PUEBLO OF LAGUNA JACKPILE URANIUM MINE RESOURCE BOOK

COMPILED SEPTEMBER 19, 1997

BY

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Testimony of: Manual Pino, Alveno Waconda, Greg Lewis, Gloria Lewis, Suwimi Lewis, Philipp Harrison.

Dorothy Purley Interview, Prairie Island Coalition, 1996

Section 6 - Selected pages from "Water Quality Impacts of Uranium Mining and Milling Activities in the Grants Mineral Belt, New Mexico" September, 1975, G.G. Eadie, et.al., compiled by USEPA, Dallas, Texas. Including:

* Summary and Conclusions,
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Section 7 - "Radionuclide and Heavy Metal Distribution in 20th Century Sediments of Major Streams in the Eastern Part of the Grants Uranium Region, New Mexico" by C.J. Popp, et. al, New Mexico Institute of Mining and Mineral Technology, Socorro, NM 1984.

Includes data on sediment samples from Mesita Reservoir and other sites in the Rio San Jose and Rio Puerco Watershed.

Section 8 - "Jackpile Mine Clean-up $50 Million Headache", Albuquerque Journal, September 8, 1995

Section 9 - "Evaluation for Post Reclamation Land Use at the Jackpile Mine Area"- December 16, 1993: An Independent Study Project by Frances Andazola and CeCilia Sadler for Adjunct Professor Wm. Paul Robinson, Community and Regional Planning Program, University of New Mexico. Includes information on:

* Reclamation Processes, Erosion, Vegetation and Livestock Water Considerations, Discussion of Post-Reclamation Land Use,
* Ground and Surface Water, Geology, Pit Backfill Discharge and Recharge, Wetlands.

Section 10 - Selected Pages from "Uranium Resources of Northwestern New Mexico", by Lowell S. Hilpert. US Geological Survey Professional paper 603, Prepared on behalf of the U.S. Atomic Energy Commission, 1969. Including information on:

- History of Mining and Ore Production,
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Section 11 - "Uranium of the Grants Region", by Dale F. Kittel, et. al., and "The AEC and the Grants Mineral Belt", M. Clifford Smith, Jr., both in "New Mexico Geological Society - 18th Field Conference Guidebook", 1967. Includes information on Uranium development in the 1950s and early 1960s and the use of uranium from that period.

Section 12 - "Uranium In The San Juan Basin"-An Overview Guidebook of San Juan Basin III, by William Chenoweth, in "New Mexico Geological Society - 28th Field Conference Guidebook", 1977.

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DRAFT

JACKPILE-PAGUATE

Uranium Mine Reclamation Project

ENVIRONMENTAL IMPACT STATEMENT

February 1985

US DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT
ALBUQUERQUE DISTRICT OFFICE

BUREAU OF INDIAN AFFAIRS
ALBUQUERQUE AREA OFFICE

BLM-NM-ES-85-001-4134


North
Gavilan Mesa
Jackpile Pit
North
Paguate
Pit
South
Paguate
Pit
Village
Paguate
SP-20

SUMMARY

Introduction

This Environmental Impact Statement (EIS) analyzes the environmental consequences of six alternatives (including the No Action and Preferred Alternatives) for reclaiming the Jackpile-Paguate uranium mine. The mine is located on three tribal leases within the Laguna Indian Reservation, about 40 miles west of Albuquerque, New Mexico. The leaseholder, Anaconda Minerals Company, mined from 1953 to 1982. Out of a total of 7,868 leased acres, 2,656 acres were disturbed by mining. This disturbance includes three open pits, 32 waste dumps, 23 protore (sub-grade ore) stockpiles, four topsoil stockpiles and 66 acres of buildings and roads.

The lease terms and Federal regulations give the Department of the Interior (DOI) the authority to require reclamation of the minesite. The two main DOI agencies involved in this project are the Bureau of Land Management (BLM) and the Bureau of Indian Affairs (BIA). The BLM acts as the overall technical adviser while the BIA is responsible for the surface aspects of reclamation.

The public scoping process was used to focus on the major issues to be considered in this EIS. The two major issues identified were ensuring human health and safety and reducing radioactive releases.

There are no Federal or State regulations or standards for reclaiming uranium mines so a range of alternatives are evaluated in this document. These alternatives are: 1) No Action 2) Green Book Proposal 3) DOI Proposal (with Monitor and Drainage Options) 4) Laguna Proposal 5) Anaconda Proposal and 6) Preferred Alternative.

Description of the Alternatives

No Action Alternative

For this EIS, the No Action Alternative would mean that no reclamation work would be performed. Anaconda would continue their security program to prevent unauthorized entry and they would continue to operate an environmental monitoring program in perpetuity. This alternative is not considered reasonable for this project due to the need to protect public health and safety.

Green Book Proposal

The Green Book Proposal was originally developed by Anaconda Minerals Company but was subsequently replaced by the 1985 Multiple Land Use Reclamation Plan on August 19, 1985. The Green Book is being carried forward in the Final EIS for continuity of impact analysis and consistency with the DEIS.

The open pits would be backfilled to at least three feet above ground water recovery levels as projected by Dames and Moore, 1983. All highwalls would be scaled to remove loose material. The rim of Gavilan Mesa would be cut back by mechanical means or blasting and the base of the highwall would be buttressed with waste and overburden. Waste dump slopes would be reduced to between 2:1 and 3:1; most slopes would be terraced. Jackpile Sandstone exposed by resloping would be covered with four feet of overburden and one foot of topsoil. All protore and waste material lying within 200 feet of the Rios Paguate and Moquino would be removed. Facilities would either be removed or cleaned up and left intact. All disturbed areas (pit bottoms, waste dumps, old roads, etc.) would be topsoiled and seeded. Reclamation would be considered complete when the weighted average for basal cover and production on revegetated sites equals or exceeds 70 percent of that found on comparable reference sites. The post- reclamation monitoring period would be a minimum of three years.

DOI Proposal (Monitor Option and Drainage Option)

This alternative was developed by the DOI. It is based on a series of technical reports, contracted studies and fiel data. Although similar to the Green Book Proposal in overall concept, it varies in important details.

Because of concerns over the environmental impacts of either ponded water or salt build-up in the open pits, DOI has identified two options for treatment of the pit bottoms: 1) a Monitor Option which would backfill the pits with protore, excess material from waste dump resloping and soil cover. Due to the excess material (approximately 19 million cubic yards), the estimated backfill elevations of the pit floors could be 40 to 70 feet higher than the Green Book proposed minimum. The pits would remain as closed basins, in which case the potential build-up of salt and saline water in the soils of the pit bottoms would be monitored. If soil problems are observed, additional backfill and revegetation would be required. The monitoring period would be of sufficient duration to determine the stable future water table conditions; and 2) a Drainage Option which would restore the natural mode of overland runoff from the pit areas. Backfill volumes and elevations would be approximately the same as for the Monitor Option, but none of the pits would be left as closed basins. Open channels would be constructed with a slope equal to or flatter than local natural watercourses to convey runoff from the pit areas to the Rio Paguate. This would avoid ponded water or undrained saline soils on the reclaimed minesite.

Laguna Proposal

This alternative was developed by the Pueblo of Laguna in consultation with their technical consultants. In May 1986, the Pueblo provided the DOI with details and/or changes to the Laguna Proposal which are reflected in the Final EIS.

Under this proposal, all pits would be backfilled 10 above groundwater recovery levels projected by Dames and Moore, 1983. In general, the top 15 feet of each highwall would be cut to a 45 degree angle. With few exceptions, waste dump slopes would be reduced to 3:1. Remove all contaminated material within 100 feet of the Rio Paguate. Remove waste dumps 50 feet back from the Rio Moquino and armor the toes of the dumps with riprap. Minesite facilities would be handled essentially the same as under the DOI's Proposal except that the rail spur would remain intact. Topsoiling, seeding techniques and other reclamation measures would be the same as DOI's Proposal. The post-reclamation monitoring period would vary from 3 to 20 years.

Anaconda Proposal

The Jackpile and South Paguate open pits would be backfilled to an extent that would prevent chronic free-water ponding with groundwater levels controlled in the backfill by phreatophytic vegetation. The North Paguate open pit would be made into a water storage reservoir by diverting the Rio Paguate through the pit. The rest of Jackpile and North Paguate pit highwalls would be scaled or trimmed back a distance of 10 feet at a 3:1 slope. No additional modification of the South Paguate pit highwall is proposed. Waste dump slope modifications and topdressing requirements would vary. All Jackpile Sandstone and waste material would be moved back 50 feet from the Rios Paguate and Moquino. All buildings and other surface structures would be left intact where it is safe to do so. Revegetation success would be based on a comparison of the entire revegetated area relative to an analogous reference area on a weighted average basis. Revegetated areas would be sampled for the third year after the last seeding or reseeding effort by or for Anaconda and year-to-year thereafter until success criteria is met.

Preferred Alternative

Pits would remain as closed basins. They would be backfilled to at least 10 feet above the Dames and Moore (1983) projected groundwater recovery levels. In general, the top 15 feet of each highwall would be cut to a 45 degree angle. All soil at the top of the highwall would be sloped 3:1. With few exceptions, waste dump slopes would be reduced to 3:1. There are two options for stream stabilization: Option A - to remove all material within 200 feet of the Rios Paguate and Moquino, and construct a concrete drop structure across the Rio Moquino and Option B: to remove all contaminated material within 100 feet of the Rio Paguate and to remove all waste dumps within 50 feet of the Rio Moquino and armoring the toes of the dumps with riprap. Facilities would either be removed or cleaned up and left intact. All disturbed areas (pit bottoms, waste dumps, old roads, etc.) would be topsoiled and seeded. Reclamation would be considered complete when revegetated sites reach 90 percent of the density, fequency, foliar cover, basal cover and production of undisturbed reference areas. The post-reclamation monitoring period would vary for each parameter.

INTRODUCTION

History and Background

The Jackpile-Paguate uranium mine is located on the Laguna Indian Reservation, 40 miles west of Albuquerque, New Mexico (Map 1-1). The mine was operated by Anaconda Minerals Company, a division of the Atlantic Richfield Company. Mining operations were conducted continuously from 1953 through early 1982. The mine was closed because of depressed uranium market conditions, and studies are underway to determine how best to permanently reclaim it.

Mining operations were conducted under three uranium mining leases between Anaconda and the Pueblo of Laguna (Map 1-2). The leases cover approximately 7,868 acres, as shown in Table 1-1 below:

TABLE 1-1

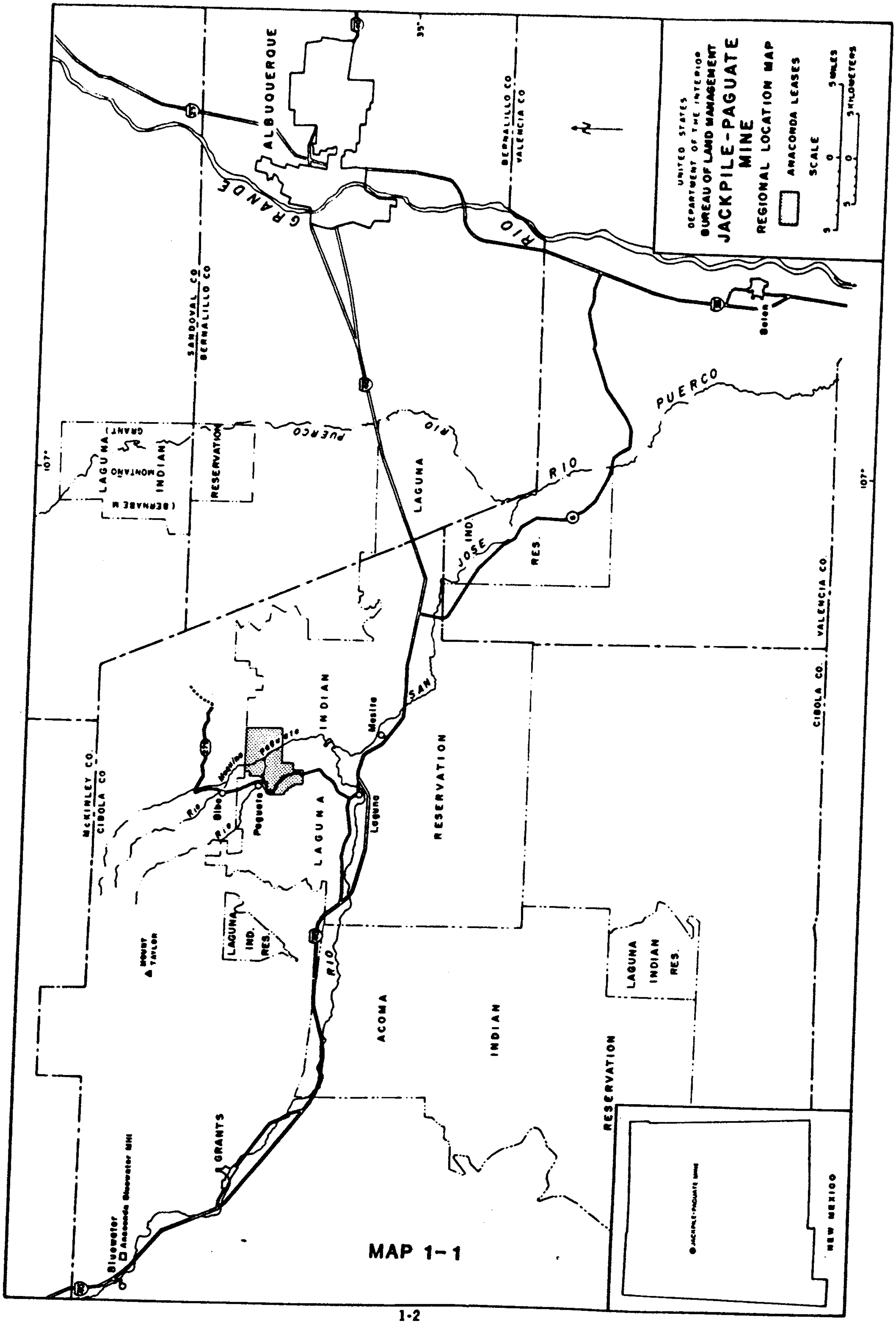
JACKPILE-PAGUATE URANIUM MINE LEASES

Lease Number	Date Signed	Size (Acres)
Jackpile	May 7, 1952	4,988
4	July 24, 1963	2,560
8	July 6, 1976	320
Total		7,868

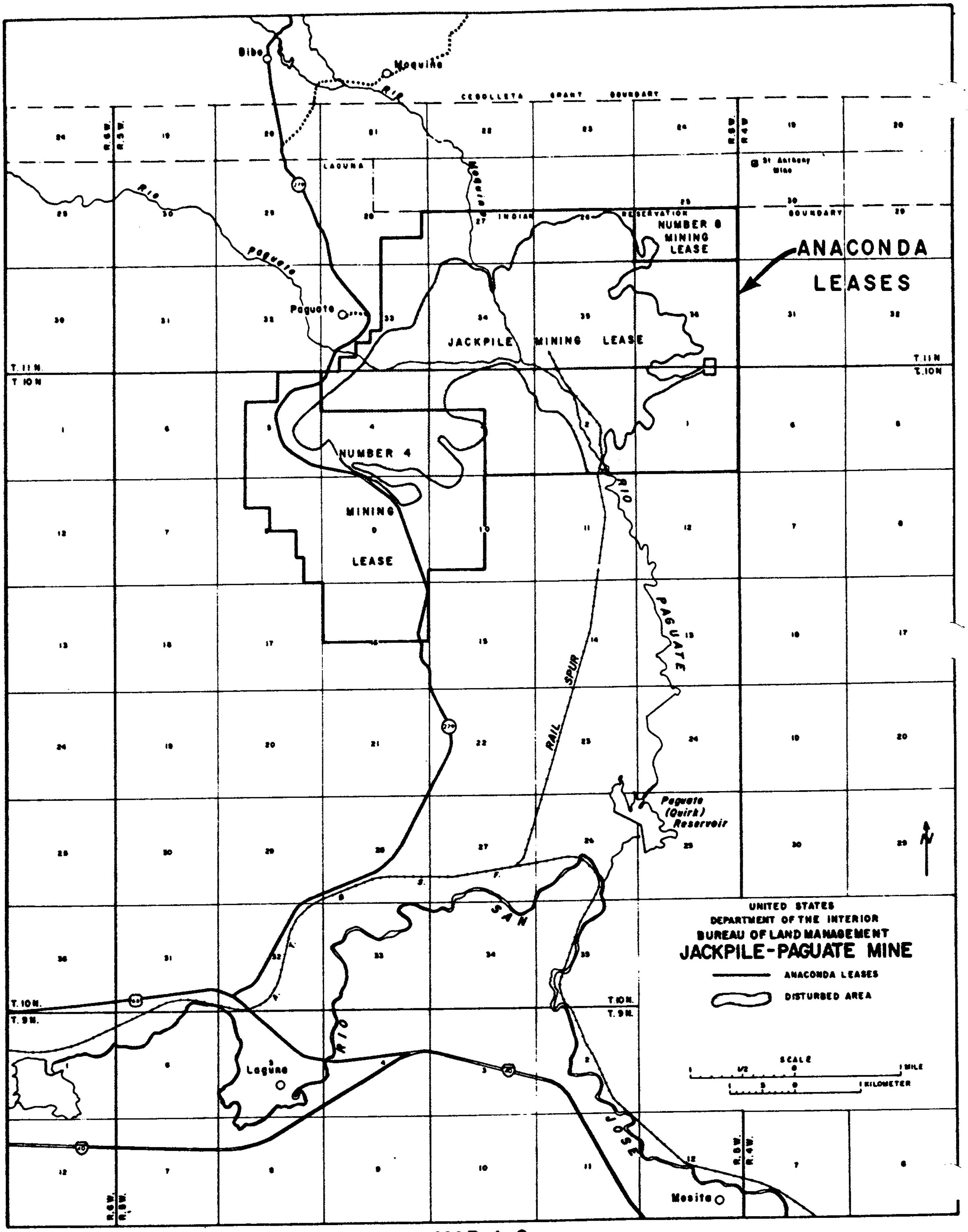
Mining operations were conducted from three open pits and nine underground mines. Open pit mining was conducted predominantly with large front-end loaders and haul trucks. The overburden, consisting of topsoil, alluvium, shale and sandstone was blasted or ripped, removed from the open pits, and placed in waste dumps. The uranium ore was segregated according to grade and stockpiled for shipment to the mill. In the later years of mining, material conducive to plant growth was stockpiled for future reclamation, and some overburden and ore-associated waste was placed in the mined-out areas of the pits as backfill.

Underground mining was conducted by driving adits, or declines, to the ore zone. Drifts were driven through the ore zone, and the ore removed by modified room and pillar methods. Ventilation holes were drilled to maintain a fresh supply of air. Mine water was collected in sumps and pumped to ponds in the open pits. Waste rock was placed in waste dumps, and the ore was stockpiled for shipment to the mill.

During the 29 years of mining, approximately 400 million tons of earth were moved within the mine area, and about 25 million tons of ore were transported from the site via the Santa Fe Railroad to Anaconda's Bluewater Mill, 40 miles west of the mine (Map 1-1).


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
JACKPILE-PAGUATE MINE
REGIONAL LOCATION MAP
ANACONDA LEASES
SCALE
5 MILES
5 KILOMETERS
ALBUQUERQUE
RIO GRANDE
SANDOVAL CO
BERNALILLO CO
BERNALILLO CO
VALENCIA CO
Belen
RIO PUERCO
PUERCO
LAGUNA
(BERNABE M. MONTANO GRANT)
INDIAN
RESERVATION
LAGUNA
SAN JOSE
IND
RES.
VALENCIA CO.
CIBOLA CO.
McKINLEY CO.
CIBOLA CO
Mesita
Laguna
Paguate
Bibo
Rio Moquino
Rio Paguate
LAGUNA INDIAN RESERVATION
LAGUNA IND. RES.
MOUNT TAYLOR
RIO SAN JOSE
ACOMA INDIAN RESERVATION
LAGUNA INDIAN RES.
GRANTS
Bluewater
Anaconda Bluewater Mill
JACKPILE-PAGUATE MINE
NEW MEXICO
35°
107°

MAP 1-1


ANACONDA
LEASES
NUMBER 8
MINING
LEASE
JACKPILE MINING LEASE
NUMBER 4
MINING
LEASE
Bibo
Moquino
CEBOLLETA GRANT BOUNDARY
LAGUNA
RESERVATION
BOUNDARY
Paguate
Paguate
(Quirk)
Reservoir
RAIL SPUR
PAGUATE
SAN JOSE
Laguna
Mesita
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
JACKPILE-PAGUATE MINE
ANACONDA LEASES
DISTURBED AREA
SCALE
1 MILE
1 KILOMETER
T. 11 N.
T. 10 N.
T. 9 N.

MAP 1-2

The mining operations resulted in 2,656 acres of surface disturbance as shown in Table 1-2.

TABLE 1-2

SURFACE DISTURBANCE

Features	Acres Disturbed
Open Pits	1,015
Waste Dumps	1,266
Protore Stockpiles	103
Topsoil Stockpiles	32
Support Facilities & Depleted Ore Stockpiles	240
TOTAL:	2,656

Additional acreage (unquantified) was disturbed by the drilling of exploration holes. Visual A, pocketed in the back of this Environmental Impact Statement (EIS), displays the mine complex as it presently exists.

Anaconda ceased all mining operations on March 31, 1982, but continues to provide security at the site to prevent unauthorized entry, and continues to operate an environmental monitoring program.

Anaconda advised the Department of the Interior (DOI) and the Pueblo of Laguna in April 1980 that open pit operations would terminate in February 1981 and subsequently submitted a reclamation plan to the DOI on September 11, 1980. Anaconda submitted a revised plan (Green Book Proposal) on March 16, 1982. On August 19, 1985, Anaconda submitted a preliminary version of a new reclamation plan entitled the 1985 Multiple Use Reclamation Plan for the Jackpile-Paguate Uranium Mine. This plan was submitted in final form on October 4, 1985. Anconda stated that this new plan rendered the 1982 Green Book Plan obsolete and withdrew it from further consideration in the EIS process. The Green Book is being carried forward in the Final EIS but is no longer endorsed by Anaconda.

Anaconda's leases are administered by the Bureau of Indian Affairs (BIA), and the mining and reclamation operations are supervised by the Bureau of Land Management (BLM). Both of these agencies are within DOI.

Purpose and Need for Reclamation

Reclamation of the Jackpile-Paguate uranium mine is necessary because:

1. The site is presently a public health and safety hazard;

2. Additional and more serious hazards would develop if the site is not reclaimed; and

3. The mining lease terms and Federal regulations (25 CFR Parts 211 and 216, and 43 CFR Part 3570) require that reclamation be performed by the leaseholder.

This EIS assesses and compares the environmental impacts of four reclamation alternatives, including proposals developed by Anaconda, the Pueblo of Laguna and the DOI. The proposed action for this EIS is the review and approval of a reclamation plan for the Jackpile-Paguate uranium mine.

The lease terms and regulations require reclamation but do not contain specific goals or standards to guide the DOI's decision. Therefore, the DOI must consider various reclamation alternatives, and choose the one that is considered to be the most appropriate.

Scope of the EIS

The scope of this EIS is 1) the reclamation (restoration to productive use) of the Jackpile-Paguate uranium mine and the affected adjacent areas, and 2) mitigation of impacts resulting from reclamation.

Federal Trust Responsibility

Indian tribes and pueblos enjoy a unique status under Federal law based upon what has been characterized as a "guardian-ward" status. Morton v. Mancari, 417 U.S. 535,551 (1974); Cherokee Nation v. Georgia, 30 U.S. (5 Pet.), (1831). This is a judicially created fiduciary status that is loosely characterized by saying that the Secretary of the Interior has a "trust responsibility" to the Indians. Chambers, Judicial Enforcement of the Federal Trust Responsibility, 27 Stanford Law Review 1213, 1214 (1975). The trust responsibility arises out of statutes, treaties, executive orders and those situations where the Bureau of Indian Affairs (BIA) holds title to Indian land and administers it "in trust" for particular tribes. United States v. Mitchell, 445 U.S. 535 (1980); Cape Fox Corporation v. United States, No. 664-801 (Ct. Cl. filed December 27, 1983), Chambers, supra. The trust responsibility is a limited one that arises from and is limited by, the authorizing statute, treaty, or executive order, and it varies according to the particular relationship being examined. See North Slope Borough v. Andrus, 642 Fed. 589, 611 (D.C. Cir. 1980).

Due to the governing regulations and the Secretary of the Interior's trust responsibility to Indians (and in this action specifically to the Pueblo of Laguna), the DOI is responsible for determining the proper level of reclamation for the Jackpile-Paguate uranium mine.

Responsibilities

The BLM and BIA share joint responsibility for a decision on approval of a reclamation plan for the Jackpile-Paguate uranium mine. However, each agency has specific responsibilities with regard to reclamation as outlined below.

The BLM is responsible for authorizing the commencement and approving the completion of the Jackpile-Paguate uranium mine reclamation. The authorities for this action are the terms of the mining leases that require compliance with applicable Federal regulations. Specifically, they include the following:

1. 25 CFR Part 211, Leasing of Tribal Lands for Mining (formerly 25 CFR Part 171);

2. 25 CFR Part 216, Surface Exploration, Mining and Reclamation of Lands (formerly 25 CFR Part 177); and

3. 43 CFR Part 3570, Operating Regulations for Exploration, Development and Production (formerly 30 CFR Part 231).

The BLM is also responsible for authorizing any necessary changes in the ongoing reclamation operations and for preparing any corresponding environmental documentation that would be required.

The BIA is responsible for determining that the surface aspects of mine reclamation, including revegetation, have been completed in accordance with the Secretary's trust responsibility as well as established requirements. In conjunction with this determination, the BIA is responsible for authorizing partial or total release of any bonding requirements, and partial or total surrender of the involved mining leases. The authorities for these actions are various terms of the mining leases and the provisions of 25 CFR Parts 211 and 216.

Due to the effective dates of the three mining leases and applicable Federal regulations, disagreement exists between the involved parties about the applicability of some of these regulations to certain leases. Debate has also occurred about the interpretation of various lease terms. It is not intended that this EIS resolve any such disagreement or debate. This section of the EIS merely identifies the Federal regulations that relate to one or more of the mining leases, and indicates that the lease terms and those regulations assign certain responsibilities to the BLM and the BIA.

Interrelationships with Other Projects

The only related project planned is the realignment of State Highway 279 through the mine area. This project is dependent on State legislative appropriation. The realignment is scheduled to take place prior to or during reclamation. This project is not precluded by any of the alternatives addressed in this EIS nor would the realignment preclude implementation of any of the reclamation proposals.

ISSUES AND CONCERNS

During the initial stages of the EIS process, public meetings were held to determine the issues of greatest concern related to the mine reclamation project and possible reclamation measures. This process is called "scoping". The DOI reviewed all the comments raised during these meetings and selected those major issues to be addressed in this EIS. The criteria DOI used for selecting major issues were whether the concerns expressed were substantive, and whether the issues fell within the scope of this EIS as stated on p. 1-5. Issues that failed to meet both criteria were dropped from further evaluation. Issues which met the criteria were used to develop reclamation objectives which in turn would be used to evaluate alternatives. Public input received during the early stages of the scoping process and in subsequent public hearings on the DEIS revealed that the issues of blast damage to Paguate Village during mining operations and possible radiological contamination in Paguate Reservoir were primary concerns raised by the Pueblo of Laguna. However, data compiled to date has been inconclusive on both issues. Therefore, DOI considers these two areas of concern to be unresolved liability issues. A more detailed discussion of scoping activities is contained in Chapter 4 - Consultation and Coordination.

Issues Dropped from Further Evaluation

1. Investigate the possible psychological effects that the mining operations and mine closure had on the Laguna people. Rejected as not within the scope of this EIS.

The present socioeconomic conditions of the Laguna people and the socioeconomic impacts of the reclamation operations are discussed in this document. However, NEPA does not require, and no useful purpose would be served by analyzing the impacts of past mining and mine closure.

2. Investigate the possible health impacts that mining operations had on former miners and residents of Paguate Village. Rejected as not within the scope of this EIS.

The predicted health impacts to the workers performing reclamation and post-reclamation impacts to the Laguna people are discussed in this document. However, NEPA does not require, and no useful purpose would be served by analyzing the impacts of past mining and mine closure.

3. Protection of the remaining on-site uranium resources (protore and unmined deposits) and existing mine workings for future production. Rejected as not within the scope of this EIS.

Projection of economic conditions suitable for recovery of the remaining reserves is speculative. A new mining project is not precluded in any of the reclamation proposals, and it is recognized that the treatment of protore and existing mine workings under various alternatives could significantly affect future mining costs. This is briefly discussed to the extent possible under each alternative.

4. Allow future residential and farming use of the minesite. Rejected as being contrary to the reclamation objective of ensuring human health and safety.

Either of these activities would require disturbing reclaimed areas to a significant degree and therefore have the potential for releasing previously covered radioactive materials into the biosphere.

5. Develop national standards for the reclamation of uranium mines. Rejected as not within the scope of this EIS.

Subtitle C of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act of 1976, directed the U.S. Environmental Protection Agency to promulgate regulations for the management of hazardous wastes. These regulations were issued, but they exclude mining wastes. Evaluation of this site-specific project does not preclude Congress from acting to designate mining wastes as hazardous materials nor does it prevent DOI from using regulations for other similar activities as guidelines.

Issues Evaluated

1. Radiological doses and health impacts to workers involved in reclamation, persons visiting the minesite, residents of Paguate Village and to the general public.

2. Non-radiological minesite hazards such as possible collapse of the underground entries and workings, collapse of abandoned mine buildings and hazards due to unstable highwalls and waste dumps.

3. Engineering the reclaimed land forms to ensure their long-term integrity and blend the visual characteristics of the minesite with the surrounding landscape.

4. Contamination of surface and ground waters.

5. Revegetation of the minesite to prevent erosion and facilitate post-reclamation land use (i.e., livestock grazing).

6. Backfilling or draining the open pits to prevent ponding of contaminated water.

7. Minimizing the concentration of airborne particulates during and after reclamation.

8. Protection of cultural, religious and archaeological sites within the minesite.

9. Socioeconomic impacts of reclamation on the Pueblo of Laguna.

10. Long-term environmental monitoring needs and procedures.

INTRODUCTION

This chapter describes the existing physical, biological and socioeconomic conditions in and adjacent to the Jackpile-Paguate uranium mine. The information in this chapter provides the basis for the assessment of impacts made in Chapter 3.

Map 1-2 in Chapter 1 shows the principal features of interest in and around the minesite. These features are also listed in Table 2-1. Table 2-2 defines terms that are used throughout this document. These definitions apply specifically to this EIS and should not be confused with other definitions for these terms.

MINING OPERATIONS

Operations at the Jackpile-Paguate uranium mine were conducted from three open pits and nine underground mines. Open-pit mining was conducted predominantly with large front-end loaders and haul trucks. The overburden, consisting of topsoil, alluvium, shale and sandstone was blasted or ripped, removed from the open pits, and placed in waste dumps. The uranium ore was segregated according to grade and stockpiled for shipment to the mill. In the later years of mining, material conducive to plant growth was stockpiled for future reclamation. Ore-associated waste and some overburden was also placed in the mined-out areas of the pits as backfill.

Underground mining was conducted by driving adits, or declines, to the ore zones. Drifts were driven through the ore zone, and the ore removed by modified room-and-pillar methods. Ventilation holes were drilled to maintain a fresh air supply. Mine water was collected in sumps and pumped to ponds in the open pits. Waste rock was placed in waste dumps, and the ore was stockpiled for shipment to the mill.

Surface Disturbance

During the 29 years of mining activity, approximately 2,656 acres of natural ground were disturbed by mine operations, as indicated in Table 2-3 and on Visual A.

Open Pits

The Jackpile, North Paguate and South Paguate open pits make up about 40 percent of the total disturbed acreage at the minesite (Figure 2-1). Approximately 101 million tons (63.6 million cubic yards) of backfill, composed principally of ore-associated waste with some overburden, have been returned to the pits. Due to irregular topography, the pits vary in maximum depth as follows: Jackpile 625-feet deep; North Paguate-200 feet deep; and South Paguate-325 feet deep.

The most prominent features within the excavated pits are the pit walls (also called highwalls), which are composed principally of shale with some intermixed sandstone beds. The overall slope angle of the pit walls ranges between 49 and 55 degrees (Figure 2-2).

TABLE 2-1

PRINCIPAL FEATURES OF INTEREST IN AREA OF JACKPILE-PAGUATE URANIUM MINE

Feature	Description
Anaconda Mining Leases	Three leases totaling approximately 7,868 acres.
NM Highway 279	Realignment is being proposed to eliminate a hazardous section of this State highway that presently passes around the mine. This realignment is not part of the overall reclamation project.
Paguate Reservoir[a/]	Constructed south of the mine area in 1940, now almost completely silted in.
Rail Spur	Constructed by Anaconda on a right-of-way across Pueblo of Laguna land.
Rio Paguate and Rio Moquino	Small perennial rivers that join within the minesite for an average combined discharge of 1.2 cubic feet per second.
Village of Laguna	Laguna Indian village with 1,565 residents.
Village of Paguate	Laguna Indian village with 1,435 residents located approximately 1,000 feet from the mine.

