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USE OF THE NEW MEXICO MINES DATABASE AND ARCMAP IN URANIUM RECLAMATION STUDIES

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ABSTRACT

NMBGMR has been collecting data on uranium mining districts, mines and mills since it was created in 1927 and has converted years of historical data into a relational database that can be imported in ArcMap. The database includes information on mining districts, mines, mills, geochemistry, photographs, and bibliography. The available data includes location, production, reserves, geologic, geochemical, resource potential, and other data. The NURE stream-sediment data provides geochemical analyses for >27,000 samples collected in New Mexico during 1970s. The NURE hydrogeochemical data provides analyses for water samples. ArcMap includes location of individual ore bodies as polygons and incorporates the mines and NURE data as individual site locations. The purposes of these databases are to provide computerized data that will aid in identifying and evaluating resource potential, resource development and management, production, and possible environmental concerns, such as physical hazards (i.e. hazardous mine openings), indoor radon, regional exposure to radiation from the mines, background geochemical data and point-sources of possible pollution in areas of known mineral deposits.

INTRODUCTION

GIS (Geographic Information Systems) technology has evolved into a powerful tool in evaluating and analyzing large, complex data in the mining, environmental, and geological fields. GIS ArcMap is a suite of geospatial processing programs that allows the viewer to examine, plot, edit, and analyze geospatial data and aid in establishing relationships between complex sets of data; more information is at the ESRI web site (http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=176&pid=175&topicname=Aoverview_of_ArcMap). As our population is expanding into rural areas, often near or adjacent to mining districts or other mineralized areas in New Mexico, there is a need to understand the distribution and migration of elements, especially uranium, potentially harmful to human population and the ecosystem in general. Elemental geochemical patterns in stream sediments and water samples can be used in environmental studies to detect areas of anomalously high concentrations of elements and perhaps to distinguish between natural background and possible contamination from mining and other anthropogenic inputs (Schreck et al., 2005), as well as identify areas for potential economic mineral resources. Stream sediments are a logical choice of medium to start a survey, because the composition of stream sediments represents a close approximation of the composition of the rocks and soils within the catchment basin sampled. The composition of waters provides insight to weathering and migration of elements in the subsurface. The NURE database is a regional data set of geochemical analyses of stream sediments and waters that covers the entire state. With new developments in statistical and GIS software, new interpretations of the NURE data along with other data can provide new insights into mineral exploration, evaluation of mineral resource potential, environmental studies, and general geochemical mapping of the state.

The purposes of this paper are to 1) demonstrate the application of GIS for analyzing, integrating, and interpreting the NURE and other data in environmental studies; 2) present and evaluate issues and concerns encountered with the NURE and other geochemical data; and 3) to present some examples of the utilization of GIS ArcMap and other data in environmental studies, with emphasis on uranium. This study is in the early stages and additional evaluation and data analysis are on-going.

DATA SETS AND METHODS OF STUDY

The New Mexico Bureau of Geology and Mineral Resources has collected published and unpublished data on mines and mining districts in New Mexico and has converted much of that data into an Access database called the New Mexico Mines Database (McLemore et al., 2005a, b). This database was entered into ArcMap along with other data sets, including the New Mexico geologic map (New Mexico Bureau of Geology and Mineral Resources, 2003), NURE data (Smith, 1997), and aeromagnetic anomaly maps (Kucks et al., 2001; Hill et al. 2009). ArcMap allowed the integration of these data sets and aided in producing the figures in this paper. Three types of data are shown in ArcMap; point data (actual locations of mines and NURE samples), linear or polyline (highways, streams, geographic boundaries, etc.), and polygon data (geologic units, mining districts, uranium ore bodies).

New Mexico Mines Database

The New Mexico Mines Database includes information on mining districts, mines, mills, geochemistry, photographs (both recent and historic), and bibliography. The available data includes location, production, reserves, geologic, geochemical, historical and recent photographs, resource potential, mining, ownership, and other data. There are six main tables that comprise this database: Mines, District, Samples, Drill hole, County, and Projects (McLemore et al. 2005a, b). Each of these tables is linked to each other, where appropriate and all of the following tables are linked to one or more of these six main tables. Mining districts are incorporated into ArcMap as polygons (Fig. 1), and locations of mines are as point data (Fig. 2). The New Mexico Mines Database is not a static database as new mines are added and existing information is updated.

Distribution of uranium ore bodies

Maps showing the approximate distribution of uranium ore bodies and mineralized areas were prepared by McLemore and Chenoweth (1991). The approximate outlines of the uranium deposits were obtained from a variety of sources listed in McLemore and Chenoweth (1991), including published and unpublished reports. These ore bodies and mineralized areas were incorporated into ArcMap as polygons and updated with newly acquired data (Fig. 3). These uranium-deposits distribution data allows for visualization of the actual mineralized areas, which can be compared with NURE and other data. Where the information is available, mined and unmined portions of the uranium ore bodies are differentiated in ArcMap.

NURE data

A regional geochemical database, including stream sediments (Fig. 4) and waters (Fig. 5), exists for the state of New Mexico that was generated from reconnaissance surveys as part of the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program during 1974-1984. Field sampling techniques are detailed in Sharp and Aamodt (1978). The NURE data is typically arranged by 1x2-degree quadrangles, although a few areas were sampled and evaluated in greater detail (Estancia Basin, Grants uranium district, and San Andres and Oscura Mountains area). Total number of stream-sediment samples in the state analyzed was 27,798 and 12,383 water samples were analyzed. Chemical analyses for New Mexico were performed at two national laboratories (Los Alamos and Oak Ridge) and each laboratory utilized different analytical techniques and analyzed samples for different elements (Hansel and Martell, 1977; Cagle 1977; Aredt et al., 1979).

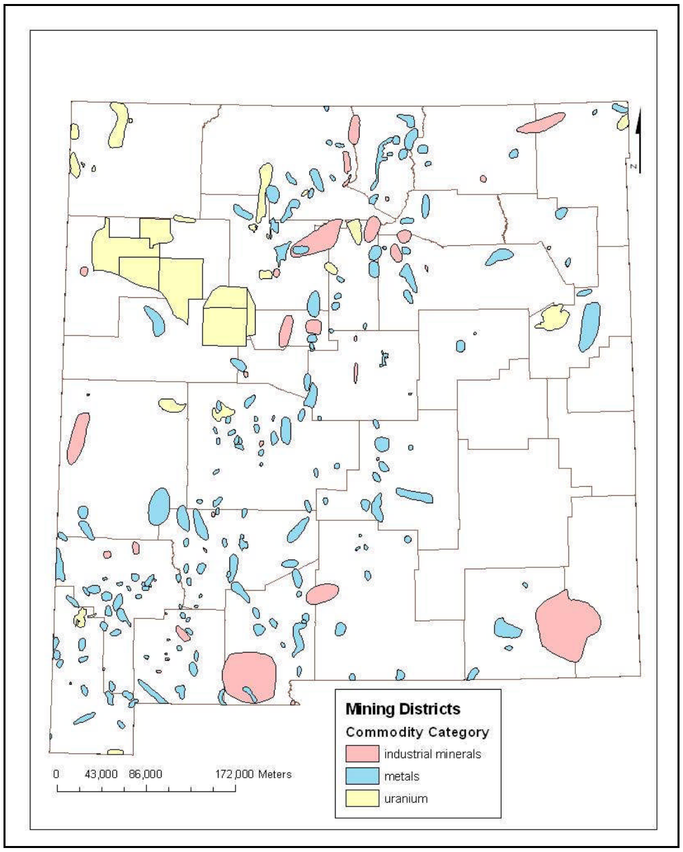


Figure 1. Distribution of mining districts in New Mexico (McLemore et al., 2005a). The coal fields are not shown.

