renewable resources had dramatically declined, to only 8 percent of total consumption. Also, the use of petroleum in the production of plastics has been an extensive growth area for organics.

The USGS is examining the general historical shifts in the consumption of materials and the significance of trends in consumption. The report, **"Overview of Materials Consumption and Their Trends,"** by Grecia R. Matos and Lorie A. Wagner is scheduled for release in late 1998. The report is based on information collected over the course of the 20th century for the United States and the world, and places U.S. consumption in its perspective with the global community. During this century, not only have the types of materials utilized by mankind changed, but also the quantity consumed in the United States has grown tremendously. U.S. materials consumption rose from 161 million metric tons in 1900 to 2.8 billion metric tons by 1995, an equivalent of 10 metric tons per person per year. Moreover, of the total amount of material by weight consumed during this century, over half was consumed in the last 24 years. Using consumption of crushed stone and sand and gravel as an example, a simple extrapolation and projection of growth in their consumption over the next 25 years indicate that as many resources will be needed during this period as were cumulatively consumed since 1900.

Estimating Total Raw Materials Consumption: A Methodology and Example Using Lead

One of the fundamental pieces of information used in material flow and sustainability analyses is materials consumption. Published materials consumption statistics do not take account of materials that are contained in products imported into, or exported from, the United States. Raw materials are consumed as raw materials directly by domestic consumers and domestic industries and materials are contained in imported goods that we use. The trend in U.S. trade makes the issue of materials contained in imports increasingly important in the measurement of materials consumption. Net imports (imports less exports) of goods by the United States has increased substantially in recent years. In 1972, they were just under $19 billion (1990 dollars). By 1993, net imports had increased to more than $120 billion (1990 dollars).

To more accurately estimate total raw material consumption, materials contained in exported products need to be subtracted from domestic consumption and materials contained in imported products need to be added to domestic consumption. USGS researchers have developed a methodology to estimate total raw materials consumption, including an adjustment for imports and exports. The methodology is designed to measure the materials contained in imports to, and exports from, the United States. It builds upon a methodology developed in the mid-1970's and utilized today by the U.S. Department of Defense (DOD) to estimate strategic and critical wartime material requirements. The DOD uses this methodology to estimate the amount of raw materials necessary to satisfy the industrial demands generated by a level of economic activity resulting from various wartime scenarios.

The USGS has applied the methodology to lead, and examines the results in the report, **"Materials Flow Studies, Total Materials Consumption—An Estimation Methodology and Example Using Lead,"** by Marilyn B. Biviano, Daniel E. Sullivan, and Lorie A. Wagner. Metals and/or plastics are two types of materials that are contained in many imported and exported goods. Construction materials, such as crushed stone and sand and gravel are relatively low value to weight and tend to be produced and used in local markets. The metal, lead was selected as the test case for the methodology that USGS modified. To estimate total materials consumption. The report indicates for the test case of lead that lead contained in net imported goods increasing. Total domestic consumption of lead as a raw material (excluding lead contained in net imports) was estimated at nearly 1.4 million short tons in 1993. After excluding lead contained in products that are exported, such as batteries and automobiles, and including lead contained in the same imported products, the U.S. total consumption of lead in 1993 is estimated to be 1.6 million short tons, which is 14 percent higher than lead consumed as a raw material.

According to the report, the importance of lead contained in imported products becomes even more important when the trends are projected to the future. According to the study, based on a sector by sector analysis of lead consuming industries and their respective historical consumption trends, total consumption of lead (which includes lead contained in manufactured imports) is projected to be about 33% higher than raw material lead consumption in ten years. Further, when per capita consumption for total lead is projected, it is estimated to increase slightly over the next ten years while per capita consumption for raw material lead is projected to decline significantly.

The methodology utilizes input-output economic tools and historical industrial raw materials consumption data to estimate the relation between physical materials consumption and economic output by industrial sector. This approach offers an opportunity to measure many other materials flows (in addition to materials contained in imported and exported goods) in the economy that we were previously unable to measure. It could also provide a means to forecast materials flows under differing technologies, industrial output, and product mixes.

Recycling Concrete to Produce Aggregates

In 1996, over 2 billion metric tons of natural aggregates were used to construct our nation's highways, roads, and buildings. Natural aggregates from crushed stone and sand and gravel are by weight the most used material in the U.S. economy. The use of crushed concrete is rapidly increasing as a substitute for natural aggregates. Crushed concrete finds applications in the manufacturing of bituminous and cement concrete, as roadbase material, and in other uses. A report in progress, **"Crushed Cement Concrete Substitution for Construction Aggregates: A Materials Flow Analysis,"** by Thomas D. Kelly examines the flow of materials used to construct our nation's roads, highways, and buildings in order to understand the substitution of crushed concrete for natural aggregates. At present, the rate of substitution is less than 0.4% per year, but the rate is increasing rapidly. The materials flow analysis helps to understand the factors influencing this recycling effort. The report details the data available and where there are important data gaps. It puts in perspective the present rate of recycling while pointing to the great potential for future recycling efforts.

Assessing Availability of Aggregates from Natural and Recycled Sources

Much of our Nation's infrastructure (roads, buildings, and bridges) built during the mid-1900's is in need of repair or replacement. A large volume of cement- and asphalt-concrete aggregate will be required to rebuild this infrastructure, and support new construction. Use of construction waste as a source of aggregate is increasingly being used to supplement the growing demand for aggregate. But is such material suitable for construction use, is it economically viable, and will it be able to make a significant contribution to growing U.S. aggregate demand?

These questions are treated in a report scheduled for release by mid-1998, **"Aggregates from Natural and Recycled Sources,"** by David R. Wilburn and Thomas G. Goonan. The work also attempts to assess the impact of recycling on the natural aggregate industry, and point out incentives and disincentives of producing natural or recycled aggregates.