Note: [a/]Paguate Reservoir is sometimes referred to as Quirk or Mesita Reservoir.

TABLE 2-2

TERMS USED IN THIS EIS

General Term	Definition	Components
Jackpile Sandstone	The ore-bearing unit at the Jackpile-Paguate uranium mine	Barren waste [less than .002 percent uranium (U_3O_8)][a/]
		Ore-associated waste (.002 to .019 percent U_3O_8)[a/]
		Protore (.02 to .059 percent U_3O_8--refer to Glossary)[a/]
		Ore (greater than .06 percent U_3O_8)[a/]
Overburden	Any material that overlies the ore-bearing unit	Topsoil, Alluvium, Mancos Shale, Tres Hermanos Sandstone, Dakota Sandstone
Soil	Material used as plant-growth medium during revegetation	Topsoil, Alluvium, Pulverized Tres Hermanos Sandstone

Note: [a/]This percentage range applies to this EIS only--refer to the Mineral Resources section of this chapter for an explanation.

TABLE 2-3

JACKPILE-PAGUATE URANIUM MINE DISTURBED AREAS

Feature	Acres
Open Pits	
Jackpile	475
North Paguate	140
South Paguate	400
	1,015
Waste Dumps	
Jackpile area	718
North Paguate area	192
South Paguate area	356
	1,266
Protore Stockpiles	
Total mine area, excluding open pits	103
Topsoil Stockpiles	
TS-1	21
TS-2(A and B)	11
TS-3[a]	(19)
	32
Other Disturbed Areas	
Depleted ore stockpiles[b]	50
General area disturbance (includes buildings, parking lots)	66
Roads	88
Rail spur and miscellaneous areas	36
	240
TOTAL ACRES DISTURBED	2,656

Source: Anaconda Minerals Company 1982.

Notes: [a] Topsoil stockpile TS-3 is located on South Dump and therefore does not constitute additional acreage of disturbed natural ground.
[b] Refers to former stockpile areas in which the ore was either relocated to the open pits or shipped to the mill.

FIGURE 2-1 VIEW SOUTH THROUGH JACKPILE PIT

FIGURE 2-2 SOUTH PAGUATE PIT HIGHWALL

Water has collected in the lowest portions of the pits as a result of surface runoff, ground water recovery and water discharged from the underground operations (Figure 2-3). As of April 1984, water levels in the pits ranged between elevations of 5830' and 5959'.

FIGURE 2-3 PONDING IN NORTH PAGUATE PIT

Waste Dumps

The minesite contains 32 waste dumps that make up about 48 percent of the disturbed area (Figure 2-4). The dumps are composed of Tres Hermanos Sandstone, Mancos Shale, Dakota Sandstone, and both barren and ore-associated Jackpile Sandstone. Characteristics of the dumps, including previous reclamation performed, are presented in Table 1-4 (Chapter 1).

Protore Stockpiles

Located outside and inside of the pits are 23 protore stockpiles (Figure 2-5 and Table 2-4). The protore that lies outside the pits covers approximately 100 acres and contains approximately 7.2 million cubic yards of material. Those stockpiles that lie inside the pits contain about 3.1 million cubic yards of matieral but do not constitute additional acreage of disturbed ground. The stockpiles are generally segregated according to grade, but some grade variation exists within each stockpile.

TABLE 2-4

PROTORE STOCKPILES AT THE JACKPILE-PAGUATE URANIUM MINE

Area	Stockpile Designation	Volume (cubic yards)
Jackpile Mine Area	J-1	328,950
	J-1A[a]	
	J-1-A	1,673,500
	JLG	
	SP-1	353,700
	J-2	156,860
	SP-6-A	1,517,000
	SP-6-B	
	SP-17BC	18,100
	17-E[a]	660,000
North Paguate Mine Area	1-B	993,760
	1-E[a]	154,500
	2-E	255,400
	10-Dike	23,920
	SP-1	620,400
	SP-1-C	284,720
	SP-2-C	1,223,790
	SP-2-D	122,660
South Paguate Mine Area	1-D[a]	
	PLG	648,700
	PLG-1	
	4-1	154,800
	SP-1-A	1,161,830
TOTALS	23 stockpiles	10,352,590

Source: Stockpile designations and locations Anaconda Minerals Company 1982; volumetric calculations Anaconda 1982 and BLM 1984.

Note: [a]Stockpiles located within pits themselves.

Underground Disturbance

Mining was conducted in nine underground mines (Visual A). Five of these mines were permanently plugged and abandoned as part of normal mining operations. The remaining four were operating when overall mining operations were suspended, and each has been temporarily closed for safety (Figure 2-7). Table 2-6 briefly describes each mine.

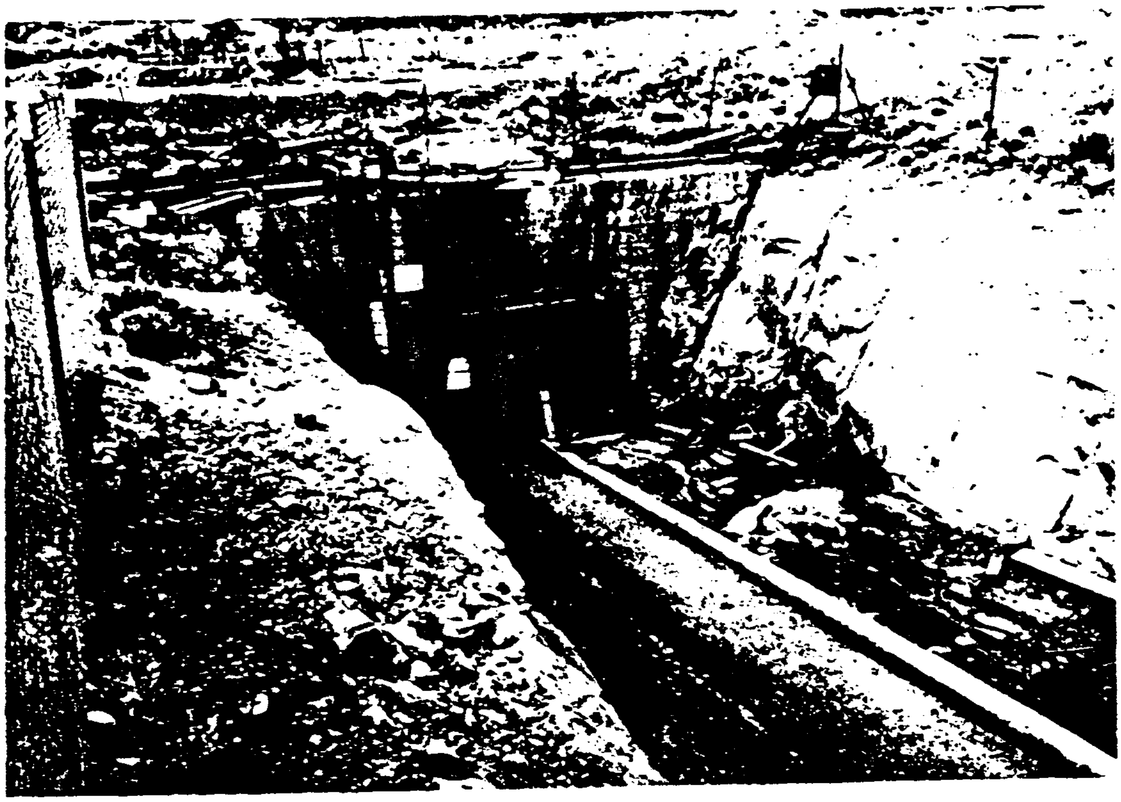


FIGURE 2-7 P-10 DECLINE -TEMPORARILY ABANDONED

Only the P-10 mine produced a substantial amount of water, and the water level has risen to render its workings inaccessible. The deposits at each of the mines, with the exception of NJ-45 and P-13, were mined as completely as the economics of the times would allow.

Previous Reclamation

Anaconda Minerals Co. began a limited reclamation program in 1976. The program consisted of returning most of the overburden removed during the stripping process to mined-out areas of the pits, clearing of stream channels, slope stabilization tests and revegetation of dumps. Each of these processes is described as follows.

TABLE 2-6

STATUS OF UNDERGROUND MINING OPERATIONS

Mine	Description	Status
Alpine	Small operation - access via 2 adits	Adits permanently plugged with waste
H-1	Small operation - access via 2 adits -3 vent holes - used as an undergroundminer's training school	Adits and vent holes permanently plugged with waste
NJ-45	Small operation begun in 1981 - access via 3 adits from Jackpile pit - 2 vent holes - approximately 1/3 of ore removed	Adits and vent holes temporarily covered - mine workings relatively stable and assumed to be inaccessible
P-7	Large operation - access via P-10 underground drifts - 6 vent holes-vertical emergency escapeway into South Paguate pit	Vent holes temporarily covered - mine workings filled with water and inaccessible
P-9-2	Large operation - access via 5 adits -8 vent holes	Adits, majority of workings, and all but 1 vent hole mined through by advances of South Paguate pit - 1 vent hole open but covered
P-10	Large operation - access via 2,000-foot decline - 11 vent holes	Decline and vent holes temporarily covered - mine workings filled with water and inaccessbile
P-13	Small operation begun in 1981 - access via 2 adits from South Paguate pit - ore body not fully opened - very small percentage of ore removed	Adits and mine workings flooded with water and inaccessible
P 15/17	Large operation approved for development but never begun	No operations conducted
PW 2/3	Small operation - access via 2 adits from North Paguate pit - 2 vent adits into pit	All adits permanently covered with backfill (highwall buttress)
Woodrow	Small operation - vertical shaft with 2 working areas to mine vertical breccia pipe deposit - mining completed in 1956	Shaft backfilled from bottom to top

Source: Anaconda Minerals Company 1982.

TABLE 2-7

ANACONDA'S ENVIRONMENTAL MONITORING PROGRAM

Item	Monitoring Frequency	Monitoring Parameters	Number of Stations Monitored
Subsidence	Quarterly[a]	Ground movement	89
Surface water	Monthly	29 chemical and radiological parameters[b]	6
Ground water	Monthly	29 chemical and radiological parameters[b]	3[c]
Particulates (radiological)	Monthly	U-natural, Ra-226, Po-210 and Th-230	4
Particulates (non-radiological)	Monthly	Total particulates	4
Gamma	Once after topsoil application	Gamma radiation	100-meter grid on each waste dump
Radon concentration	Monthly	Rn-222	4
Radon exhalation	Twice after topsoil application	Radon release per unit area	100-meter grid on each waste dump
Vegetation	Once	Th-230, Ra-226, Po-210, uranium and radon	Each reclaimed waste dump
Vegetation	Variable	Density, diversity and basal cover	Each revegetated area
Soils	Once	11 chemical and radiological parameters	One composite sample on each reclaimed waste dump
Meteorology	Continuous	Wind speed and direction, temperature and precipitation	1

Notes: [a] On June 9, 1983, subsidence monitoring of P-13 and P-15/17 was discontinued because these mine workings were never developed. At the same time, the monitoring frequency for the P-10 and PW-2/3 mines was reduced to semi-annual.
[b] pH, conductivity, TDS, HCO_3, Cl, SO_4, Na, K, Ca, Mg, NO_3, F, SiO_2, Mn, As, Ba, Cd, Cr, Pb, Hg, Se, Cu, Fe, Zn, Mo, Ni, V, U, Ra-226.
[c] Sampling of the Old Shop Well was discontinued in May 1983. Sampling of the New Shop and #4 wells was discontinued in August 1983. A new ground water monitoring program using nine wells was started in September 1983.

The Gavilan Mesa highwall is the tallest at the mine; its crest measures just over 500 feet (Figure 2-9). Its slope angle ranges up to 74 degrees, with an overall angle of 49 degrees (Seegmiller 1981a.) This highwall has up to six benches 25 to 50 feet wide. Several tension cracks occur on the first bench below the crest of the highwall. Numerous overhanging and loose sandstone blocks are also present and are most common where several joints intersect with bedding planes and the cliff face. Under present conditions, sections of the Gavilan Mesa highwall are only marginally stable for the long-term. The most likely slope failure would be a rotational one. This type failure would involve most benches and result in a large volume of material sliding to the toe of the highwall.

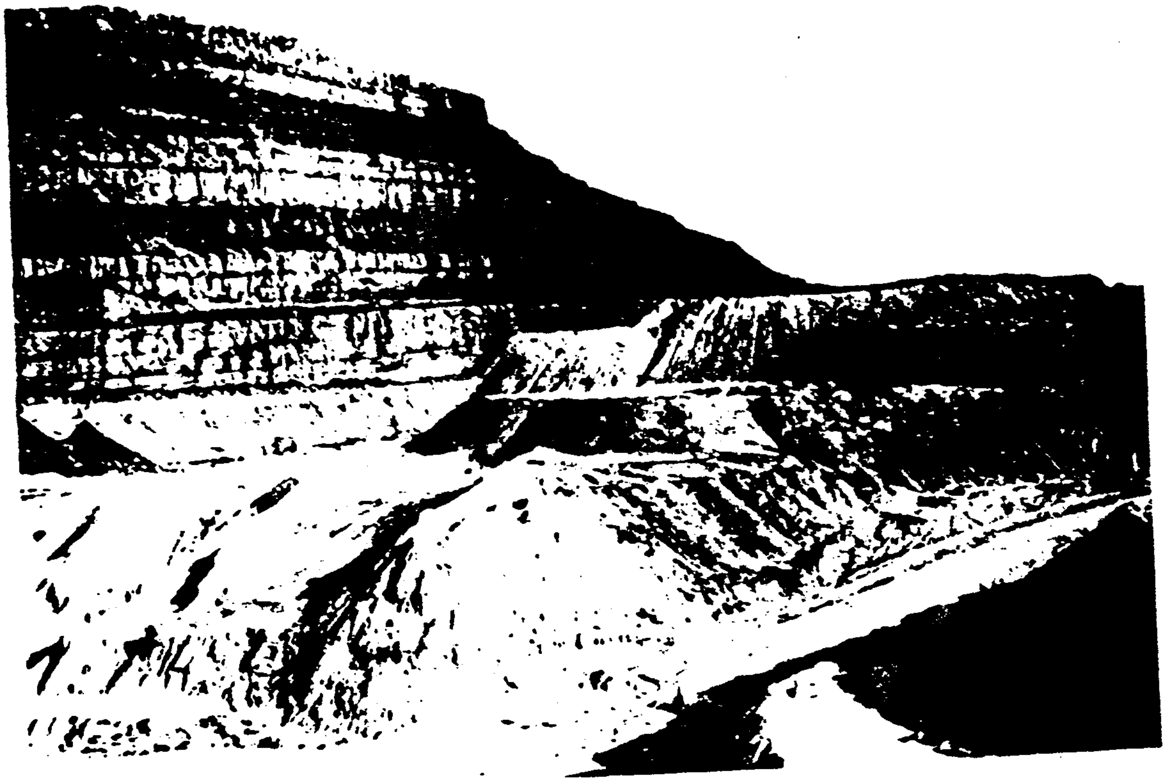
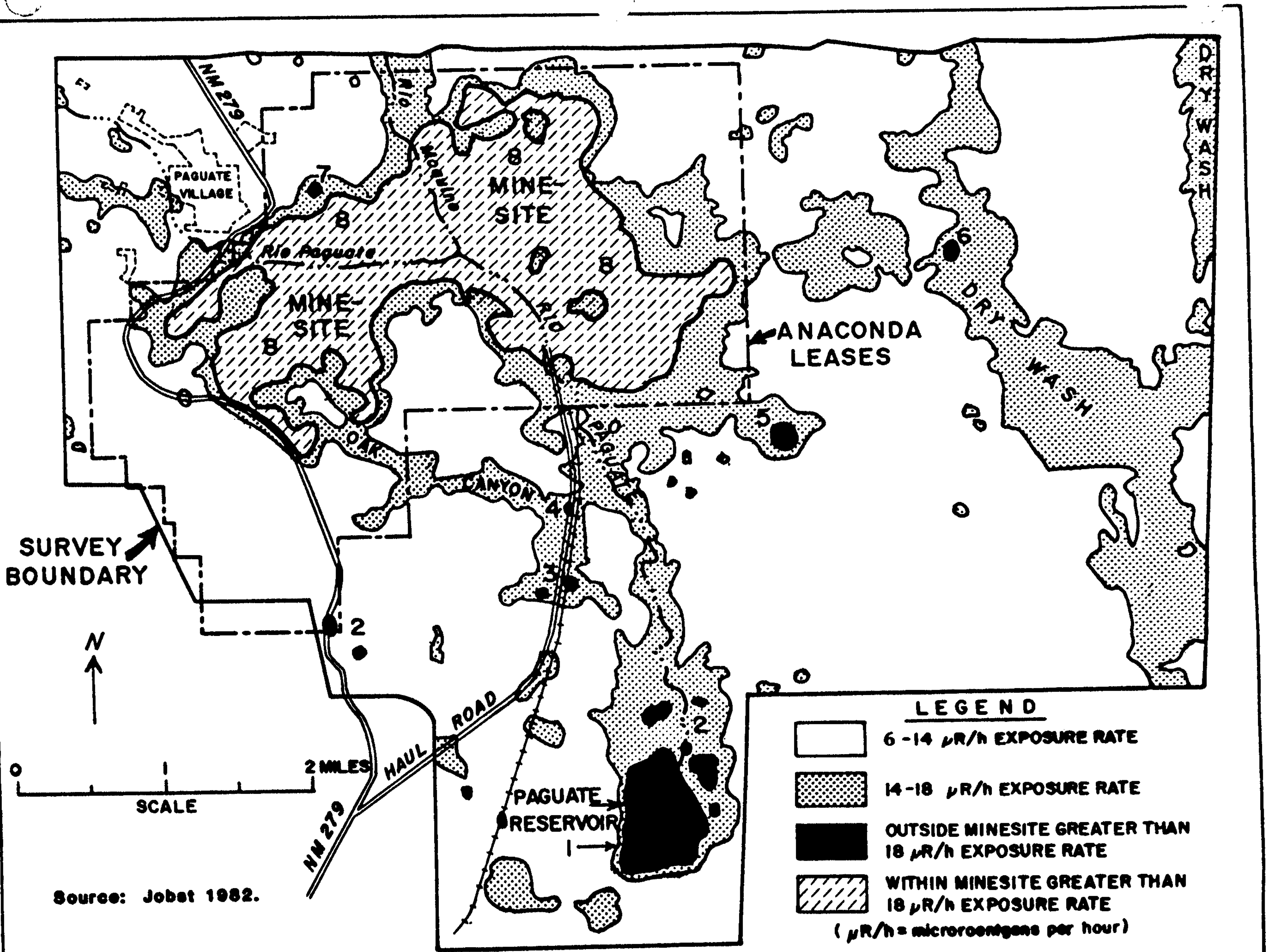


FIGURE 2-9 JACKPILE (GAVILAN MESA) PIT HIGHWALL WITH BUTTRESS MATERIAL AT BASE

Toward the end of mining operations, Anaconda placed waste material against the base of Gavilan Mesa to help stabilize the highwall. The rim of the highwall is not fenced.

The North Paguate pit highwall has a maximum height of 200 feet and a slope angle that ranges up to 70 degrees; the maximum overall slope angle is 55 degrees (Seegmiller 1981a). This highwall has up to three benches 15 to 20 feet wide. It is considered stable for the long term. That portion of North Paguate pit highwall close to the Village of Paguate is fenced with six-foot chain link.



Source: Jobst 1982.

MAP 2-1 Aerial Gamma Survey of the Minesite and Surrounding Area

FIGURE 2-10 FD-2 DUMP ON EAST SIDE OF GAVILAN MESA

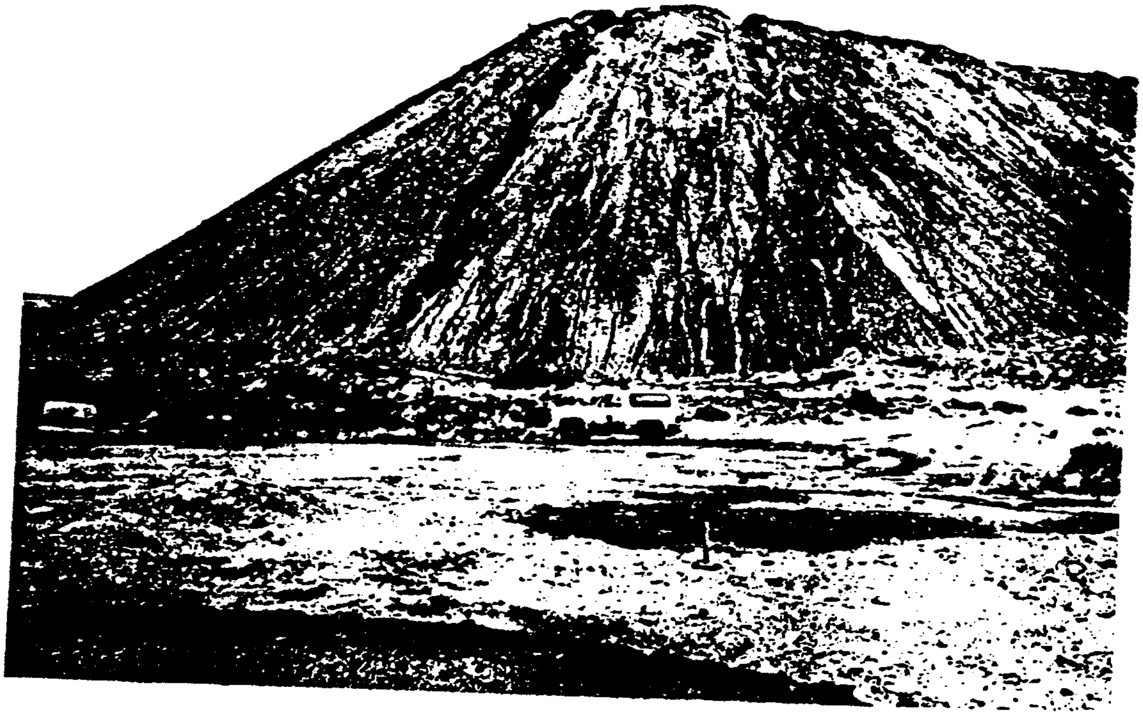
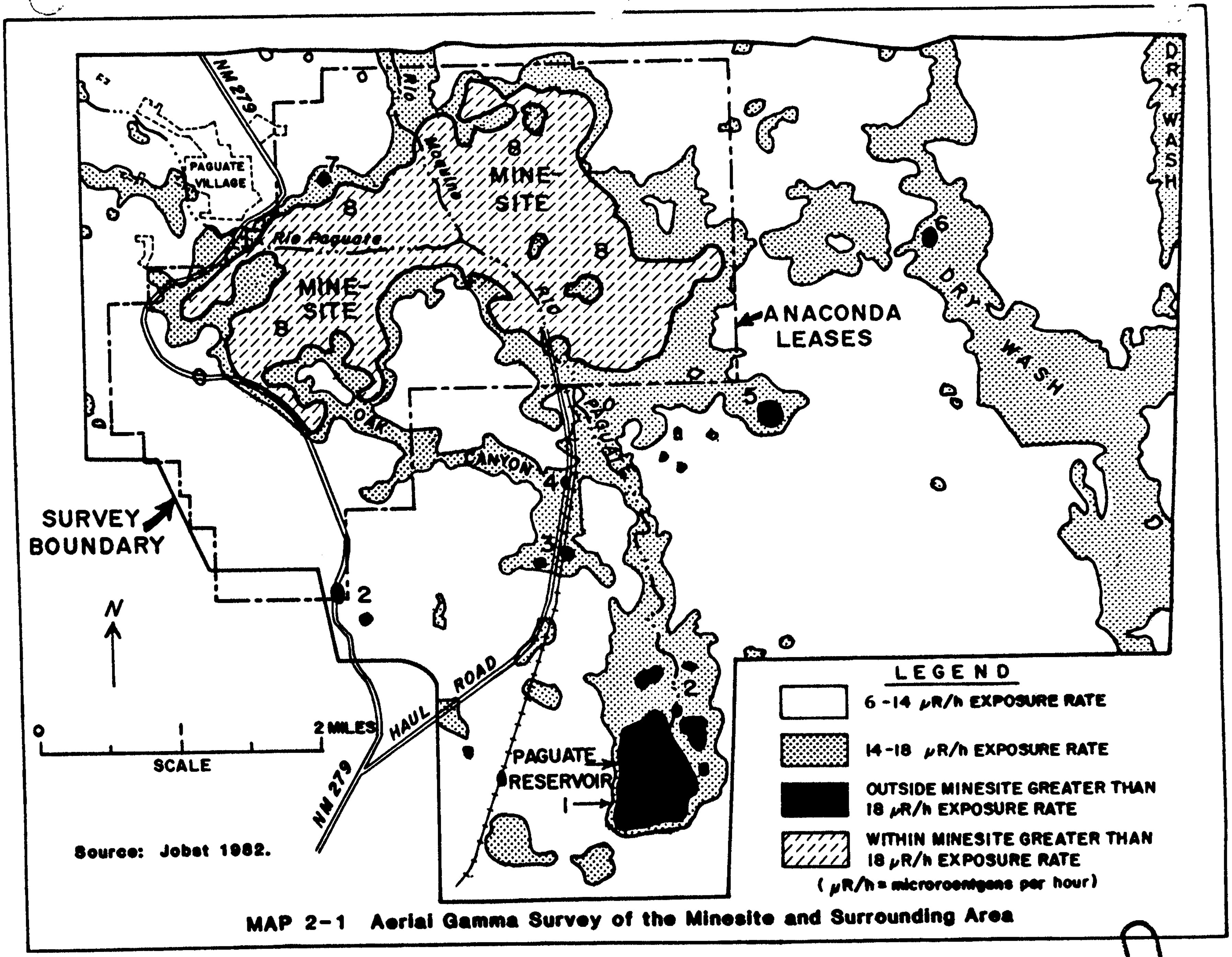
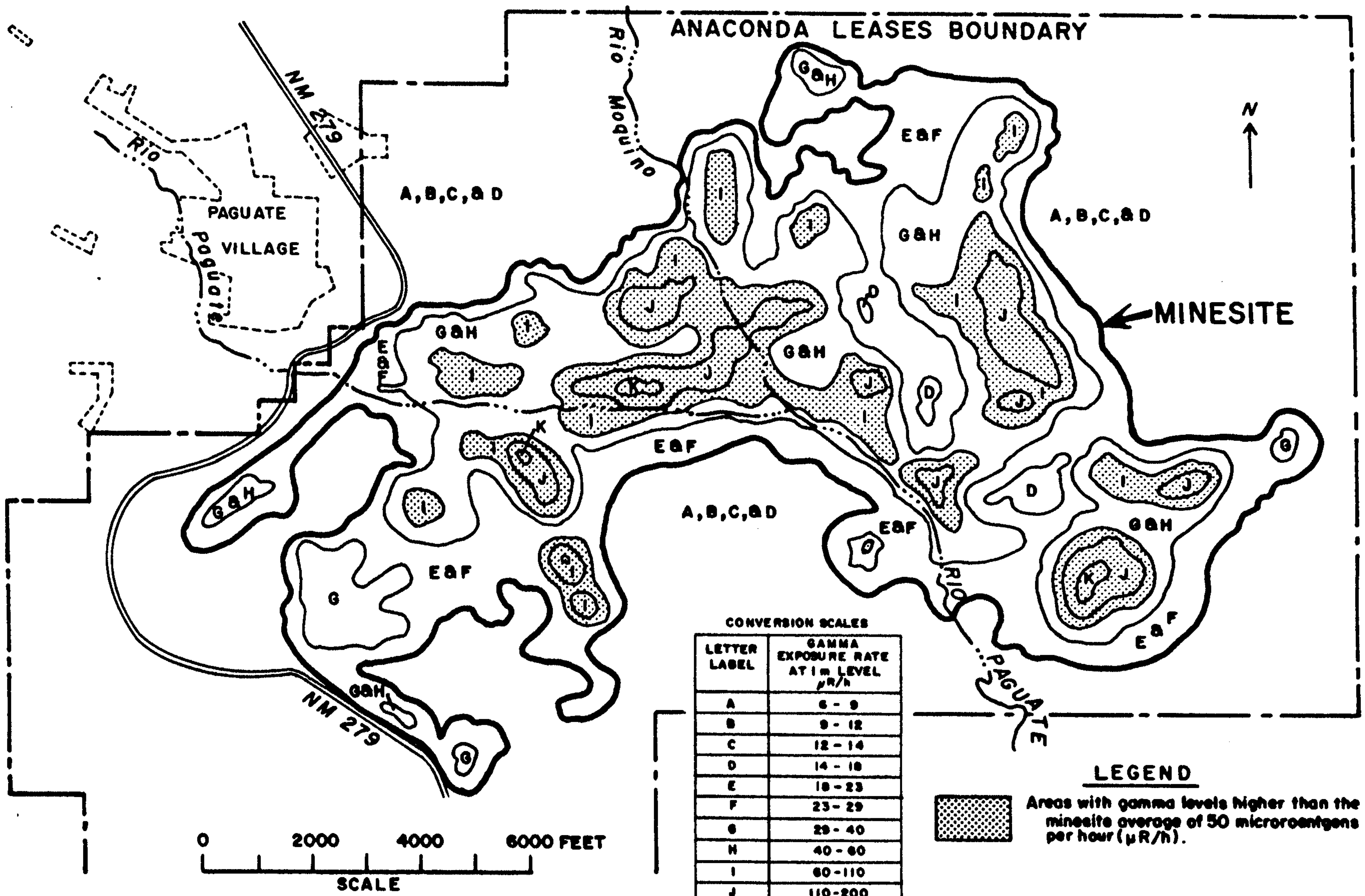


FIGURE 2-11 V DUMP SHOWING ACTIVE EROSION



MAP 2-1 Aerial Gamma Survey of the Minesite and Surrounding Area



CONVERSION SCALES

LETTER LABEL	GAMMA EXPOSURE RATE AT 1 m LEVEL μR/h
A	6 - 9
B	9 - 12
C	12 - 14
D	14 - 18
E	18 - 23
F	23 - 29
G	29 - 40
H	40 - 60
I	60 - 110
J	110 - 200
K	200 - 460

Source: Jobst 1982.