Some of the NURE data are problematic (Haxel, 2002) and the entire data set should be used with caution. Some of the recognized problems of the NURE data include inconsistent sampling techniques, variability in density of samples, different size fractions used for analysis, different laboratories, different analytical techniques and analytical errors, and different analytical detection limits. Methods of evaluating if the validity of NURE data in New Mexico, include examining histograms, comparing the NURE data with average upper crustal values, comparing data for pairs of statistically similar elements, such as Zr-Hf, Th-U, and La-Ce (Haxel, 2002), comparing descriptive statistics and histograms for different laboratories, and examining the descriptive statistics between the 1x2-degree quadrangles. In addition, there are several areas in New Mexico where subsequent stream-sediment surveys have been completed and show similar geochemical patterns as the with the NURE data (Ellinger and Cepeda, 1991; Ellinger, 1988; Watrus, 1998; New Mexico Bureau of Mines and Minerals Resources et al., 1998).

The main purposes of the NURE program were to provide an assessment of the nation's uranium resources and to identify areas favorable for uranium mineralization. The NURE data were not designed to reveal uranium or other mineral deposits, but if the NURE data are used with caution, the data can be used to identify areas of potential geochemical interest for further study. Ultimately, field examination of these identified areas must be conducted.

Numerous studies have utilized the NURE data for New Mexico to 1) evaluate mineral resource potential (Laughlin et al., 1985; Bartsch-Winkler and Donatich, 1995; Bartsch-Winkler, 1997; New Mexico Bureau of Mines and Mineral Resources et al., 1998; McLemore et al., 2001), 2) regional geochemical mapping (Zumlot et al., 2009), 3) identify areas of geochemical anomalies (Chamberlin, 2009), 4) provide insight into sedimentological processes (Chamberlin et al., 1992), and 5) environmental studies. Zumlot (2006) presented an evaluation of the NURE data for the entire state and used slightly different statistical techniques then used in this report and presented much of the data analysis on a web site (https://webspace.utexas.edu/howarifm/www/NURE/1nm.htm/). Different approaches to evaluating the NURE data is another method of validating the data set.

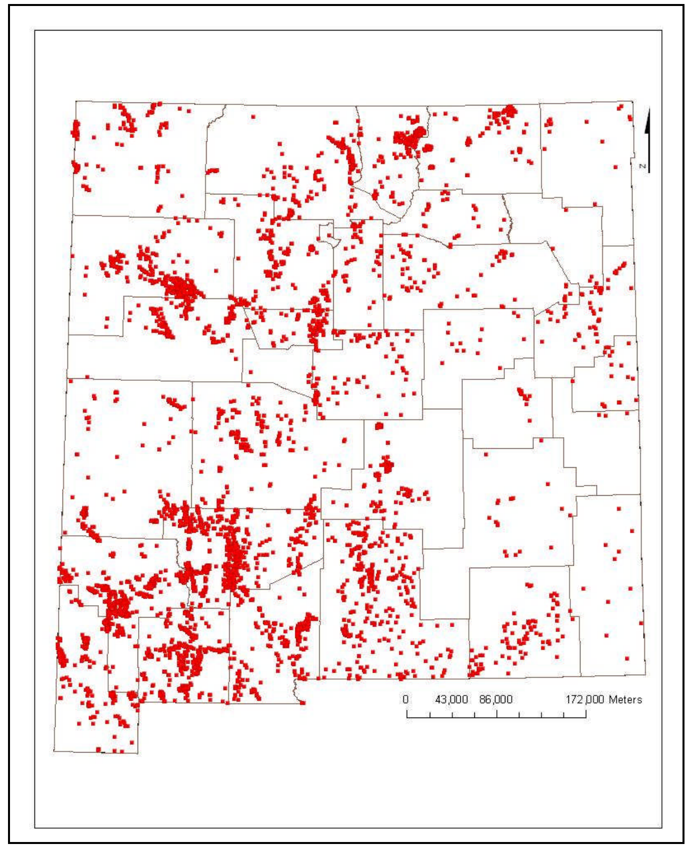


Figure 2. Distribution of mines (including aggregate pits and coal mines) in New Mexico (McLemore et al., 2005a, b).

Methods of study

The NURE data for New Mexico were downloaded from Smith (1997). Below detection values (i.e. concentrations of 0 and negative values) were eliminated from the data set to form a processed data set. Statistical analysis was performed on the processed data. The processed NURE data were entered into GIS ArcMap, along with mining districts (Fig. 1), mines from the New Mexico Mines Database (Fig. 2; McLemore et al., 2005a, b), and the state geologic map (Fig. 6; New Mexico Bureau of Geology and Mineral Resources, 2003). Single element maps were plotted for selected areas. Descriptive statistics, histograms, box plots, scatter plots, and cumulative frequency plots were created using data for the entire state and for each 1x2-degree quadrangle. Outliers were identified, located (using search in ArcMap), and determined if they were due to analytical error or atypical abundance (i.e. anomalies). Many times, three or more outliers are found together, as described below. Since the sample density is not very detailed, single outliers could have geochemical significance.

ISSUES AND CONCERNS ENCOUNTERED WITH THE NURE DATA

Different laboratories

Uranium in stream sediments collected in New Mexico was analyzed by Los Alamos laboratory. However, two different laboratories analyzed the NURE data for other elements in samples collected from New Mexico (Las Alamos and Oak Ridge) and used different analytical techniques and detection limits. Although, examining and analyzing the combined NURE data for the entire state is a first step in evaluating the NURE data, it has limited value, especially in performing multi-variant, correlation, and spatial statistics. Since uranium was analyzed by one laboratory, evaluation of uranium for the entire state is appropriate. The next step is to examine each individual quadrangle separately, since each quadrangle was sampled during a shorter time period and the samples were analyzed by the same laboratory. This of course takes more time, but will provide some improvements over the analysis of the entire combined data set, such as that performed by Zumlot (2006).

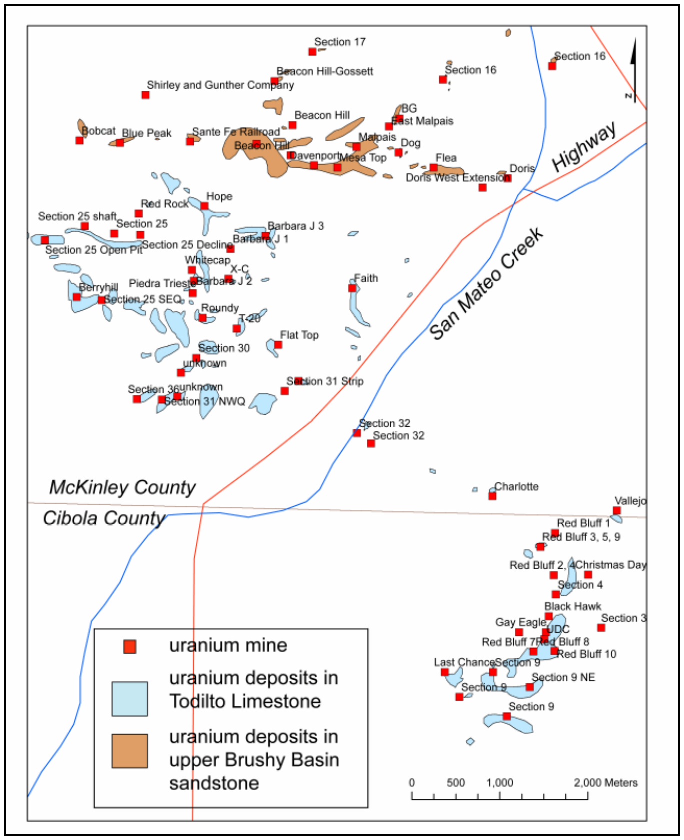


Figure 3. Example of distribution of uranium ore bodies and areas of mineralization in the western Ambrosia Lake mining district, Albuquerque quadrangle, New Mexico (updated from McLemore and Chenoweth, 1991).