The report, based on 1996 and 1997 data, offers insights into questions that would be posed by policy makers, land managers, land-use planners, and interested industry participants to make informed decisions about aggregate recycling. Recycled aggregate is increasingly being used to supplement natural aggregates in road construction in a variety of applications, but its use varies widely among states. The total demand for aggregates, driven by demographics, urbanization, infrastructure needs, and the economy, is expected to remain strong in the near term. Recycling currently accounts for less than 3 percent of total aggregates consumption. Whereas this appears to be small on a national scale, it can be much more significant on a local or regional basis. The success of an operation depends upon favorable transportation and fee structures when compared to alternatives. This study fills a gap in research efforts on aggregate recycling, and provides a possible framework for future studies on construction materials.

Energy used in production processes raises concerns about future energy availability (because most current energy use is from non-renewable sources) and present environmental impacts (air, water, and soil pollution). Aggregates production outstrips all other minerals production in the United States. Recycling, in general, is seen as a way to conserve materials and energy. In a paper scheduled for release in 1998, **"Energy Consumption for Recycled and Natural Aggregates,"** by Thomas G. Goonan, energy requirements for producing aggregates from demolished portland cement concrete and reclaimed asphalt pavement are estimated and compared with reported requirements for producing aggregates from crushed stone, sand and gravel. While it take less energy to produce aggregates from the recycled material than it does from crushed stone, it takes still less to produce them from sand & gravel. Energy requirements for production and transportation of aggregates from both virgin and recycled sources is discussed and a methodology to use audit data to generate these comparisons is demonstrated. A brief discussion of water use in recycling is also presented.

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Infrastructure Resources for Expanding Metropolitan Areas -- An Overview

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Construction and maintenance of a community's infrastructure are critical to a community's sustainability and vitality. Rapid population growth has resulted in an inadequate or deficient infrastructure in communities in many areas of the country. Maintenance and development of the infrastructure, such as roads and airports, require large volumes of three natural resources: aggregate (primarily crushed stone, sand, and gravel), water, and energy. As urban areas expand, local sources of these resources are becoming inaccessible (for example, gravel cannot be extracted from under a subdivision), or the cost of recovery of the resource becomes prohibitive (oil and gas drilling in an urban area is costly), or the resources may become unfit for some uses (pollution of ground water may preclude its use as a water supply). Resources that are unavailable or inaccessible locally must be imported from more distant areas, usually at greater costs. As available resources are consumed or become inaccessible, the cost of maintaining or expanding the infrastructure increases and costs are passed onto the public in the form of higher taxes or reduced services.

The U.S. Geological Survey (USGS) Front Range Infrastructure Resources (FRIR) Project is a 5-year effort to improve the knowledge about the location and characteristics of aggregate, water, and energy resources that are vital to sustaining the infrastructure of the Colorado Piedmont. The project will provide the public and decision makers with objective scientific information to determine the rate at which these infrastructure resources are being preempted by one another or by other conflicting land uses.

Presented at GIS in the Rockies Symposium, September 1997, and Southwest Arc/Info Users Group meeting, October 1997.

Fractal Lognormal Percentage Analysis of the U.S. Geological Survey's 1995 National Assessment of Conventional Oil and Gas Resources

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Fractal lognormal percentage analysis was made for the oil and gas resource estimates of the conventional plays in the United States. For example, 20% of the 274 oil plays account for 73.05% of the total oil resources of the plays if the lognormal distribution is used, or for 75.52% empirically.

Crovelli, R.A., Schmoker, J.W., and Balay, R.H., 1997, Fractal lognormal percentage analysis of the U.S. Geological Survey's 1995 National Assessment of conventional oil and gas resources [abs.]: Institute for Operations Research and the Management Sciences (INFORMS) Conference Program, San Diego, May 4-7, 1997, p. 78.

3-D Distribution of Gas Production Across the Wattenberg Field, Denver Basin, Colorado

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3-D distribution of gas production for perforated zones in the Lower Cretaceous Muddy ("J") Sandstone is shown by a computer-generated model of the Wattenberg field. Upper surface of the 3-D model is the elevation of the top of the Muddy ("J") Sandstone; the lower surface is -3,200 ft elevation. The western margin of the field borders the north-south trending axis of the Denver Basin. A northeast-trending trough across the center of the field is coincident with a northeastern extension of the Colorado Mineral Belt towards the Transcontinental Arch. The field area is within a thermal "hot spot." Bounding hydrocarbon source rocks are thermally mature for gas generation (vitrinite reflectance contours range from 0.9% to 1.5% Ro).

More than 7.3 million cubic feet of gas have been produced from greater than 1,300 wells in the field. Both the model and 2-D maps show highly irregular distribution of gas production across the field area. Initial and best-year-cumulative gas production are closely associated to locations of fault and fracture networks. Heterogeneity also results from variation in depositional energy of producing intervals. Primary producing intervals are low-porosity and low-permeability delta-front and nearshore-marine, thin-bedded, fine-grained, sandstone-shale units of the Fort Collins Member. Gas is also produced from overlying fine-to-medium-grained valley-fill sandstones of the Horsetooth Member.

American Association of Petroleum Geologists, 1997 Rocky Mountain Section Meeting; Abstracts, AAPG Bulletin, 1997, v. 81, no. 7, p. 1225.

Petrified Forest National Park Upper Triassic Trace Fossils Yield Biochemical Evidence of Phylogenetic Link to Modern Bees (Hymenoptera, Apoidea)

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Ichnofossils suggestive of primatively-social bees have been identified morphologically, architecturally and behaviorally from lithified logs of the Gymnosperm *Araucarioxylon arizonicum* of the 220 Ma. Black Forest bed, Petrified Forest Member of the Upper Triassic Chinle Formation, Petrified Forest National Park, Arizona, U.S.A. These well-preserved trace fossils exhibit cell shapes, cell wall linings and spiral cap plugs observed in some modern, phylogenetically regulated, social and solitary Apoidea brood cell construction techniques.