MAP 2-2 Aerial Gamma Survey of the Minesite

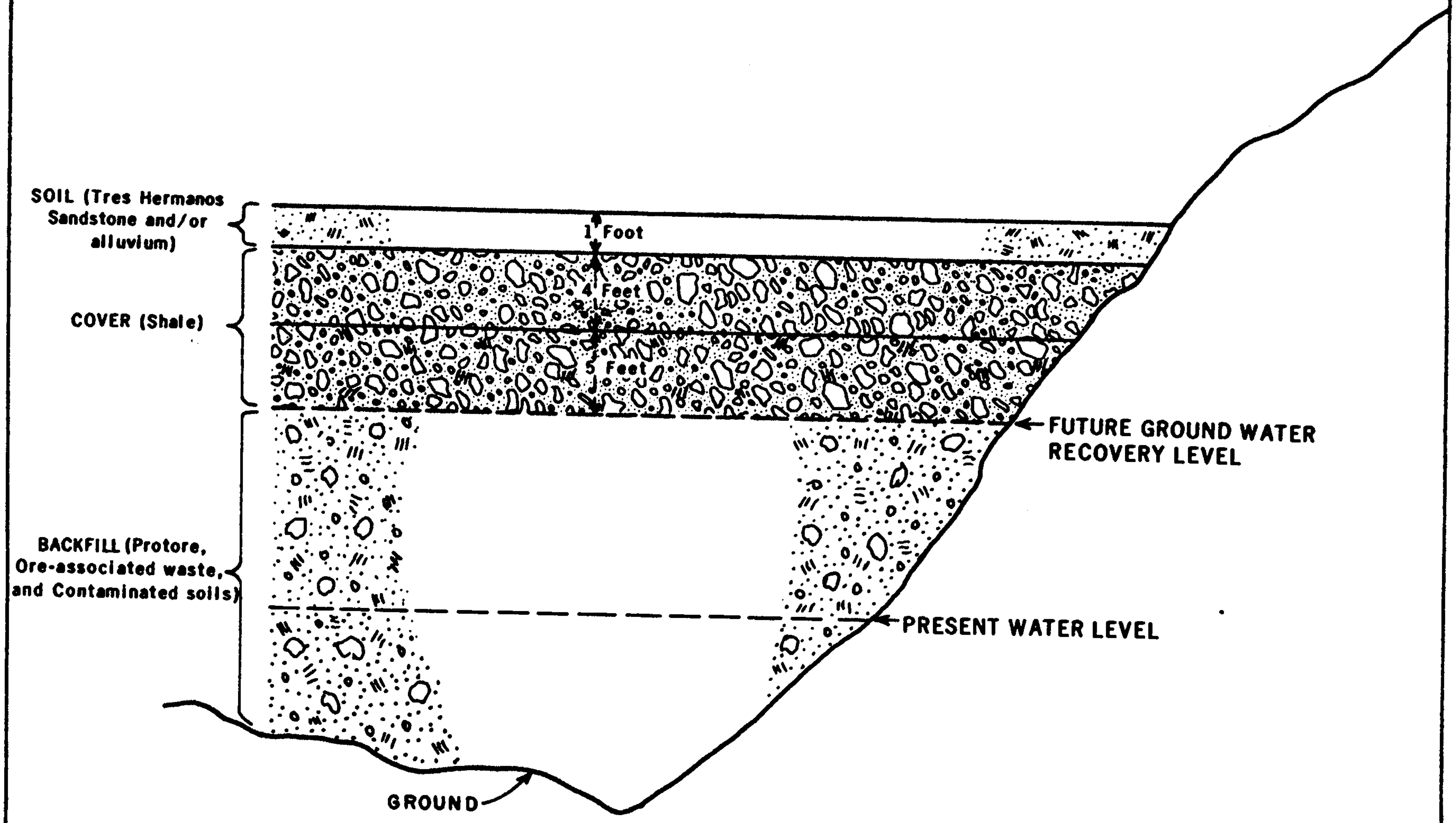
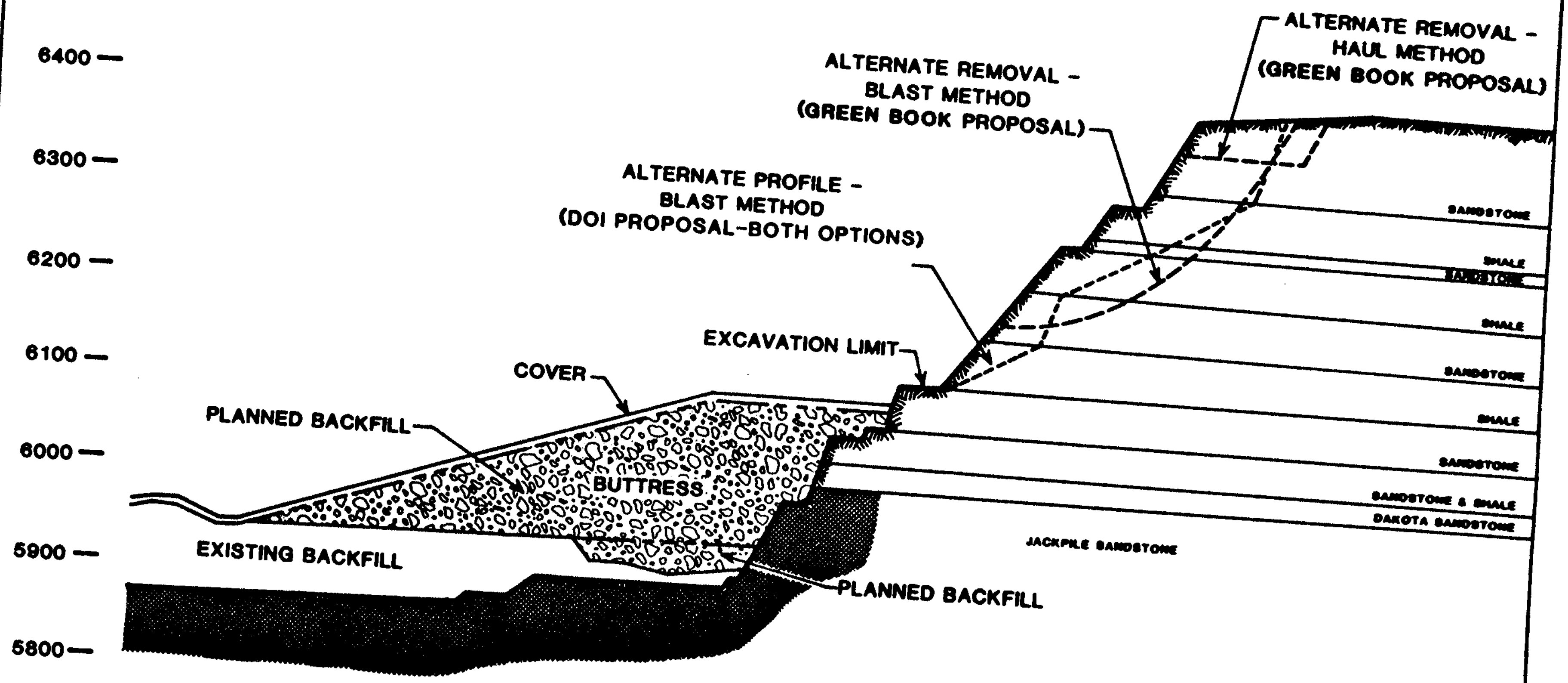


FIGURE A-4
Cross-sectional schematic diagram of pit backfill level – Laguna Proposal.



NOTES:
1. ALL DIMENSIONS APPROXIMATE
2. COVER; 1 FOOT TOPSOIL
4 FEET OVERBURDEN MATERIAL
3. GEOLOGIC SECTION IS APPROXIMATE

0 100 200 300 400 FEET
SCALE

FIGURE A-6
Gavilan Mesa Highwall Cross-Section - Alternate Methods of Stabilization

RADIATION

Introduction

The following information is excerpted from Appendix C of the report, Radiological Guidelines for Application to DOE's Formerly Utilized Sites Remedial Action Program (U.S. Department of Energy 1983). A copy of this document is on file at the BLM Albuquerque District Office, Rio Puerco Resource Area.

Radiation is the transmission of energy through space. Many kinds of radiation exist--including visible light, microwaves, radio and radar waves, and X-rays. All of these are electromagnetic radiations because they consist of a combined electrical and magnetic impulse traveling through space. Although much of this radiation (e.g., light) is vital to us, it can also be harmful; prolonged exposure to ultraviolet radiation from the sun can cause sunburn or even skin cancer.

Energy can also be transmitted through space by the motion of particulate radiations. These are either one of the fundamental particles of atoms (protons, neutrons, and electrons) or are a simple combination of the three fundamental particles.

The class of radiation of concern in evaluating the health risks of the material at the Jackpile-Paguate minesite is "ionizing" radiation. Ionizing radiation consists of either waves or particles with sufficient energy to knock electrons out of the atoms or molecules in matter. This disruption is termed "ionization."

The simplest example is the ionization of a single atom. The "nucleus," or center of the atom, is composed of particles called "protons" and "neutrons," the proton having a positive charge and the neutron having no charge. Negatively charged particles called "electrons" orbit the nucleus and are held in place by the attraction between the positive and negative charges. A neutral atom contains exactly the same number of electrons as protons, balancing the positive and negative charges.

When ionizing radiation knocks out an electron from an atom, the atom is left with a positive charge while the free electron is negatively charged. These parts of the atom are chemically active and react with neighboring atoms or molecules. The resulting chemical reactions are responsible for causing changes or damage to matter, including living tissue.

Types of Ionizing Radiation

The most common ionizing radiations of interest in this EIS are gamma rays, alpha particles and beta particles. The relative ionizing power of alpha to beta to gamma radiation is 100,000:100:1.

Gamma Rays

Gamma rays, like X-rays, are pure energy having no mass. They are part of the electromagnetic spectrum, as are light and microwaves, but have much shorter wavelengths and, therefore, have the ability to transmit larger amounts of energy than light and microwaves. Gamma rays are identical to X-rays, except that gamma rays originate in the nucleus of an atom whereas X-rays are produced by disruption and relocation of electrons. An X-ray or gamma ray, having no electrical charge to attract or repel it from protons or electrons, can pass through the free space in many atoms and, hence, through relatively thick materials before interacting. High-energy gamma rays can travel for about 500 yards in air.

Alpha Particles

Alpha particles are made up of two neutrons and two protons, a combination the same as the nucleus of a helium atom. Because of the presence of two protons with no counter-balancing negative electrons, the alpha particle is positively charged. Alpha particles transmit energy as kinetic energy, or the energy of motion, and travel 1 1/2 to 3 inches in air.

Because of the comparatively large size and the positive charge of an alpha particle, it interacts readily with electrons and does not easily pass through the spaces between atoms. It causes many ionizations in a short distance of travel. Because each of these ionizations dissipates energy, the alpha particle travels a very short distance. For example, most alpha particles will not pass through a piece of paper or the outer protective layer of a person's skin. However, if an alpha particle is produced by radioactive material inhaled or ingested into the body, it may cause many ionizations in more sensitive tissue.

Beta Particles

Beta particles are electrons moving at high speeds, some approaching the speed of light. They transmit energy as kinetic energy, and can travel up to 15 feet in air. Having comparatively small mass and a negative charge, their penetration through matter is intermediate between the alpha particle and the gamma ray.

Beta particles produce fewer ionizations along their path than do alpha particles. They can be absorbed by a sheet of rigid plastic or a piece of plywood. However, they can pass through the protective outer layer of the skin and reach the more sensitive skin cells in inner layers. If produced by radioactive materials inside the body, beta particles can damage internal tissue.

Radioactive Elements and Their Half-Lives

An atom is the smallest unit of an element; elements are the basic building blocks of all materials in nature. Over 100 known elements exist. In addition, elements may have several isotopes (atoms with the same number of protons but a different number of neutrons). Isotopes of an element react the same chemically.

Most atoms of the element carbon in a tree or in our bodies will remain atoms of carbon. In time, a carbon atom may change its association with other atoms in chemical reactions and become part of other compounds, but it will still be a carbon atom.

However, some isotopes are unstable. Unstable atoms spontaneously emit radiation and change to atoms of another element. These atoms are said to be "radioactive"; they exhibit the property of "radioactivity" (the spontaneous emission of radiation). Unstable isotopes of an element are referred to as "radioactive isotopes" or "radionuclides".

Radioactive atoms emit radiation (decay) at a characteristic rate dependent upon the degree of stability of the individual atom. The decay rate is characterized by a period of time called the "half-life." In one half-life, half the initial number of atoms decay, and the amount of radiation emitted also decreases by one-half. In the next half-life, the number of atoms and the amount of radiation will again decrease by one-half, thereby decreasing to one-quarter of the original amount. Half-lives are unique for each particular type of radioactive atom--that is, each isotope has its own half-life that cannot be changed. Half-lives for different radioactive materials range from a fraction of a second to billions of years. (In fact, some half-lives are so long that certain radioactive materials made at the time of the formation of the universe still exist. Examples include some isotopes of thorium and uranium.)

When an atom decays, radiation may be emitted from the nucleus as alpha particles, beta particles, neutrons or gamma rays. This changes the character of the nucleus, and the atom changes to an atom of a new element. Each type of radioactive atom decays with emission of characteristic types of radiation, each carrying away energy.

Atoms resulting from radioactive decay are called "decay products" or "progeny," whereas the original atom is called the "parent" atom. In some cases, the progeny resulting from the decay of a radioactive atom are also radioactive. For naturally occurring uranium and thorium, a sequence of as many as 12 to 14 radioactive decay products occur before the original uranium or thorium atom finally reaches stability as an atom of lead.

The half-lives of some of the radioactive materials in the uranium-238 chain that are important in this EIS, and the principal types of radiation emitted during decay, are shown in Figure B-1.

Units of Measure for Radioactivity and Radiation

The basic unit for measuring the amount of radioactivity or quantity of radioactive material is the "curie," named in honor of Madame Curie. The curie (Ci) is the amount of radioactive material in which 37 billion atoms are decaying each second; this is the approximate number of atoms decaying each second in one gram of radium-226, the element discovered by Madame Curie. The amount of material that releases one curie of radiation varies from one isotope to another, because of the differences

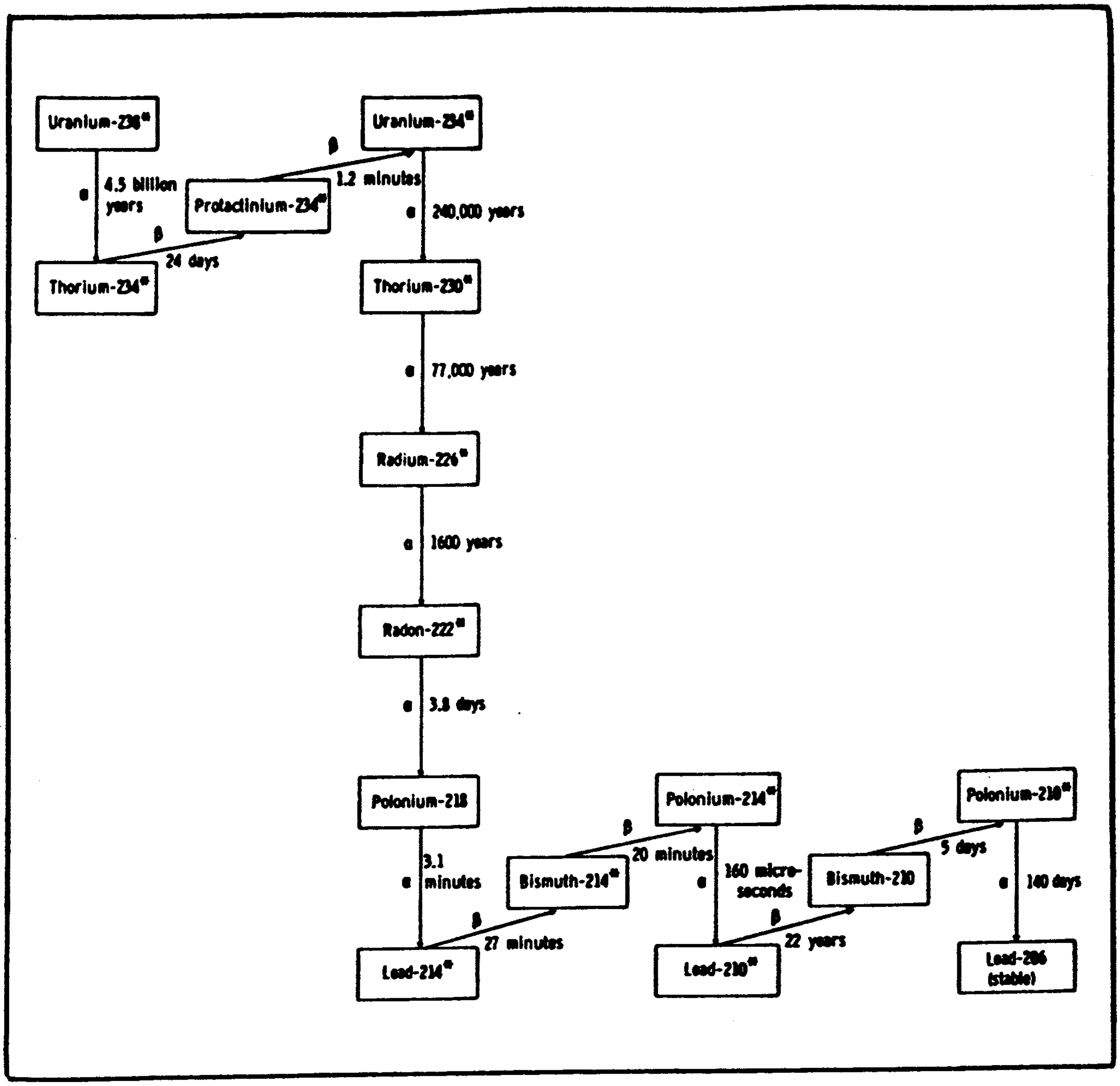


FIGURE B-1

Uranium-238 Decay Series

Source: Argonne National Laboratory (1982).

Note: Only the dominant decay mode is shown, and the times shown are half-lives. The symbols α and β indicate alpha and beta decay; an asterisk (*) indicates that the isotope is a gamma emitter.

in half-lives and atomic weights among the various radioactive isotopes. For materials with short half-lives, more of the atoms present are decaying in any given second, and the weight of the material releasing one curie is smaller than a gram of radium-226. For radioactive material with a long half-life, the weight of the material releasing one curie will be larger. For example, the amount of naturally occurring potassium-40 releasing one curie of radiation weighs about 310 pounds, or about 140,000 times as much as the amount of radium releasing one curie.

The curie is a relatively large quantity of radioactivity for purposes of this EIS. The units used most often in this EIS are listed in Table B-1.

TABLE B-1

UNITS OF RADIOACTIVITY

Unit	Abbreviation	Disintegrations per Second	Equivalent Value in Other Time Units
Curie	Ci	37,000,000,000	---
Millicure	mCi	37,000,000	---
Microcurie	μCi	37,000	---
Picocurie	pCi	0.037	2.22 disintegrations per minute

In this EIS, radioactivity in environmental media such as air or soil is often discussed. In these cases, radioactivity is reported as a concentration, or the amount of radioactivity in or associated with a certain amount of air or soil. Much of the data on radioactivity in soils is reported in picocuries of some particular radioactive isotope per gram of soil (pCi/g). For example, a value of 2 pCi/g means each gram of soil has an associated radioactivity of about 4.4 disintegrations each minute. Concentrations of radioactivity in air are often reported as picocuries per cubic meter (pCi/m^3). This means that a certain number of picocuries of a radioactive isotope is dispersed throughout the volume of air equivalent to a cube that is 1 meter on each side (1 meter = 1.09 yards).

The basic unit for measuring radiation dose is the "rad" (acronym for radiation absorbed dose). It is the amount of radiation that deposits a specified amount of energy by ionization in each gram of material. The amount of energy released in the material is small--it increases the temperature of the gram of material by only a few billionths of a degree. However, it is not the amount of heat liberated or the temperature rise that is important; rather, it is the ionization that induces chemical changes. The rad is used to measure the dose from all types of radiation in all types of material that absorbs the radiation.

As discussed previously, different types of radiation produce ionizations at different rates as they pass through tissue. The alpha particle travels only a short distance, causing intense, closely spaced ionization along its path. The beta particle travels much farther, causing much less ionization in each portion of its path. Therefore, the alpha particle is more damaging to internal tissue than the beta particle for the same number of ionizations because the damage to cells in the tissue is more localized.

Besides the rad, the other commonly used radiation dose unit is the "rem" (acronym for roentgen equivalent in man). The rem quantifies the relative biological response to radiation rather than the amount of energy delivered to the tissue.

The biological damage done by an alpha particle is greater than that by a beta particle for the same total amount (rads) of energy deposited, and this difference is accounted for by the use of "quality factors" (1 for X- or gamma radiations and most beta particles, and 10 to 20 for alpha particles). Thus, 1 rad of energy from gamma rays would result in 1 rem of dose, while 1 rad from alpha particles would result in 10 to 20 rems of dose.

Because the relative degree of damage from each type of radiation is known, the rem can be used to estimate the approximate biological effect. The rem permits evaluation of potential effects without regard to the type of radiation or its source. One rem of exposure from natural cosmic radiation results in the same biological consequences as 1 rem of medical X-rays or 1 rem delivered by radiation produced by either natural or man-made radioactive decay.

A frequent error in the use of radiation units is their application to a standard weight of tissue rather than all of the tissue irradiated. A person can receive one rad or one rem of radiation from any of the following: (1) an X-ray of the teeth, where little tissue is irradiated; (2) a chest X-ray, where a moderate amount of tissue is irradiated; or (3) whole-body radiation, where all tissue in the body is irradiated. Although all these sources give 1 rem of radiation, the effects are different depending upon the organs involved. Thus, one must always keep in mind the portion of the body or organs involved and make comparisons only for corresponding exposures. For example, whole-body doses must be compared only to other whole-body doses or to whole-body dose standards.

In some cases, radiation measurements are expressed as a "dose rate," or the amount of radiation received in a unit of time. For example, some instrument measurements of background are reported in "microrem(s) per hour" (μrem/h). To calculate total dose, the rate is multiplied by the time of exposure. This is conceptually similar to multiplying speed (rate of travel--e.g., in miles per hour) by time to get total distance travelled. Dose may be expressed using rads or rems, depending on whether the emphasis is on the energy deposited or the biological effect.

Because many of the radiation doses discussed in this EIS are small, the metric prefixes "milli" for one-thousandth (1/1000 or 0.001, symbolized as "m") or "micro" for one-millionth (1/1,000,000, or 0.000001, symbolized as ("µ") are often used; 1,000,000 microrem (µrem) = 1,000 millirem (mrem) = 1 rem.

What Is Known About the Health Effects of Radiation

If molecules vital to the function of a cell are ionized by radiation, the cell may be destroyed; if enough cells are destroyed, an organ may be damaged. However, organ damage is usually associated with large doses and is generally referred to as a "short-term" effect of radiation.

People who receive high radiation doses also increase their risk of developing cancer and producing genetic damage to their progeny; these are "long-term" effects. The risk is proportional to the dose. How low-level exposure to radiation results in cancer is not fully understood, and the relationship between the amount of exposure and the probability that cancer will develop cannot be accurately predicted.

Radiation levels around uranium minesites are not generally considered to be high enough to cause short-term effects. They may, however, be sufficient to raise the risks of long-term effects, depending on conditions and length of exposure.

In spite of the uncertainties in the risk estimates, more is known about radiation and its health effects than is known about certain chemical hazards. Radiation has been studied extensively since the 1920's. Also, it is possible to detect the various types of radiation easily, making it possible to avoid areas of potential risk.

An important distinction exists between external and internal radiation sources and their impacts. When external radiation interacts with a person's body, it is quickly dissipated as ionization and eventually heat. However, radioactive materials can enter a person's body and remain there for some period of time, emitting radiation. Thus it is incorrect to say that "radiation is in a person's body." It is correct to say that the person has radioactive materials in his/her body and that radiation is emitted from these radioactive materials.

Background Radiation

"Background" is the term used to represent the natural levels of radiation (radioactivity) that are typical for an area. Naturally occurring radioactive elements are present in air, water and soil.

Background radiation results from cosmic and terrestrial sources. Cosmic radiation originates in the cosmos and enters the earth's atmosphere, while terrestrial radiation originates from the naturally occurring radionuclides in the soil. The level of background radiation in any particular area depends on such factors as altitude, local geology and meteorological conditions.

Radioactivity in the human body originates from the intake of naturally occurring radioactive elements in the food and water consumed, and in the air inhaled by each person. Human exposure to background radiation depends on personal lifestyle, diet and type of residence.

The annual background radiation dose rate in the area around the minesite as compared to U.S. averages is indicated in Table B-2. The local rates are higher than U.S. averages because the minesite is at a fairly high elevation (6,000 feet above mean sea level) and because of the elevated concentration of uranium throughout the Grants mineral belt.

TABLE B-2

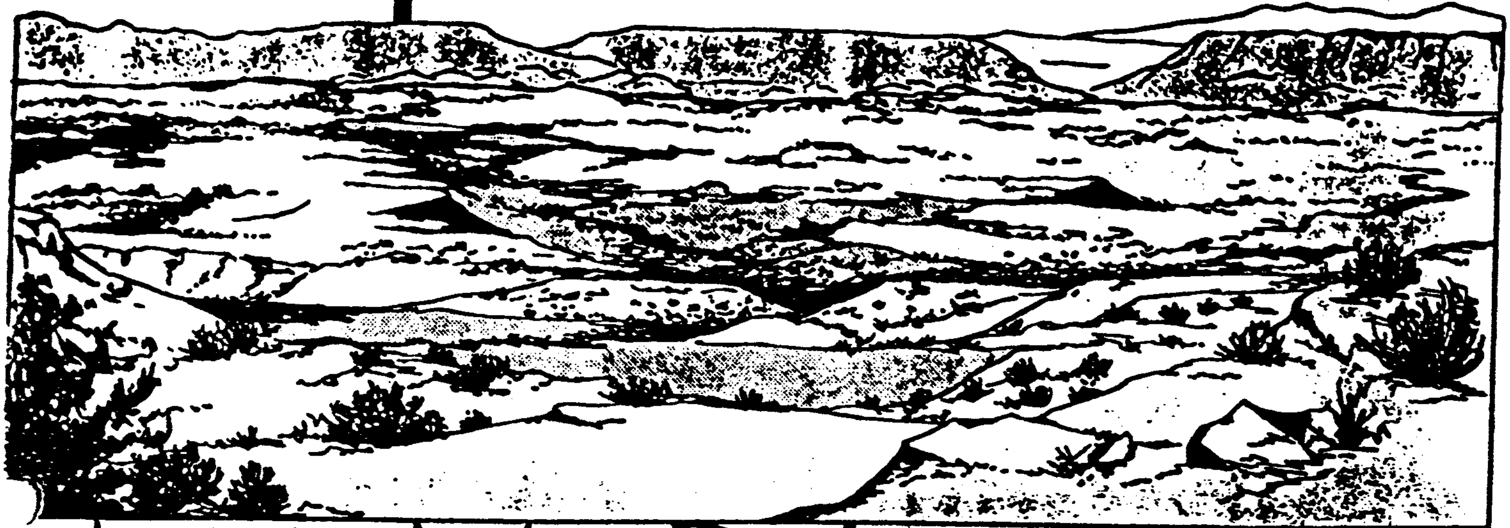
ESTIMATED AVERAGE ANNUAL BACKGROUND WHOLE-BODY DOSE RATES (1970)
(millirems per year)

Source	U.S. Average Dose Rate	Colorado	Jackpile-Paguate Minesite
Environmental			
1. Natural			
Cosmic Radiation	44	90	70
Terrestrial Sources a/	40	46	90
Internal Sources b/	18	18	18
Subtotals	102	154	178
2. Global Fallout	4	4	4
3. Nuclear Power	0.003	0.003	0.003
Medical	73	73	73
Occupational	0.8	0.8	0.8
Miscellaneous	2	2	2
TOTALS (rounded)	182	234	258

Sources: Iowa Energy Policy Council 1975 (for U.S. average and Colorado figures); Momeni, et al. 1983 (for minesite).

Notes: a/Crustal and building materials.
b/Principally potassium-40.

JACKPILE-PAGUATE



Uranium Mine Reclamation Project

RECORD OF DECISION

DECEMBER 1986

US DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT
ALBUQUERQUE DISTRICT OFFICE

BUREAU OF INDIAN AFFAIRS
ALBUQUERQUE AREA OFFICE

This document records the decisions reached by the Bureau of Land Management (BLM), New Mexico State Office and the Bureau of Indian Affairs (BIA), Albuquerque Area Office for the level of reclamation required for the Jackpile-Paguate Uranium Mine.

SUMMARY

Alternatives for reclaiming the Jackpile-Paguate Uranium Mine are analyzed in a Final Environmental Impact Statement prepared by the BLM and BIA and filed with the U.S. Environmental Protection Agency (EPA) on October 31, 1986.

The Final Environmental Impact Statement presents six alternatives for reclamation of the Jackpile-Paguate Uranium Mine. The alternatives are:
1) No Action; 2) Green Book Proposal; 3) Department of the Interior (DOI) Proposal (two options); 4) Laguna Proposal; 5) Anaconda's 1985 Reclamation Plan; and 6) Preferred Alternative.

ALTERNATIVES CONSIDERED

The reclamation alternatives were originally analyzed in a Draft Environmental Impact Statement prepared by the BLM and BIA and filed with the EPA on March 5, 1985. The alternatives consisted of No Action, Anaconda's 1982 Proposal (called the Green Book), the Laguna Proposal, and the DOI Proposal (with two options for dealing with groundwater recovery levels and associated impacts). The Final Environmental Impact Statement modified the alternatives in response to public comments received on the draft. These modifications include the addition of a new plan submitted by Anaconda in 1985 and modification of the Laguna Proposal. The following is a brief summary of the reclamation alternatives analyzed in the Final Environmental Impact Statement. A more complete description of these proposals is given in Tables 1-3, 1-4, and 1-5 of the document.

DESCRIPTION OF ALTERNATIVES

No Action Alternative

The No Action Alternative would mean that no reclamation work would be performed. The area would be secured to prevent unauthorized entry and an environmental monitoring program would be implemented. Additional requests by the Pueblo of Laguna to utilize certain facilities for storage could be accommodated, provided such use would be temporary and deemed safe.

This alternative is not feasible because it does not provide a reasonable measure of protection to public health and safety, and does not reduce environmental impacts to the extent possible. This alternative is included and analyzed only to provide a benchmark that would allow decisionmakers to compare the magnitude of environmental effects for a given range of alternatives.

Green Book Proposal

The Green Book Proposal was originally developed by Anaconda Minerals Company in 1982 but was subsequently replaced by Anaconda's 1985 Multiple Land Use Reclamation Plan on August 19, 1985. The Green Book was carried forward in the Final Environmental Impact Statement for continuity of impact analysis and consistency with the Draft Environmental Impact Statement, but it is no longer endorsed by Anaconda. Under this alternative, the open pits would be backfilled to at least three feet above groundwater recovery levels projected by Dames and Moore, 1983. All highwalls would be scaled to remove loose material. The rim of Gavilan Mesa would be cut back by mechanical means or blasting and the base of the highwall would be buttressed with waste and overburden. Waste dump slopes would be reduced to between 2:1 and 3:1 (horizontal to vertical); most slopes would be terraced. Jackpile Sandstone exposed by resloping would be covered with four feet of overburden and one foot of topsoil. All protore and waste material lying within 200 feet of the Rios Paguate and Moquino would be removed. Facilities would either be removed or cleaned up and left intact. All disturbed areas (pit bottoms, waste dumps, old roads, etc.) would be topsoiled and seeded. Reclamation would be considered complete when the weighted average for basal cover and production on revegetated sites equals or exceeds 70 percent of that found on comparable reference sites. The post-reclamation monitoring period would be a minimum of three years.

<u>DOI Proposal (Monitor Option and Drainage Option)</u>

This alternative was developed by the BLM and BIA. It is based on a series of technical reports, contracted studies and file data. Although similiar to the Green Book Proposal in overall concept, it varies in important details. Because of concerns over the environmental impacts of either ponded water or salt build-up in the open pits, DOI identified two options for treatment of the pit bottoms: 1) a Monitor Option which would backfill the pits with protore, excess material from waste dump resloping and soil cover. Due to the excess material (approximately 19 million cubic yards) generated in this proposal, the estimated backfill elevations of the pit floors could be 40 to 70 feet higher than the Green Book proposed minimum. The pits would remain as closed basins, in which case the potential build-up of salt and saline water in the soils of the pit bottoms would be monitored. If soil problems were observed, additional backfill and revegetation would be required. The monitoring period would be of sufficient duration to determine the stable future water table conditions; and 2) a Drainage Option which would restore the natural mode of overland runoff from the pit areas. Backfill volumes and elevations would be approximately the same as for the Monitor Option, but none of the pits would be left as closed basins. Open channels would be constructed with a gradient equal to or flatter than local natural watercourses to convey runoff from the pit areas to the Rio Paguate. This would avoid ponded water or undrained saline soils on the reclaimed minesite.

For both options, other aspects of reclamation would be the same. Highwall stability techniques would essentially be the same as the Green Book Proposal. With few exceptions, waste dump slopes would be reduced to 3:1, with no terracing. Treatment of Jackpile Sandstone and minesite facilities would be the same as the Green Book Proposal. All protore and waste material lying within 200 feet of the Rios Paguate and Moquino would be removed. In addition, a permanent base or bridge would be constructed on the Rio Moquino. All disturbed areas would be topsoiled and seeded. Reclamation would be considered complete when revegetated sites reach 90 percent of the density, frequency, foliar cover, basal cover and production of undisturbed reference areas. The post-reclamation monitoring period would vary for each parameter.

<u>Laguna Proposal</u>

This alternative was developed by the Pueblo of Laguna in consultation with their technical consultants. In May 1986, the Pueblo provided the DOI with details and/or changes to the Laguna Proposal which are reflected in the Final Environmental Impact Statement.

Under this proposal, all pits would be backfilled 10 feet above groundwater recovery levels projected by Dames and Moore, 1983. In general, the top 15 feet of each highwall would be cut to a 45 degree angle. With few exceptions, waste dump slopes would be reduced to 3:1. All contaminated material within 100 feet of the Rio Paguate would be removed. Waste dumps would be moved 50 feet back from the Rio Moquino and the toes of the dumps would be armored with riprap. Minesite facilities would be handled essentially the same as under the DOI's Proposal except that the rail spur would remain intact. Top-soiling, seeding techniques and other reclamation measures would be the same as DOI's Proposal. The post-reclamation monitoring period would vary from 3 to 20 years.

Anaconda Proposal (1985 Multiple Land Use Reclamation Plan)

Under this alternative the Jackpile and South Paguate open pits would be backfilled to an extent that would prevent chronic free-water ponding with groundwater levels controlled in the backfill by phreatophytic vegetation. The North Paguate open pit would be made into a water storage reservoir by diverting the Rio Paguate through the pit. The Jackpile and North Paguate pit highwalls would be scaled or trimmed back a distance of 10 feet at a 3:1 slope. No additional modification of the South Paguate pit highwall is proposed. Waste dump slope modifications and topdressing requirements would vary. All Jackpile Sandstone and waste material would be moved back 50 feet from the Rios Paguate and Moquino. All buildings and other surface structures would be left intact where it is safe to do so. Revegetation success would be based on a comparison of the entire revegetated area relative to an analogous reference area on a weighted average basis. Revegetated areas would be sampled for the third year after the last seeding or reseeding effort by or for Anaconda and year-to-year thereafter until the success criteria is met.