Normality of the data

Normal distributions of geochemical data should not be assumed Rollinson, 1993) and can be determined by histograms or other statistical methods. Classical statistical analysis requires that the data are normal or log-normal and represent one population. However, regional geochemical data such as the NURE data typically are not normal or log-normal distributions, especially if the data consists of large number of samples because the data are characterized by a variety of factors. More than one process could have produced the concentrations in the samples and this could be interpreted as more than one population of data. Some of these factors affecting geochemical data include variations in sampling technique, different analytical procedures, sampling and analytical errors, variations in lithology, terrain differences, changing climate, different stream orders, flash floods, and existence of permanent and ephemeral streams sampled, and, ultimately most of these factors result in different processes that control elemental distribution in the samples (i.e. mineralization, pollution; Reimann and Filzmoser, 2000; Bounessah and Atkin, 2003). Some additional factors affecting analyses of water samples are seasonal effects of chemistry, flow rates, depth and source of the same, among others.

Statistical analysis can be (and generally is) performed on the data even though the data are not normal or log-normal distributions, but the resulting analysis does not produce consistent or statistically valid results (Rollinson, 1993; Reimann and Filzmoser, 2000; Matschullat et al., 2000). Robust statistics can be used (Rollinson, 1993), where the data are transformed. The data can be logarithmically transformed to approach normality, but geochemical data rarely results in normal distributed data. Outliers of statistically determined outliers (both low and high) can be identified using box plots and, then the outliers are subsequently removed to produce a more normal distribution (Bounessah and Atkin, 2003). Another approach is to use statistics only as a guide and plot the elements as point data in GIS ArcMap and visually examine for distribution patterns.

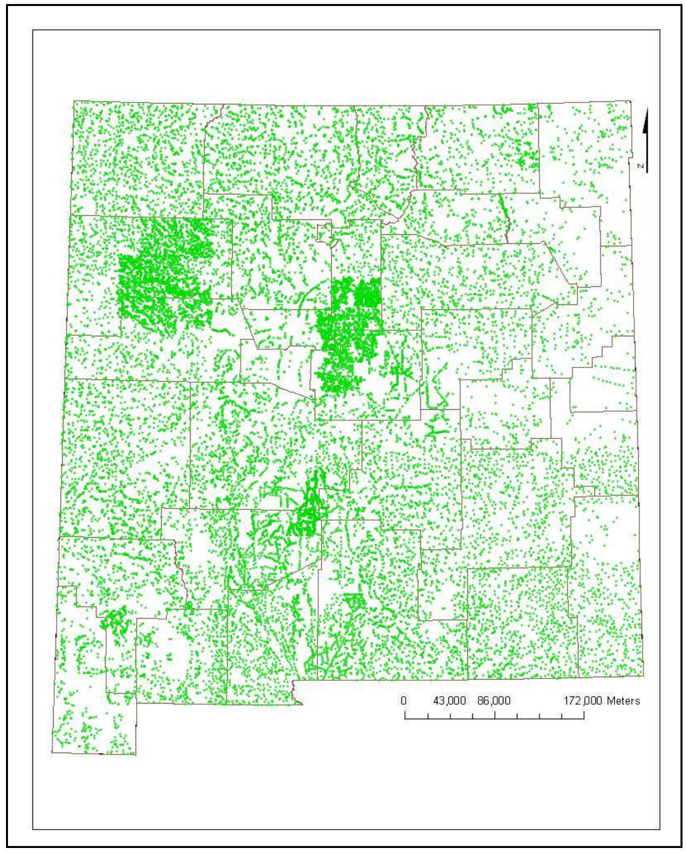


Figure 4. Distribution of NURE stream-sediment samples in New Mexico (Smith, 1997).

Below detection values

For some elements, much of the geochemical data are values of zero or below the detection limit for a specific element. These values can be eliminated from the database (method used in this evaluation), but subsequent analysis could be skewed to the higher end of the concentration range for that element. Another technique is to arbitrary assign the concentration value as 0.5% or 0.75% of the detection limit (used by Zumlot, 2006). Some studies do not examine elements where too many samples are below the detection limit.

Identification of geochemical anomalies and background

Geochemical anomalies or outliers are concentrations that are different from what is considered normal (or above background) and are due to:

- Unusual processes concentrating particular elements, such as mineralization or weathering
- Accumulation of elements over a long period of time, such as formation of regolith or scavenging by ironstones or ferricretes
- Contamination of sites by man-induced activities
- Analytical noise or error resulting from poor precision of the analytical method used.

Identification of geochemical anomalies and background concentration is not always simple. An orientation or analog study can be performed in a non-mineralized or uncontaminated site to define a local threshold against which anomalies can be judged. Anomalies can be determined by statistical methods such as selecting the upper 2.5% of the data or the mean plus 2σ (standard deviation) as geochemical anomalies (Hawkes and Webb, 1962). However, these statistical methods do not always account for different geochemical processes that form the anomalies nor do they always account for two or more overlapping populations. The geochemical threshold also can be determined by plotting a histogram or cumulative frequency plot and the threshold value is at the break in slope (Matschullat et al., 2000). The box plot also can be used to define the upper and lower threshold (Bounessah and Atkin, 2003; Reimann et al., 2005). These later two techniques begin to account for different geochemical processes and for two or more overlapping populations. The data also can be compared to average crustal abundance or other averaged data.

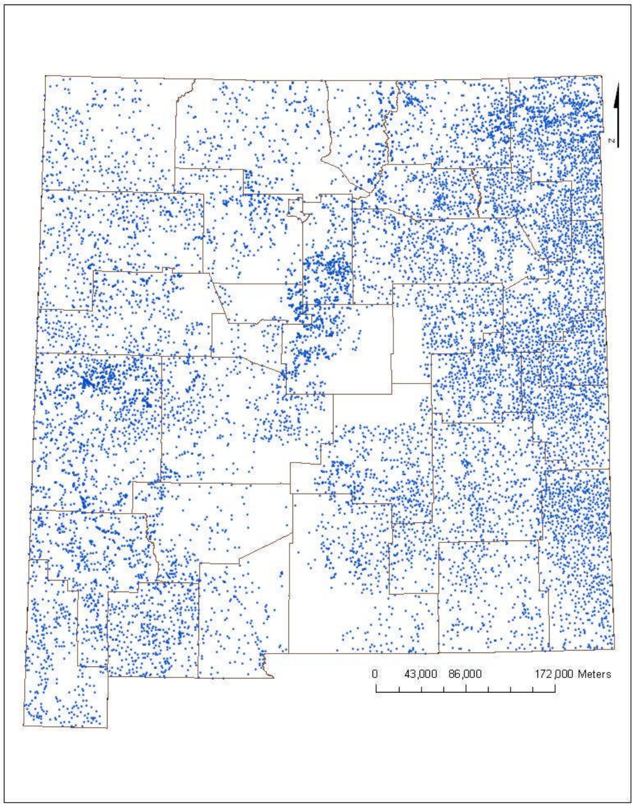


Figure 5. Distribution of NURE water samples in New Mexico (Smith, 1997).