Here we present preliminary organic geochemical results from solvent extractions obtained from six such fossil linings and their adjacent permineralized matrices using Electron Impact ionization Gas Chromatography - Mass Spectrometry / Mass Spectrometry, thus demonstrating additional diverse evidence suggestive of Apoidean origin for these approximately 1.5 cm long, flask shaped ichnofossils. Three components identified in the extractables are: a homologous series of three *straight-chained aliphatic esters* — C_{14}-C_{14}, C_{14}-C_{16} and C_{14}-C_{18} — seen only in the fossil linings; a homologous series of n-alkanes — C_{14} through C_{34} having no odd/even preference; and total ion chromatograms of numerous isoprenoids. The esters and n-alkanes gave molecular ions, while the isoprenoids fragmented when ionized. Only the esters are significantly interpretable at this time. Interestingly, some terpanes are seen only in the cell linings. We regard the three tetradecyl (C_{14}-) esters with particular significance in that it raises the possibility of *in situ* preservation of whole, unaltered, *de novo* biomolecules; although diagenetic ring-opening of *de novo* macrocyclic lactones catalyzed by *in vitro* free radicals within sedimentary porespace water is another interpretation.

The combined evidence suggests and is consistent with the notion that these trace fossil builders were rooted in ancestral stock that produced similar exocrine coatings via the Dufour's gland, still functional in some of today's socially varied bees. Various taphonomic processes pertinent to an explanation for the preservation of these biolipids remain active research topics. These ongoing efforts include XRD and various techniques employing electron beam microscopes and further elucidation of molecular structure.

Kay, Paul. T., King, J. David, Hasiotis, Stephen T., 1997, Petrified Forest National Park Upper Triassic Trace Fossils Yield Biochemical Evidence of Phylogenetic Link to Modern Bees (Hymenoptera, Apoidea): 1997 Geological Society of America Annual Meeting Salt Lake City, Utah, October 20-23, 1997.

The Dominance of Vertical Attenuation Over Simple-Shear Translation During Tertiary Extension in the Salina, Utah Area--A Role for Dissolution?

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Highly attenuated Tertiary sedimentary and volcanic rocks near Salina, UT are separated from underlying Jurassic Arapien Shale by an undulatory gently dipping contact that has many attributes common to detachment faults. Fragments and blocks of variously tilted Tertiary strata that initially formed a layered assemblage more than 2 km thick are distributed in a chaotic to well-organized faulted style above the contact, forming a zone of attenuation that is currently less than 200 m thick. Geologic mapping and detailed structural study of the contact zone shows that the attenuation cannot result from either detachment-style faulting or a history of erosion and deposition, thus requiring an alternative explanation. In a zone 10 - 100 m thick directly below the contact, lower-plate Jurassic shale, sandstone, and gypsum are oxidized to a conspicuous red color and contain secondary halite and gypsum suggesting alteration and low-temperature mineralization associated with the contact. The Jurassic rocks are folded on east-trending axes and, at many localities, are truncated sharply at the contact with overlying attenuated Tertiary rocks. Relative to the directly adjacent Wasatch Plateau on the east, the Tertiary rocks were lowered structurally during formation of the contact. Conversely, a published cross section through the area shows that the Jurassic rocks were elevated relative to rocks that form the Plateau. This uplift probably occurred simultaneous with lowering of the Tertiary strata as suggested by the fact that holocrystalline synvolcanic Tertiary plutons enclosed in the Jurassic rocks have been uplifted hundreds of meters above the adjacent coeval volcanic rocks. This spectacular vertical convergence toward the gently dipping contact cannot be explained by detachment-style large-magnitude shear translation because the attenuation occurred directly adjacent to the undeformed plateau. We speculate that synextensional (mainly Miocene?) dissolution, associated with highly channelized large-volume fluid flow, was an essential process accompanying attenuation. The dissolution zone decoupled highly contrasting deformation styles: strong north-south contraction and uplift below and east-west extension and collapse above.

Geological Society of America, Abstracts with Programs, 1997, v. 29, no. 6, p. A-221.

GEOCHEMICAL AND PETROGRAPHIC EVIDENCE FOR FLUID FLOW AND DISSOLUTION IN SOME LOW-ANGLE NORMAL FAULTS, UTAH AND NEVADA

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Geochemical and petrographic studies of fault gouge, breccia, and veins from four low-angle normal faults (LANFs or detachment faults) show that fluid flow and dissolution are closely associated with fault movement. The LANFs studied are: (1) the Castle Cliff fault, southwestern Washington Co., UT, (2) the Tule Springs and (3) Petroglyph faults in the Mormon Mountains, southern Lincoln Co., NV, and (4) a newly discovered fault near Salina, Sevier Co., UT. Each fault has abundant evidence of brittle fracture and brecciation that could have resulted from seismogenic failure.

The Castle Cliff, Tule Springs, and Petroglyph LANFs are characterized by attenuated carbonate stratigraphic sections. The fault zones are typically composed of layers of solution boudins, bounded by calcite-cemented breccia. In both the upper and lower plates, pressure solution seams and the surrounding characteristically altered grayish pink host rock has significant negative shifts in ^{18}O values (to -14.50 ‰ PDB). We interpret the depleted ^{18}O values in zones of solution boudins as evidence of the passage of hydrothermal fluids, with accompanying dissolution of the host rock. Oxygen isotopes are less depleted (a 5-7 ‰ shift) at distances less than a meter from the solution boudins.