Preferred Alternative

This alternative was evaluated in the Final Environmental Impact Statement and was developed from revisions to the Draft Environmental Impact Statement, review of public comments, and technical discussions with specialists within the BLM and BIA. The Preferred Alternative presents a combination of reclamation procedures which best meets the Decision Factors on which this Record of Decision is based.

Under this alternative, pits would remain as closed basins. They would be backfilled to at least 10 feet above the Dames and Moore (1983) projected groundwater recovery levels. In general, the top 15 feet of each highwall would be cut to a 45 degree angle. All soil at the top of the highwall would be sloped 3:1. With few exceptions, waste dump slopes would be reduced to 3:1. There are two options for stream stabilization: Option A - remove all material within 200 feet of the Rios Paguate and Moquino and construct a concrete drop structure across the Rio Moquino, and Option B: remove all contaminated material within 100 feet of the Rio Paguate and remove all waste dumps within 50 feet of the Rio Moquino and armor the toes of the dumps along the Rio Moquino with riprap. Facilities would either be removed or cleaned up and left intact. All disturbed areas (pit bottoms, waste dumps, old roads, etc.) would be topsoiled and seeded. Reclamation would be considered complete when revegetated sites reach 90 percent of the density, frequency, foliar cover, basal cover and production of undisturbed reference areas. The post-reclamation monitoring period would vary for each parameter.

DECISION FACTORS

The following reclamation objectives were developed to assist in determining the most appropriate level of reclamation for the Jackpile-Paguate Uranium Mine. These criteria, in order of importance, are as follows:

1. Ensure human health and safety.
2. Reduce the releases of radioactive elements and radionuclei to as low as reasonably achievable.
3. Ensure the integrity of all existing cultural, religious and archeological sites.
4. Return the vegetative cover to a productive condition comparable to the surrounding area.
5. Provide for additional land uses that are compatible with other reclamation objectives and that are desired by the Pueblo of Laguna.
6. Eliminate the need for post-reclamation maintenance.
7. Blend the visual characteristics of the minesite with the surrounding terrain.
8. Employ the Laguna people in efforts that afford them opportunities to utilize their skills or train them as appropriate.

DECISION

Based on the above decision factors, public comments, and analysis contained in the Final EIS, it is the decision of the Bureau of Land Management and the Bureau of Indian Affairs that the level of reclamation to be performed at the Jackpile-Paguate Uranium Mine will consist of the following measures. As shown by the analysis presented in the Final Environmental Impact Statement, these measures would best stabilize and restore the minesite to productive use and ensure that adverse environmental impacts are reduced to the extent possible. This alternative is also the environmentally preferred alternative.

The scope of this Record of Decision is to determine the level of reclamation to be performed. The party or parties responsible for performing reclamation will continue to be determined by the conditions specified in the leases. Options as to how reclamation will be financed are not included in this Record of Decision. However, at a minimum, the level of reclamation must adhere to the measures listed below. The following measures are approved as the level of reclamation required:

1. Pit Bottoms

A. Backfill Levels

Pits will remain as closed basins. Pit bottoms will be backfilled to at least 10 feet above the Dames and Moore (1983) projected ground water recovery levels as indicated below. A schematic diagram is shown in the FEIS, Appendix A (Figure A-1, DOI Proposal).

Pit	Proposed Minimum Backfill Levels
Jackpile	5939'
North Paguate	5958'
South Paguate	5995'
South Paguate (SP-20)	6060'

A groundwater recovery level monitoring program will be implemented. Additional backfill will be added as necessary to control ponded water. The duration of the monitoring program will be a minimum of 10 years.

B. Backfill Materials

Backfill materials will consist of protore, waste dumps H and J, and excess material obtained from waste dump resloping and stream channel clearing. These materials will be covered with 3 feet of overburden and 2 feet of topsoil (i.e., Tres Hermanos Sandstone or alluvial material).

C. Stabilization

All backfill slopes will be reduced to no greater than 3:1 (horizontal to vertical) Surface water control berms will be constructed within pit bottoms to reduce erosion and retain soil moisture for plant growth. Surface runoff will also be directed to small retention basins in the pit bottoms. All areas in the pits will then undergo surface shaping, topsoil application and seeding as outlined under "Revegetation Methods" below.

D. Post-Reclamation Access

Human and animal access to pit bottoms will be prevented. Livestock grazing will be prevented with the use of sheep-proof fencing due to the uncertainties of predicting radionuclide and heavy metal uptake into plants (forage).

2. Pit Highwalls

A. Jackpile Pit Highwall

The top 15' of highwall will be cut to a 45 degree slope. All soil and unconsolidated material at the top of the highwall will be sloped 3:1. The highwall will be scaled to remove loose debris. A schematic diagram is shown in the FEIS, Appendix A (Figure A-7).

B. North Paguate Pit Highwall

The top 15' of highwall will be cut to a 45 degree slope. All soil and unconsolidated material at the top of the highwall will be sloped 3:1. The highwall will be scaled to remove loose debris. A schematic diagram is shown in the FEIS, Appendix A (Figure A-7). Additionally, the highwall will be fenced with 6-foot chain link.

C. South Paguate Pit Highwall

The top 15' of highwall will be cut to a 45 degree slope. All soil and unconsolidated material at the top of the highwall will be sloped 3:1. The highwall will be scaled to remove loose debris. A schematic diagram is shown in the FEIS, Appendix A (Figure A-7). Additionally, the highwall will be fenced with 6-foot chain link.

3. Waste Dumps

Waste dumps H and J will be relocated to Jackpile pit as backfill. Most dump slopes will be reduced to 3:1 or less and the dump slopes will be contour furrowed; exceptions are noted in Table 1-4 of the FEIS. Dumps which have Jackpile Sandstone on their outer surface and any Jackpile Sandstone exposed during resloping will be covered with 3 feet of overburden and 18 inches of topsoil. Dumps that do not contain Jackpile Sandstone on their outer surface will be covered with 18 inches of topsoil. Berms will be installed on all dump crests to control erosion. All dump tops will slope slightly away from their outer slopes. Dump slopes will be contoured so their toes are convex to prevent formation of major gullies on slopes. Additional surface treatment is outlined under "Revegetative Methods" below. Detailed modifications and treatments are presented in Table 1-4 of the FEIS. A schematic diagram is shown in the FEIS, Appendix A (Figure A-9).

4. Protore Stockpiles

All protore will be used as backfill material in pit areas. Backfill will be covered with 3 feet of overburden and 2 feet of Tres Hermanos Sandstone or alluvial material.

5. Site Stability and Drainage

A. Stream Stability

All contaminated soils and fill material within 100 feet of the Rio Paguate west of its confluence with the Rio Moquino will be excavated and relocated to the open pits. For the Rio Moquino, waste dumps S, T, U, N and N2 will be pulled back 50 feet from the centerline of the stream channel. The toes of these dumps will be armored with riprap. A concrete drop structure will be constructed across the Rio Moquino approximately 400 feet above the confluence with the Rio Paguate.

B. Arroyo Headcutting

Arroyos south of waste dumps I, Y and Y2, and the arroyo west of waste dumps FD-1 and FD-3 will be armored as shown in the FEIS, Appendix A (Figure A-13).. Other headcuts encountered during reclamation will also be stabilized by armoring.

C. Blocked Drainages

Waste dump J and protore stockpiles SP-17BC and SP-6-B will be removed to unblock ephemeral drainage on south side of minesite. Two blocked drainages north of FD-1 and F dumps will remain blocked. Remainder of minesite, excluding open pits, will drain to Rios Paguate and Moquino.

6. Surface Facilities/Structures

A. Lease No. 1 (Jackpile Lease)

All buildings on Lease No. 1 will be demolished and removed except for the Geology building, miner training center and buildings at Old Shop and the Open Pit offices. The land surface (except pit highwalls and natural outcrops) will be cleared of radiological material (e.g., Jackpile Sandstone) until gamma readings of twice background or less are achieved. These areas will then be graded and seeded.

B. Lease No. 4

All structures and facilities associated with P-10 Mine and New Shop, including all buildings, roads, parking lots, sewage systems, power lines and poles will be left. All operational and maintenance equipment, including tools, machinery, supplies will be removed. All permanent structures and land surfaces (except pit highwalls and natural outcrops) will be cleared of radiological material until gamma readings of twice background or less are achieved. These areas will then be graded and seeded. Nonsalvageable contaminated buildings and materials will be removed to the pits for disposal.

C. Access Routes

The four major roads within minesite will be cleared of radiological material and left after reclamation for post-mining use. These access routes include: 1) access road from P-10 and New Shop to State Highway 279; 2) main road through mine; 3) road that passes between housing area and North Oak Canyon Mesa and then proceeds to P-10; and 4) road to Jackpile Well No. 4. All other roads (except on Lease No. #4) will be removed. These areas will then be graded and seeded.

D. Water Wells

Jackpile Well No. 4, P-10 Well, New Shop Well and Old Shop Well, and 3 wells and their associated sheltering structures (near housing area) will be left. The pumps, riser pipe, wiring and water storage tanks will be removed. Wells established for future monitoring purposes will also be left. All wells will be capped to prevent dust, soil and other contaminants from entering the well casing.

E. Rail Spur

The rail spur will be left intact and cleared of radiological material until gamma readings of twice background or less are achieved. Quirk loading dock will be demolished and hauled to the pits.

7. Drill Holes

All drill holes will be plugged according to the State Engineer's requirements. A 5-foot surface concrete plug will also be placed in each hole. Any cased holes will have the casing cut off at the surface. In addition, areas around drill holes will be seeded. Any exploration roads not wanted by the Pueblo will be reclaimed.

8. Underground Modifications

A. Ventilation Holes

Vent holes will be backfilled with waste material (Dakota Sandstone and Mancos Shale) to within 6 feet of surface. Surface casing will be removed, steel support pins installed in walls of vent holes, and sealed with a 6-foot concrete plug from backfill to surface. Areas around vent holes will be contoured and seeded.

B. Adits and Declines

A concrete bulkhead will be constructed approximately 680 feet below portal of P-10 decline. The decline will be backfilled from bulkhead to ground surface with Dakota Sandstone and Mancos Shale.

Sufficient material will be placed over the portal to allow for compaction and settling. The ground surface above the buried portal will be sloped and then top-dressed and seeded. The Alpine mine entry will be bulkheaded and backfilled. Mine entries not previously plugged by backfilling will be covered. Additionally, the H-1 mine adits will be bulkheaded and backfilled and the adits at the P-13 and NJ-45 mines will be backfilled..

9. Revegetation Methods

A. Top Dressing

Following final sloping and grading, pit bottoms will be top dressed with 24", waste dumps with 18" and all other areas within the minesite with 12" of material composed primarily of Tres Hermanos Sandstone (stockpiled at three locations within minesite). In order to meet top dressing volume requirements for the northern portion of the minesite, additional material may be obtained from a topsoil borrow area in the Rio Moquino floodplain comprising 44 acres. For the southern portion of the minesite, additional topsoil borrow material located east of J and H dumps may be needed. Following topsoil removal, disturbed borrow areas, will be contoured, fertilized, seeded and mulched.

B. Surface Preparation

After applying top dressing, areas to be planted will be fertilized, followed by disking to a depth of 8 inches and then contour furrowing.

C. Seeding and Seed Mixtures

Before seeding operations begin, the entire minesite will be fenced to prevent livestock grazing. In most situations, seed mixtures will be planted with a rangeland drill. Broadcast seeding combined with hydromulching may be used on inaccessible sites or if determined to be more feasible than drilling. For both methods, the seed mixture will consist mainly of native plant species possessing qualities compatible with post-grazing use and adapted to local environment (Tables 3-10 and 3-11, FEIS). Following drill seeding, straw mulch will be applied at about 2 tons per acre, and crimped into place with a notched disk.

D. Revegetation Success

Using the Community Structure Analysis (CSA) or comparable method, plant establishment will be considered successful when revegetated sites reach 90 percent of the density, frequency, foliar cover, basal cover and production of undisturbed reference areas (but not sooner than 10 years following seeding). Livestock grazing will be prevented until 90 percent comparability values are met. At the end of the 10-year monitoring period, if an unsuccessful trend is shown retreatment may be necessary to achieve success criteria. In the pit bottoms, vegetation will be sampled annually for radionuclide and heavy metal uptake.

10. Monitoring

The monitoring period will vary for each parameter. Existing monitoring activities to be continued will include: meteorologic sampling, air particulate sampling, radon sampling (ambient), radon exhalation sampling, gamma survey, soil and vegetation sampling, water monitoring and subsidence. In addition, the monitoring program will be expanded to include: radon daughter levels (working levels) in any remaining mine buildings and ground water recover levels/salt build-up in the open pits. The ground water monitoring period will be of sufficient duration to determine the stable future water table conditions. Refer to Table I-5 of the FEIS for details of the monitoring plan as described under the Preferred Alternative.

11. Security

Control of minesite access and security will continue during reclamation and monitoring activities. However, security during monitoring phase will require cooperation from Pueblo of Laguna and BIA to prevent livestock grazing on revegetated sites.

12. Reclamation Completion

Reclamation will be considered complete when revegetated sites reach 90 percent of the density, frequency, foliar cover, basal cover and production of undisturbed reference areas (but not sooner than 10 years following seeding). In addition, gamma radiation levels must be no greater than twice background over the entire minesite. Outdoor radon - 222 concentrations must be no greater than 3pCi/l. Radon daughter levels (Working Levels) in any remaining surface facilities must not exceed 0.03 WL.

13. Post-Reclamation Land Uses

Limited livestock grazing, light manufacturing, office space, mining and major equipment storage will be allowed. Specifically excluded are habitation and farming.

IMPLEMENTATION

The responsible party or parties as determined by the leases will be responsible for implementing the above reclamation requirements. A Plan of Operations prepared in accordance with this decision will be submitted to the BIA and BLM for approval.

COMPLIANCE

The Department of the Interior will monitor and inspect every aspect of reclamation activities to ensure compliance with the above reclamation requirements.

Monte Jordan
Acting State Director
Bureau of Land Management

DEC 05 1986
Date

Sidney L. Mills
Area Director
Bureau of Indian Affairs

DEC 05 1986
Date

JACKPILE RECLAMATION PROJECT-DATA SHEET

LOCATION: 8 miles north of Old Laguna, NM; Laguna Indian Reservation (approximately 50 miles west of Albuquerque, NM);

PROJECT OWNER/MANAGER: The Pueblo of Laguna

CONSTRUCTION CONTRACTOR: Laguna Construction Company, Inc. (a New Mexico Chartered Corporation wholly-owned by the Pueblo of Laguna)

PROJECT OBJECTIVE: Reclaim & stabilize the site of the Jackpile-Paguate Uranium Mine, once the world's largest; mine operated by the Anaconda Company from 1951-1982; approximately 400 million tons of rock handled yielding 24 million tons of uranium ore; comply with all health, safety, and restoration criteria established in the Record of Decision issued by the Department of the Interior in 1986;

PROJECT START UP: August 15, 1989;

PROJECT COMPLETION: mid-1994 (est.)

PROJECT COST: $45,000,000 (approx.)

PERSONNEL LEVELS: Approximately 70 equipment operators, mechanics, technicians, and administrative professionals;

PROJECT VOLUME: 33,000,000 cubic yards (25,000,000 cubic meters);

AREA TO BE RECLAIMED: 2700 acres (1200 hectares);

REGULATORY OVERSIGHT: United States Department of the Interior Bureau of Indian Affairs & Bureau of Land Management;

ENVIRONMENTAL MONITORING: thru the year 2004;

Planning, Rehabilitation, and Treatment of Disturbed Lands

Billings Symposium, 1993

JACKPILE RECLAMATION PROJECT–History & Progress Update

by

James H. Olsen, Jr., PE[1]

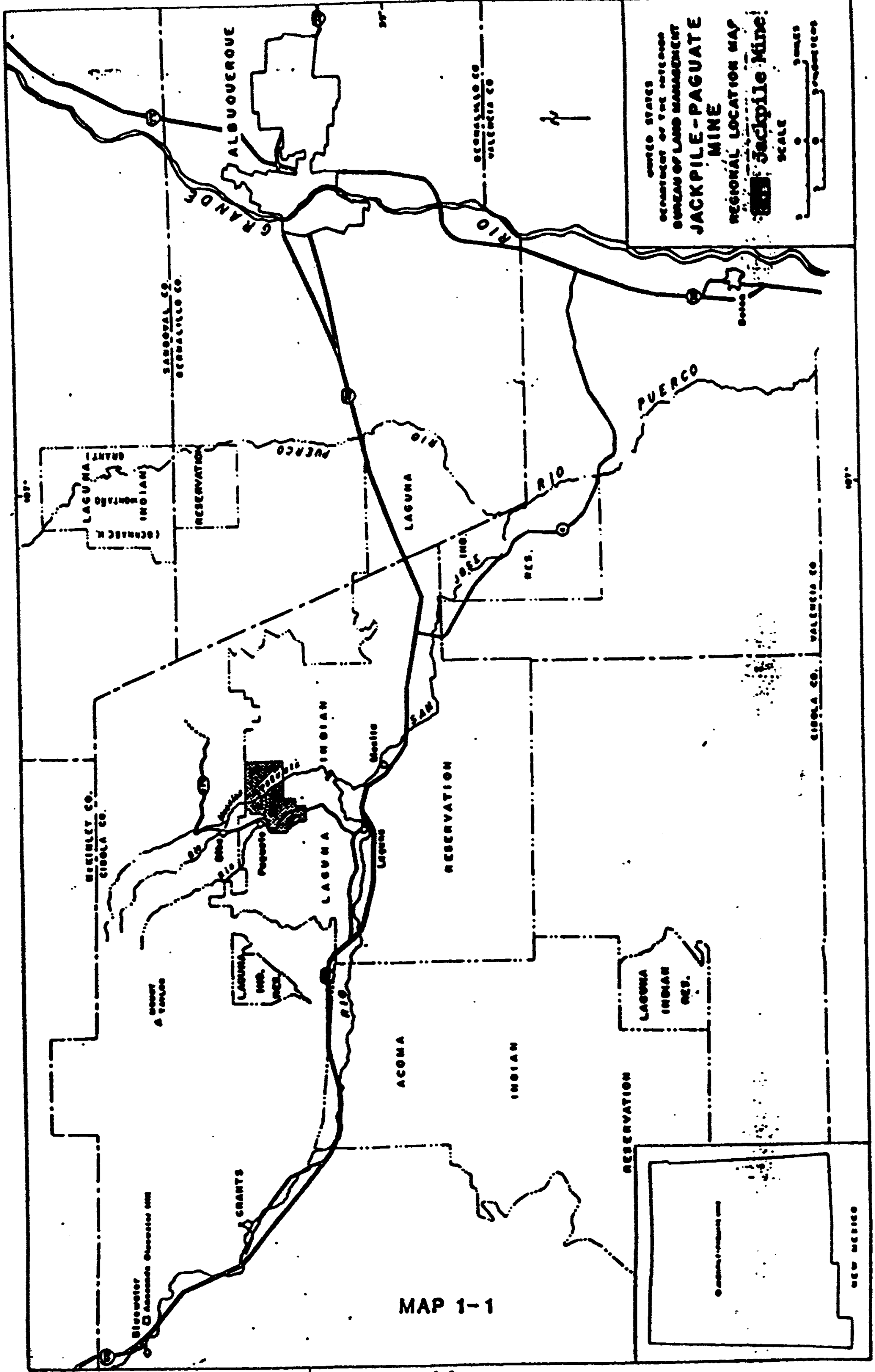
Abstract

The Jackpile Reclamation Project involves the reclamation of what was once the world's largest surface uranium mining operation. The mine is situated on the Laguna Indian Reservation about 50 miles west of Albuquerque, NM and operated from 1951-1982, producing over 24 million tons of uranium ore and handling almost 400 million tons of overburden and mine material. The reclamation of the site was undertaken by the Pueblo of Laguna in 1989 after the Environmental Impact Statement and Record of Decision were formalized by the Department of the Interior (1985-1987).

The Project has some unique features. It is the largest project of its kind undertaken and is under the direction of the Pueblo of Laguna. Many techniques used on this site may have applications in other situations, i.e., reclamation of metal mines. Particular attention to the environmental and design engineering is achieving Project goals along with cost-effectiveness. The combination of theregulatory and jurisdictional responsibilities has afforded an opportunity to develop a "common sense" approach to dealing with the previously-unregulated metal- mining reclamation area.

The Laguna Construction Company (a State-chartered corporation wholly-owned by the Pueblo of Laguna) is the construction contractor and one of the largest Native American corporations of its kind.

[1] J.H. Olsen, Jr, PE is currently serving the Pueblo of Laguna as the Reclamation Project Manager. He is a Registered Professional Engineer in the State of New Mexico. He holds an engineering degree from the New Mexico Institute of Mining & Technology and the MBA degree from the Anderson School of Management at the University of New Mexico. Experience includes 17 years of technical, engineering, and management duties in a variety of mineral, energy, environmental, and water resource areas.


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
JACKPILE-PAGUATE
MINE
REGIONAL LOCATION MAP
Jackpile Mine
SCALE
ALBUQUERQUE
RIO GRANDE
RIO PUERCO
RIO SAN JOSE
LAGUNA INDIAN RESERVATION
ACOMA INDIAN RESERVATION
LAGUNA IND. RES.
CANONCITO NAVAJO INDIAN RESERVATION
BERNALILLO CO.
VALENCIA CO.
SANDOVAL CO.
CIBOLA CO.
McKINLEY CO.
Paguate
Laguna
Mesita
GRANTS
Bluewater
NEW MEXICO

MAP 1-1

Jackpile Reclamation Project--*History & Progress Update*

I. Mine History

The Jackpile Mine, located approximately 50 miles west of Albuquerque, NM, is situated on the Pueblo of Laguna. The mine was once the world's largest surface uranium producer and was operated by the Anaconda Company (later merged with Atlantic-Richfield Corporation in the mid-1970's). The Anaconda Company had obtained exploration and mining leases from the Pueblo of Laguna in the early 1950's. Three open pit mines and nine adjacent underground mines operated from 1951 to 1982 when economic conditions and the demand for uranium collapsed. During the active life of the operation, some 24 million tons of uranium-bearing ore were produced and approximately 400 million tons (235 million cubic yards) of ore, mine waste, and overburden were handled during the mining operations. The disturbed area encompassed about 2700 acres. All ore material was shipped off-site for milling and processing, the bulk of which went by rail from the mine site to Anaconda's Bluewater Mill, about 60 miles west of the Jackpile Operations. The uranium was originally sold to the Federal Government under the old Atomic Energy Commission (AEC) provisions. In the 1960's, government controls were eased and private utilities were securing uranium supplies for electrical power generation.

Approximately 650 people were employed in the mines, most of whom were Tribal members. The jobs were in equipment operation, maintenance, administration, engineering & geology, and other support activities. Royalties on the uranium content were paid by Anaconda to the Pueblo of Laguna.

II. Environmental Impact Statement

Given that the mine operation pre-dated the National Environmental Protection Act and the normally-required Environmental Impact Statements, final reclamation of the Jackpile Mine was originally addressed in the late 1970's when discussion among Tribal, Company, and Federal officials began to consider the ultimate disposition of the Site. Specific regulations did not (and still do not as of this writing-1992) exist which would determine the required reclamation criteria for uranium and other metal mines. A nominal bond was in-force as had been required by the Department of the Interior for companies leasing minerals on Tribal lands but it was not felt to be adequate to effectively stabilize the site. The lack of specific regulations further complicated the situation along with some jurisdictional complexities since the site did not fall under the NRC's tailing regulations (i.e., the ore was not processed on the site and thus the materials did not meet the definition of *tailings*); coal mine reclamation regulations did not apply since those are specific to coal strip and surface mines; other waste regulations which may have been in force did not apply to metal mine wastes. The proposals submitted by the Anaconda Company had not been accepted by the Pueblo of Laguna nor the Department of the Interior.

Because of this lack of specific regulations and the desire of the Pueblo of Laguna to assess the impacts and needed action, a formal Environmental Impact Statement (EIS) process was initiated thru the Department of the Interior since they have oversight responsibilities on Tribal Lands.

The lead agency was the Bureau of Indian Affairs (BIA) with technical assistance provided by the Bureau of Land Management (BLM) This step was taken to allow for an objective evaluation of the Tribal, Company, and no-action alternatives for the Site and was an unprecedented action as it related to a previously unregulated area. The "draft" EIS[1] was issued in 1985.

The EIS process culminated in the issuance of the "final" EIS[2] in October, 1986 which included one volume of technical considerations of the six alternatives examined and a second volume of public comments on the proposals.

III. The Record of Decision

Following the completion of the EIS process, the Record of Decision[3] (ROD) was issued jointly by the BIA and BLM in December, 1986. The decision factors identified in the ROD were:

1. Ensure human health & Safety.
2. Reduce the releases of radioactive elements and radionuclei to as low as reasonably achievable.
3. Ensure the integrity of all existing cultural, religious, and archaeological sites.
4. Return the vegetative cover to a productive condition comparable to the surrounding area.
5. Provide for additional land uses that are compatible with other reclamation objectives and that are desired by the Pueblo of Laguna.
6. Eliminate the need for post-reclamation maintenance.
7. Blend the visual characteristics of the minesite with the surrounding terrain.
8. Employ the Laguna people in efforts that afford them opportunities to utilize their skills and train them as appropriate.

The specific actions to be taken included: placing all low-grade ore and contaminated material in the pit bottoms, reducing waste dump slopes to 3:1 (horizontal:vertical), stabilize high walls, seal drill holes and underground mine entries, place topsoil over the disturbed areas, revegetate the area with suitable plant species, and perform environmental monitoring activities (air, soil, water, radionuclide releases, radon-222 concentrations, gamma radiation surveys, etc.) Upon reclamation activity completion, the site is to be monitored for a period of ten years during which the success of the vegetative cover will be evaluated and any corrective measures taken.
Based upon the preliminary cost estimates, a financial settlement was reached between the Pueblo of Laguna and ARCO-Anaconda to cover the costs of the required work.

IV. Cooperative Agreement and Public Law 638 Contract

In keeping with Decision Factor No. 8 (above) and pursuing a course of self-determination, the Pueblo of Laguna chose to take full responsibility for the reclamation work. This would maximize the Pueblo's potential employment benefits and allow for control of the work. In order to formalize this arrangement, a Cooperative Agreement consistent with Public Law 638 was consummated between the Pueblo of Laguna and the Bureau of Indian Affairs. Public Law 638 provides for Tribal entities to contract for various activities between themselves and the Federal "trust agencies". The Agreement basically provides that the Pueblo of Laguna has control of the reclamation funds and all associated work but must use those funds to reclaim the site as per the Record of Decision. The Pueblo of Laguna would manage the Project activities and the Bureau of Indian Affairs would have oversight responsibilities to insure compliance with all the

ROD provisions. The Bureau of Land Management would provide technical assistance to the BIA. The Agreement was signed on March 27, 1987.

The details of the Agreement specified the roles of the participants in the Project as well as the required design work, management structure, reporting schedules (financial, construction progress, environmental monitoring), annual planning and budgeting, contract management, approval processes, and the qualifications of the "key" personnel.

V. Project Management & the Laguna Construction Company

Extensive work was done by the Pueblo of Laguna, its technical subcontractor, and the Bureau of Indian Affairs to develop a detailed management plan for the reclamation work. An unprecedented step was taken by the Pueblo of Laguna in the establishment and incorporation of its own construction company to perform all the required construction activities. The Laguna Construction Company was incorporated in 1988 under the laws of the State of New Mexico as a wholly-owned enterprise of the Pueblo of Laguna. A significant "side benefit" of this step was the continuance of the construction company as a going concern after the reclamation work was performed, thereby providing some longer-term employment opportunities for Pueblo members.

The Pueblo of Laguna, as the owner of the Project, formalized a contract with its wholly-owned construction firm in 1989 to do the work. The Pueblo of Laguna, through its Project Management Office, had direct control and oversight from the Pueblo Governor's Office and the Tribal Council. Hiring preference was afforded Pueblo members, and over 90% of the personnel associated with the construction and project management activities are Tribal members.

VI. Preliminary Technical Design & Project Mobilization

Detailed design work was undertaken by the Pueblo of Laguna thru its technical subcontractor (Jacobs Engineering) in 1988 and the initial design work was completed in August, 1989. This work included preliminary, detailed cost estimate, volumes, and various Project specifications, inspection procedures, health & safety plans, and environmental monitoring/regulatory compliance criteria. The Laguna Construction Company specified and purchased the heavy equipment fleet and support vehicles in the summer of 1989 and all deliveries were completed in the fall. Mobilization work began in August, 1989 to begin dewatering the North Paguate Pit, refurbish the maintenance Shop and Field Office facilities, and hire/train the operating and maintenance personnel. The Mobilization Phase ran through December, 1989 and full-scale earthmoving activities began in January, 1990.

VII. Technical/Design Enhancements

Concurrent with the first year's construction activities, some refinements to the original design concepts were completed jointly by the Pueblo's Reclamation Project Management Office, Laguna Construction Company, and Roy F. Weston Engineering. The goal of this effort was to utilize newer reclamation technologies, specifically in the areas of vegetation specifications[4] and erosion controls[5] and still be applicable within the financial constraints of the Project. Since funding was fixed, the most cost effective approach was paramount to insure that the goals and priority items in the Record of Decision were met. These recommendations and revised specifications were approved by the Pueblo of Laguna Council and the Bureau of Indian Affairs in the Spring, 1990.

VIII. Environmental Monitoring Requirements and Programs

The Jackpile Project addresses several environmental program to insure the construction specifications and long-term goals are met.

a. Ground & surface water monitoring: This program involves semi-annual water quality analysis from the Jackpile formation wells, alluvial wells, and pit bottom monitoring wells in addition to upstream, Project site, and downstream surface water courses. The Rio Paguate and Rio Moquino are low-flow streams which course through the site and discharge into the Rio San Jose which, in turn, empties into the Rio Puerco. The well data includes water levels information to ascertain ground water level recovery and heavy metal & radionuclide content in ground and surface water. Water monitoring will continue into the 10-year monitoring program following completion of the Project. Pit water is used for dust control and no water is discharged.

b. Radon-222 Monitoring: Radon emanations from the low-grade ore and natural Jackpile sandstone outcrops are monitored at 14 locations in and adjacent to the Project site with passive radon detectors which are changed and analyzed on a quarterly basis. In addition, an RGM-2 continuous radon measurement device is used which composites samples taken at five-minute intervals. The RGM-2 unit is next to the North Paguate Pit and about 300 yards from the village of Paguate, NM. The site standard adopted for the Project is 3.5 picocuries/liter. Readings taken since 1989 have shown a site average of just over 1 picocurie/liter and only background levels in the village locations.

c. Personnel Monitoring: All personnel on the project are monitored for radiation exposure through thermoluminescient dosimeter (TLD) badges changed and analyzed on a quarterly basis by an outside radiological laboratory. Maximum exposure to-date have not exceeded 5% of the allowable limits set by the Nuclear Regulatory Commission.

d. Particulate and Meteorological Monitoring: Air particulates for radionuclide concentrations are taken at various locations upwind, inside, and downwind from the site. The data collected since 1989 to the present will be evaluated in a meteorological model to estimate any outside exposures as a check against the predictions made during the EIS analysis. An on-site weather stations is recording temperature, wind speed, wind direction, and precipitation data on a continuous basis.

e. Gamma & Other Radiation Surveys: Final reclaim sites must meet a specification of 28 micro r/hour or less. Natural background in the vicinity was measured at about 14 micro r/hour so the adopted standard for the Project is nominally "two times background or less". The one foot shale cover over the low-grade ore materials achieves this standard and the reclaimed areas are essentially at background gamma levels. Areas are measured with a gamma meter on a 200 ft. X 200 ft. grid pattern and are verified by an outside laboratory. Work sites, shops, offices, and lunch areas are routinely measured by the Reclamation Techs for gamma levels and adjustments made as needed to achieve the "as low as reasonably achievable" goal. Alpha particulate samples are taken on equipment. operator's cabs, and materials released for use off-site. All alpha measurements indicate good house-keeping and well below NRC standards.

f. Vegetation and Soils: Soil analyses were taken in 1990 to determine the best native seed mixture for the site. Two mixes were developed (see Tables 1 and 2) which would be applied depending upon the soil type. Only during the last years of the mining operations had any "topsoil" been stockpiled for future reclamation use. The "topsoil" material is composed of the Cretaceous Tres Hermanos Sandstone and other alluvial

Table 5.2. Seed Mix 1, Rates and Costs - Soil with 20% to 50% Rock in Profile

Genus and Species[a]	Common Name[a]	Seed Mixture (%)	Seeding Rate (PLS)[b] lbs/acre	Seeding Rate (PLS)[b] seeds/ft^2	Estimated[c] Cost ($)/Acre
Bouteloua gracilis var. Hachita	Blue grama	30	3.6	59.0	$21.60
Bouteloua curtipendula var. Niner	Sideoats grama	25	3.0	10.0	9.75
Hilaria jamesii var. Viva	Galleta	15	1.8	7.0	45.00
Agropyron smithii var. Arriba	Western wheatgrass	10	1.2	3.0	6.72
Sporobolus airoides var. Salado	Alkali sacaton	10	1.2	37.0	4.68
Atriplex canescens	Fourwing saltbush	5	0.6	0.5	2.37
Melilotus officinalis var. Madrid	Yellow sweetclover	5	0.6	3.6	0.51
	TOTALS	100%	12.0	120.1	$90.63/acre

[a]Seed types based on Curtis & Curtis Seed Catalog (Curtis & Curtis, Inc. 1989).
[b]PLS - pure live seed.
[c]Estimated costs based on 8/15/90 vendor price quotes (Curtis & Curtis, Inc. 1989).