Scale of the survey

The scale of the geochemical survey or the distance between samples is dependent upon the purpose of the geochemical survey. The purpose of the NURE data was to identify regions in the United States that could have uranium deposits at the surface. Thus, the sampling techniques employed were not always sufficient for the detection of individual deposits or mines or that required for most environmental studies.

Geochemical anomaly maps

There are several ways to display geochemical element maps. Point maps of the raw data are used to display absolute concentrations of individual samples. The point data can be kriged (Laughlin et al, 1985) or contoured. Other techniques can be employed.

RESULTS

The mean for 27,351 stream-sediment samples from the NURE data for New Mexico is 3.38 ppm U. The median is 2.9 ppm U and the values range from 0.1 to 445.1 ppm. The data are not normal according to the Kolmogorov-Smirnov Normality Test. Histograms for uranium analyses for the Albuquerque quadrangle are in Figure 7. Box plots are in Figure 8. The upper concentration of thresholds for uranium as determined by different techniques is summarized in Table 1. Elemental maps were plotted using ArcMap and examples of selected areas in New Mexico are discussed below.

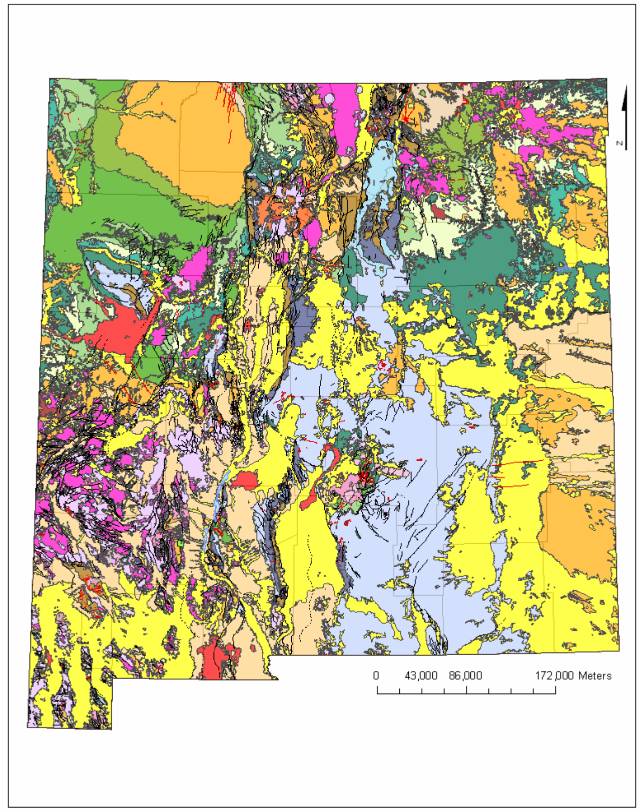


Figure 6. Geologic map of New Mexico (simplified from New Mexico Bureau of Geology and Mineral Resources, 2003). The key to geologic units can be viewed on the original map.

EXAMPLES

Several examples demonstrating the utilization of NURE data and ArcMap in environmental studies throughout New Mexico are summarized below. In most areas in New Mexico, the NURE sampling density was too large to adequately delineate areas in detail of anomalously high uranium or other elements or to examine most areas at the detailed scale of an individual mine or mill site. However, these data along with other data can be used to identify some areas for additional study and to aid in understanding processes involved in uranium and other element mineralization, contamination and in migration of uranium and other elements in the environment.

San Mateo mine area, McKinley area

The San Mateo mine (also known as Rare Metals and Section 30 mine), located in NE section 30, T13N, R8W, is one of numerous mines in the Grants uranium district in McKinley County (McLemore, 1983; McLemore and Chenoweth, 1991) and the mine is currently under reclamation by the U.S. Forest Service. The mine operated from 1959 to 1971 by several companies through an 1107 ft deep shaft. Total uranium production from the mine amounts to 842,463 tons of 0.17% U_3O_8 (2,863,024 pounds of U_3O_8; from U.S. Atomic Energy Commission, production records; McLemore, 1983); there may have been additional production after 1971. The ore is in the Poison Canyon sandstone of the Brushy Basin Member of the Morrison Formation (Jurassic). Foundations and mine waste piles are found at the site. The mineral deposits shown in Figure 9 are not exposed at the surface; thus, any high uranium concentrations are likely due to mining activities rather than natural distribution.

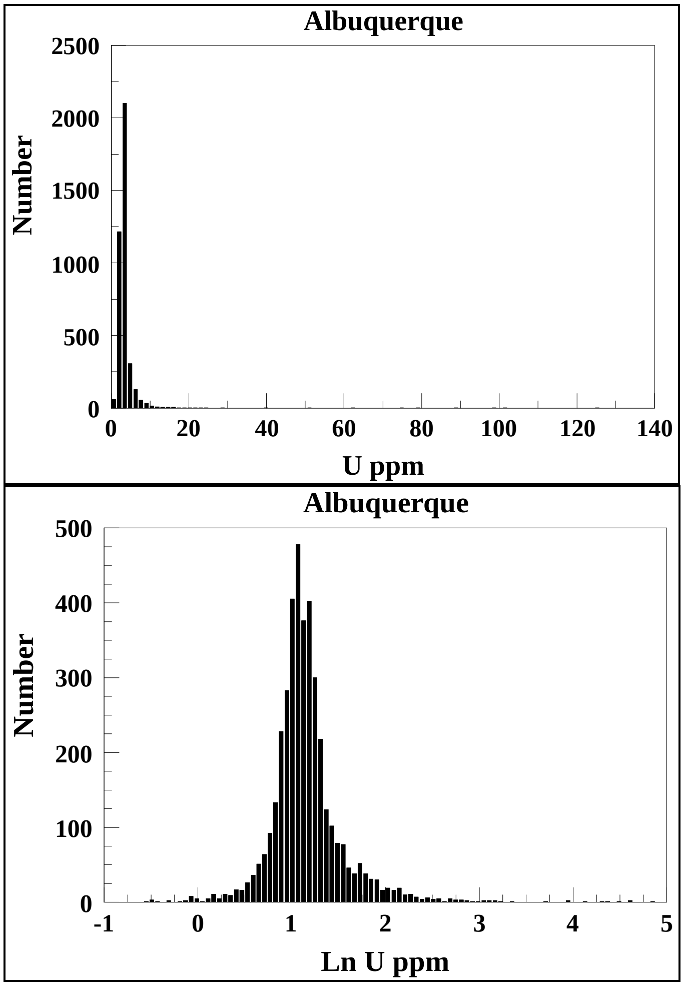


Figure 7. Histogram of uranium analyses for the Albuquerque quadrangle.

NURE stream-sediment data shows that little contamination resulted at other mines in the area (at the scale of the NURE data), but that some contamination of uranium into an adjacent arroyo did occur at the San Mateo mine (Fig. 9). Additional stream sediment and soil studies are recommended after reclamation to ensure that all contamination is remediated. Since the sampling density was so low, additional samples from the entire area is recommended to ascertain the lack of uranium contamination into the streams as suggested by the NURE data.