At scales ranging from <1 mm to tens of meters, steeply dipping normal faults in upper-plate strata terminate at or merge with dissolution surfaces. These dissolution surfaces probably record an open fluid-flow system that operated along the LANF and accommodated upper-plate faulting and brecciation. If so, the prospect that these LANFs and their upper-plate structures produced large earthquakes is diminished.

At Salina, the LANF separates folded and faulted lower-plate Jurassic Arapien Shale from faulted and tilted upper-plate Tertiary sedimentary and volcanic rocks. The LANF is marked by a conspicuous red alteration zone 1-30 m thick in lower-plate rocks. As much as 2 km of stratigraphic section is missing at the LANF. Brecciation and shear fabrics are poorly developed and are restricted to a zone <2 m thick. This LANF, with its unspectacular minor structures and fabrics, has many attributes of detachment faults, but its direct proximity to the western margin of the Colorado Plateau province makes large-magnitude simple shear an unviable process to explain the missing strata. Although dissolution has occurred at this LANF, it does not appear to be the dominant process.

Diehl, S.F., Humphrey, J.D., Anderson, R.E., and Nealey, D.L., 1996, Geochemical and petrographic evidence for fluid flow and dissolution in some low-angle normal faults, Utah and Nevada: Geological Society of America, Abstracts With Programs, v. 28, no. 7, p. A387.

GEOLOGIC, HYDROLOGIC, AND AEROMAGNETIC MAPS OF THE PUEBLO OF ISLETA, CENTRAL NEW MEXICO

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Geologic mapping by the U.S. Geological Survey and New Mexico Bureau of Mines and Mineral Resources depicts the geology, hydrology, and aeromagnetometry of parts of the Pueblo of Isleta. Our mapping is part of the Middle Rio Grande Basin Study and shows the western three-quarters of the reservation from just west of the foothills of the Manzano Mountains on the east to the Rio Puerco on the west. Major geologic features within the area are: (1) five basaltic volcanic fields; (2) deposits of the Santa Fe Group; (3) post-Santa Fe terrace deposits; (4) widespread calcic soils; and (5) high-angle normal faults.

The basaltic fields in the western half of the area include the following, listed from youngest to the oldest; (1) Cat Hills; (2) Black Mesa; (3) Isleta, (4) Cat Mesa; and (5) Wind Mesa. The Cat Hills field is composed of seven lava flows and 21 cinder cones. Samples from the oldest flow have $^{40}Ar/^{39}Ar$ whole-rock ages of 0.11±0.03 and 0.098±0.02 Ma. A previous K-Ar age for the oldest flow is 0.14±0.04 Ma (Kudo and others, 1977). Samples from the youngest flow have discordant $^{40}Ar/^{39}Ar$ whole-rock ages of 0.49±0.16 Ma and 0.25±0.08 Ma. A dike exposed in the northernmost cinder cone has an $^{40}Ar/^{39}Ar$ whole-rock age of 0.18±0.08 Ma. This and other cinder cones are aligned on a north-northeast striking fissure zone.

The Black Mesa basaltic lava flow is exposed northeast of the Isleta field and is interbedded with Rio Puerco sand and gravel facies of the upper part of the Santa Fe Group. No volcanic source for this flow has been identified. A sample from this field has an $^{40}Ar/^{39}Ar$ age of 2.68±0.04 Ma.

The Isleta field is composed of five lava flows, two cinder cones, and one tuff ring (Kelley and Kudo, 1978). The lowest flow has an $^{40}Ar/^{39}Ar$ age of 2.75± 0.12 Ma and the overlying flow an $^{40}Ar/^{39}Ar$ age of 2.72±0.08 Ma and a previous K/Ar age of 2.78±0.12 Ma (Kudo and others, 1977).

The Cat Mesa field consists of a thick lava flow found locally at the base of the clay and silt facies of the Santa Fe Group (discussed below). A sample from this field indicates an $^{40}Ar/^{39}Ar$ whole rock age of 3.00±0.10 Ma.

The Wind Mesa field consists of three lava flows with minor cinder deposits. The flows are faulted and appear to be part of an exhumed volcano. Lag pebbles of the ancestral Rio Puerco lie on the lava flow 5 m above the present Santa Fe-lava flow contact supports this interpretation. A sample of the oldest flow has an $^{40}Ar/^{39}Ar$ whole-rock age of 4.01±0.16 Ma.

The exposed Santa Fe Group is considered to be part of the Sierra Ladrones Formation of Machette (1978) and composed of piedmont deposits from the Manzano-Manzanita Mountains and fluvial deposits of an ancestral Rio Puerco and ancestral Rio Grande. We have divided the ancestral Rio Puerco deposits in the westernmost part of the map area into three main lithofacies that are based on coarseness and clast content. From youngest to oldest, the facies are the following: (1) sand and gravel; (2) clay and silt; and (3) coarse sand and gravel. The fluvial deposits of the ancestral Rio Grande, exposed east of the

Rio Grande valley, are divided into mapable lithofacies consisting of a lower fine-grained facies and an upper coarse-grained facies. The upper facies contains pumice and reworked ash and large clasts of the 1.22 Ma-Tshirge Member of the Bandelier Tuff.

Post Santa Fe terrace deposits are found along the present Rio Grande valley inset against the Santa Fe Group. The most extensive terrace deposit is called the Los Duranes Formation. Its age is restricted by the oldest Cat Hills flow (0.14, 0.11, and .098 Ma) that overlies it.

West of the Rio Grande, widespread calcic soils are divided into two mapable types (1) calcic soils of the Llano de Alburquerque and (2) younger calcic soils. The calcic soils of the Llano de Alburquerque overlie the sand and gravel facies of the Rio Puerco and are overlain by the basaltic flow of the Cat Hills. Therefore the Llano surface is older than the discordant range of ages (0.098 Ma to 0.49 Ma) of the Cat Hills basalt flows and considerably younger than the basalt of Cat Mesa (3 Ma). The younger calcic soils are found interbedded with and below eolian deposits and are commonly found on the flanks of the Cat Hills cinder cones.