NOTE: *Andropogon scoparius* may be added to this seed mix at 1.2 lbs/acre PLS.

Table 5.3. Seed Mix 2, Rates and Costs - Fine-Textured, Sandy Soils

Genus and Species[a]	Common Name[a]	Seed Mixture (%)	Seeding Rate (PLS)[b] lbs/acre	Seeding Rate (PLS)[b] seeds/ft^2	Estimated[c] Cost ($)/Acre
Sporobolus airoides var. Salado	Alkali sacaton	20	2.0	62.0	7.80
Sporobolus cryptandrus	Sand dropseed	10	1.0	128.0	3.00
Oryzopsis hymenoides var. Paloma	Indian ricegrass	15	1.5	8.0	12.38
Bouteloua curtipendula var. Niner	Sideoats grama	25	2.5	8.0	8.13
Bouteloua gracilis	Blue grama	5	0.5	8.2	3.00
Andropogon scoparius	Little bluestem	10	1.0	13.0	2.00
Atriplex canescens	Fourwing saltbush	5	0.5	0.4	1.98
Eurotia (Ceratoides) lanata	Winterfat	5	0.5	1.2	3.75
Melilotus officinalis	Yellow sweetclover	5	0.5	3.0	0.43
	TOTALS	100%	10.0	231.8	$42.47/acre

[a]Seed types based on Curtis & Curtis Seed Catalog (Curtis & Curtis, Inc. 1989).
[b]PLS - pure live seed.
[c]Estimated costs based on 8/15/90 vendor price quotes (Curtis & Curtis, Inc. 1989).

NOTE: *Festuca ovina duriscula* may be added to this seed mix at 1.0 lbs/acre PLS.

germination was inadequate, etc. The Pueblo of Laguna will have responsibility for implementing and completing this program with the BIA providing an oversight function. The Post-Reclamation Long-Term Monitoring Program was approved by the Pueblo of Laguna Tribal Council and Bureau of Indian Affairs in late 1992.

XI. Construction/Operations

Given the large volume of material to be handled and the surface area involved, a heavy equipment fleet was selected to meet the varying conditions and design criteria.

Pit dewatering consist of the use of two Gorman-Rupp 3000 gpm pumps powered by Caterpillar 200 kw generators. No dumping of pit waters is done and the water is disposed of via evaporation enhanced by dust control in the earthmoving areas. Three 5000 gallon tankers are used.

Sloping of waste dumps (from the 1.5:1 horizontal to vertical) to the required 3:1 angle is being accomplished with a fleet of Caterpillar dozers consisting of five D8N size and two D9N models. They are equipped with rippers and reclamation blades. Virtually all dozer work has been sloping in a down-ward direction and better-than-anticipated production was realized. "Slot dozing" techniques were used. Many slope lengths exceeded 1000 feet when finished. The weathered shales and sandstone materials, while not particularly dense or hard, did have some large boulders that were encountered periodically.

Handling of low-grade ore and shale/soil cover materials is being accomplished by the scraper and belly dump truck fleets. The length-of-haul dictates the equipment application since the character of the materials is the same for either fleet. The scraper fleet is composed of five Caterpillar 631E models which are "push-loaded" with a D9N equipped with a "push cushion." Scraper hauls are in the range of 3000 feet and grades have been predominantly downhill at 3-5%. The truck fleet handles the longer hauls and is composed of seven 70-ton belly dump trucks pulled by Haulpak tractors. The tractors can be converted to an end-dump configuration, giving them additional flexibility. The belly-dump trailers were fabricated by Mega, Inc. of Albuquerque, NM under Laguna Construction Company's specifications. The trucks are loaded with two Caterpillar 988B model front-end loaders. A Caterpillar D10N dozer loosens the materials in the stockpile source and pushes the material down to the loader locations. Low-grade ore and supplemental backfill materials needed to achieve the required elevation in the pit bottoms are dumped by the scrapers and trucks and then pushed into the pit by two Caterpillar 824C rubber-tired dozers, which also perform cleanup around the area. Grade of the backfill is controlled by a laser unit.

Upon completion of backfilling and sloping of dumps containing uranium-bearing material, cover materials are placed. Prior to placement of the cover materials, the area is disced with a farm disc pulled by a Caterpillar D6LPG dozer. Discing on slopes is done at a 45° angle to the slope direction in order to interrupt any erosional drainage patterns and increase the shear area for the cover materials. This technique was a result of the design analysis on the hydraulic stability of the slopes since they were relatively steep and in some cases in excess of 1000 linear feet. In areas were low-grade ore or uranium-bearing waste was exposed, a 12" thickness of shale is placed. This has been demonstrated both by technical calculation and by actual field measurements to reduce the gamma radiation emissions by an order of magnitude and will also inhibit Radon-222 emanations. Soil cover is then placed over the shale cover to a depth of 18-inches. Cover materials on the sloped areas are typically dumped at the slope crest by either materials adjacent to the mine site that were tested for a variety of chemical constituents and characteristics during the 1990 test program. In addition, specifications for "interseeding" previously-reclaimed areas were also developed. Soil is placed in a specified 18" thickness and measured with an auger drill on a 200 ft. X 200 ft. grid. Seeding is done with either seed drill or hydroseeding techniques. Seeding is preferred during the cooler fall months (September-November) since this follows the summer rain season when most of the annual precipitation is received. Seeding, however, can be done during the spring months and the scheduling is dependent upon soil moisture conditions. No irrigation is used d ue to the lack of water resources as well as the problem of "die back" when artificial irrigation is stopped. Reliance on natural precipitation made sense since the vegetation must ultimately be self-sustaining. No vegetation analysis has been done to-date since the first seeding work was completed in late 1991. During the monitoring phase, however, the vegetation will be checked for cover density and uptake of any potential heavy metals or radionuclides. Inclusion of a re-forestation program is currently being evaluated in a joint effort between the Reclamation Project Office and the Southwestern Indian Polytechnic Institute. Controlled grazing methods will be examined once the vegetation is judged to be adequately established.

g. Health & Safety Program: A Health & Safety Plan was developed for the Project and approved by the POL-Council and Bureau of Indian Affairs. The program was fashioned after the provisions of the Occupational Safety & Health requirements. All Project personnel have received forty hours of training in an OSHA-certified hazardous waste training program.

h. Other Permits & Compliance Measures: The Site had been cleared archaeological in the late 1970's when the Anaconda Company contracted a study through the University of New Mexico. No work is planned outside the previously-cleared areas requiring further archeologically work or an examination of any threatened or endangered species above that done in the EIS process. A water heater was the only asbestos disposal requiring special treatment and no special Tribal permits for sand & gravel, water well use, or other revocable uses was required. No waters are discharged, negating the need for an NPDES permit. At this writing, there have been no other regulatory compliance requirements placed upon the Project.

IX. Project Progress

From January, 1990 thru November, 1992, (thirty-five months of full scale operations and the end of the third Operating Year) approximately 23 million cubic yards of low-grade ore, contaminated soil, dump sloping and cover material had been handled. About 600 acres had been reseeded. The Project is about sixteen months ahead of the baseline estimate and costs are running about 80% of the estimated amounts. All project technical and construction specifications have been met. At current levels of activity, heavy earthwork and the initial reseeding should be completed sometime in 1994. However, outside work opportunities for the Laguna Construction Company could delay final completion but this is not seen as a difficulty since the priority items have been completed.

X. Post-Reclamation Monitoring

The ROD requires a ten-year monitoring period following the revegetation work. The detailed monitoring program (which is currently under POL-Council and BIA review) specifies the activities, analytical work, reporting, funding, and associated work to evaluate the success of the reclamation effort and also take any corrective actions which may be necessary, i.e., repairs due to erosion, reseeding areas where the initial scraper or truck and then spread over the area with the dozers. The required thickness is controlled by survey stakes.

Seeding of the areas upon completion is done by seed drill on the flat and short slope areas; the longer sloped areas are seeded with hydroseeding techniques. No artificial irrigation is used for two reasons: lack of available water for this purpose and the philosophy that the vegetation must establish and sustain itself under the prevailing natural conditions.

In addition to the reclamation activities, other work has included demolition/salvage of old mine structures and fencing of the site to prevent unauthorized grazing/access.

Maintenance effort is supported by two service lube trucks, three maintenance trucks with welding equipment, transport trailers, and a utility backhoe and a small loader/forklift unit.

Operations works one-shift per day, forty hours/week. Maintenance work is staggered during the work day to service equipment during lunch breaks. Equipment availability has been above 96% for the Project to-date.

XII. Conclusion

The Pueblo of Laguna has achieved considerable success in not only reclaiming and stabilizing the mine site but also in the development of its wholly-owned construction company. Many of the approaches taken on this Project could have application in other situations, especially in arid environments. Unlike some other projects, this one paid considerable attention to prioritizing the effort to address the most important problems in a cost-effective manner. It is important to point out that no financial resources other than those obtained by the Pueblo of Laguna in their settlement with the operating company are being used; the Pueblo took on an unprecedented effort both in terms of the complexity of the Project and complete Tribal control consistent with the ideal of self-determination. The effort has not been without its difficulties but the experiences gained on this Project (environmental, managerial, technical, etc.) may be of value to other situations and an effort is being made to share those experiences.

$3.00

MINE TALK

July - August 1981 Vol. 1 No. 2

"We have lived here for many years, and a lot has changed. I used to be able to breathe here."
—Ben Lorenzo, Former Governor, Laguna Pueblo

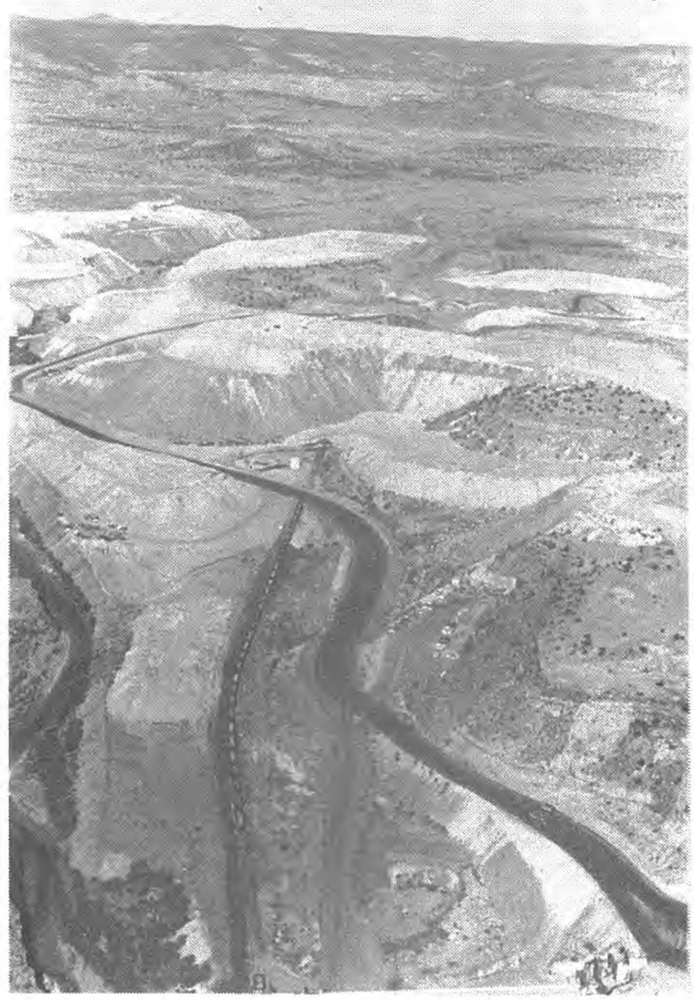
IN THIS ISSUE: Crested Butte vs. AMAX   Can Anaconda Reclaim Jackpile?   Radiation and Birth Defects
CERT On An Energy Mission   Mining the McDermitt Caldera   State-by-State Reports

Can Anaconda Reclaim Jackpile?

Paul Robinson

Through 1975, Laguna provided 14% of the country's uranium supply, but we're finding some conflicts. We've had some severe effects on the quality of our air and water. The village of Paguate is just 150 yards from the boundaries of the open pit mines and has suffered from noise and dust pollution. In severe weather, radioactive materials may be flowing downstream from the area. But without any regulations, we are in a dilemma.

–Floyd Correa, Laguna Governor, 1978



Jackpile Mine–5,000 acres of open pits and waste piles that dwarf the railroad line. The mine drainage stream flows toward the village of Paguate and pueblo grazing areas. Photo by John Liebendorfer

On February 28, 1981, Anaconda Company halted operations at its Jackpile-Paguate mine at Laguna Pueblo, the largest open-pit uranium mine in North America. The company, an ARCO subsidiary, had initially proposed a 1984 closing date but escalated its schedule when uranium prices fell.

Under conditions of the lease, Anaconda cannot leave the scene without completing a mine reclamation plan, to be assessed by the U.S. Geological Survey (USGS) and the Bureau of Indian Affairs (BIA). The agencies' joint Environmental Statement will evaluate the plan's impact on the environment and surrounding Pueblo communities and weigh appropriate reclamation alternatives. The Anaconda plan will be the first attempt to reclaim an open-pit uranium mine in the United States.

The mine site covers 5,000 acres of Laguna Pueblo land in northwestern New Mexico, including 3,000 acres (4.7 square miles) of open pits, with waste piles and buildings, two active and three inactive underground mines, and a widespread exploration drilling network. The pits cross the Rio Paguate and Rio Moquino — the main streams in the northern part of Laguna Pueblo.

The area was first leased by Anaconda in 1951, after a company geologist, while flying over the region, noted high aerial radiation readings which were later interpreted by surface examination and core drilling as a huge uranium ore body. The original leasehold was expanded westward to Paguate, to exploit additional ore viens.

Continuous operation of the mine through 1980 has resulted in the excavation of more than 100 million tons of material, including about 15 million tons of ore. Most of this rock is at the mine in waste piles, low-grade ore stockpiles, or ore piles awaiting shipment to the mill. The Jackpile ore processed at Anaconda's mill in Bluewater, New Mexico has created a 400-acre landscape of mill tailings piles and evaporation ponds.

The scale and complexity of the reclamation job translates into a five- to ten-year program. Marc Nelson, USGS project coordinator, anticipates an 18-month EIS study process, followed by five years of earth moving, revegetation, and fencing work. If things go well, after two or three years of study and some reworking, reclamation will be complete.

The mechanics of this timetable should be clearer after

Laguna miners at Jackpile. Photo by Tom Barry

It used to be all peaches, wheat and corn in the valley. The irrigation water came from the mountains by way of a series of dams.
–Franklin Lewis, a retired Laguna miner

People dry their meat outside and the dust settles on it, especially when it's really blowing. The uranium gets into our lungs and into the food on our tables. We don't know what it's doing to our health, to our kids, and later on their babies.
–Frank Aragon, an Anaconda employee

publication of the EIS. However, there is no question that it will be a long time before the land can be put to its original use as grazing and farming areas.

A key concern of the people of Laguna is the quality of their water, which was contaminated by the mining process. Water flowing through the mine, both surface and groundwater, is used for stock watering, irrigation, and domestic supplies.

Little sampling has been done in the area, but the few samples taken, by the Environmental Protection Agency in 1975 and the Indian Health Service in 1979, show consistent increases in Radium-226, a radioactive decay product of uranium. Groundwater samples range from 0.17 pCi/l (picocuries per liter) upstream of the mine to 3.7 pCi/l on the southwest side of the mine. Surface water samples downstream of the mine were up to 4.8 pCi/l in 1975.

The U.S. Public Health Service limits the Radium-226 in drinking water to 5 pCi/l. (The rate of radioactive decay is measured in picocuries per liter. 1 pCi/l equals about two decays per minute.)

The numbers are of concern for several reasons. The groundwater samples were collected where people use water, and indicate trends of increasing radioactivity in subsurface water supplies. The surface water samples with high radium content were taken upstream of a main Laguna grazing area. There is also evidence of increased radium contamination of streambeds below the Jackpile mine since mining began. This increase could mean there will be long-term radioactive releases from the mine sites.

Selective Reclamation

Meanwhile, Anaconda has extensive plans for surface reclamation, but is relatively silent on the issue of restoring water quality. What receives most attention in the Jackpile plan is the restoration of mined land. Anaconda has proposed changing the contour of parts of the mine but otherwise leaving "over-steep" embankments and highwalls amidst the wide "previous reclamation" areas. Highwalls are especially difficult to maintain against erosion and severely impede grazing use. The "previous reclamation" was done without performance criteria or monitoring, and often does not meet current standards. In addition, Anaconda has a large expanse of unreclaimed drill sites which it has not even proposed to reclaim. Until regraded, resoiled, and replanted, these will be sites of increasing erosion and diminishing vegetation.

The next year and a half will be an important period to refine the Jackpile reclamation plan. There will inevitably be changes that reflect criticisms of the USGS, the BIA, the Laguna Pueblo, and other concerned people, as well as the advances in reclamation technology.

The final plan — a pioneer effort in open-pit mining — will set the standard for the uranium industry. It should be closely monitored as it is being formulated and implemented. A series of public meetings during the development of the EIS will allow people to make recommendations to the USGS and BIA and also to keep up to date with Anaconda's proposals. Documents on the plan will be available for review through Marc Nelson, USGS, 505 Marquette NW, Albuquerque, NM 87102.

Paul Robinson is program director and environmental analyst at Southwest Research and Information Center in Albuquerque.

POISON FIRE SACRED EARTH

TESTIMONIES LECTURES CONCLUSIONS

THE WORLD URANIUM HEARING SALZBURG 1992

come and visit me, visit us! Come and see how the Altai Mountains with its ancient peoples look. Thank you very much.

Father John (Moderator)

Thank you. That was an inspiring speech from one of us from Mongolia. As some of us have read, the guest from Mongolia got the German Literature Award in 1992. Thank you very much for that award.

Now I ask people from Laguna and Acoma, please come to the stage. And please feel free to come with your traditional clothes.

So please, a team from Acoma, we welcome Manuel Pino.

Manuel Pino

Manuel Pino, Acoma Nation, New Mexico, USA. Currently working on a Ph.D. about the effects of uranium mining on the identity of the Indian people, i.e. loss of traditional values and an increase in suicide and alcoholism.

(Greetings in Keres)

Greetings to all the Indigenous people and European people! We are here representing our Elders from Acoma and the Laguna Pueblo. We bring our Elders' message because flying across the great Atlantic Ocean is something they cannot conceive. We are still a very traditional people. Us, like the Hopis and Acoma, claim to be the oldest continuous village in North America. As you can see by the transparency upon the screen here, we come from the southwestern part of the United States and like numerous of the groups that have preceeded here today, we have been impacted by uranium development for over 40 years, and we bring the message of our Elders because they are our wisdom. They are our future and they are our past.

We brought some of our children with us to give you an idea of how they feel about this development and how it impacts them and their children and their children's children. As we speak to you here today we are very humble people. That is the traditional way of the Acoma and the Laguna. We come here to address the issues that have confronted our people. One of the hardest things for us to deal with as human beings, is to watch and sit throughout this 30 year period of development as our sacred montain, Mount Taylor, was desecrated. They stuck the world's deepest uranium mine shaft into our sacred mountain.

I ask you, people of Salzburg, how would you feel if we came here and stuck a jack hammer into the Salzburg Cathedral? That's the way we feel about what is being done to our sacred mountain. It is our life, it is our existence, it is our future, it is our present and it is our past. We come to you here in your western culture which examplifies the characteristics of western culture, and that is the idea that humans are superior to the world they inhabit. According to your book of Genesis, humans were made in the image of God who told them: "Be fruitful and multiply and replenish the earth and subdue it and have dominion over the fish of the sea and over the birds of the sky and every living thing that moves upon this earth." This is the way western culture tends to view nature as a wilderness to be conquered and tamed by human effort. The art, the literature and the folk tales of the West repeatedly show people in heroic struggles against the forces of nature.

Well, us Indian people contradict that argument. We live the opposite. We believe that Mother Earth is not to mess with. And all those species and living things from the smallest insects that crawl to the elk, to the buffalo, they are all our brothers and sisters. So, when we come to your land that has shoved these types of ideologies down the throats of our people, our youth, in school curriculums, through the BIA boarding school assimilation process that our grandfathers, grandmothers and parents had to endure. Part of this struggle is tied to uranium development. It is that generation that had to live through the assimilative policies of this country that made the decision to mine uranium on our land. They had been to World War II, they had been through World War I, and they were told that they were heroes and that in order to continue to protect our land, uranium would have to be mined. This is the generation that has affected us for the future, that made those decisions.

In the bureaucracy of our federal government in the United States is the Bureau of Indian Affairs who helped negotiate these leases on behalf of the tribe in the 1950's. As our trustee, the Bureau of Indian Affairs misled our peole - granted, uranium was still a new industry in the United States, but they didn't tell our people the truth. The economic benefits that the corporations received compared to my people is outrageous, and they leave us with the contaminants that my brothers and sisters will address here today. I showed you the map of the region where we come from. This is the San Juan Basin Mineral Belt in New Mexico, Arizona, Colorado and Utah, the Four Corners. In this area, over 30 years uranium was developed from the 1950's to the closing of the last mine, the Chevron mine, which had the world's deepest uranium mining shaft into our sacred mountain. The Grants Mineral Belt extends from about 15 miles West of Albuquerque to the Arizona border. It's approximately 60 miles wide and 100 miles long.

At the height of uranium development within a 30 miles radius of our reservation are Laguna Pueblo, Acomita, McCartys - all communities within the Acoma Reservation - and Paraje and Paguate on the Laguna Reservation. You can see by the numbers of all the mines that existed were downwinders from the Grants Mineral Belt and the Ambrosia Lake Area to the West and the uranium that was developed on the Navajo Land. You know, this area produced great amounts of uranium during the height of development.

In this area, Indians owned or controlled about 50 percent of the nation's uranium supply and mostly concentrated on Navajo and Laguna reservations. Within the Grants Mineral Belt, 25 percent of the United States' uranium in the 1970's and eleven percent of the world's uranium were mined in this area within a 30 mile radius of our people's native lands. Along with the world's deepest mineshaft was also the world's largest uranium mill at Ambrosia Lake. Within the Pueblo of Laguna lay the world's largest open pit strip mine, in operation from 1953 to 1982. You know, these are "world bests" we don't want on our land anymore, we don't want to be known for all the world's deepest and worst uranium atrocities on our land, never again!

As Jackpile opened in 1953, 24 million tons of ore were mined over a 30 year period. This was a 24-hour-a-day, 365-days-a-year operation for 30 years until it shut down on March 31, 1982. The Atomic Energy Commission was the primary buyer of uranium from Jackpile, so we know this uranium went directly to build the nuclear arsenal of the United States of America, which has the capacity to blow the world, I don't know how many times, over. But this was coming from our land, our sacred mountain, at the disgust of our traditional Elders and our traditional leaders.

Right now, Jackpile Mine lies like a sore in the middle of the New Mexico desert. And within 1,000 feet from the world's largest open pit uranium mine lies the village of Paguate. When the wind blows from an easterly to westerly direction, these people are directly in line with the waste overburden and tailings that laid unreclaimed from when the mine closed in 1982 till the reclamation project began in 1989. Seven years these people had to endure radioactivity in their backyard. This is what we had to deal with, this is what we have to live with, and this is what my people will reiterate to you here, today.

Granted, uranium development improved the quality of life on the reservation when you look at it from a monetary perspective. Over 800 Laguna Pueblo Indians were employed at the mine at the height of development, the unemployment rate dropped to less than 20 percent. Prior to uranium mining it was in the 70 percentiles. But after the bust it has returned to that percentage. With an improved quality of life came increased wages. For Indian people, that is not always a positive outcome. Increased wages meant increased access to alcohol. Increased alcohol meant greater crime rate, more domestic violence among our people, spouse abuse, child abuse, an increased suicide rate and drug-use. All these issues that the technological culture does not consider that we have to live with in their environmental impact statements: destruction to our traditional life styles.

We went from being agriculturalists and livestock raisers to wage earners, and that impacted our traditional culture, our traditional language, participation in our ceremonies. During the height of uranium mining, people prioritized their eight-to-five-job, their eight-hour-a-day-job over participating in the ceremonies. This is what lies undocumented among our people. Our Elders cry today that the generation below us cannot speak our language. Some of them don't have any idea of how to participate in the ceremonies. These are the issues that go unaccounted for, that we bring to you here, that we bring to the world.

If uranium mining would have continued in the Grants Mineral Belt, this is what we would be looking at today. These many mines within the San Juan Basin area and the aboriginal homelands of the Diné and the Acoma and Laguna people. So I ask you today here at this World Uranium Hearing: Put yourself in our place! Think about with what we have to live, what we have to endure, what we have to continue to endure, and I will leave you with the words and wisdom of my grandfather who entered the spirit world four years ago. I've been in this struggle a long time, when it was unpopular to speak out about the mine. When those 800 people were employed, I was a very unpopular person because I was speaking the issues that I speak here today. No one wanted their job threatened, no one wanted the tribal budget threatened, no one wanted to take a stand about these issues that we're talking about here today. But my grandfather gave me a basic philosophy that I continue to live by today and that is: "To destroy the land is to destroy the people."

My brothers and sisters, my fellow panel members will show you how this destruction has taken place. As a humble Acoma man I thank you for giving me this opportunity to come half way around the world to address you here today.

Father John (Moderator)

Thank you very much. That was a touching speech and we have been challenged. Thank you very much. So we have the next speaker. Please mention your name in full, some names are very difficult.

The next guest speaker ist from Laguna, Colorado Plateau, USA.

Alveno Waconda

Alveno Waconda, Laguna Nation, New Mexico, USA. Former uranium miner.

Good morning! My name is Alveno Waconda and I come from the village of Paguate. Paguate is one of six villages on the Laguna Pueblo. I live less than one mile from the Paguate Jackpile Mine. My parents, brothers and sisters lived in Paguate for most of their lives. My father and mother raised their family by making a living from farming and raising livestock. My early childhood days were spent helping my father in the raising of livestock and farming. As a child I never had the luxury or technology of fancy new clothes that children have today. Thinking back I can't say I wished for all the material things of today. We were more family-oriented back then, and managed to make a living from what we did all together.

When the uranium mine became part of our lives I feel that, as a family, we lost a lot. The family values, culture and tribal traditions changed. My father became employed at the mine and we never farmed on a large scale basis again. My father sold his livestock because he could no longer tend to his livestock and all the work involved at the mine. As I look back on my early teenage years, it angers me now to see how quickly money can change your whole life. By this, I mean that during the time my siblings and I began to have a different attitude about money and what it could provide. Those things which were a vital part of our childhood no longer seemed important.

I was invited here today to express my personal concerns of our people who have lived next to the mine and the people who have worked in the Jackpile uranium mine. I was employed at the Anaconda Mine from 1971 to 1982. For seven years I was employed as a heavy equipment operator. I drove haulage trucks, operated dozers and loaders. Some of our haulage trucks were very old. The steering was hard whenever you took your foot off the accelerator pedal. In winter time the heaters never worked well. I recall times when fellow employees would rap their legs with rags, so they could keep warm.

Most dozers did not have caps to protect from dust and the weather. There was a time when the loader would just shake your body when you tried to steer it. And it took the company many days to fix the problem. The uranium ore was always around us, whether the wind blew it on us, from dusty conditions. There were times when we were having our lunch sitting on the high-grade ore stock pile. We had lunch sitting in loader buckets to get out of the hot sun. No one warned us that the buckets were contaminated from the ore.

Nearly every day the company would blast two times a day or more to get to the ore. There were times when the dust blew in our direction at work and many times toward the village of Paguate. Dust was in the air, settled on the soil, crops, clothes and home. For a period of four years I worked in underground mining. The main reason I moved from open pit to underground mining was because of the money that miners were making. I can truly say the underground mining was good at pay-day. If you ask anyone of us, anyone of the workers if they were there because they like the job, then they were crazy just like us for working there. But what can you do when the money is so good and provides for your family.

Underground mining is very dangerous, and there were many things that you could get hurt from or even killed, not including the effects of radiation. Underground I was employed as a loader operator and miners' helper, and my personal experiences with the dangers of mining included a time when the miner and myself were blasted from loaded rams of dynamite. We had just come for the evening shift and headed to our working area. The blasting lines were still hooked up, so we disconnected them and went back to our main area of work. We began to wonder why the blast did not go off when suddenly they started going off. The four men had reconnected the blasting lines and blasted our area without further checking if anyone was in there. I was farther away from the two areas of blasting, but the miner was not as fortunate. He was caught in the middle of both blasts. Luckily we survived, but my partner has not worked [further] because of damage to his hearing and to his eyes.

My other experiences with the dangers of mining included poor ventilation when operating loaders, dusty conditions, mud on our clothing and body, taking chances and shortcuts. In the mornings, after waking up from a shift, I always remember coughing up the phlegm and seeing it black as the result of all I breathed in the night before. Although we had leadmen and formen come to our areas to check on us, we always knew they were coming because of the mine lamps headed towards our area. As soon as they would leave we would go back to our dangerous ways. Why did we do all those dangerous things? Money is the answer. The more work we produced the more we got payed, whether it was safe or not. When we had safety inspections, somehow we always knew in advance when the inspectors were coming on a certain day, giving us enough time to straighten up our area. A lot of times we were just put out, "keep out" signs for the inspectors to see. Then we would remove when they left and work in that section again. When we had safety meetings we were never given information on the dangers of radiation, there was only concern of equipment hazards. The dangers and effects of mining were always with us, even at payday.

Most of us workers would go to the bars and cash our checks there and spend the money on alcohol. After drinking all night we would get in our cars and drive home, sometimes getting into accidents and causing all kinds of family problems. When the mine terminated we were given physical examinations. But I do not know where those records are. No one has given us miners any other physicals to check on the effects of radiation

Father John (Moderator)

She said that she is ten years and most of us here are above 25 years. And if we are 25 years, it means that we are trying to let her and other future generation not to reach at that stage. So for special clapping of hands, please, stronger this time. One, two, three, four, five and then to all her sisters, six... Thank you. Now we have a few minutes on slides, please.

Manuel Pino

We just like to give you a visual idea of how beautiful our land is, and despite the fact that we live within such close proximity to uranium mining, we still revere the land very much, and for our future generations hopefully it will continue to replenish and nourish us as human beings.

[Slides]

This is Mount Taylor, our sacred mountain, also sacred to the Navajo. - This is another shot of Mount Taylor. If you look right in the middle of the photograph you'll see some of the largest unreclaimed mill tailings piles in the United States. This has been identified as a super fund-site for the Environmental Protection Agency of the United States Government that has been unreclaimed for over ten years now. This is one of the reasons we come to you, because our government continues to have no eyes and no ears when it looks at cleaning up the mess that they created for us.

This is a closer shot of those unreclaimed mill tailings. Cows in this area graze within a half mile radius. In the desert southwest, between the months of March and May, we have some of the most violent sandstorms in the country that can reach up to 60 mph. So you can get an idea how these tailings blow all over our Mother Earth, and we are downwind from these sites at Acoma and Laguna.

This is the abandoned mill of which the mill tailings were created. It still lays unreclaimed or decomissioned. - The same shot of that mill tailings pile. This is all that keeps people away from these highly contaminated tailings: Just a chain-line fence like this is going to stop the wind blowing contamination or seepage into the ground water.

This is the Gulf Mine, which was later bought out by Chevron Corporation that had the world's deepest uranium shaft in the world into our sacred mountain. Within 200 yards from that mill tailings pile is the Hispanic Chicano community of San Mateo. 200 yards from that mill tailings pile was a school and, even worse, was a vent coming out from the underground shaft that, when the wind blew in certain directions, would blow radon right into the playground of that school in San Mateo. This was going on for about ten years and nobody ever did anything to stop it.

This is the Quivara Mine, one of the first sites that has been attempted to be reclaimed in the Ambrosia Lake Area. They are sloping there a reclamation project and burying the mill tailings which to me just seems insufficient.