La Cueva mining district, Taos County

REE-Th-U veins, veins in Proterozoic rocks (±U, Th, REE, Cu, Au, Zn), and pegmatites (±U, Th, REE, Be, mica) are associated with the southern part of the Proterozoic Costilla granitic massif in La Cueva district (also known as Vermejo Park and Costilla Creek district) in the vicinity of Costilla Creek, northern Taos County (Zelenka, 1984; Goodnight and Dexter, 1984; McLemore, 1990; McDonnell, 1992). The Costilla massif consists of granite gneiss, pegmatitc granite, and granite to quartz monzonite. The radioactive pegmatites intruded the granite and both intruded a complex Proterozoic terrain of metamorphic and igneous rocks. The Proterozoic rocks are overlain by Tertiary volcanic and volcaniclastic rocks related to the Questa caldera to the south and the Rio Grande rift. The granitic rocks are subalkaline, metaluminous to peraluminous. Mineralization in the district was discovered in the 1950s during prospecting for radioactive veins and pegmatites and exploration was carried out in the 1970s and 1980s by Phillips Petroleum Company and Duval Corporation. There has been no mineral production from the area.

Mineralized zones at the surface contain U, Th and REE minerals along fractures and in veins and pegmatites, including zircon, uraniferous magnetite, allanite, uranothorite, thorite, uraninite, thorgummite, uranophane, and uranium-bearing hematite (Zelenka, 1984). Clay-rich zones at the La Cueva prospect contain uranophane and thorogummite and as much as 1522 U, 1643 ppm Th, 625 ppm La, and 1560 ppm Ce in selected samples (Zelenka, 1984). Stream sediments downstream of known prospects contain as much as 202.2 ppm U, 51 ppm Th, 48 ppm La, and 96 ppm Ce (Fig. 10). Note the highest uranium sample (202.2 ppm U) along Costilla Creek is the second highest uranium sample in the entire NURE data set for New Mexico. These stream-sediment anomalies are most likely due to weathering of natural anomalously high concentrations of U, Th, and REE associated with the mineral occurrences in the area.

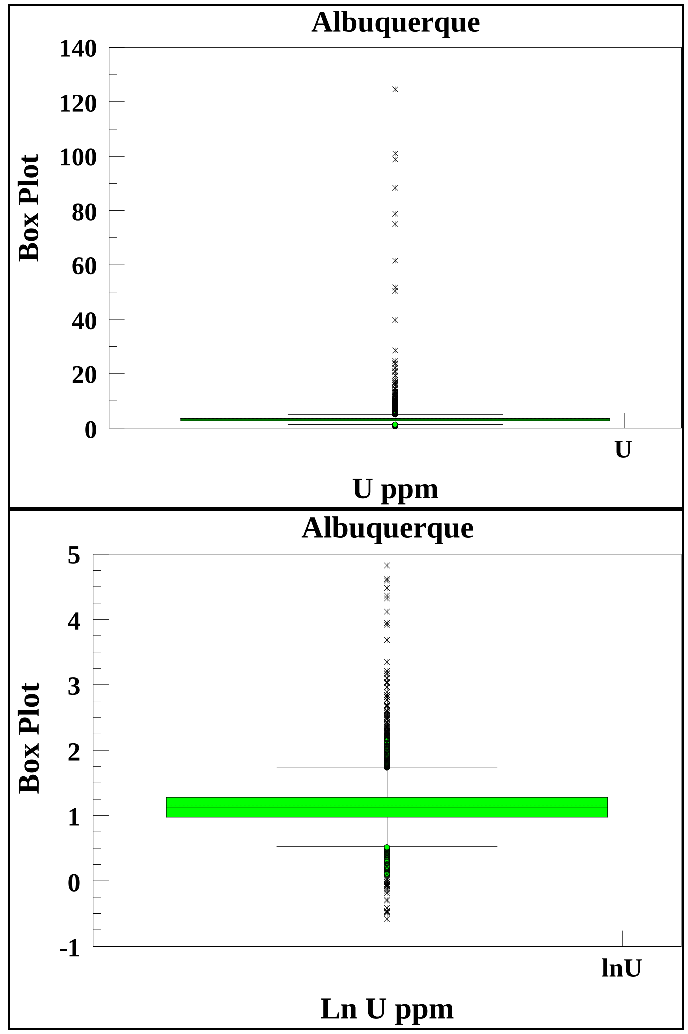


Figure 8. Box plots of uranium analyses for the Albuquerque quadrangle.

San Jose mining district, Santa Fe County

The San Jose mining district, Santa Fe County is particularly interesting because the district includes uranium prospects, one small mine that yielded some uranium production, uranium anomalies in both NURE water and stream-sediment samples (Fig. 11), and residents locally have high concentrations of uranium and radon in their drinking water. Uranium prospects and geochemical uranium anomalies in both water and stream-sediment samples are found in the Tesuque Formation in the San Jose district, Santa Fe County. Sediments of the Tesuque Formation were derived from the Proterozoic rocks in the Sangre de Cristo Mountains to the east and Tertiary volcanic rocks in the Jemez Mountains to the west (Hilpert, 1969). The uranium occurrences in the Tesuque Formation probably represent natural precipitation and concentration from uraniferous ground waters, likely derived from 1) the Sangre de Cristo Mountains to the east, 2) Jemez volcanic rocks to the west, or 3) the alteration of granitic and/or volcanic detritus in the sedimentary host rocks. Uranium in the Tesuque Formation typically occurs as coatings around opal and chert grains, with organic debris, and in clay zones. One property, the San Jose no. 13 in Santa Fe County, yielded 12 lbs (5 kg) of U_3O_8 at a grade of 0.05% U_3O_8 in 1957 (U.S. Atomic Energy Commission file data; McLemore, 1983). The uranium in the waters in this area is most likely a result of weathering of uranium from rocks in the adjoining mountains and subsequent migration of uranium and radon in the ground water. Uranium then precipitated from the waters to form the geochemical anomalies found in the stream sediments and prospects. This area warrants further examination to understand the significance of these geochemical anomalies and to determine if public health is at risk.

Table 1. Upper concentration thresholds for uranium calculated by different methods. Any stream-sediment value above 12 ppm could be considered a geochemical anomaly.

Method	U concentration (ppm)	Reference
Upper crustal abundance	2.7	Rudnick and Gao (2005)
Mean (entire state)	3.38	NURE data
Median (entire state)	2.9	NURE data
Mean (Albuquerque quadrangle)	3.62	NURE data
Median (Albuquerque quadrangle)	3.06	NURE data
Mean + 2σ (Albuquerque quadrangle)	12.2	Hawkes and Webb (1962)
Mean +2σ of ln-normal data (Albuquerque quadrangle)	6.69	NURE data
Box plot (Albuquerque quadrangle)	3.59	Bounessah and Atkin (2003)
Box plot of ln-normal data (Albuquerque quadrangle)	3.58	NURE data