Calcic soils on the llanos east of the Rio Grande developed at the top of the ancestral Rio Grande deposits and on top of piedmont deposits that overlie the ancestral Rio Grande deposits. The piedmont-capped llano is 10 to 15 m lower than the ancestral Rio Grande upper surface.

A northerly striking high-angle normal fault zone forms a complex of grabens, half grabens, and horsts in the map area. From west to east, seven major fault zones include the: (1) Garcia (new name), (2) Cat Mesa, (3) Cedar Wash (new name), (4) Palace-Pipeline (new name), (5) McCormick Ranch, (6) Hubbell Spring, and (7) Sanchez faults.

The signatures on the aeromagnetic map reflect the major faults and volcanic fields that have been identified on the surface and shown on the geologic map. Both the hydrologically important Cat-Mesa and Hubbell-Spring faults are expressed on the aeromagnetic map. In addition, the map suggests that some segments considered part of the Hubbell Spring fault actually may not be connected.

The ground-water level contour map shows steep gradients in the western and eastern part of the map separated by a trough (Titus, 1963). The western (Cat Mesa) gradient on the west side of the Cat Mesa fault may reflect the juxtaposition of fractured basaltic rocks and coarser-grained Santa Fe Group against finer-grained facies of the Santa Fe Group. Another possible model is the presence of a northerly-striking fissure system that may be a steep ground-water barrier that parallels the Cat Mesa fault. The wide ground-water trough, which appears to plunge to the south, separates the Cat Mesa gradient from the eastern steep gradient. The eastern gradient, located along the Hubbell Spring fault and referred to here as the Hubbell Spring gradient, may represent juxtaposition of basin-fill material with bedrock.

GEOLOGIC-TECTONIC MAP AND STRUCTURAL DOMAINS OF ARMENIA

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Armenia, a country the size of the state of Maryland, contains complex geological relationships that result from several periods of plate convergence. Digitized maps and landsat imagery for the Lesser Caucasus region show a strong northwest trending structural fabric consisting of broad folds and reverse, thrust, and strike-slip faults. Pull-apart basins related to strike-slip faults are common. These structures represent a contractional period related to plate convergence of Late Cretaceous-early Tertiary age. Strike-slip and high-angle faults and nested grabens and half grabens also characterize this terrane and are related to a late Tertiary period of extension.

The country is underlain by approximately 75 percent volcanic or volcanic-derived sedimentary rocks that range in age from Proterozoic to Quaternary. Most of these volcanic rocks are shallow marine rocks deposited in an island arc setting. Terrestrial volcanic rocks of Pliocene and Quaternary age include those at Mount Aragatz (4090 m), a giant stratovolcano, and Mount Ararat (5165 m), just across the border in eastern Turkey. Two northwest- trending ophiolitic belts are located in the northern and southern parts of Armenia and probably represent suture zones and melanges. Carbonate, clastic, and plutonic rocks are present in the country but represent a small percentage of rock types.

At least five major structural domains that appear to young from north to south and reflect major periods of deformation have been identified. These domains from north to south: (1) the Somkhlet-Karabakian anticlinorium (SKA) zone, a Cretaceous fold-and thrust-belt of island-arc-derived rocks of Jurassic-Cretaceous age located just south of the Kura Depression, (2) Sevan-Akera synclinorium (SAS) zone, a Tertiary forearc basin, underlain by a ophiolitic suture zone, that subsequently became a foreland basin with the SKA zone thrusted over it after the late Eocene; (3) Tsakhkunk-Zangezur anticlinorium zone; containing Proterozoic rocks that may represent part of the Arabian plate; the north edge of the zone forms the south edge of the foreland basin of the SAS zone; (4) Yerevan-Ordubad synclinorium zone; a fold belt that contains ophiolitic melange(?); and (5) Central Armenian-Ararat Basin zone, characterized by recent extension that portioned the crust into a nest of grabens and half grabens. The Quaternary volcanism occurred during this period of extension.

Geological Society of America Abstracts with Programs, 1996, v. 28, no. 7, p. A-443.

A Smaller Big Pine Fault: New Interpretations of Fault Architecture in the Western Transverse Ranges, Southern California

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New geologic mapping of Cenozoic sedimentary and volcanic rocks along the northern edge of the western Transverse Ranges, in support of the USGS Southern California Areal Mapping Project (SCAMP), allows for reinterpretation of fault architecture that bears on potential seismic hazards of this transpressional tectonic province 80 km northwest of Los Angeles. Previous mapping had depicted the eastern Big Pine fault (BPF) as a northeast-striking, sinistral strike-slip fault that extends for 30 km northeast of the Cuyama River to its intersection with the San Andreas fault (SAF). In contrast the new mapping indicates that the eastern BPF is a thrust fault that curves from a northeast strike to an east strike, where it is continuous with the San Guillermo thrust fault, and dies out further east about 15 km south of the SAF. This redefined segment of the BPF is a south-dipping, north-directed thrust, with minor dextral and sinistral slip components (rakes > 60°), that places Eocene marine rocks over Miocene and younger nonmarine rocks. Although a broad northeast-striking fault zone, exhibiting large sinistral components of slip (rakes < 45°), does extend towards the SAF, this fault does not connect to the southwest with the BPF but instead curves into a north-dipping thrust fault that dies out to the west a short distance north of the BPF. The geometry of this thrust fault precludes connection with the BPF at depth and, thus, this separate fault is here informally renamed the Lockwood Valley fault (LVF). Oligocene to Pliocene(?) nonmarine sedimentary and volcanic rocks are folded on both sides of the LVF, such that the fold axes are parallel to the curved LVF trace. Asymmetric folds have southward vergence, with overturned folds most prominent south-southeast of the LVF. Several moderate-displacement (< 50 m), mainly northwest-dipping thrust and reverse faults, exhibiting mostly sinistral-oblique slip, flank and strike parallel to the overturned folds. The fold vergence and thrust direction associated with the LVF is opposite to that of the redefined BPF, providing further evidence that the two faults are distinct structures. These revised fault interpretations bring into question earlier estimates of net sinistral strike-slip displacement of as much as 13 km along the originally defined eastern BPF, which assumed structural connection with the LVF. Also, despite evidence for repeated Quaternary movement on the LVF (e.g., Dibblee, 1982), the potential for a large earthquake involving coseismic slip on both the LVF and the central BPF to the southwest may not be as great as once believed.