This is a sign indicating that the mill is closed and they don't allow people within close proximity to the area, but it's virtually unmonitored. When we took these photographs we could walk on the tailings piles and no one would have been there to see us.

Again, the world's deepest uranium mine shaft. The ARCO Bluewater Mill. Quivara Mine, which is currently being reclaimed. The city of Grants for over 30 years prided itself as "the uranium capital of the world". And they have built a museum in commemoration of that distinction. Although, to us Indian people that is a direct insult to us, to the way we feel about Mother Earth, especially as I keep reiterating time and time again the destruction to our sacred mountain.

This is the Mesita Dam which is downstream from the Paguate Mine. At the height of production at Jackpile, this holding reservoir which was used for irrigation of agriculture was found to have some of the highest levels of radon our children are our future decision-makers and leaders of our people. And I hope that the work that we started today will be continued, and that is the reason I brought my children, that they will learn from us and carry on these hearings and make the world safe.

Thank you.

Father John (Moderator)

Thank you very much. Our future depends mostly on our children. That's why we have our next speaker on the stage to tell us more.

Suwimi Lewis

Suwimi Lewis, Laguna Nation, New Mexico, USA. Daughter of Gloria and Greg Lewis.

Hello! My name is Suwimi Lewis and I live in the pueblo village Paguate, New Mexico. I am ten years old. I got interested in the safety of the Jackpile Mine because my schoolbus route goes directly through the mine.

This mine was once the largest open pit and underground uranium mine in the world. It was closed in 1982. I have lived in Paguate all my life. I have always wondered if the mines would ever be safe enough for my friends and I to play in, or safe enough for our people to plant and graze their animals there. My family and I contacted the mines and asked if we could take a tour. Mr. Victor Sarracino, who is a monitor technician, gave us information about the reclamation project that is being done at the Jack Pile Mine. The Pueblo of Laguna formed their own construction company to do the reclamation project themselves. This is costing the tribe 43 million dollars to finish. All the work that is done is kept on computer so that technicians will know exactly how much progress they are making. The project is ahead of schedule as of this month. Mr. Sarracino explained that when the low-grade ore is pushed into the ground, 12 inches of shale and 18 inches of top, soil is put on top. Is this enough to stop any radiation leaks from the ground? Mr. Sarracino explained that once the monitoring is done for ten years it should be safe for our people to use again.

There are no future plans for any recreation projects for the people of Paguate. I found out that the village of Paguate has a very big natural resource that can hopefully be reclaimed again. Some day I hope my friends and I will be able to use the mines and that we can safely use the land for a good purpose. I hope the uranium will never be mined again, this can only destroy not only my generation but future generations of Indian children and Mother Earth.

Thank you.

concentration in the water. It had to be drained and closed, and the irrigation system to the village of Mesita which is downstream from Paguate had to stop, and it virtually brought agriculture to a standstill.

The ongoing reclamation project at the Jackpile Mine, which is the first attempt of its kind in the world to reclaim an open pit uranium mine. The Environmental Impact Statement estimated that it would cost 400 million dollars to successfully reclaim the Jackpile Mine, and as my little sister Suwimi said here, we have only been given 43 million by ARCO to reclaim that land. So you know, big contradiction in that wide gap of dollars.

Again, the Jackpile Mine being reclaimed: They are doing this at three-to-one slopes. And the three-to-one slopes seem to be too steep, because after a very wet winter and a large amount of snow fall, that three-to-one sloping has dendridic pattern run-off that flows through the Rio San José, that flows through the Rio Paguate and Rio Moquino(?), which flows right through the middle of the Jackpile Mine during operations, that eventually feeds the Rio San José, that feeds the Mesita Dam, that eventually flows into the Rio Grande in New Mexico, which is the life blood of our state. And this three-to-one sloping now is eroding so bad because of the heavy snowfall that you can see beyond the 18 inches of top soil and the 12 inches of shale that have been used to cover it. They have had to terrace off those three-to-one slopes because they are too steep and it doesn't seem like this reclamation is stopping the so-called "low-level contaminants" to continue to get into the river and impact people downstream.

Suwimis' school bus going right through the middle of the Jackpile Mine. In fact, they found high levels of radon in the pavement on this road that goes right through the bottom of the mine, and they had to tear it up and repave it again. I wouldn't rely on the repaving job not having any radon in it.

Some of the structural damage to a traditional sandstone pueblo house in the village of Paguate as a result of blasting, which Greg addressed. This is our house that was repaired by the company, and although it looks uncracked, all they did was stucco over the cracks. This is another traditional pueblo dwelling. It was insulting to the intelligence of our people when they came in and would repair the houses, repair the cracks. One thing the company did was put panelling on the interior walls of the houses, so that the cracks wouldn't show - like we didn't know there were cracks behind the panel! And there was a time there, in the 1970's, if you went into almost any house in Paguate you would see the wall panelled.

Again our mountain. - Greg and Suwimi taking the reclamation tour. - Victor Sarracino, a Laguna Pueblo man who is monitor technician with the reclamation project. And that concludes our video presentation.

Again, for the panel and myself, as indigenous people from the Southwest we are very honoured to have met all the other indigenous groups that have presented their testimony and their cases here at The World Uranium Hearing, and we would like to continue to develop this communication network and communicate with you, so that we continue the struggle as a unified one people or, as Floyd Westerman suggested, "United Indigenous Nations".

Father John (Moderator)

Those were the voices of fathers, the voice of a mother and the voice of a child. And everybody of us will understand. We have seen from the slides how beautiful that country is. But due to the craziness of man they have destroyed and are continuing to destroy this Mother Land.

Ladies and gentlemen, this is why we as priests come in when the environment, our Mother Land, is destroyed, because if we stay aloof we'll have nobody to preach to. Because they are all gone. That is why you see some of us here as priests. We are here because we are all involved in this Mother Land. God created everything and found it was good. So who are we, to say that it is not good?

Before we wind up, there are people from the same Colorado Plateau, from the Diné Nation. Please feel welcome.

Philipp Harrison

Philipp Harrison, Diné (Navajo) Nation, Arizona, USA. President of the Uranium Radiation Victims Committee, co-founder of the Four Corners Navajo Millers' Association, Navajo Compensation Officer of the Navajo Nation for the compensation of miners.

Hello! My name is Phil Harrison from the Navajo Nation which is near the Four Corners of America. I am of the Red House Clan on my mother's side and Red-Sand-Run-Into-The-Water [Clan] of my father. I'm currently serving as President of the Uranium Radiation Victims Commitee and co-founder of the Four Corners Navajo Millers' Association, which is located in my area in Shiprock, in the Navajo Nation. It's my pleasure to be a participant in this Hearing. It is our commitment, sacrifice and dedication that we educate the people all over the world about radiation and other uranium poison. I have been in this work for ten years.

In my presentation today I will share with you the experience of nightmares of what my family and my people have endured for five decades. I'm listed to give a presentation of the compensation which I'll briefly touch. I'll share with you as much as I can, of our suffering and humiliation that was put upon us. We live, work and play in the Four Corners Area. This area is part of the Colorado Plateau where the region contains one of the largest reserves of uranium. From the 1940's to the 1970's, uranium was mined and milled for weapons and nuclear development. The Red Valley Area was the center of the mining activity. This is where hundreds of Navajo men have been enslaved.

My father was one of these men who have worked in this area. This was also the introduction to America's industrialized system. The unemployment was high back then and there was no jobs available. The early mines were very unsafe and dirty. There was no ventilation of these mines, no safety equipment, no respirators, no gloves were provided. They were constantly exposed to radiation and other gases and smoke from the blasting. The mine water was used for public consumption and often taken home and used for baby-formulas. I have heard all kinds of stories the men have faced. Like, for example, a miner would pass out in the mine, they would be dragged out of the mine and given smelling salts and they were driven back to go back to work, for 24 hour shifts, seven days a week. Most of them were not told of the dangers of mining, nor of the exposure of radiation. The households were also contaminated when the miners would go home with their clothes dirty. 40 years later, men died of lung cancer and other respiratory illnesses.

My father, when he died two years ago, was only 43 years old. It was very, very hard for me to see him die a painful death. He weighed only 90 pounds when he left us. I have never witnessed anything like the way he died. And I watched my mother suffer. My mother had to pick up the responsibilities of raising us. My young brother and two sisters were too young and hardly knew their father. Today, they ask why and how he died, and why the uranium company and the U.S. government treated them like guinea-pigs. Many other questions remain unanwered.

I'm constantly asked how did I get involved. Seeing this happen and having the nightmares, I decided to get involved and help those who are suffering. Hundreds have died now of similar patterns mostly from lung cancer and respiratory problems. The first 16 miners that died, their average age was only 43 years.

Based on the physical evidence and devastation left behind by the uranium companies, law suits were drawn up and they went nowhere. The uranium companies said they were never responsible for the dying of miners nor the radioactive wastes they left behind.

This left us no alternatives but to resort to Congress. Finally, after so many years, the U.S. Congress had passed the Radiation Exposure Compensation Act in October of 1990. We did not realize that the elegibility criteria were very strict. To make the long story short, you had to be on the death bed to qualify for the compensation. I personally had asked the Department of Justice why, why was the compassionate payments mentioned, why they just paid the miners, why that law was so strict.

For example, the living miner had to produce x-rays that were certified, fibrosis- and pulmonary function tests, a blood status test had to be done. All of this had to be most recently updated. The widows were asked to come up with death certificates, medical records, work history and other pertinent records that would make them eligible. We did not keep vital records because we did not know what the uranium was going to do later on. As of today, we don't have high-tech facilities or specialized equipment to assess and help to validate the needed documents. All of this garbage is just another way, another scheme to manipulate the Indian nation. They did not want to pay out the money. I'm assisting a lot of miners and families by collecting documents, instructing them where to go to get registered. I do the interpreting, corresponding and reconducting their work history. This job requires being on duty seven days a week, ten to twelve hours a day; much more remains with this program. DOJ (Dpt. of Justice) had established this unit for 20 years, so there is a lot of work that remains.

Not only were the miners victims, but the Navajo mill workers were all showing symptoms of this very exposure to uranium and the other elements when they were processing uranium. The miners and millers were not the only victims of exposure. There are land, water, air and livestock, and our young generations were severely impacted. Birth defects are very high by this poisoning. Today, we still have to look for solutions and continue to explore options of how we have to deal with this, providing proper health services and cleaning up of left-over tailings and abandoned uranium mines. There is over 1,200 mines abandoned right now. The radioactive wastes are still very hot and range 50 to 100 times over the natural background. The abandoned mines are still hot and pose health risks by emitting radon gases. One of these mines that leak water, the livestocks feed on it. 26 years after the mining has stopped, we are left with the waste, the sickness and sometimes no alternatives to restore what was the original. The genocide will never be forgotten.

After 22 years after my father died I still remember him well, I still dream with him and seems like it was only yesterday. Yes, compensation is available, but money will not make up for the loss of our loved ones. The radioactive waste they say is safe, why can't they be placed in their own backyard? I speak the truth and sometimes work very hard at, I'm like Manuel, who has stated before, I'm not very popular at home among the politicians. Now, myself and all of us here, it's up to us to continue in our work and make our world a safe environment for all the living things and the young generation to live on.

Thank you.

Anna Rondon

Anna Rondon, Diné (Navajo) Nation, Arizona, USA. Member of Southwest Indigenous Uranium Forum.

Greetings, yat'e! My name is Anna Rondon, my Christian name. My Navajo name is (...?), and at this time, I like to give you a presentation that is going to include the Southwest Indigenous Uranium Forum, how we're networking, and my second statement would be a statement read from our president, Peterson Zah, who is the leader of the Navajo Nation.

First of all, at this time I really like to tell the European people that we come over here and it's very significant the indigenous peoples, especially from the Southwest, come and voice our concerns. The European people must also realize, to be indigenous means that we can still practice the traditions, our culture, which was given to us directly from the Great Creator. We still have that. I've learned that the European people have lost that. So, I feel you are not indigenous. I used to think you were, but somewhere along the time during your history you lost direction. In this building here, I see Christianity. I think you, too, were victims of Christianity. You need to research on your tribal, indigenous teachings. Research it! You need to research the roots, you need to find your roots in this land here, the European countries. Your roots are here. As I heard, the oldest tree is here in Austria. Prove it, prove it to us!

There is a lot of technical information I'd like to share with you, but I think the Pueblo delegation, the Acomas and Lagunas did a fine job on

Dorothy Purely

Paguate, Pueblo of Laguna

"My fellow Native Americans and friends. My name is Dorothy Purley. I would like to greet you in Keresan, which is the language that I speak. Gaawa-zee. Gaa daawa sstradraask? It means, "Hello. How are you this morning?

"I would like to tell you a little about myself. I am from the Pueblo of Laguna which is about 60 miles or so west of Albuquerque, New Mexico. We have seven villages in the Pueblo of Laguna. The village that I live in is called Paguate. Paguate is where you can find the world's largest open pit uranium mine. As you may know, uranium is radioactive and can be deadly to the human body. It can cause all sorts of problems if a person should live in close proximity to it. It has caused much damage to us that live in the village of Paguate. Although the mine is no longer in operation, it continues and will continue to harm us for generations to come. It has caused so much damage. This is the reason I speak out against uranium mining, Monitored Retrievable Storage and other toxic dumping on our beautiful Mother Earth.

"Our tribal leaders were never told that they would be jeopardizing their peoples' health. They were never told that radiation is dangerous."

"I am going to start by talking about my personal health problems. I was diagnosed with lymphoma about 2 years ago. Lymphoma is cancer of the immune system. It affects the entire human body because the white blood cells are a part of every bit of living tissue that we have. I have gone through some pretty rough times with this cancer. I endured one year of high dose chemotherapy which caused me to lose my hair, my teeth and my healthy immune system. I have to take special care of myself even if I catch a simple cold. I can no longer feel the sen-sation in my fingers and toes. I have to use a cane because I fall easily. There are so many things I can no longer do. Please don't let this happen to you.

"I guess if I could compare this with the emotional side of having cancer, it would be nothing in comparison. All kinds of things come to mind when you think that you are going to die. My main concern when I learned that I had cancer was my beautiful daughter. You see, my daughter is my only child. If I die, who is going to care for her? I also have two grandsons. They are the joy of my life. Who will love them like I do? All these things come to mind. I toss and turn at night and constantly worry about this. Don't let this happen to you while you still have a choice.

"I never had the privilege of having a choice. I was just a teenager when the Anaconda Jackpile Mine first began its operation. Our tribal leaders at the time thought that they were making a wise decision for the Pueblo of Laguna. They were never told that they would be jeopardizing their people's health. They were never told that radiation is dangerous.

and that their children and their children's children would suffer the ill effects of their decision. But you have the knowledge. You know what damage radiation can do. You have the power to stop the same thing from happening to you and your generations. Make the right choice.

"Lately, I have started taking a health survey. Some concerned citizens and I have formed a group. Our group is called the Laguna-Acoma Coalition for a Safe Environment. Our hope is that we might get a health study done in the Paguate area. We are planning to work along with the doctors at the University of New Mexico cancer center. We have been lucky enough to receive a grant from CCRI which is the Childhood Cancer Research Institute. One of our ultimate goals is to start a compensation act for mill workers and open-pit miners. When I started the survey, I can tell you that I was not ready to see and hear what has been happening with the health of my people. It was a very rude awakening. I have found out so many things. We have case after case of death by cancer. Just recently, my brother-in-law, my aunt and two close cousins have died from cancer. We have mental retardation, physical deformity. Our children are developing leukemia. Young women are experiencing miscarriages. We have an alarming rate of upper respiratory diseases such as asthma and bronchitis. This is just the tip of the iceberg. I have only just begun with uncovering the damage that our once prosperous uranium mine has left for us. I sometimes think to myself, 'If I only had been given a choice...'

"I would like to close and say that I will pray for all of you. May our Great Spirit bless you and guide you in all your decisions. May you always be able to face our Great Spirit with clean hands and open heart. Thank you."

Lenore Sarracino near her home in Paguate (left - photo by Deb Preusch), only 150 yards from the Jackpile Mine boundary. Laguna miners at the Jackpile Mine (above - photo by Tom Berry). All 5 miners in this picture have died of cancer related illnesses.

EPA 906/9-75-002

WATER QUALITY IMPACTS OF URANIUM MINING AND MILLING ACTIVITIES IN THE GRANTS MINERAL BELT, NEW MEXICO

U. S. ENVIRONMENTAL PROTECTION AGENCY

REGION VI, DALLAS, TEXAS 75201

September 1975

Purpose and Scope

In September 1974, Mr. John Wright of the New Mexico Environmental Improvement Agency requested that the staff of EPA Region VI assist in implementing a survey of the uranium mining and milling activities of the Grants Mineral Belt to determine the impact of these activities on surface and ground water in the area.

The objectives outlined for the survey were:

1. Assess the impacts of waste discharges from uranium mining and milling on surface and ground waters of the Grants Mineral Belt.

2. Determine if discharges comply with all applicable regulations, standards, permits and licenses.

3. Evaluate the adequacy of company water quality monitoring networks, self-monitoring data, analytical procedures and reporting requirements.

4. Determine the composition of potable waters at uranium mines and mills.

5. Develop priorities for subsequent monitoring and other follow-up studies.

In response to the request by the New Mexico Environmental Improvement Agency, plans were developed to conduct a joint, cooperative study involving Region VI, EPA; the Office of Radiation Programs - Las Vegas Facility (ORP-LV); the National Enforcement Investigation Center, Denver (NEIC-Denver), and the New Mexico Environmental Improvement Agency (NMEIA).

A reconnaissance was conducted in January 1975 to view the study areas, meet with mining/milling company officials, and plan the data collection effort. Sample collection began in late February 1975, and was completed in early March 1975. Laboratory analyses for trace metals, gross alpha, radium-226 analysis and other radiological analyses were completed in July 1975.

Study Results

The details of the study are presented in two reports which are appended to this summary report: Surface Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico, and Ground-Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico.

Based on the data collected and analyzed, the following conclusions and recommendations were developed.

SUMMARY AND CONCLUSIONS

I. TASK: Assess the Impacts of Waste Discharges from Uranium Mining and Milling on Surface and Ground Waters of the Grants Mineral Belt.

1. Ground water is the principal source of water supply in the study area. Extensive development of ground water from the San Andres Limestone aquifer occurs in the Grants-Bluewater area where the water is used for agriculture, public water supply, and uranium mill feed water. Development of shallow, unconfined aquifers in the alluvium also occurs in this area. Principal ground-water development in the mining areas at Ambrosia Lake, Jackpile-Paguate, and Churchrock is from the Morrison Formation and, to a lesser extent, from the Dakota Sandstone or the Tres Hermanos Member of the Mancos Shale. The Gallup water supply is derived primarily from deep wells completed in the Gallup Sandstone using well fields located east and west of the urban area and 11 kilometers north of the city.

2. In proximity to the mines and mills and adjacent to the principal surface drainage courses, shallow ground-water contamination results from the infiltration of (1) effluents from mill tailings ponds; (2) mine drainage water that is first introduced to settling lagoons and thence to watercourses, and (3) discharge (tailings) from ion exchange plants. In the case of the Anaconda mill, seepage from the tailings ponds and migration of wastes injected into deep bedrock formations is observed in the San Andres Limestone and in the alluvium, both of which are potable aquifers. With the exception of seepage from the Kerr-McGee Section 36 mine in Ambrosia Lake, significant amounts of wastewater from the remaining mines and mills probably does not return to known bedrock aquifers. Deterioration of water quality results from conventional underground mining as a result of penetration or disruption of the ore body. The most dramatic changes are greatly increased dissolved radium and uranium. Induced movement of naturally saline ground water into potable aquifers is also likely but undocumented. Similarly, the ground-water quality impacts of solution (<u>in situ</u>) mining are unknown.

3. The Grants, Milan, Laguna, and Bluewater municipal water supplies have not been adversely affected by uranium mining and milling operations to date. For the Grants and Milan areas, chemical data from 1962 to the present indicate that near the Anaconda mill some observation wells have increased slightly in total dissolved solids, sulfate, chloride and gross alpha but domestic wells have generally remained unchanged. Projections made in 1957 of gross nitrate deterioration of ground water have not been substantiated by subsequent data. Of the municipal supply wells in the study area, the Bluewater well bears additional monitoring because of its location relative to the Anaconda tailings ponds.

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I. TASK: Assess the Impacts of Waste Discharges from Uranium Mining and Milling on Surface and Ground Waters of the Grants Mineral Belt.

1. Ground water is the principal source of water supply in the study area. Extensive development of ground water from the San Andres Limestone aquifer occurs in the Grants-Bluewater area where the water is used for agriculture, public water supply, and uranium mill feed water. Development of shallow, unconfined aquifers in the alluvium also occurs in this area. Principal ground-water development in the mining areas at Ambrosia Lake, Jackpile-Paguate, and Churchrock is from the Morrison Formation and, to a lesser extent, from the Dakota Sandstone or the Tres Hermanos Member of the Mancos Shale. The Gallup water supply is derived primarily from deep wells completed in the Gallup Sandstone using well fields located east and west of the urban area and 11 kilometers north of the city.

2. In proximity to the mines and mills and adjacent to the principal surface drainage courses, shallow ground-water contamination results from the infiltration of (1) effluents from mill tailings ponds; (2) mine drainage water that is first introduced to settling lagoons and thence to watercourses, and (3) discharge (tailings) from ion exchange plants. In the case of the Anaconda mill, seepage from the tailings ponds and migration of wastes injected into deep bedrock formations is observed in the San Andres Limestone and in the alluvium, both of which are potable aquifers. With the exception of seepage from the Kerr-McGee Section 36 mine in Ambrosia Lake, significant amounts of wastewater from the remaining mines and mills probably does not return to known bedrock aquifers. Deterioration of water quality results from conventional underground mining as a result of penetration or disruption of the ore body. The most dramatic changes are greatly increased dissolved radium and uranium. Induced movement of naturally saline ground water into potable aquifers is also likely but undocumented. Similarly, the ground-water quality impacts of solution (<u>in situ</u>) mining are unknown.

3. The Grants, Milan, Laguna, and Bluewater municipal water supplies have not been adversely affected by uranium mining and milling operations to date. For the Grants and Milan areas, chemical data from 1962 to the present indicate that near the Anaconda mill some observation wells have increased slightly in total dissolved solids, sulfate, chloride and gross alpha but domestic wells have generally remained unchanged. Projections made in 1957 of gross nitrate deterioration of ground water have not been substantiated by subsequent data. Of the municipal supply wells in the study area, the Bluewater well bears additional monitoring because of its location relative to the Anaconda tailings ponds.

4. Contamination of the Gallup municipal ground-water supply by surface flows, consisting mostly of mine drainage, has not occurred and is extremely unlikely because of geologic conditions in the well field and the depth to productive aquifers. Another well field north of the City will, in no way, be affected by the drainage.

5. With the exception of the area south and southwest from the United Nuclear-Homestake Partners mill, widespread ground-water contamination from mining and milling was not observed in the study area. Throughout the study area widespread contamination of ground water with radium was not observed despite concentrations of as much as 178 pCi/l in mine and mill effluents. Radium removal is pronounced, probably due to sorptive capacity of soils in the area. In the vicinity of the Anaconda mill, radium and nitrate concentrations in the alluvial aquifer decline with distance from the tailings ponds, but neither parameter exceeds drinking water standards.

6. Ground water in at least part of the shallow aquifer developed for domestic water supply downgradient from the United Nuclear-Homestake Partners mill is contaminated with selenium. Alternative water supplies can be developed using deep wells completed in the Chinle Formation or in the San Andres Limestone. Potential well sites are located in the developments affected or in the adjacent area. A third alternative includes connecting to the Milan municipal system. Further evaluations are necessary to determine the best course of action.

7. Mining practices, per se, have an adverse effect on natural water quality. Initial penetration and disruption of the ore body in the Churchrock mining area increased the concentration of dissolved radium in water pumped from the mines from 0.05 - 0.62 pCi/l to over 8 pCi/l. According to company data, the concentration rose to over 75 pCi/l, or at least 75 times the natural concentration in the two-year period during which the mine was being developed. The pattern of increasing radium with time, also seen in Ambrosia Lake, is being repeated. Ground-water inflow via long holes in the Kerr-McGee Section 36 mine contain a relatively low concentration of dissolved radium-226. Therefore, much of the radium loading of mine effluent is apparently a result of leaching of ore solids remaining from mucking and transport within the mine. In some cases, this could be reduced by improved mining practices such as provision of drainage channels along haulage drifts.

8. Radium concentrations in Arroyo del Puerto, a perennial stream, exceed New Mexico Water Quality Criteria as a result of discharges from the Kerr-McGee ion exchange plant and Section 30W and 35 mines, and from the United Nuclear-Homestake Partners ion exchange plant. Selenium and vanadium concentrations exceed EPA 1972 Water Quality

8. (Continued)

Criteria for use of the water for irrigation and livestock watering, and render the stream unfit for use as a domestic water source.

9. Company data show that seepage from the Anaconda tailings pond at Bluewater averages 183 million liters/year (48.3 million gallons) for 1973 and 1974. The average volume injected for the same time period was 348 million liters/year (91.9 million gallons). Therefore, approximately one-third of the total effluent volume remaining after evaporation (531 million liters/year) enters the shallow aquifer, which is a source of potable and irrigation water in Bluewater Valley. From 1960 through 1974, seepage alone introduced 0.41 curies of radium to the shallow potable aquifer. Adequate monitoring of the movement of the seepage and the injected wastes is not underway.

10. There are indications that waste injected into the Yeso Formation by the Anaconda Company are not confined to that unit as originally intended in 1960. Three nearby monitoring wells, completed in the shallower San Andres Limestone and/or the Glorieta Sandstone, show a trend of increasing chloride and uranium with time. Positive correlations of water quality fluctuations with the volumes of waste injected are a further indication of upward movement. The absence of monitoring wells in the injection zone is a major deficiency in the data collection program.

11. Rainfall and runoff at the Anaconda Jackpile Mine erode uranium- and selenium-rich minerals into Rio Paguate. This erosion can be mitigated by waste stabilization and runoff control.

12. The maximum concentration of radium observed in shallow ground water adjacent to the Kerr-McGee mill at Ambrosia Lake was 6.6 pCi/l. According to company data, seepage from the tailings ponds occurs at the rate of 491 million liters/year (130 million gallons/year). This is 29 percent of the influent to the "evaporation ponds" and attests to their poor performance in this regard. Radium and gross alpha in the seepage are 56 pCi/l and 112,000-144,000 pCi/l, respectively. Total radium introduced to the ground water to date is estimated at 0.7 curies. Wells completed in bedrock and in alluvium, and located near watercourses containing mine drainage and seepage from tailings ponds, contain elevated levels of TDS, ammonia, and nitrate. One well, which contained 1.0 pCi/l in 1962 now is contaminated with 3.7 pCi/l of radium. Sorption or bio-uptake of radium is pronounced, hence concentrations now in ground water are not representative of ultimate concentrations.

13. Water-quality data from 11 wells over a 200-square kilometer area in the Puerco River and South Fork Puerco River drainage basins reveal

13. (Continued)

essentially no noticeable increase in concentrations of radionuclides or common inorganic and trace constituents in ground water as a result of mine drainage. Natural variations in the uranium content of sediments probably account for differences in radium content in shallow wells. Dissolved radium in shallow ground water underlying stream courses affected by waste water is essentially unchanged from areas unaffected by mine drainage. None of the samples contained more than recommended maximum concentrations for radium-226, natural uranium, thorium-230, thorium-232, or polonium-210 in drinking water. However, the paucity of sampling points and the absence of historical data make the foregoing conclusion a conditional one, particularly in the reaches of the Puerco River within approximately 10 kilometers downstream of the mines.

14. Four wells sampled in the vicinity of the Jackpile mine near Paguate contained 0.31 to 3.7 pCi/l radium-226. With the exception of the latter value from the new shop well in the mine area, remaining supplies contain 1.7 pCi/l or less radium. The Paguate municipal supply contains 0.18 pCi/l. None of the wells were above maximum permissible concentrations (MPC) for the other common isotopes of uranium, thorium, and polonium. Ground water from the Jackpile Sandstone may contain elevated levels of radium as a result of mining activities. Mine drainage water ponded within the pit contained 190 pCi/l radium and 170 pCi/l of uranium in 1970. The impacts of mining on groundwater quality downgradient from the mining area are unknown due to the lack of properly located monitoring wells. No adverse impacts from mining on the present water supply source for Paguate are expected.

15. Of the 71 ground-water samples collected for this study, a total of 6 had radium-226 in excess of 3 pCi/l PHS Drinking Water Standard. Two of the 6 involved potable water supplies. One containing 3.6 pCi/l serves a single family and is located adjacent to Arroyo del Puerto and downgradient from the mines and mills in Ambrosia Lake. The second contains 3.7 pCi/l and is used as a potable supply for the labor force in the new shop at the Jackpile Mine.

16. The highest isotopic uranium and thorium, and polonium-210 contents for any potable ground-water supplies sampled in the study area are less than 1.72% of the total radionuclide population guide - MPC as established in NMEIA regulations.

17. The lowest observed concentration (background levels) in ground water are summarized as follows:

17. (Continued)

Radionuclides	Range (pCi/l)	Average (pCi/l)
Radium-226	0.06 - 0.31	0.16
Polonium-210	0.27 - 0.57	0.36
Thorium-230	0.013 - 0.051	0.028
Thorium-232	0.010 - 0.024	0.015
U-Natural	14 - 68	35

18. The uranium isotopes (uranium 234, 235 and 238) are the main contributors to the gross alpha result; however, in several determinations, gross alpha underestimated the activity present from natural uranium.

19. No correlation was found between gross alpha content of 15 pCi/l (including uranium isotopes) and a radium-226 content of 5 pCi/l.

20. It is doubtful that the gross alpha determination can even be used as an indicator of the presence of other alpha emitters (e.g. U-natural and polonium-210); and since the gross alpha results have such large error terms, no meaningful determination of percentage of radionuclides to gross alpha can be implied.

21. Gross alpha determinations also failed to indicate the possible presence of lead-210 (primarily a beta emitter) which, because of the lower MPC of 33 pCi/l, may be a significant contributor to the radiological health hazard evaluation of any potable water supply.

22. Radium-226 in ground water is a good radiochemical indicator of waste-water contamination from mines and mills. Due to the low maximum permissible concentration, it also provides a good means for evaluating health effects. Selenium and nitrate also indicated the presence of mill effluents in ground water. Polonium-210, thorium-230 and thorium-232 concentrations in ground water fluctuate about background levels and are poor indicators of ground-water contamination from uranium mining and milling activities.

23. For routine radiological monitoring of potable ground-water supplies, isotopic uranium and thorium and polonium-210 analyses do not appear to be necessary due to their high maximum permissible concentrations (chemical toxicity of uranium may be a significant limiting factor, however).

II. Task: Determine if Discharges Comply with all Applicable Regulations, Standards, Permits, and Licenses.

1. At the time of sampling, the effluent from the Kerr-McGee ion exchange plant contained dissolved radium-226 at concentrations in excess of the applicable NPDES permit and New Mexico uranium-milling license conditions. This radium discharge was partly responsible for violations of New Mexico Water Quality Standards for Arroyo del Puerto, a perennial stream. The discharge also contained uranium at concentrations in excess of NPDES permit criteria. No treatment other than settling is currently in operation.

2. The Kerr-McGee Section 30W mine discharge contained dissolved radium-226 at concentrations in excess of the applicable NPDES permit condition. No treatment other than settling is currently in operation. This radium discharge also was partly responsible for violation of New Mexico Water Quality Standards in Arroyo del Puerto.

3. Kerr-McGee Nuclear Corporation has not applied for a discharge permit for their Section 35 mine, although the effluent reaches Arroyo del Puerto, a perennial stream. The discharge contains an average of 51 pCi/l of dissolved radium-226. No radium-removal treatment is currently in operation.

4. Sampling at the United Nuclear Corporation Churchrock mine was conducted when the operation was inactive due to a power failure and subsequent mine flooding. Indications are that the present treatment facility is inadequate to meet existing NPDES permit conditions.

5. Approximately 15 percent of the total flow through the United Nuclear-Homestake Partners ion exchange plant is discharged to Arroyo del Puerto, with the balance of the flow returning to the mines for in situ leaching. The discharge to Arroyo del Puerto is not regulated by an NPDES permit, and contributes to the violation of New Mexico Water Quality Standards for radium-226 in this perennial stream. Uranium is lost from the ion exchange facility. The facility is currently violating conditions of the applicable State license.

III. Task: Evaluate the Adequacy of Company Water Quality Monitoring Networks, Self-Monitoring Data, Analytical Procedures, and Reporting Requirements.

1. Company sponsored ground-water monitoring programs range from inadequate to nonexistent. Actual monitoring networks are deficient in that sampling points are usually poorly located or of inadequate depth/location relative to the hydrogeologic system and the introduction of contaminants thereto. Compared to the multi-million dollar uranium industry, producing multi-billion liters of toxic effluents, the ground-water sampling and monitoring programs represent minimal efforts in terms of network design, implementation, and level of investment.