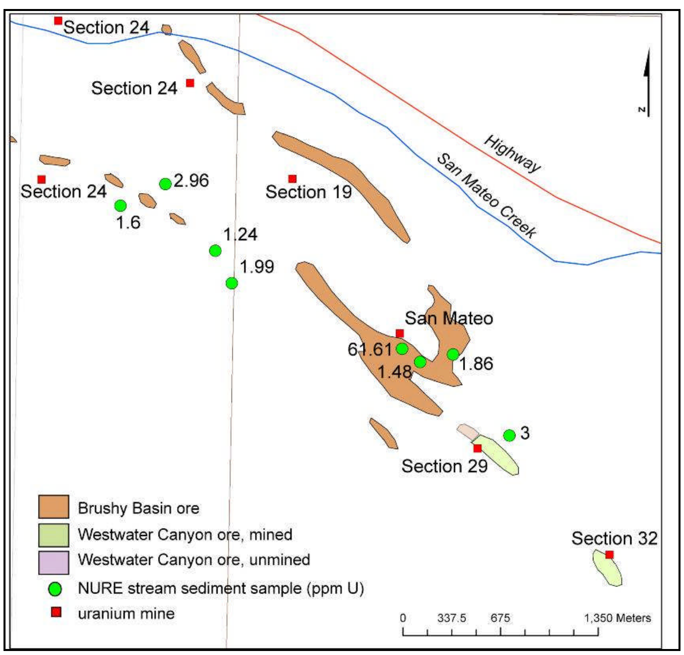


Figure 9. Distribution of ore bodies and uranium in stream-sediment samples in the San Mateo area (T13N, R8W), Grants uranium district, McKinley County, New Mexico. Note the high sample (61.61 ppm U) south of the San Mateo mine that is likely due to contamination from the mine site. None of these deposits shown in this figure are exposed at the surface.

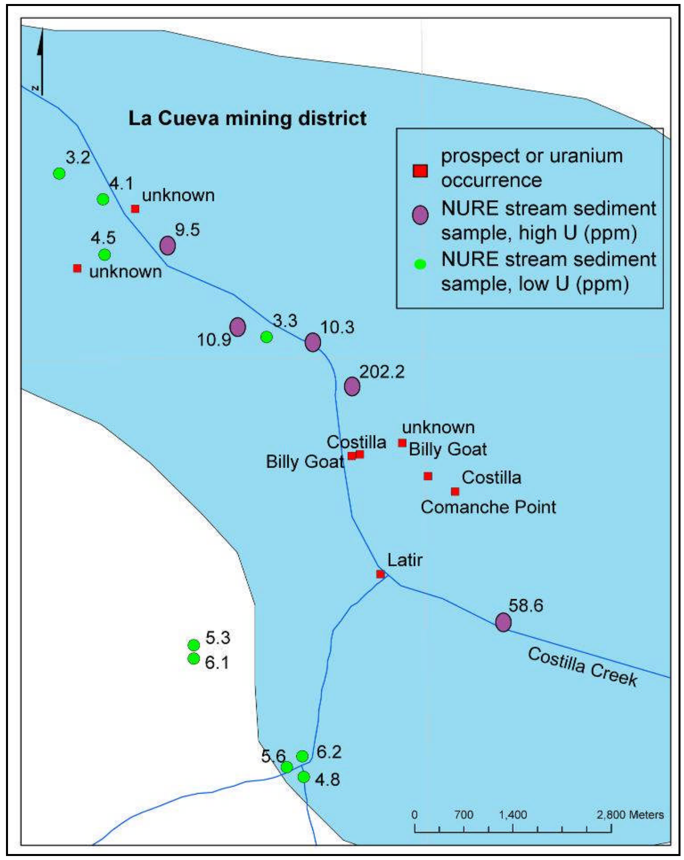


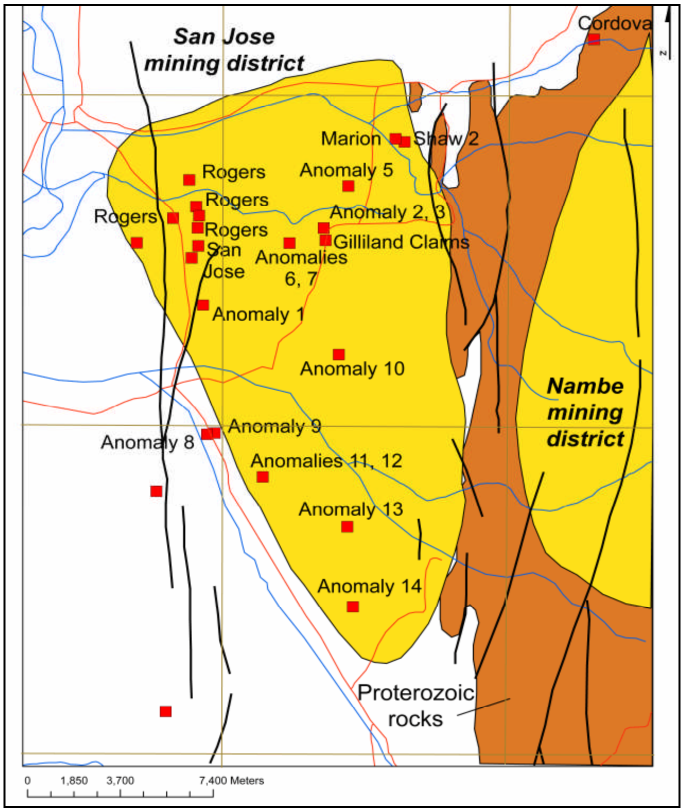
Figure 10. Uranium in stream-sediment samples in the La Cueva mining district, Taos County, New Mexico. Note the highest uranium sample (202.2 ppm U) along Costilla Creek is the second highest uranium sample in the entire NURE data set for New Mexico. The uranium anomalies (purple) are downstream of several identified uranium prospects.

Area south of Laguna, Cibola County

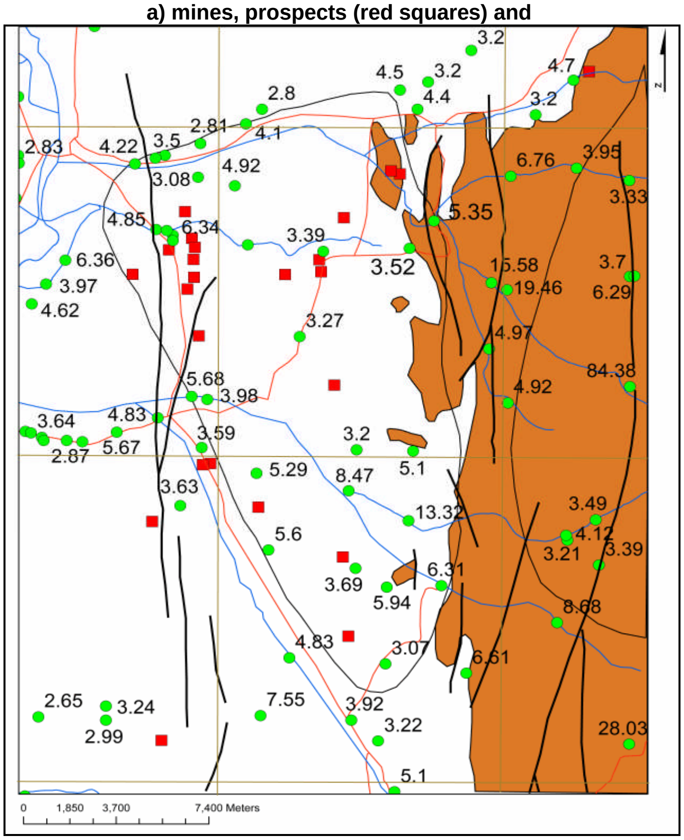
The stream-sediment sample containing the highest uranium concentration in the NURE data in New Mexico is a single sample south of the Laguna mining district in Cibola County Fig. 12). There are no uranium prospects in the immediate area, but the sample is in Jurassic sedimentary rocks. This area would need to be examined in the field to determine if this sample is indicative of a uranium occurrence or if it is an erroneous analysis.