Minor, S.A., and Kellogg, K.S., 1997, A smaller Big Pine fault: New interpretations of fault architecture in the western Transverse Ranges, southern California [abs.]: Eos, v. 78, no. 46 sup., p. F700.

1924-1994: Evidence for a Global Moment Release Sequence

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The pattern of global seismic moment release described here is based on the Pacheco-Sykes catalog of large, shallow earthquakes, extended to the present with data from the Harvard and USGS moment catalogs. Beginning in about 1924, worldwide seismic moment release rate (Mw ≥ 7) slowed and then increased over several decades preceding the occurrence of the great May 1960 Chile earthquake, most dramatically in the last decade. Decadal moment release rates accelerated from 3*10^21 Nm/yr in 1930-1940 and 1940-1950 to 8*10^21 Nm/yr in 1950-1960. Following the Chile earthquake, mean moment release rate was anomalously low (7*10^20 Nm/yr) for 3.4 years until the occurrence of the South Kurile Islands earthquake in October 1963. The moment release rate rose dramatically with the occurrence of the great Alaskan earthquake of March 1964, and decelerated from 1.2*10^22 Nm/yr in 1960.5 through 1969 to a low of 1.5*10^21 Nm/yr in 1980-1989. This deceleration may have ended with the occurrence of the Kuriles/Hokkaido earthquake of October 1994. At Mw 8.3, this event is arguably the largest earthquake since the 1965 Rat Islands event. The moment release rate has increased to 8*10^21 Nm/yr during 1994.8-1997.5. This, however, is a short-term rate and may not be sustained.

The observed global moment release pattern (large event clustering, with acceleration before and deceleration after the main shock) is similar to behavior observed on a more local scale in the San Francisco Bay region (see, for instance, Bufe and Varnes, JGR, 1993). This suggests that Earth, over many decades, may respond as a coherent, non-random, non-linear system of stress redistribution. The observed pattern of accelerating moment release preceding the Chile earthquake can be described as a power law dependence on remaining time to failure, with an exponent of 0.1 to 0.2. As has been noted for regional seismicity before and after the Loma Prieta earthquake, the worldwide rate of smaller earthquake occurrence before and after the 1960 Chile earthquake does not appear to change systematically over time.

Bufe, C. G., 1997, 1924-1994: Evidence for a global moment release sequence: EOS (American Geophysical Union Transactions), v. 78, no. 46, p. F476.

Public Seismic Network (PSN): a Model for Preparing People to use Real-time Information About Natural Hazards

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When an earthquake occurs, unlike any other natural hazard, every individual in the population at risk is aware within seconds that a dangerous event has happened. Without the aid of any technology, the consciousness of everyone affected is almost instantaneously focused on the same subject. Instead of soliciting that information, authorities broadcast the redundant message that an earthquake has occurred. A program of monitoring natural hazards for the public requires public participation to effectively mitigate those hazards. The Public Seismic Network (PSN), rather than relegating them to the role of sitting ducks waiting to be devastated by the unexpected, enables people to become aware that earthquakes are part of normal, on-going Earth processes. The PSN is a rapidly growing international group of amateur seismologists, concentrated in California, who record earthquakes with their own digital seismographs and exchange waveform time series and communicate with each other *via* the Internet. At present, the PSN consists of about 50 seismograph stations, about 250 subscribers to its email list server, and about 10 websites. In urban areas of high seismic risk, a grassroots organization like the PSN -- equipped with low-cost, mass-produced, standardized strong-motion seismographs -- could vastly increase the spatial density of sampling ground motions. This organization would form a constituency of well-informed residents who not only know how to respond to catastrophic earthquakes but also support hazard mitigation programs in the community. Rather than just building faster ambulances to mitigate the impact of heart attacks, it is more effective to modify the public habits of exercise and diet. The PSN is a model for using technology to connect human awareness to, rather than shield it from, the environment.

Cranswick, E., Gardner, B. and Public Seismic Network, 1997, Public Seismic Network (PSN): A Model for Preparing People to Use Real-Time Information About Natural Hazards: Eos (American Geophysical Union, Transactions), v. 78, no. 46, p. F46 (AGU 1977 Fall Meeting, San Francisco, CA).