2. Company radiochemical analytical methods are inadequate for measuring environmental levels of radionuclides and have high minimum detectable activities and large error terms. Incomplete analysis of radionuclide contents prevails. Few data are reported on other naturally occurring radionuclides such as isotopic thorium, polonium-210, and radium-228. In some cases, monitoring has been restricted to analysis of radium-226 and natural uranium, without consideration of these other radionuclides or toxic metals.

3. Monitoring of hydraulic and water-quality impacts associated with conventional mining and with solution (<u>in situ</u>) mining is not reported to regulatory agencies. It is likely that such monitoring is limited to meeting short-term economic and engineering needs of the companies rather than addressing long-term, general environmental concerns. As a result, overall impacts on ground water are not routinely determined and reported.

4. Off-site ground-water sampling networks do not utilize wells specifically located and constructed for monitoring purposes. Reliance on wells already in existence and utilized for domestic or livestock use falls short of the overall monitoring objectives (i.e., to determine impacts on ground water and to adjust company operations to acceptable levels). Deficiencies of this type can allow contamination to proceed unnoticed. On-site wells constructed specifically for monitoring are generally not completed to provide representative hydraulic and water quality data for the aquifer most likely to be affected.

5. Proven geophysical and geohydrologic techniques to formulate environmental monitoring networks are apparently not used. Such techniques can assist in specifying sampling frequencies, and provide the basis for adjustment of monitoring and operational practices to mitigate adverse impacts on ground water.

6. Monitoring the effects of the Jackpile and Paguate open pit mines on ground-water quality is nonexistent, despite the magnitude of these operations. Drainage water within the pits has contained as much as 190 pCi/l. Two wells, used for potable supply and completed in the ore body contain elevated levels of radium, further indicating a need for data to determine what the future impacts might be when mining ceases and before additional programs for heap leaching and <u>in situ</u> mining are implemented.

7. Careful analysis of material and water balances to determine seepage input to ground water for the various tailings disposal operations is not evident. For the Anaconda Company, the method utilized has not been altered in 14 years. For Kerr-McGee, overland flow presents a potential threat to the structural integrity of the retention dams. At the United Nuclear-Homestake Partners Mill, no quantitative estimates of seepage are available.

8. Records of U. S. Atomic Energy Commission (USAEC) inspection reports, mill license applications, seepage reports, etc., on file with the State appear to be incomplete and disorganized. No interpretive summary or review-type reports utilizing the monitoring data reported by industry are available from either the State or the U. S. Atomic Energy Commission files now held by the State. Liberal mill licensing conditions with respect to ground-water monitoring and water-quality impacts were initially established by the USAEC. Subsequently, there has been essentially no review, in any critical sense, of company operations with respect to ground-water contamination. The uranium mining and milling industry has not been pressed to monitor and protect ground-water resources. The limited efforts put forth by industry to date have largely not been reviewed by regulatory agencies at the State and Federal levels.

IV. Task: Determine the Composition of Potable Waters at Uranium Mines and Mills.

1. Four industry potable water supply systems, obtained from mine waters, exceeded 1962 U. S. Public Health Service Drinking Water Standards for selenium. Three such potable systems exceeded both the existing USPHS and proposed EPA Interim Primary Drinking Water Standards for radium. Such mine water is supplied as potable to families of miners at the United Nuclear Corporation Churchrock mine. These conditions are considered intolerable as they bear on the long-term health of those using the supplies. Non-potable systems at the Kerr-McGee mill and Churchrock mine have high radium and selenium concentrations, and are not adequately marked as non-potable.

V. Task: Develop Priorities for Subsequent Monitoring and Other Follow-up Studies.

See RECOMMENDATIONS

RECOMMENDATIONS

Action Required

1. Procedures be initiated to require United Nuclear Corporation to immediately provide potable water which meets Federal Drinking Water Standards for their Ambrosia Lake and Churchrock operations.

2. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately provide potable water supplies which meet Federal Drinking Water Standards at their mill and Section 35 and 36 mines; the mill and Churchrock mine non-potable water supplies be clearly marked.

3. NMEIA initiate appropriate action to insure safe industrial potable water supplies at the United Nuclear Corporation's Ambrosia Lake and Churchrock operations and at the Kerr-McGee Nuclear Corporation's mill and Section 35 and 36 mines.

4. NMEIA should conduct periodic sampling of potable water supplies at operating uranium mines and mills throughout the State.

5. Improved industry-sponsored monitoring programs should be implemented and the data made available to State and Federal Regulatory Agencies. Programs should be designed to detect likely hydraulic and water quality impacts from uranium milling and mining (open pit, underground, in situ). Revamped programs, specifically developed by joint concurrence of industry and regulatory agencies, should be incorporated in licenses, where possible. Licenses should specify minimal radiochemical analytical methods for detecting specific radionuclides as well as requirements for participation in quality assurance programs. Specific reporting procedures should include raw data, summary reports, and interpretations of data. Conclusions concerning impacts of operations on ground-water quality and remedial steps taken to abate or eliminate adverse impacts should be prepared. It is essential that the programs developed, as well as the data and interpretive reports prepared therefrom, be critically reviewed by the State to meet continuing regulatory responsibilities.

6. Because seepage from the Anaconda and Kerr-McGee tailings ponds constitutes a significant portion of the inflow to the ponds, it is recommended that seepage control measures be adopted. According to company records, such seepage presently totals some 674 million liters per year. Water budget analyses of the United Nuclear-Homestake Partners tailings pond should be made to determine how much seepage is occurring and thereby contributing to contamination of the shallow aquifer locally developed for domestic water supplies in two adjacent privately owned housing developments.

7. Improved mining practices should be adopted to reduce the amount of radium leached from ore solids by ground water present in operating mines.

8. Procedures should be initiated to require Anaconda Company to improve its present efforts at stabilizing waste and ore piles at the Jackpile Mine in order to prevent water erosion from transporting uranium and selenium into Rio Paguate.

9. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately install necessary treatment systems to reduce the dissolved radium-226 concentration in the Section 30W mine discharge to applicable NPDES permit conditions.

10. Procedures be initiated to require Kerr-McGee Nuclear Corporation to file an application for discharge from their Section 35 mine. The permit should provide limits on total suspended solids, radium-226 and uranium, consistent with the permit conditions for the Section 30W mine.

11. Procedures be initiated to require Kerr-McGee Nuclear Corporation to immediately install necessary treatment systems to ensure that effluent from their ion exchange plant meets applicable NPDES permit and State uranium-milling license conditions. The Company should develop operating schedules to guard against undetected uranium breakthrough and subsequent discharge of uranium to Arroyo del Puerto.

12. United Nuclear-Homestake Partners should install necessary pumps and pipe lines necessary to achieve complete recycle of ion exchange discharge. If unable to accomplish this, it will be necessary to apply for an NPDES permit, and immediately install necessary treatment facilities to come into compliance with the applicable State uranium-milling license.

ADDITIONAL STUDIES REQUIRED

1. Studies should be immediately initiated to verify whether the source of ground-water contamination in the Broadview Acres and Murray Acres subdivision is from the nearby uranium mill. A sound monitoring program should be developed to predict contaminant migration and to provide the basis for subsequent enforcement action. Necessary action should be taken to provide potable water for the affected area. Studies should be undertaken to determine the means to prevent continuing contamination.

2. With regard to the Anaconda waste injection program, all available chemical and water level data for pre-injection and post-injection periods should be evaluated to ascertain if waste is migrating out of the Yeso Formation and into overlying aquifers containing potable water. Of particular concern are radium-226 and thorium-230 because of their abundance in the injected fluid. Limited chemical data indicating migration of waste beyond the injection interval necessitate that a thorough re-evaluation be made of the long term adequacy of this method of waste disposal. Construction of additional monitoring wells in the Yeso Formation and the Glorieta-San Andres is in order. Because of low MPC values, this is particularly true if increasing concentrations of radium-226 and possibly lead-210 are appearing in the aquifers above the injection zone. The Anaconda Company should also evaluate the current loss of uranium resources to the subsurface through their current disposal technique.

3. Available chemical data for ground-water samples collected by Kerr-McGee from wells located adjacent to Arroyo del Puerto and San Mateo Creek should be evaluated for long-term trends in water quality. Data for the Wilcoxson (P. Harris), Bingham, Marquez, and County Line Stock Tanks wells are of principal concern.

4. Water-quality data from the newly completed monitoring wells peripheral to the Kerr-McGee mill should be cross-checked using non-industry laboratories to determine the extent of contamination in the Dakota Sandstone.

5. The breadth of mining and milling activities in the Grants Mineral Belt clearly requires additional study if ground-water impacts are to be understood in any detailed or quantitative sense. The present study provides a preliminary assessment of but a small facet of the overall activity in the district. Further study is recommended to determine impacts of past operations or expected impacts from mines and mills now in the planning or construction stage. Site specific investigations are necessary to determine the hydraulic and water quality responses to dewatering and solution mining.

6. Additional ground-water samples should be collected from wells adjacent to the Rio Puerco and east of Gallup to determine if radium concentrations are acceptably low and to establish baseline conditions for future reference. It is recommended that concentrations of trace metals should also be measured.

7. Resampling should be scheduled at the United Nuclear Corporation Churchrock mine during normal operations.

VI. WASTE SOURCE EVALUATION

Five companies are currently engaged in mining and/or milling operations in the Grants Mineral Belt, and several other companies are presently in design or construction phases. The results of waste-source evaluations at each of the operating companies are presented below.

KERR-MCGEE NUCLEAR CORPORATION

Kerr-McGee operates mines in both the Ambrosia Lake and Churchrock Mining Districts of the Grants Mineral Belt. Water from five of the Ambrosia Lake mines (Sections 17, 22, 24, 30 and 33)* is pumped to an ion-exchange plant at the Kerr-McGee mill [Fig. 2]. The majority of ion-exchange discharge (also referred to in the mining industry as tailings) is used in the mill as process water and non-potable water. A small remainder receives additional ion-exchange treatment for potable water use within the mill. Excess ion-exchange tailings are discharged into Arroyo del Puerto. The NPDES permit** and State uranium milling license for this discharge requires that the radium 226 concentration not exceed 100 pCi/l and 30 pCi/l, respectively. The data [Table 2] shows that this discharge contained an average of 151 pCi/l radium-226 during the survey. This exceeds both the NPDES permit immediate limitations and the State license. This latter license has been in effect since the time of the construction of the ion-exchange plant. The

* *The names of mines are based on the section in which they are located; all of these are in T14N, R9W, McKinley County, New Mexico.*

** *Kerr-McGee has requested an adjudicatory hearing on its permits for the ion-exchange plant and Section 30W mine. The company contends that an NPDES permit is not required to discharge to Arroyo del Puerto. The Kerr-McGee State license is effective for the Kerr-McGee ion-exchange plant.*

Add BaCl to Ra226 to lower Ra counts

concentration of radium in the ion-exchange discharge could be reduced to meet permit conditions with the relatively simple addition of barium chloride. The New Mexico Water Quality Standards for Arroyo del Puerto, a perennial stream, limits radium concentrations to a maximum of 30 pCi/l. The Kerr-McGee ion-exchange discharge to Arroyo del Puerto contributes to violations of these standards (see Section VII. *STREAM SURVEYS*).

Ra

The NPDES permit for the Kerr-McGee ion-exchange discharge limits uranium to a daily maximum concentration of 1 mg/l. During the three days of composite sampling, the uranium concentration in the discharge ranged from 1.3 to 4.2 mg/l for an average of 2.5 mg/l, or 2.5 times the permitted maximum concentration. This violation of the permitted level probably resulted from overloading of the resin and failure to switch resin columns. The Company should adopt a regeneration cycle that will prevent resin saturation by uranium (breakthrough) which results in permit violation.

Ura

Selenium is an extremely toxic substance which behaves very similarly to arsenic. It is present in the ore of the Grants Mineral Belt, and thus it could reasonably be expected to be present in water from processing plants. The Kerr-McGee ion-exchange tailings contained from 0.03 to 0.07 mg/l, an average of 0.05 mg/l. These tailings also contained almost 1 mg/l vanadium, which has been shown to be toxic to plants when present in irrigation water. The high selenium and vanadium concentration precludes the use of Arroyo del Puerto for irrigation (discussed in Section VII).

Selen

Vanad

Mine water from other Kerr-McGee Ambrosia Lake mines (Sections 19, 30W, 35, and 36) does not receive ion-exchange treatment. Section 19 Mine, currently under development, discharges approximately 378 l/min (100 gpm) of wastewater which contains 9.3 pCi/l of radium on the land surface. Since this discharge does not reach a surface water course, the Company has not applied for an NPDES permit.

The NPDES permit for the Kerr-McGee Section 30W mine imposes immediate limits on the radium-226 content of this discharge. The initial maximum limit is 150 pCi/l, with a final limit of 3.3 pCi/l [Table 1]. During the survey, this discharge contained an average concentration of 163 pCi/l of radium-226 [Table 2] which exceeds permit conditions. The discharge enters Arroyo del Puerto upstream of the Kerr-McGee ion-exchange discharge and contributes to the water quality standards violation in Arroyo del Puerto (see Section VII). The 30W discharge also contained selenium and vanadium [Table 2] and contributes to the high concentration of these elements in Arroyo del Puerto.

The uranium concentration of Section 30W mine discharge is limited to 2 mg/l daily maximum by the NPDES permit. During the survey, the uranium concentration of this discharge ranged from 5.9 to 6.7 mg/l, for an average of 6.2 mg/l, a violation of the NPDES permit conditions. The company reportedly plans to pipe this discharge to their ion-exchange plant.

During the Grants Mineral Belt survey, 14,300 m^3/day (3.77 mgd) of water was discharged from Kerr-McGee Section 35 mine settling ponds into a marshy area south of the mine. Company officials claim this discharge does not reach any surface water and therefore an NPDES discharge permit is not required. Visual observations by NEIC personnel showed that this discharge, estimated at several hundred gallons per minute, does enter Arroyo del Puerto. The flow rate was highly variable, depending on climatic conditions. The radium concentration in this wastewater ranged from 32 to 69 (average 51) pCi/l which exceeds limitations currently specified in permits for similar discharges. The radium concentrations can be reduced to less than 30 pCi/l with the addition of a barium chloride treatment system. Gross alpha concentrations were high, ranging from 2,400 to 3,000 pCi/l. ORP-LVF conducted analyses for the alpha emitters other than radium contained in this discharge. The analyses indicated that lead-210 may be significant in this and other discharges; however, the data are not available at this time. Uranium, selenium, and vanadium are also present in this discharge [Table 2] and contribute to high values in Arroyo del Puerto. Suspended solids in the Section 35 mine discharge were high, ranging from 86 to 120 mg/l with an average of 100 mg/l. Analysis of incoming mine water from long holes within the area indicates that the radium concentrations in natural ground water are less than 10 pCi/l. However, water moves over the entire floor of the drift, and it is subject to agitation by passage of haulage trains and during mucking. Accordingly, the suspended solids concentration in the mine water is high, producing a high dissolved radium concentration. The suspended solids and radium concentrations in the effluent could be greatly lowered by improved housekeeping in the mining operations, such as providing drainage channels along the sides of the mine workings.

Section 36 mine has two discharges, identified as the east and west discharges in relation to the mine shaft. Samples from each discharge were collected and analyzed. Except for a minor amount of water used by drilling rigs in the area, the entire mine pumpage receives treatment in sedimentation basins before discharge into a large closed basin over the San Mateo fault. During the survey, all the water was sinking into the subsurface and moving as ground water. Survey results [Table 2] show the west discharge contained an average of 131 pCi/l radium-226 compared to 65 pCi/l in the east discharge. These concentrations exceed license criteria (10 CFR20) for discharge to an unrestricted environment. The discharge also contained from 0.4 to 1.0 mg/l vanadium, which precludes use of this water for crop irrigation on acid soils, or long-term use on any soil (Committee on Water Quality Criteria, 1972).

Company officials stated that the Section 35 and 36 mine discharges will be diverted to a new set of treatment ponds for biological removal of radium 226, utilizing algal growth and radium incorporation. If

removal of Ra 226 by Algae

necessary, radium-226 concentrations can be further reduced by barium chloride treatment. These new ponds, to be constructed sometime during 1975, will discharge into the closed basin currently receiving the Section 36 mine discharge. The increased flow into this closed basin may result in a surface discharge to San Mateo Creek. In this case, an NPDES permit will be required which should specify an immediate radium-226 limit of 30 pCi/l.

Kerr-McGee Nuclear Corporation is developing a new mine in the Churchrock mining district. The mine water receives treatment in two sedimentation ponds. Some of the effluent from the pond is used in the mine change-house for non-potable uses such as showers and commodes, and the remainder is discharged into Rio Puerco. The immediate NPDES permit limitations for this discharge include 100 mg/l daily average and 200 mg/l daily maximum total suspended solids concentration, 2 mg/l daily maximum uranium concentration and 30 pCi/l dissolved radium-226. The lack of ongoing mining activities in the mine is reflected in the relatively low radiochemical concentration in the water from this mine [Table 2], with an average radium-226 concentration of 7.9 pCi/l.

The Kerr-McGee Nuclear Corporation mill near Ambrosia Lake removes uranium from the ore by an acid leach technique, followed by solvent extraction to concentrate the uranium, and by ammonia precipitation of yellow cake. A molybdenum byproduct recovery is also practiced at the Kerr-McGee mill. Approximately 75% of the mill water is recycled, while the other 25% is lost through seepage and evaporation. Because of dissolved solids buildup, it is thought to be impossible to practice 100% recycle without dissolved solids removal techniques. Process water for the Kerr-McGee mill is obtained from the Kerr-McGee ion-exchange treatment plant. Tailings are discharged to a single large tailings pond on the company property. Seepage from the pond is collected in a catchment basin and is then pumped to a pond upgradient from the tailings pond. Overflow from this pond is pumped upstream to another pond.

Tailings + Seepage Workings

In this way, all seepage from the evaporating ponds should be captured by the catchment basin. However, physical inspection of the area indicated that a quantity of seepage is lost to the subsurface, with a portion of the seepage possibly appearing in the flow in Arroyo del Puerto. This will require control under proposed NMEIA ground-water regulations, or regulations to be proposed under the U.S. Safe Drinking Water Act.

An 8-hr composite was collected from the catchment basin and analyzed to determine the quality of waste which might enter the ground water. The sample contained 144,000 pCi/l and 65 pCi/l, respectively, of gross alpha and radium-226. The radium concentration exceeds the AEC license criteria (30 pCi/l) for discharge to a nonrestricted environment. The gross imbalance which exists between gross alpha and radium indicates high concentrations of other alpha emitters. Identification and quantification of these emitters, and the effect on ground water, is discussed in the report by ORP-LVF. This water is extremely high in sulfate (15,000 mg/l) due to the use of sulphuric acid for leaching the Kerr-McGee ore. Suspended solids concentration in the seepage was approximately 38 mg/l. Selenium was present in 0.70 mg/l concentration, or 70 times the drinking water standard. Vanadium was present in the seepage at a concentration of 5.6 mg/l.

RANCHERS EXPLORATION AND DEVELOPMENT CORPORATION

Ranchers Exploration is currently developing the Johnny M. mine. Mine water is treated in two settling ponds before being discharged into San Mateo Creek. An NPDES permit application was filed by Ranchers Exploration, however the permit had not been issued at the time of the survey. The data [Table 2] show that the gross alpha and radium-226 concentrations were 20 and 1.6 pCi/l, respectively. This reflects the lack of ongoing mining activities in the operation. Uranium concentration in the water was 0.12 mg/l, while the suspended solids concentration was 7 mg/l.

UNITED NUCLEAR CORPORATION

United Nuclear Corporaton has three mines (two active and one on standby) in the Ambrosia Lake area. All mine water is pumped to an ion-exchange plant for uranium recovery. Over 99% of the ion-exchange effluent is used for solution mining. The remainder is either used as potable water or is discharged into a holding pond for use in sand backfill operations. There was no discharge from the pond at the time of the survey. Although an application has been filed, company officials stated that wastewater does not reach Arroyo del Puerto; therefore an NPDES permit is not required.

Samples were collected from the ion-exchange effluent at a point ahead of its return to the underground mines. The ion-exchange effluent contained an average of 31 pCi/l radium-226 and 1,800 pCi/l of gross alpha. Suspended solids concentration in the ion-exchange discharge were from 3 to 7 mg/l. As shown in Table 2, selenium concentration ranged from 0.02 to 0.12 mg/l, for an average of 0.08 mg/l.

United Nuclear Corporation also operates an underground mine in the Churchrock mining district. The NPDES permit limits the radium-226 concentration to a maximum of 30 pCi/l. Other NPDES permit criteria include 100 mg/l of suspended solids daily average, 200 mg/l suspended solids daily maximum, and 2 mg/l uranium daily maximum. A power failure at the mine during the last week in February resulted in flooding of work areas. During the survey, company personnel were pumping out the mine and repairing underground equipment. Composite samples collected during the clean-up operations contained an average radium-226 concentration of 23.3 pCi/l. After the survey, NMEIA personnel collected a grab sample on 14 March 1975 following the resumption of mining activities. This sample contained 57 pCi/l of radium-226 which exceeds the permit limitation. The composite samples contained from 33 to 71 mg/l suspended solids concentration, while the later grab sample contained 320 mg/l suspended solids. Uranium was present in the discharge at an average concentration of 7.2 mg/l. Additional sampling is suggested to check for NPDES compliance, once the mine returns to typical operation.

UNITED NUCLEAR-HOMESTAKE PARTNERS

The United Nuclear-Homestake Partners joint venture operates four underground mines (Sections 15, 23, 25 and 32) in the Ambrosia Lake mining district. Uranium in the mine water is removed in an ion-exchange plant. About 85% of the effluent is recycled through the mines and used for in situ leaching (solution mining). The remaining 15% (0.08 mgd) of the ion-exchange effluent is discharged into Arroyo del Puerto upstream of the Kerr-McGee mill. An NPDES application has recently been filed for this discharge. During this survey, the radium-226 concentration in this discharge exceeded 100 pCi/l. The radium-226 concentration in this discharge can be reduced to 30 pCi/l or less with the addition of a barium chloride treatment system. These high concentrations exceed the NPDES permit issued for similar discharges and the State uranium milling license currently in effect for this facility. This discharge contributes to the violation of the New Mexico Water Quality Standards for Arroyo del Puerto (see Section VII).

Suspended solids concentration in the United Nuclear-Homestake Partners ion-exchange discharge are low, ranging from 7 to 10 mg/l. Selenium concentrations range from 0.30 to 0.33 mg/l, more than 30 times the drinking water standard for selenium. These concentrations would pose a health hazard if the water were used for a potable supply.

The presence of a large supply of clear water suggests an attractive alternative to plant personnel bringing their own drinking water to the plant. Uranium concentrations averaged 3.7 mg/l, indicating a need for closer monitoring of resin loading, or more frequent resin regeneration.

The United Nuclear-Homestake Partners Uranium mill recovers uranium by alkaline leaching of the ore, followed by ammonia precipitation of yellow cake. No ion-exchange or solvent extraction is practiced. Tailings-pile decant water is recycled through the mill. Seepage from the pile also enters ground water as determined by visual observation and ORP-LVF sampling. A sample of the decant, which is indicative of the quality of the seepage, contained 29,000 pCi/l and 52 pCi/l, respectively, of gross alpha and radium-226. The radium concentrations exceed the 10CFR20 criteria for discharge to a nonrestricted environment. The seepage also was found to contain 0.92 mg/l of selenium, or 92 times the drinking water standard. This is indicative of the geochemistry of selenium, which is found to be highly mobile in alkaline solutions. Results of the seepage on ground water are discussed in the ORP-LVF report.

Additional samples have been collected from a number of wells in the area downgradient from the United Nuclear-Homestake Partners tailings pond and are currently undergoing analyses. Problems of interlaboratory agreement are being resolved by appropriate Analytical Quality Control (AQC) programs. AQC data for the NEIC determinations are included in Appendix A. Results to date indicate that alkaline leaching of uranium milling tailings or uranium ore produces water high in a mobile form of selenium, and it presents definite problems of groundwater pollution. Seepage control measures should be required at this facility. Additional laboratory analysis of existing samples, and additional sampling to define the extent of the problem are planned for the near future.

ANACONDA COMPANY

The Anaconda Company operates the world's largest open pit uranium mine, the Jackpile Mine on the Laguna Indian Reservation. There is no discharge of mine water to Rio Paguate or Rio Maquino. Precipitation runoff from the disturbed land surface, however, adds radiochemical-bearing solids to these streams. Stream samples [Table 3] show a definite increase in radium-226 and selenium concentrations downstream from the mining operation. The data show the need for stabilization of waste material and improved handling of storm runoff.

The Anaconda Company uranium mill at Bluewater uses a Resin In Pulp (RIP) ion-exchange process on an acid leach operation (Anon, Aug. 1974). In this circuit, baskets of ion-exchange beads are agitated in a crushed slurry ore. The beads, when loaded, are eluted with a dilute solution of sulfuric acid and sodium chloride. Uranium is precipitated in two steps, with the addition of calcium hydroxide during the first step and magnesium hydroxide during the second step. This precipitate is then washed with ammonium sulfate to remove sodium and produce a saleable yellow cake.

injection well

Process wastes from the Anaconda mill are discharged into a 70-acre tailings pond constructed on a highly permeable basalt flow. The water which does not seep from this pond is decanted, filtered to remove suspended solids, and fed at a rate of 1,100 l/min (300 gpm) to an injection well. A sample of the well feed, which is indicative of the seepage to the ground water, contained 62,500 pCi/l and 53 pCi/l, respectively, of gross alpha and radium-226 [Table 2]. Vanadium was present in a concentration of 6.3 mg/l. The well feed contained 150 mg/l uranium, which corresponds to a uranium loss of 245 kg (540 lb)/day. At present values of yellow cake, this would have a market value of $8,100 to $10,800/day. This uranium could be recovered by the installation of an ion-exchange plant between the present filter and injection well.

VII. STREAM SURVEYS

When the mines and mills were evaluated, selected stream stations were sampled to determine the effect of mine and mill discharges on water quality. The New Mexico Water Quality Standards limit the radium concentration in surface streams to a maximum of 30 pCi/l. Data on the samples collected from surface streams are provided in Table 3.

ARROYO DEL PUERTO

Arroyo del Puerto receives waste from the United Nuclear-Homestake Partners and Kerr-McGee ion-exchange plants and from Kerr-McGee Section 30W and 35 mines. There is no flow in the creek upstream of these discharges.

Radium-226 concentrations of samples collected downstream from the Kerr-McGee mill were from 45 to 50 pCi/l. These concentrations not only violate the New Mexico Water Quality Standards, but exceed the AEC criteria (30 pCi/l) for radium in water discharged to an unrestricted environment. Radium concentrations in Arroyo del Puerto decreased near the mouth to levels ranging from 6.1 to 7.2 pCi/l. This decrease is due to the adsorption of radium on sediment and/or vegetation. During periods of heavy run-off, the radium concentration can be expected to increase due to scouring of the stream bed.

The selenium concentration of Arroyo del Puerto downstream from the Kerr-McGee mill was 0.15 mg/l, decreasing to 0.04 mg/l near the mouth. Vanadium concentrations in Arroyo del Puerto near the Kerr-McGee mill averaged 0.8 mg/l, increasing to 1.1 mg/l near the mouth. Selenium and

Table 3

SUMMARY OF ANALYTICAL DATA FOR SURFACE WATER SAMPLING

Station Description	Number of Samples	Gross Alpha (pCi/l) Max.	Gross Alpha (pCi/l) Min.	Gross Alpha (pCi/l) Avg.	Radium-226 (pCi/l) Max.	Radium-226 (pCi/l) Min.	Radium-226 (pCi/l) Avg.	Uranium (mg/l) Max.	Uranium (mg/l) Min.	Uranium (mg/l) Avg.	Selenium (mg/l) Max.	Selenium (mg/l) Min.	Selenium (mg/l) Avg.	Vanadium (mg/l) Max.	Vanadium (mg/l) Min.	Vanadium (mg/l) Avg.
Arroyo del Puerto downstream of Kerr-McGee Mill	3	1,700	1,400	1,500	50	45	47	12	5.0	7.7	0.16	0.13	0.15	1.0	0.6	0.8
Arroyo del Puerto near the mouth	3	1,500	750	1,100	7.2	6.1	6.5	6.6	4.7	5.8	0.07	0.01	0.04	1.9	0.5	1.1
San Mateo Creek at Highway 53 Bridge	1	-	-	1,000	-	-	1.09	-	-	4.7	-	-	0.02	-	-	<0.3
Rio Puerco downstream of Churchrock Mines	3	500	470	490	2.60	0.97	2.04	5.0	3.8	4.2	0.07	0.03	0.04	0.6	0.5	0.6
Rio Puerco upstream of Wingate Plant	3	510	720	440	1.63	0.36	0.81	4.8	3.7	4.2	0.01	0.01	0.01	0.9	0.3	0.6
Rio Puerco at Highway 666 Bridge	3	350	210	260	0.42	0.09	0.22	2.5	1.7	2.0	<0.01	<0.01	<0.01	0.6	0.3	0.5
Rio Paguate at Paguate	1	-	-	2.8	-	-	0.11	-	-	<0.02	-	-	<0.01	-	-	0.6
Rio Moquino upstream of Jackpile Mine	1	-	-	11.2	-	-	0.17	-	-	<0.02	-	-	<0.01	-	-	1.8
Rio Paguate at Jackpile Ford	1	-	-	270	-	-	4.8	-	-	1.2	-	-	<0.05	-	-	0.5
Rio Paguate at Paguate Reservoir Discharge	1	-	-	230	-	-	1.94	-	-	1.1	-	-	<0.01	-	-	0.6
Rio San Jose at Interstate Bridge	1	-	-	38	-	-	0.37	-	-	0.10	-	-	<0.01	-	-	0.3

vanadium have harmful effects when present in high concentrations in water used for irrigation or livestock watering. The 1972 EPA Water Quality Criteria (Committee on Water Quality Criteria, 1972) suggests that irrigation waters not exceed 0.02 mg/l selenium and 0.1 mg/l vanadium, while livestock waters should not exceed 0.05 mg/l selenium and 0.1 mg/l vanadium. On this basis, Arroyo del Puerto is rendered unfit for irrigation and livestock watering by the uranium mining discharges throughout its entire length. This is contrary to New Mexico Water Quality Standards which require that discharges not render a water unfit for a beneficial use.

The flow of Arroyo del Puerto enters San Mateo Creek where the entire flow enters the aquifer within three miles of the confluence. This recharge adds a large loading of radium and selenium to the ground water. Ground-water evaluations by ORP-LVF will address this question.

RIO PUERCO

The Rio Puerco receives drainage from Kerr-McGee and United Nuclear Corporation Churchrock mines. Samples collected downstream from these discharges contained a maximum radium-226 concentration of 2.6 pCi/l [Table 3]. The concentration decreased to 0.4 pCi/l at the town of Gallup. These concentrations meet the New Mexico Water Quality Criteria of 30 pCi/l, as well as the PHS Drinking Water Standard of 3 pCi/l for radium-226. Selenium concentrations downstream from the mine discharges ranged from 0.03 to 0.07 mg/l for an average of 0.04 mg/l, or four times PHS Drinking Water Standards. The selenium concentration decreased downstream to 0.01 mg/l at the Wingate plant and to less than detection limits at Gallup.

RIO PAGUATE, RIO MOQUINO, RIO SAN JOSE

The Rio Paquate and Rio Moquino flow through the Anaconda open pit mines on the Laguna Indian Reservation. The combined flow enters Rio San Jose near Laguna, New Mexico. Samples collected from these three streams had radium concentrations of less than 5 pCi/l, which is less than the Water Quality Standard of 30 pCi/l set by the State of New Mexico. An increase in the selenium concentration of Rio Paguate was noted downstream from the Jackpile Mine. However, the concentration of selenium at Paguate reservoir and in Rio San Jose were less than detection limits.

sampling points, together with revised analytical programs are strongly recommended improvements to the existing industrial efforts.

By comparison, the effects of mining on the concentration of radium in ground water are pronounced. Present discharge from the Kerr-McGee mine, which is in the development versus mining stage, averages 7.9 pCi/l as compared to 23.3 pCi/l for the United Nuclear mine. The latter is producing ore. In both cases, elevated radium concentrations are present. In large part, these are attributable to mining operations and practices and do not represent natural water quality, evident from samples of ground water collected from 4 wells and 3 long holes, all in the Westwater Canyon Member (Hiss and Kelley, 1975). Radium varied from 0.05 to 0.62 pCi/l compared to 0.28 to 184.8 pCi/l uranium. An additional sample collected in November 1973 from the settling pond discharge at the United Nuclear mine contained 8.1 pCi/l radium and 847 pCi/l natural uranium. Thus, initial penetration of the ore body increased radium at least 10-fold and subsequent mine development work over a two-year period resulted in another three-fold increase. Compared to natural concentrations, radium increased some 23 times. Similar trends also seen in the Ambrosia Lake area prevail, indicating that ultimate radium concentrations on the order of 50 to 150 pCi/l are likely. This has been tentatively confirmed by company, self-monitoring data.