Possible uranium occurrences in the Ogallala Formation, eastern New Mexico

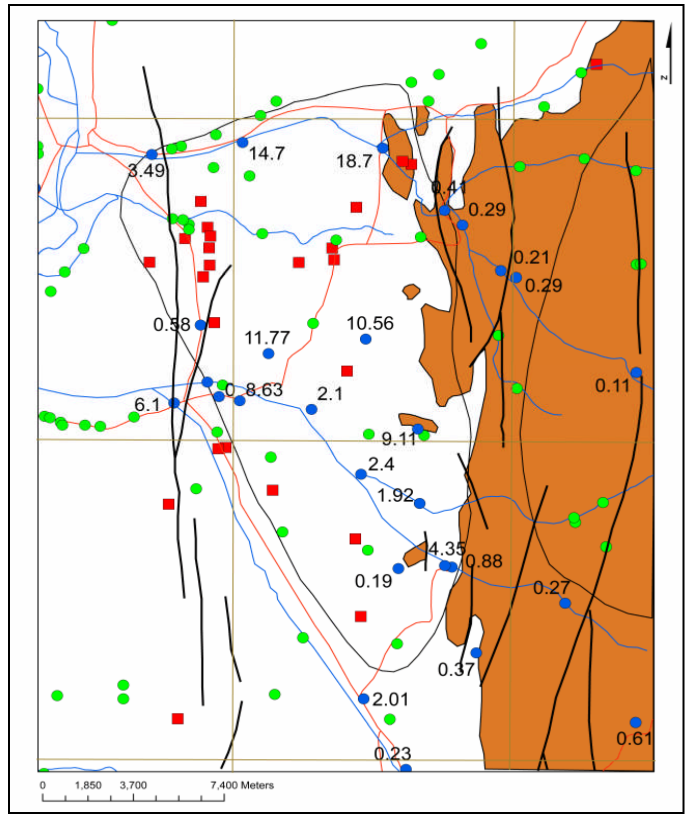
Several anonymously high uranium concentrations, including the water sample with the highest uranium concentration in the NURE data for New Mexico (Fig. 13), are found in water samples in eastern New Mexico and are thought to be in the Miocene-Pliocene Ogallala Formation (McLemore and Chenoweth, 1989). The Ogallala Formation consists of fluvial, aeolian, and lacustrine deposits and layers of calcrete or caliche that formed during alternating wet and dry climatic periods (Otton, 1984). The uranium found in the Ogallala Formation is likely a result of diagenic weathering of volcanic ash detritus found in the sedimentary rocks. Surficial uranium deposits, also known as calcrete uranium deposits, are found in several areas in the Ogallala Formation in the Lubock, Texas area, where one occurrence is 1.5-2.5 m thick, contains carnotite, and contains 0.5-5% Sr, 27-245 ppm U, and 44-120 ppm V (Otton, 1984). None of the calcrete deposits found in New Mexico have been found to contain high concentrations of uranium, but numerous water samples, some in sample clusters of three or more samples, as shown in Figure 13, are found throughout eastern New Mexico. It also is possible that some of these water geochemical anomalies are a result of uranium leaching from agricultural fields since phosphate fertilizer is known to carry high uranium concentrations (Kratz and Schnug, 2006). This area warrants further examination to understand the significance of these geochemical anomalies and to determine if public health is at risk.



a) mines, prospects (red squares) and



b) stream sediments (green circles) mining districts (yellow)



c) water samples (blue circles)

Figure 11. Location of uranium mines, prospects, mining districts, stream-sediment samples, and water samples in the San Jose and eastern Nambe mining districts, Santa Fe County, New Mexico. Note that high uranium concentrations also are found in the Proterozoic terrain (Nambe district), which are related to radioactive pegmatites that intruded Proterozoic granitic and metamorphic rocks.

Uranium in Estancia playa lakes

Several NURE water samples near a playa lake in the northern Estancia Basin, Torrance County, contain anonymous high uranium, including two samples containing the 2nd and 3rd highest uranium concentrations in the NURE water data in New Mexico (Fig. 14). The Estancia Basin is a closed basin bounded on the east by the Pedernal Hills and on the west by the Sandia and Manzano Mountains. The water samples also contain anonymously high concentrations of Li (as much as 624 ppb), Sr (as much as 6091 ppb), Mg (as much as 1320 ppm), and B (as much as 5013 ppb). These geochemical anomalies are probably valid and could indicate migration of uraniferous waters from the Pedernal Hills or Manzano Mountains. Another possibility is that these anomalies suggest that the basement rocks in the subsurface of the Estancia Basin consists of REE-U-Th-rich alkaline syenites and granites, similar to those exposed in the Lobo and Pedernal Hills as described by McLemore et al. (1999) and McLemore (2010). Another possible explanation for these anomalously high concentrations of Li could be that Li-rich brines occur in the area. This area warrants further examination to understand the significance of these geochemical anomalies and to determine if public health is at risk.

Orogrande smelter, Otero County

The area southeast of the Orogrande mining district, Otero County exhibits anomalous copper concentrations in the NURE stream-sediment samples (Fig. 15). No mineralized areas were identified during field examination and no other geochemical anomalies were observed in the area during subsequent characterization sampling program in the area (New Mexico Bureau of Mines and Mineral Resources et al., 1998). The most likely source for this copper anomaly is the abandoned copper smelter located in the northern part of the town of Orogrande. The 250-ton matte smelter was operated by the Southwest Smelting and Refining Co. from approximately 1907 to 1910. The area surrounding the smelter and sample locations is covered by Quaternary alluvium, mostly sand dunes and desert soils. The remains at the site include a cement water tower, approximately 20 ft high, piles of cement, bricks, and fire bricks labeled St. Louis Laclede, a 80 ft wide, 115 long holding pond, and a slag pile (V.T. McLemore, field notes, January 26, 1996). The slag pile is approximately 350 ft long, 35-200 ft wide, and <1-4 ft high. There are no indications of any acid leaching or areas barren of vegetation. The slag pile is stable. The prevailing wind in this area is east to southeast and would account for these geochemical anomalies.

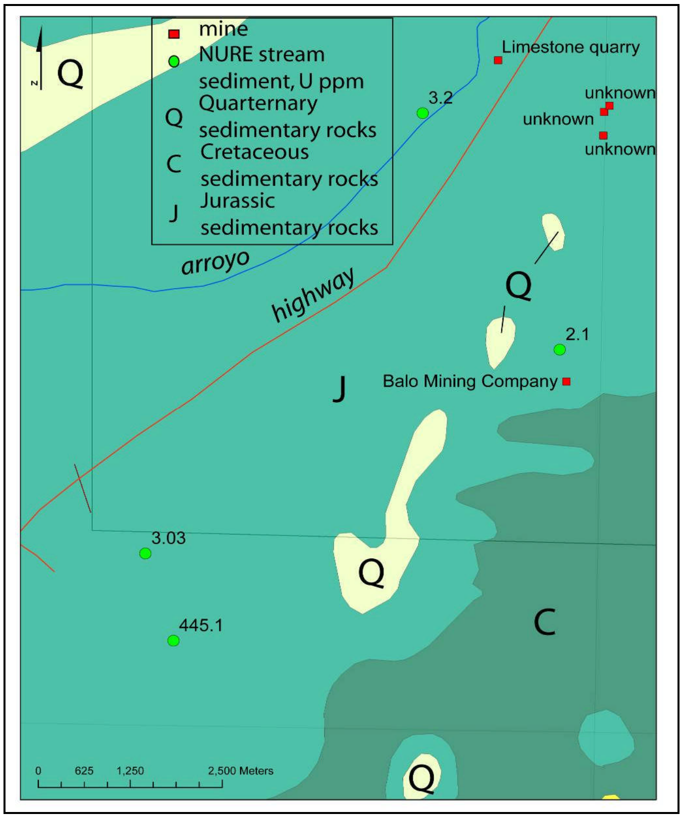


Figure 12. Location of the sample containing the highest uranium concentration in the NURE stream-sediment data in New Mexico (445.1 ppm U).