Metal Emissions from Kilauea - - Proportions, Source Strength, and Contribution to Current Estimates of Volcanic Injection to the Atmosphere

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Ordinarily-rare metals are abundant in the plumes of quiescently-degassing volcanoes. These include volatile metals such as Pb, Cd, Cu, Zn, Tl, In, Sb and others. Collections of metals from the Kilauea plume have been made during the present eruptive cycle which began in 1983, most recently in 1996. Metal emissions are assessed by normalizing to those of sulfur, for which total emissions are closely monitored at Kilauea and some other volcanoes in the world. We measured metals by ICP-MS, and sulfur and other anionic species by ion chromatography. Kilauea is representative of an important volcanic type (hotspot, basaltic) and its emissions are significant for defining worldwide fluxes. It emits metals in proportions different from those reported from other volcanoes (at Kilauea, Pb:Cd:Cu:Zn are 1:2.5:6:~30; compare Indonesia 1:0.01-0.1:0.1-2:0.1-0.2. The metal proportions, and metal- to-sulfur ratios, vary less wildly over short times at Kilauea than elsewhere. The Kilauea metal emissions also have different proportions from what has been suggested as a worldwide volcano average (Nriagu, 1988, Pb:Cd:Cu:Zn are 1:0.3:3:3). Also different from worldwide estimates are the metal/sulfur ratios at Kilauea, which appears to emit only about half of the metal per unit of sulfur that has been proposed worldwide: Kilauea might be expected to emit more than the average, because its low-viscosity lava should rapidly convect metals to the melt-vapor interface, feeding its plume. Worldwide estimates of volcanic metal emissions currently rely on data predominantly from surprisingly old, pioneering studies. If these estimates are accepted, Kilauea might account for 3-4 percent of the worldwide total metal emissions.

The problem of why ordinarily-rare metals are abundant in the atmospheric load (atmospheric deposition) persists after being known for several decades, and proposed contributions to the anomaly by ocean surface spray, plants, mineral surfaces, and anthropogenic activity have not been thoroughly documented. Recent data on long term deposition of rare metals in Antarctic ice suggest that volcanic metal emissions alone can account for the masses found in the ice, although the proportions of metals do not appear to correspond perfectly between the ice and volcanic emissions at Kilauea or other volcanoes (Pb dominates in ice of all ages). The depth-concentration profiles of trace metals in the oceans may be influenced or controlled by atmospheric deposition. Because Kilauea metal emission measurements differ from those at other volcanoes and from worldwide estimates, and because of the continuing uncertainty about he reasons for trace metal abundance in the atmospheric load, we feel that measurements of metal emissions should continue and should be extended, at Kilauea and at other quiescently-degassing volcanoes of key types around the world.

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Urban Dynamics of the Middle Rio Grande Basin

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Introduction

Urban dynamics is the study of changing landscapes or metropolitan areas in motion. A new housing subdivision, such as Huning Highlands, or a new shopping center, such as Winrock, is each an example of a city in motion. We measure the motion when we compare the geographic extent of urbanization through time. However, we can also characterize human-induced land transformations by temporally analyzing the conversion of land cover to land use categories, as well as by calculating population density, housing unit density, density of the transportation network, and water consumption rates. Withdrawal of groundwater by wells is an example of a human-induced stress on the Middle Rio Grande Basin landscape (McAda, 1996). We can anticipate the motion of an urban area, such as the city of Albuquerque, when we model and predict future urban growth patterns to understand the impact that the motion has on the region's water resources, economy, and people.

Population Growth

Urbanization of the landscape is an ongoing land use trend as more than 50 percent of the world's population will reside in urban areas in the next century. During the timeframe from 1900 to 1990, the population of the Southwestern United States that is, Arizona, California, Colorado, New Mexico, Nevada, and Utah increased by approximately 1,500 percent as compared with the entire U.S. population, which increased by only 225 percent (Chourre, 1997). The Middle Rio Grande Basin's 1990 total population of 564,000 accounted for 37 percent of the State of New Mexico's populace and, specifically, the Albuquerque urban area contributed 89 percent of the basin's residents (McAda, 1996). Most of the basin's urban growth has occurred during the time period of 1950-80. Until the 1970's, the North Valley and East Mesa accounted for most of Albuquerque's urban growth. However, because of lower land prices, the West Side began to urbanize in the mid-1980's. The Greater West Side Area, including Rio Rancho and Corrales, accounted for 60 percent of the total Albuquerque urban growth between 1980 and 1995 (Middle Rio Grande Council of Governments, 1997). If Rio Rancho's population continues to increase in the future at the same growth rate as from 1980 to 1995, the municipality will soon surpass Santa Fe as the second largest city in New Mexico.

Land Transformations

For more than 600 years, a seemingly endless supply of water resources and natural north-south and east-west travel routes have attracted residents to the Middle Rio Grande region. From 1970 to 1990, a national increase in population of 1 percent resulted in a 6- to 12-percent increase in land use (Middle Rio Grande Council of Governments, 1997). The land surface being transformed because of increased population has typically meant the proliferation of asphalt and concrete and the displacement of agricultural lands, forest lands, and wetlands that are conducive to ground-water recharge. From 1945 to 1992, the Southwestern United States exhibited general land use trends, such as decreasing forest and pasture land, often because land was transformed into transportation, open space, industrial, and urban uses (O' Donnell, 1997). The impact of urban land transformation has been demonstrated in the Middle Rio Grande Basin with an ongoing decline in irrigated agricultural lands. In 1975, 14,000 acres were irrigated cropland in

the Albuquerque area, compared to 9,600 acres in 1992 (McAda, 1996). In comparison with a 31 percent decline in irrigated agriculture, the urbanized land for the Albuquerque metropolitan area grew 71 percent, or 35,143 acres, from 1973 to 1991 (Braun and others, 1997).

Water Consumption

Major urban areas, such as the city of Albuquerque, require water, building materials, food, goods, and services from the surrounding region to sustain the city's economy and population. A general water consumption trend affecting most urban areas is that the cost and engineering difficulty for collecting and distributing water resources are influencing the location and intensity of future land use development. In addition, the introduction of new high-technology industries for example, Intel's relocation to Rio Rancho to the local economy has resulted in a higher demand being placed on the existing ground-water resources. Another factor affecting water consumption by urban areas has been an increasing number of single-family dwellings with fewer inhabitants per housing unit (O' Donnell and Rademaekers, 1997). The land in the Southwestern United States is arid (for example, the most populated part of the Middle Rio Grande Basin receives less than 9 inches annual precipitation), and the total ground-water withdrawal has generally increased; this increase can be attributed to population growth, land use transformations, climatic variances, and changing socioeconomic characteristics. For instance, Albuquerque's annual ground-water withdrawal has increased from about 2,000 acre-feet in 1933 to about 123,000 acre-feet in 1994, with more than 50 percent of the withdrawal occurring from 1980 to 1994 (McAda, 1996).