SUMMARY

Incorporation of various data sets into GIS ArcMap has resulted in identification of several areas with anonymously high uranium concentrations and a better interpretation of the processes involved in creating these geochemical anomalies. This and other studies have demonstrated the usefulness of the NURE data set when used with caution and understanding of the problems with the data. Only a few areas examined thus far in New Mexico at the scale of the NURE data are a result of solely contamination from mining and other anthropogenic inputs; most areas are a result of natural processes related to local rock chemistry, weathering, or formation of mineral deposits. However, as more residents are building houses in and near mining districts, even natural geochemical anomalies could become a health problem and may have to be addressed in some manner. More detailed sampling is required in these areas. Additional analysis and evaluation of these data sets is on-going.

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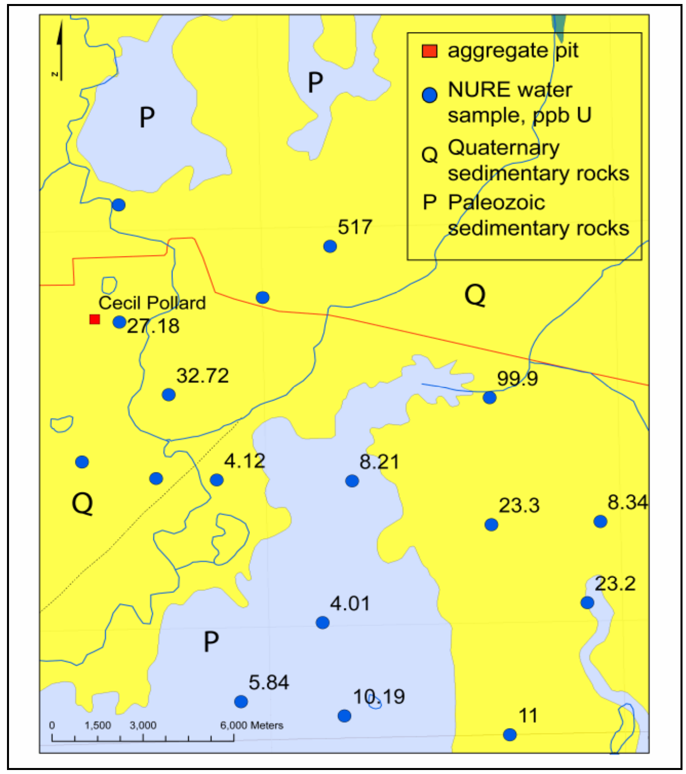

Figure 13. Uranium in water samples in eastern New Mexico, possibly from the Ogallala Formation.

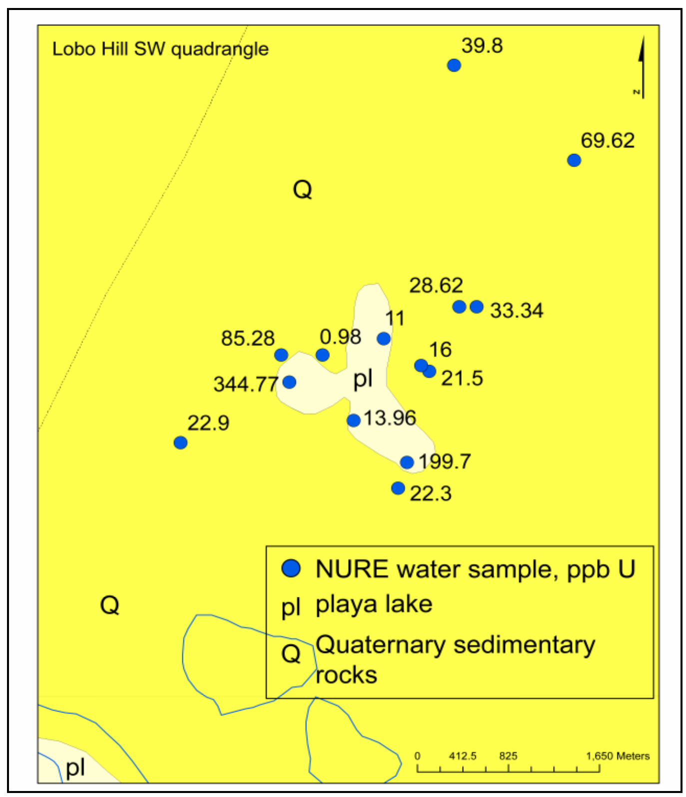

Figure 14. Uranium in water samples in and near a playa lake in northern Estancia Basin, Torrance County, New Mexico. Two of these samples are the 2nd (344.7 ppb U) and 3rd (199.7 ppb U) highest uranium concentrations in the NURE water data for New Mexico.

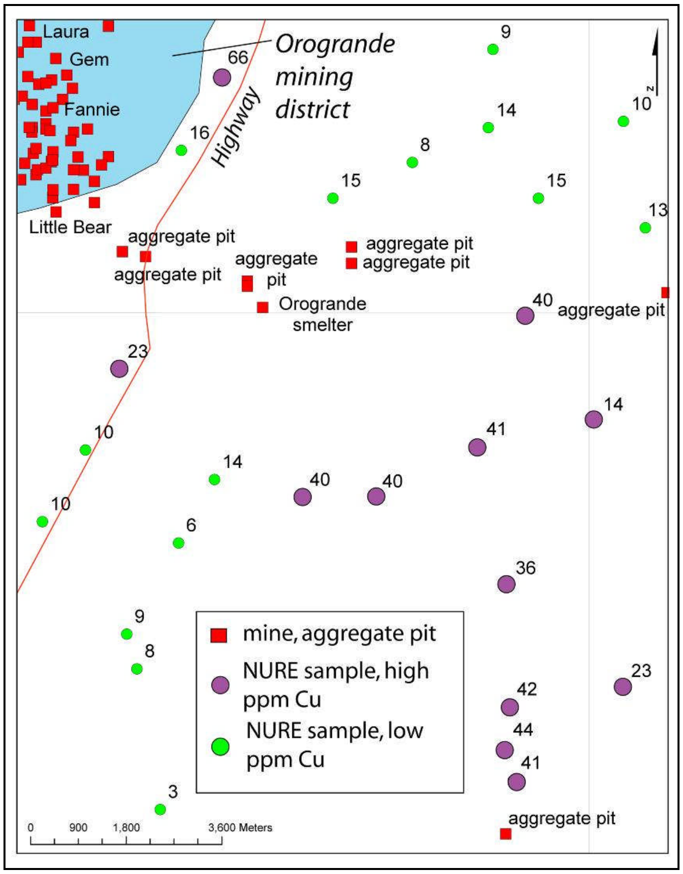

Figure 15. Copper in stream-sediment samples in the Orogrande area, Otero County, New Mexico. Note the samples (in purple) high in copper south and east of the Orogrande smelter (section 14, T22S, R8E) that is likely due to contamination from the smelter. Field examination of the area found only the smelter site and no mineralized outcrops.

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