Urban Growth Modeling

The dominant land transformation is the transition of unsettled land to human settlement. Future urbanization of the Middle Rio Grande Basin may be constrained by the quantity and quality of ground-water resources available. However, future landscapes are also influenced by a region's terrain, land use zoning, areas protected from development, and accessibility to transportation. To analyze the effects of urban sprawl, the U.S. Geological Survey (USGS) Global Change Research Program funded the development of an urban growth model (UGM) by Hunter College - City University of New York. The purpose of the UGM is to predict the urban areal extent of future landscapes and visually represent the land mass that would be consumed by urbanization. The UGM produces both quantitative output and a generalized visualization of probable areas where urban expansion might occur. The USGS plans to use the UGM for a pilot area within the Middle Rio Grande Basin study area that encompasses the cities of Albuquerque, Rio Rancho, Edgewood, and Moriarty. To be operable, the UGM requires at least three snapshots of historical urban extent from different times. Consequently, the USGS is compiling datasets of historical urbanized areas from 1935, 1951, 1973, and 1996 aerial photographs. The historical urban extent for each temporal snapshot is used as the starting point for urban growth modeling and as a standard for calibrating the UGM's output (Clarke, Hoppen, and Gaydos, 1996). In addition to using historical urban extent, the UGM requires datasets for slope, historical roads, areas excluded from development, and shaded relief. The UGM model incorporates four types of growth that is, spontaneous, diffusive, organic, and road-influenced, as well as five growth parameters and five growth constants (Clarke, Hoppen, and Perez, 1996). The USGS will use the UGM to predict future urbanization for a time period that is, 1996-2060 similiar to the historical data that is, 1935-96 that are used to calibrate the model output.

Conclusion

The UGM provides a regional prediction of areas most at risk of future urbanization. Future urban growth is most likely to occur around the fringe or in the vicinity of existing urban areas rather than from the creation of satellite urban centers. Between 1891 and 1995, Albuquerque's built-up environment increased from 1,996 acres to 103,357 acres (Price, 1996). Will urban sprawl continue to increase at the same rate over the next hundred years, and what will be the ecological and climatic impacts of the resulting urban land transformation? The Middle Rio Grande Council of Governments has projected that the population for the Middle Rio Grande region will grow to 1,555,000 by the year 2050. Future Middle Rio Grande Basin urban growth is constrained by the fact that approximately 42 percent, or 3,900 square miles, of the region is covered by public and Indian lands (Middle Rio Grande Council of Governments, 1997); therefore, can the region's water resources sustain not only an increasing population, but also an increase in the land use intensity for example, more housing units per acre? The USGS Middle Rio Grande Basin urban growth modeling will help to identify which areas are most at risk of future urbanization and analyze the potential environmental impacts of the resulting urban land transformation.

References

Braun, Paul, Chourre, Martin, Hughes, Dave, Schubert, Jamie, Streibek, Heike, and Thorstad, Rick, 1997, Land use change in the Albuquerque Metropolitan Area: U.S. Geological Survey, http://geochange.er.usgs.gov/sw/changes/anthropogenic/albuquerque/.

Chourre, Martin, and Wright, Stewart, 1997, Population growth of the Southwest United States, 1900-1990: U.S. Geological Survey, http://geochange.er.usgs.gov/sw/changes/anthropogenic/population/.

Clarke, K.C., Hoppen, S., Gaydos, L., 1996, Methods and techniques for rigorous calibration of a cellular automaton model of urban growth, Third International Conference/Workshop on Integrating GIS and Environmental Modeling: Santa Fe, N. Mex., National Center for Geographic Information and Analysis, UC-Santa Barbara.

Clarke, K.C., Hoppen, S., Perez, S., 1996, Clarke Urban Growth Model: U.S. Geological Survey, http://geo.arc.nasa.gov/usgs/clarke/hilt.html.

McAda, Douglas P., 1996, Plan of study to quantify the hydrologic relations between the Rio Grande and the Santa Fe Group Aquifer System near Albuquerque, Central New Mexico: Albuquerque, N. Mex., U.S. Geological Survey Water-Resources Investigations Report 96-4006, 58 p.

The Middle Rio Grande Council of Governments, DRAFT October 15, 1997, FOCUS 2050 snapshot: Existing conditions, significant trends, and projections in the Middle Rio Grande Region: Albuquerque, N. Mex., 34 p.

O' Donnell, Michael, 1997, Land use trends in the Southwestern United States: U.S. Geological Survey, http://geochange.er.usgs.gov/sw/changes/anthropogenic/cropland/.

O' Donnell, Michael, and Rademaekers, Jonathan, 1997, Water use trends in the Southwestern United States 1950-1990: U.S. Geological Survey, http://geochange.er.usgs.gov/sw/impacts/hydrology/water_use/.

Price, V.B., 1996, Albuquerque's environmental story - People create their own environment: Albuquerque, N. Mex., http://www.cabq.gov/aes/s2arch.html.

Presented at the Second USGS Middle Rio Grande Basin Study Workshop, February 1998.
Slate, Janet L, ed., 1998, U.S. Geological Survey Middle Rio Grande Basin Study - Proceedings of the Second Annual Workshop, Albuquerque, New Mexico, February 10-11, 1998: U.S. Geological Survey Open-File Report 98-XXX, In-Press.