Jackpile-Paguate Area

Sampling in the vicinity of the Jackpile-Paguate open pit uranium mine included four wells located as shown in Figure 12. One of these (#9233) is the Paguate municipal supply which is a flowing artesian well completed in alluvium at a depth of 22.9 meters. The remaining three wells are property of the Anaconda Company and are used for potable supply and for equipment washing, etc. It is believed that all three were former exploration holes that have been reamed out, cased, and equipped with a submersible pump. The water quality is probably representative of the Jackpile Sandstone Member of the Morrison Formation, which also is the principal ore body in the Laguna mining district.

Dissolved radium in water from the Jackpile Sandstone aquifer ranges from 0.31 to 3.7 pCi/l. The latter value is from the new shop well which is a source of potable and nonpotable water for the facility. Continued consumptive use of this water is not recommended because the radium exceeds the PHS Drinking Water Standard of 3 pCi/l.

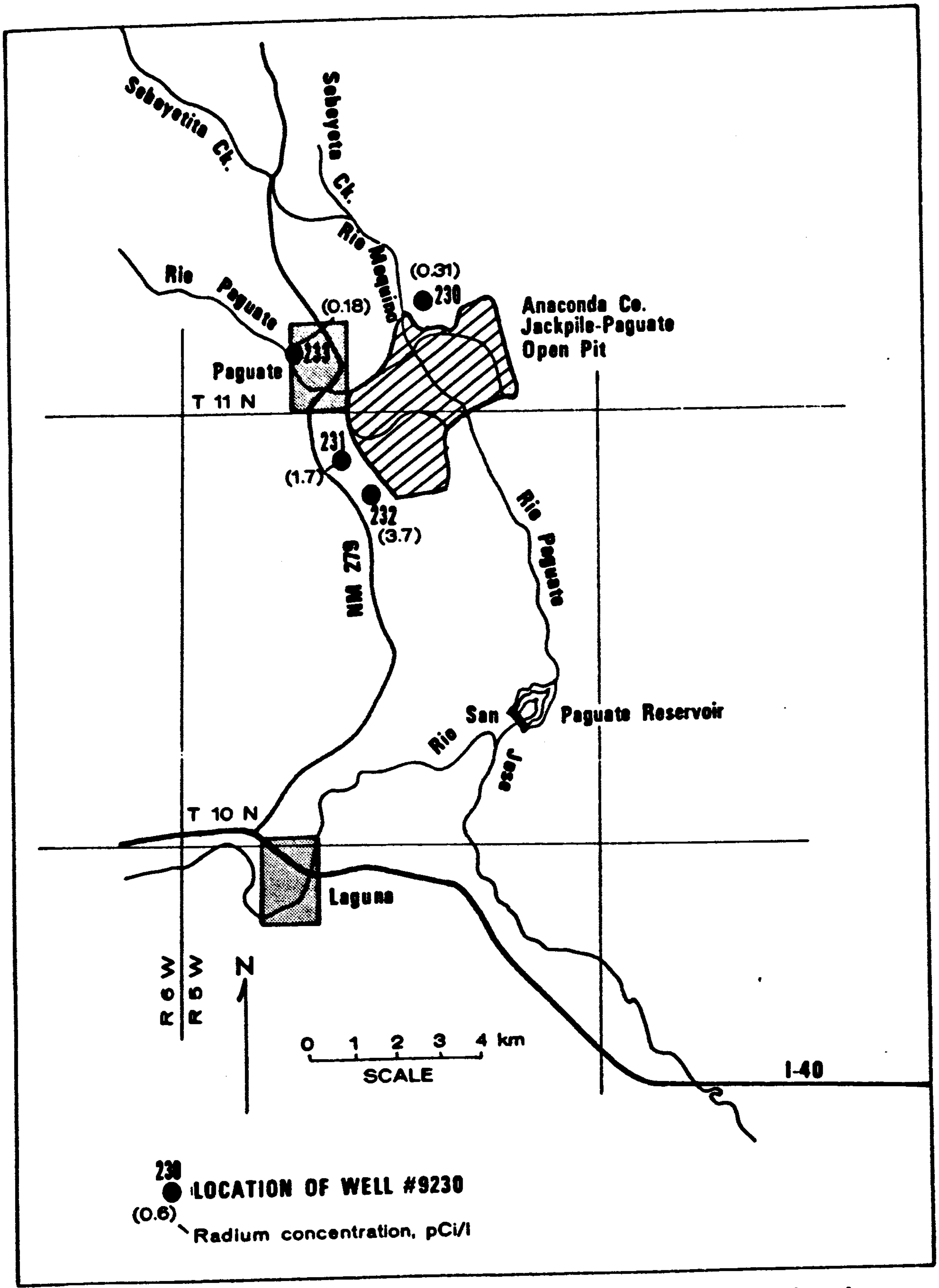

Figure 12. Radium Concentrations in Ground Water in the Paguate-Jackpile Area

The village of Paguate water supply is well below the recommended maximum level for not only radium but also the other isotopes considered in the present study. Selenium, however, is at the maximum recommended level of 0.01 mg/l. It is extremely unlikely that the present shallow-well supply will be affected by mining unless the open pit would be extended close to the well field. Recharge to the shallow aquifer is derived from runoff which infiltrates to the west and north. After percolating southward, it then reappears in a marshy area west of the village. Springs and artesian conditions are likely the result of decreasing transmissivity due to the near surface occurrence of shales and poorly permeable sandstones in the lower reaches of Pueblo Arroyo.

The downstream impacts of the Jackpile-Paguate mine on ground water were not determined because of the absence of suitable sampling points. It is recommended that shallow monitor wells be installed at several points along the Rio Paguate to ascertain the chemical, radiochemical, and trace element species present. Limited coring in the sediment-filled Paguate reservoir would provide data on variations in the radium and uranium content before and during mining. Such data would also provide information on radioactivity associated with sediment transport during periods of peak runoff and erosion.

Significance of Radiological Data

Regulations and Guidelines

On August 14, 1975, the U.S. EPA published in the Federal Register (40 FR158, p. 34323-34328) a "Notice of Proposed Maximum Contaminant Levels for Radioactivity" to be included in 10 CFR Part 141 - Interim Primary Drinking Water Regulations. The following are the proposed maximum contaminant levels for radium-226, radium-228, and gross alpha particle radioactivity:

1. Combined radium-226 and radium-228 not to exceed 5 pCi/l.

2. Gross alpha particle activity (including radium-226 but exclusive of radon and uranium contents) not to exceed 15 pCi/l.

The proposed regulations also discuss maximum contaminant levels of beta particle and photon radioactivity from man-made radionuclides.

Therefore, with respect to these proposed radioactive contaminant levels, the following conclusions were reached:

1. Additional analysis for radium-228 and lead-210 will proceed and be reported in a separate report at a later date.

2. Since radium-228 is a daughter product of thorium-232 and thorium analyses of these waters fluctuated around background concentrations, it appears that the radium-228 content should also be at background levels (i.e., less than 0.02 pCi/l. Hence, the radium-228 content, under assumed equilibrium conditions, should be less than 0.042 pCi/l, the highest reported thorium-232 content.

3. Only two locations out of the 71 ground-water locations sampled have radium-226 concentrations in excess of 5 pCi/l. Therefore, the proposed new standard of 5 pCi/l for combined radium-226 and radium-228 contents is therefore exceeded at these two locations.

4. Sixty of the 71 ground-water locations had gross alpha results in excess of the proposed 15 pCi/l limit; however, the gross alpha results reported here include uranium isotopes. Included in the list of sixty locations are several locations where the gross alpha results are less than 15 pCi/l, but consideration of the 2 sigma confidence level would then indicate a gross alpha possibly in excess of the 15 pCi/l limit.

5. The proposed maximum gross beta limit excludes naturally occurring radionuclides (e.g., lead-210); therefore, there is no presently proposed maximum contaminant level for lead-210. The NMEIA population guide MPC of 33 pCi/l appears to be the only current applicable guideline for lead-210 content.

Since the above radioactivity contaminant levels are proposed and not final interim primary drinking water regulations, the following discussions of the radiological analyses of water samples obtained during this study will be based on the U.S.P.H.S. Drinking Water Standards (1962) and current NRC/NMEIA maximum permissible concentration levels.

Radium-226

Of the 71 ground-water sampling locations of this study, only 6 locations showed radium-226 concentrations in excess of the 3.0 pCi/l drinking water standard (U.S.P.H.S. Drinking Water Standards, PHS Publication

No. 956; 1962). The population guide--maximum permissible concentration (10CFR, Part 20, Table II, column 2, unrestricted areas) is 10 pCi/l for radium-226. Table 7 lists the 6 locations and presents the gross alpha and radium-226 results.

The Jackpile-New Shop well, Paguate (#9232), is a potable water supply having a radium concentration in excess of the drinking water standard. This water need not be used for human consumption since other nearby wells have much lower radium concentrations (e.g., the Paguate municipal supply (#9233) or the Jackpile well (#9230)).

The Phil Harris well, Grants (#9201), is the only other potable water supply with a radium concentration in excess of 3.0 pCi/l. The Berryhill Section 5 windmill, Bluewater (#9121), is used as a stock water supply; and since there are no nearby human consumers, the radium concentration of 6.3 0.1 pCi/l is of no immediate health hazard.

Samples from two Kerr-McGee monitoring wells (#9208 and #9213), located within 800 meters of the main tailings retention dam, contain radium in excess of 3.0 pCi/l. These wells are not fitted with pumps, are in a restricted area, and contain water otherwise unfit for comsumption. For example, TDS varies from 7500 to 8900 mg/l. Therefore, these wells do not constitute a health hazard in terms of dissolved radium. Similarly, station #9212 consists of seepage return water collected at the base of the retention dam. Aside from the radium content of 4.9 pCi/l, the water is in a restricted area, is not used for any purpose, and contains 36,000 mg/l TDS. Therefore, consumptive use and creation of a health hazard is extremely unlikely.

For comparison purposes, Table 8 shows the radium concentrations for municipal water supplies surveyed during this study.

A radium concentration of 0.68 pCi/l from the Erwin well north of Gallup (#9233) was the highest radium concentration for the municipal supplies. It appears that, on the whole, municipal water supplies in the Grants Mineral Belt area do not exceed 23% percent of the drinking water standard of 3.0 pCi/l.

Ten privately owned, potable water supplies were surveyed in the Murray Acres-Broadview Acres and other areas surrounding the United Nuclear-Homestate Partners mill. The highest radium concentration was 0.72 pCi/l

Table 7

Locations with Radium-226 in Excess of the PHS Drinking Water Standard[1]

Location Description	Radium-226[2] Dissolved pCi/l	Radium-226[2] Two Sigma pCi/l	Gross Alpha[2] Dissolved pCi/l	Gross Alpha[2] Two Sigma pCi/l	Remarks
#9121-Berryhill Section 5 Bluewater	6.3	0.1	12	14	Windmill Stock Feed Water
#9201-P. Harris Grants KM-46	3.6	0.1	110	40	Potable Water Supply
#9208-KM-43 Grants	4.0	0.1	49	35	Monitor Well
#9212-KM Seepage Return-Grants	4.9	0.1	112,000	3,000	Surface Water Sample
#9213-KM-B-2 Grants	6.6	0.1	8	32	Monitor Well
#9232-Jackpile-New Shop Well Paguate	3.7	0.08	18	13	Potable Water Supply

1 PHS Drinking Water Standard, 1962, is 3.0 pCi/l for Radium-226.

2 Radium and gross alpha analysis by NEIC-Denver.

Table 8

Radium and Gross Alpha Concentrations for Municipal Water Supplies[1]

Location Description	Radium-226 Dissolved pCi/l	Radium-226 Two Sigma pCi/l	Gross Alpha Dissolved pCi/l	Gross Alpha Two Sigma pCi/l
#9112-Grants City Hall	0.42	0.02	19	13
#9116-Milan City Well #1	0.14	0.01	12	10
#9125-LDS Bluewater	0.22	0.01	8	10
#9137-Erwin Well Gallup	0.68	0.03	10	9
#9233-Municipal Well Paguate	0.18	0.02	2	4
#9141-Churchrock Village	0.12	0.01	3	7

1 Radium and gross alpha results by NEIC-Denver.

at the Worthen well (#9107), and the lowest concentration was less than 0.05 pCi/l at the Schwagerty well (#9105). The average radium concentration for these 10 private wells was 0.26 pCi/l.

Six privately owned, potable water supplies in the Ambrosia Lake area contain 0.07 to 3.6 pCi/l. Of nine privately owned potable water supplies surveyed in the Grants-Bluewater area, the maximum radium concentration was 0.24 pCi/l. Only two privately owned wells were used solely as potable water supplies in the Gallup area. These were the Hassler (#9139) and Boardman (#9138) residences. The radium concentrations at these two locations were 0.22 and 0.64 pCi/l, respectively. The other 8 wells in the Gallup-Churchrock area were used mainly as stock water supplies and had an average radium concentration of 0.35 pCi/l.

Other Radionuclides

Table 9 entitled "Maximum Permissible Concentrations in Water" presents the unrestricted area - MPC and the population guide - MPC for selected radionuclides. The PHS Drinking Water Standard of 3 pCi/l for radium-226 is more restrictive than the population guide - MPC; therefore, the radium content evaluations were based on the 3 pCi/l drinking water standard. The other radionuclide content evaluations are based on the soluble MPC value since filtered ground-water samples were analyzed. The MPC values listed are from the NRC regulations which are also consistent with the NMEIA regulations (June 16, 1973).

Only 3 potable water supplies had complete isotopic uranium analysis - Wilcox (#9102), Enyart (#9133), and Dixie well (#9140). The highest reported results (for the Wilcox well) indicate less than 0.1%, 0.002%, and 0.06% of the population guide - MPC for uranium-234, uranium-235, and uranium-238, respectively.

Of all the potable water supplies analyzed for thorium-230, the Worthen well (#9107) had the highest concentration of 0.99 pCi/l. However, this is less than 0.15% of the population guide - MPC. The Meador well (#9113) had the highest thorium-232 content of 0.042 pCi/l and polonium-210 content of 2.3 pCi/l. These are 0.006% and 0.98% of the population guide - MPC, respectively.

Table 9

Maximum Permissible Concentrations in Water[1]
(Above Natural Background)

Radionuclide		Appendix B Table II, Column 2 (Unrestricted Areas) pCi/l	Population Guide[2] pCi/l
^{226}Ra	Soluble	30	10+
	Insoluble	30,000	10,000
^{228}Ra	Soluble	30	10
	Insoluble	30,000	10,000
^{210}Po	Soluble	700	233
	Insoluble	30,000	10,000
^{210}Pb	Soluble	100	33
	Insoluble	200,000	66,667
^{230}Th	Soluble	2,000	667
	Insoluble	30,000	10,000
^{232}Th	Soluble	2,000	667
	Insoluble	40,000	13,333
^{234}U	Soluble	30,000	10,000
	Insoluble	30,000	10,000
^{235}U	Soluble	30,000	10,000
	Insoluble	30,000	10,000
^{238}U	Soluble	40,000	13,333
	Insoluble	40,000	13,333
U-Natural	Soluble	30,000	10,000
	Insoluble	30,000	10,000

1 10CFR-Part 20--Standards for Protection Against Radiation--U.S.N.R.C. (April 30, 1975).

2 Population Guide = 1/3 times Unrestricted Area MPC--Table II Values.

+ A maximum permissible concentration of 3.33 pCi/l for ^{226}Ra is the Handbook 69 population guide (i.e., 1/30th of the HB69 continuous occupational exposure limits).

All 6 municipal water supplies were analyzed for thorium-230, thorium-232, and polonium-210. The highest thorium-230 content was for Grants (#9112), with 0.046 pCi/l (0.007% population guide - MPC). The highest thorium-232 content was for the Churchrock Village, with 0.016 pCi/l (0.002% of the population guide - MPC). The highest polonium-210 content was for the Municipal well at Paguate (#9233) with 0.39 pCi/l (0.17% of the population guide - MPC). In summary, exclusive of the radium-226 content, the highest isotopic uranium, thorium, and polonium-210 contents for any potable water supply in the Grants Mineral Belt area is less than 1.72% of the total radionuclide population guide - MPC. Exclusive of the Kerr-McGee seepage return sample (#9212) and the Anaconda injection well sample (#9107), the Worthen private well (#9107) had the highest gross alpha result of 2500 pCi/l. This gross alpha result underestimates the U-natural content reported as 9800 pCi/l (i.e., 98% of the allowable MPC). There are other examples of inconsistencies between gross alpha and natural uranium data. For example, samples #9102 and #9113 have gross alpha results of 3 pCi/l and 31 pCi/l, respectively. Comparable U-natural contents are 49 and 56 pCi/l (less than 0.56% of the U-natural MPC). In general, it appears that the uranium isotopes represent the greatest contributor of alpha activity. Considering the total radionuclide values to be the summation of uranium isotopes, thorium-230, thorium-232, and polonium-210 concentrations, the percentage of total radionuclides compared to gross alpha ranged from 31% (#9219) to 639% (#9102), exclusive of #9132 which has an extremely large discrepancy of results. Therefore, it appears that the gross alpha determinations have underestimated the natural uranium contents. It is doubtful that the gross alpha determination can even be used as an indicator of the presence of other alpha emitters (e.g., U-natural and polonium-210). Since the gross alpha results have such large error terms, no meaningful determinations of percentage of other radionuclides to gross alpha result can be implied.

With respect to the use of 15 pCi/l gross alpha (including uranium isotopes) as a "scan level" to indicate radium contents in excess of 5 pCi/l, only 2 locations fall in this category. Location #9121 had a gross alpha of 12 ± 14 pCi/l and a radium-226 content of 6.3 ± 0.1 pCi/l. Because of the large error term in the gross alpha determination (8 ± 32 pCi/l) for location #9213, this sample would be included in the group of locations having a gross alpha result greater than 15 pCi/1. This location had the highest radium-226 content of all the ground-water locations sampled (6.6 pCi/1). Of the 58 remaining ground-water locations with gross alpha results greater than 15 pCi/1 (range: <3 ± 13 to 2500 ± 200 pCi/1), the radium-226 contents ranged from 0.19 to 0.72 pCi/1, respectively. For ground-water samples with gross alpha greater than 15 pCi/1, the radium-226 concentration ranged from 0.06 to 6.6 pCi/1. Therefore, there appears to be no correlation between a gross alpha level of 15 pCi/1 (including uranium isotopes) and a radium-226 content of 5 pCi/1.

It is appropriate to conclude that for routine radiological monitoring of potable water supplies, isotopic uranium and thorium, polonium-210, and radium-228 analyses are not necessary. Accurate radium-226 and lead-210 analyses for each sample yield the most information for radiological evaluations of drinking water conditions.

RADIONUCLIDE AND HEAVY METAL DISTRIBUTION IN 20TH CENTURY SEDIMENTS OF MAJOR STREAMS IN THE EASTERN PART OF THE GRANTS URANIUM REGION, NEW MEXICO

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ABSTRACT

Geomorphic and geochemical techniques were combined to study radionuclides and heavy metals in historic deposits of the Rio Puerco drainage in order to establish baseline geochemistry of sediments derived from the eastern part of the Grants uranium region and to evaluate possible impacts of uranium mining and milling. Because these elements adsorb to clays, we chose sample sites where relatively thick sequences of fine-grained sediments accumulated along drainages, including deposits behind a dam on the Rio Paguate and in abandoned channels (oxbows) along the Rio San Jose and Rio Puerco. Comparison of old and more recent sets of aerial photographs and maps established the age of formation of the sampled channels; stream-flow records and modern channel geometry provided estimates of possible numbers of flood events at each site; and the presence or absence of Cs-137 in sediments established whether they had been deposited prior to or after 1950 (pre- or post-mining). Concentrations of radionuclides and heavy metals in sediments show regionally high values of U, As, Se, Cd, Hg, and U-decay products related to regional mineralization but unrelated to mining. Surface samples show higher levels of U-decay products than subsurface samples. Locally increased amounts of decay products of U-238 and Se which clearly postdate the onset of mining are trapped in Paguate Reservoir downstream from an extensive mine complex. Further refinement of the age of sediments may be possible using flood data combined with oxbow stratigraphy and dendrochronology, or using stratigraphic changes in relative abundance of Cs-137 or Pb-210.

INTRODUCTION

The lack of pre-1979 baseline studies complicated evaluation of a spill from a uranium tailings pond of 95 million gallons of pH 1.5 waste water containing high concentrations of radionuclides, trace metals and suspended sediments that contaminated the Puerco River in western New Mexico (Millard and others, 1983; Gallaher and Cary, in press). We initiated a study of the Rio Puerco drainage along the eastern margin of the Grants uranium region to (1) obtain baseline data on chemical and physical properties of

EXHIBIT 1

sediments in the drainage and (2) determine whether uranium mining and milling which began there in 1950 are contributing elevated amounts of trace metals and radionuclides to the drainage. We used both geomorphological and chemical techniques to determine (A) the sources, mechanisms of transport and deposition, and physical characteristics of the fluvial sediments, (B) the most favorable places to sample historical fine-grained sediments, (C) the ages of deposits, and (D) the radionuclide and trace metal content of the samples. This report summarizes the techniques and results of the study; Popp and others (1983) give details of the procedures used and the results at each sample site.

The strategy for determining the age of the samples depends on using both geomorphological and chemical techniques. Abandoned channel loops (oxbows) were chosen for study because they are easy to locate on aerial photographs taken since 1935, can be assigned an age for development using subsequent photographs and maps, and commonly have thick, clay-rich fill. Adjacent reaches of the present stream channel were studied for comparison and to determine frequency of floods.

The use of radionuclides with relatively short half-lives, such as Pb-210 and Cs-137, to date recent sediments is well established (Krishnaswami and Lal, 1978). Cesium 137 is an artificial radioisotope formed by nuclear fission and has a half-life of about 30 years (Lederer and others, 1967). This isotope has been introduced into the atmosphere in irregularly varying amounts since above-ground nuclear testing began in 1945 (Durham and Joshi, 1980). Dating methods based on Cs-137 depend on the imprint of an irregular influx of wet and dry atmospheric deposition in sediment layers and/or on its absence before 1945. Lead 210 is a naturally occurring radioisotope in the uranium-238 decay series with a half-life of approximately 22.3 years (Lederer and others, 1967). The presence of Pb-210 in atmospheric deposition is due to the escape of a fraction of its precursor, Rn-222, from the earth's crust into the atmosphere and subsequent rapid decay to Pb-210 which undergoes deposition like Cs-137. The exponential decay of the atmospherically derived Pb-210 can then be used to estimate the age of a sediment layer as long as the sediment is significantly higher in activity than the Pb-210 already present.

Both Pb-210 and Cs-137 are strongly bound by sediments and tend to remain trapped in a sediment layer which may become buried. Generally, radionuclides and associated trace metals are significantly enriched in the finest size fractions (Robbins and Edgington, 1975; Smith and Walton, (1980), due to the greater surface area, cation exchange capacity, hydrous metal oxide, and organic contents of these fractions. As a result, activities of radionuclides may be significantly affected by the silt and clay content of the samples.

In previous studies, deposition occurred in environments under regular and continuous sedimentation where individual

samples typically represented a year or more of accumulation. Sediment deposition is complicated in the ephemeral, flashy-discharge streams in this study, however, and occurs over a matter of a few hours or a few days in highly irregular episodes. Moreover, significant mixing, dilution, and redeposition of sediments may occur.

METHODS

SELECTION AND CHARACTERIZATION OF SAMPLE SITES

Because metals and radionuclides are adsorbed on clays, we looked for thick deposits of fine-grained sediments, particularly in oxbows formed after 1935, and in some cases, after 1954. The oxbows were chosen upstream, near, and downstream from uranium mine-mill activity (fig. 1). We also selected a sample site in the delta of Paguate Reservoir, a small impoundment 7 km downstream from the Jackpile uranium mine. Oxbows along the Rio Puerco and Rio San Jose were located by comparing maps and aerial photographs from the 1930's, 1940's, 1950's and 1970's.

After site selection, we dug pits in both the oxbows and in adjacent modern channels to sample and describe sedimentary structures, colors and textures. We augered from 1.5 to 5 m to sample deeper sediments. We constructed topographic profiles across channels and oxbows to interpret flow characteristics of the channels and to estimate the possible number of floods reaching the oxbows. Possible sources of radionuclides were determined by examination of geologic reports (e.g. McLemore, 1983; Anderson, 1981), geologic maps (Dane and Bachman, 1965), and local reconnaissance studies (Young, 1982; Love and Young, 1983).

LABORATORY PROCEDURES

In the laboratory, 450 ml of material were removed from each sample using a riffle splitter with 1 cm openings. Any objects larger than 1 cm were removed from the sample. A series of smaller samples were processed to determine grain size, grain mineralogy, percent clay, clay mineralogy, and trace-metal chemistry. About half the sample was saved in case a duplicate sample was needed.

Determination of Radionuclides

Each 450 ml split was mixed to ensure homogeneity and put in plastic Marinelli beakers for gamma ray counting. The beakers were sealed with tape and, for Pb-210 analyses, allowed to stand for a minimum of two weeks to allow for Rn-222, and hence Pb-214 ingrowth (see Schery, 1980).

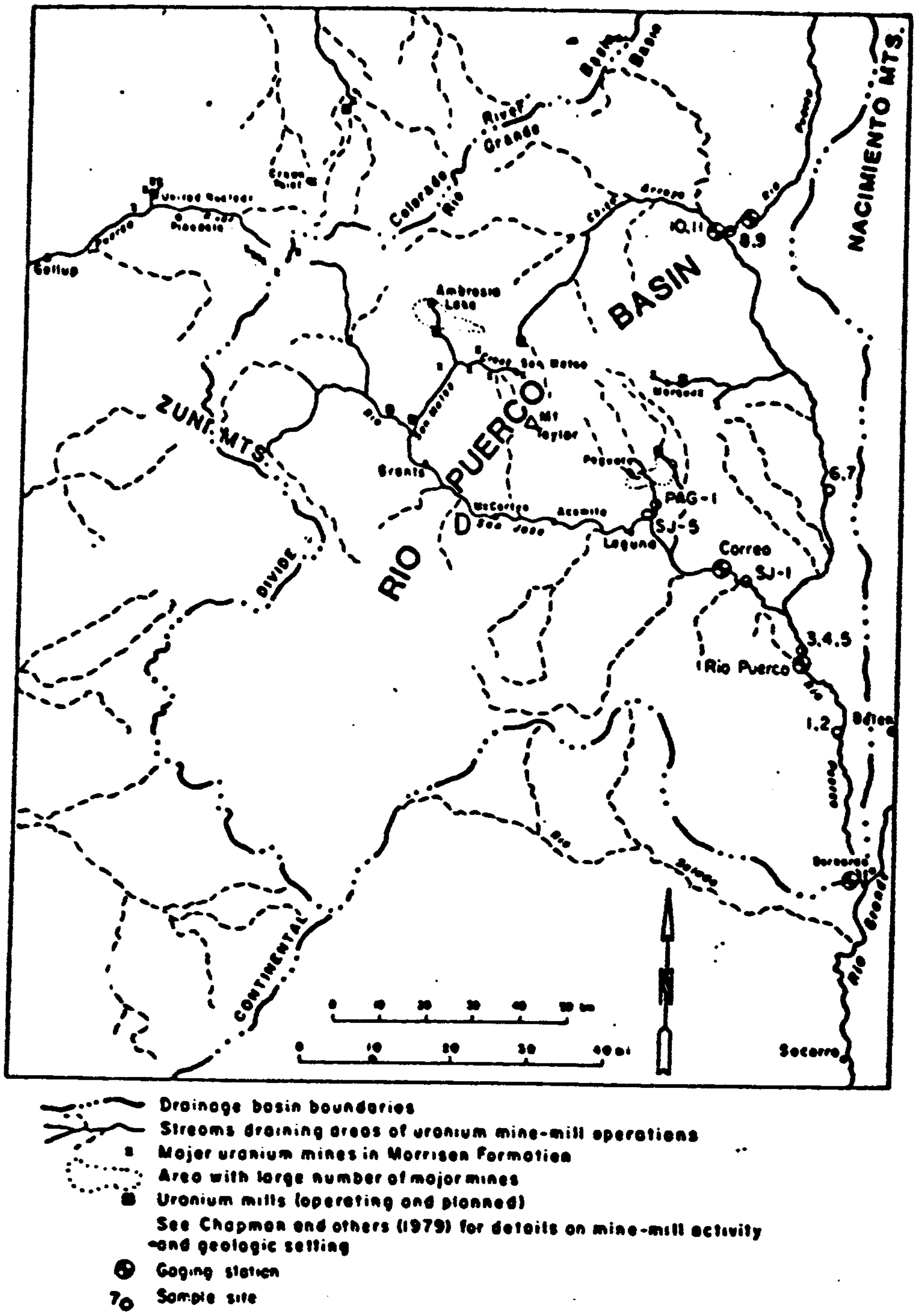

Figure 1. Location of mines and mills of the Grants uranium region, gaging stations, and sample sites in the Rio Puerco drainage basin.

Activities of the radioisotopes were obtained by gamma spectrometry using an N-type, high purity, low background, lithium-doped germanium detector. The gamma spectra were obtained using one of three lead-shielded Ortec Gamma-X spectrometers linked to a 4096-channel pulse-height analyzer. Minimum counting times for Cs-137 and Pb-210 were 4,000 and 16,000 seconds respectively. The energy range of the spectra in both cases was approximately 0.1500 KeV. For low levels, counting times of about 40,000 seconds were sufficient. Activities of each isotope (in pCi/g) were calculated from the peak areas, sample weights, and branching ratios using previously determined efficiencies at these energies (see Popp and others, 1983, for details).

Determination of Trace Metals

Trace metals were measured by atomic absorption (A.A.). Samples were prepared for A.A. by digesting selected silt (<63 MM) and clay (<2) fractions in hydrofluoric acid-aqua regia-perchloric acid (Johnson and Maxwell, 1981). In general, 2.00 g of silt fraction and 0.25 g of clay samples were digested and brought up to 100 ml using 10% nitric acid. Standard materials SY-2, SY-3 (Canadian Certified Reference Material), SL-1 (Canadian Atomic Energy Commission), and NBS 1645 river sediment were used to test analytic procedures.

Mercury was determined by cold vapor A.A. according to USEPA (1979) procedure No.'s 218.1 and 220.1. Mo, Ni, Cd, Pb, and V were determined by furnace techniques as described by USEPA (1979) method No.'s 246.2, 249.2, 239.2, and 286.2, respectively. Uranium was analyzed spectrophotometrically with dibenzoylmethane after separation by solvent extraction with tri-n-octylphosphine (adapted from Horton and White, 1958).

RESULTS

FIELD RELATIONS

Oxbows were found where predicted from interpretation of aerial photographs and maps. Changes in the configuration of the channel of the Rio Puerco between 1954 and 1983 (29 years) are much larger than between 1935 and 1954 (19 years). These changes may be related to hydrologic changes in the drainage basin and to changes in vegetation along the floodplain. Spot sampling within each oxbow and within each pit showed that the oxbows have extremely variable amounts of clay. Unexpectedly, some oxbows (particularly those formed between 1935 and 1954) have more sand than clay. Moreover, sediment eroded from adjacent arroyo walls contributed major proportions of surficial and shallow deposits in some of the oxbows. Along the Rio San Jose and the lower Rio Puerco, sediments from different source areas may be distinguished in a general way by color.

None of the deposits contained artifacts to help date sediments more closely, but dendrochronology of tamarisks colonizing abandoned parts of the floodplain was used successfully to date one site. Based on present channel configuration, all the sites probably have been flooded between 8 and 22 times since mining began in 1950.

MINERALOGY OF SEDIMENTS

Eighteen samples from four sample sites were analyzed for mineralogy of clay and non-clay-size fractions. The most abundant non-clay mineral in all size fractions is quartz. Feldspar (largely albite and microcline) and calcite are also present in clay-sized fractions. Although evaporites and magnetite were noted in the field, these minerals were not detected using X-ray diffraction.

The most abundant clay mineral group in all eighteen samples is kaolinite. Significant quantities of smectite, illite, and chlorite are common, but show a wide range among samples. Randomly oriented mixed-layer illite-smectite is also common.

No systematic variations in mineralogy of individual size fractions occurred between sites or with depth at each site, except for a possible increase in the proportion of chlorite in the clay-size fraction with depth. No systematic variations were noted in the proportion of fine-grained sediment (silt and clay) in samples of a given mean grain size, nor in the silt/clay ratio.

RADIONUCLIDE ACTIVITIES

Naturally occurring radionuclides which commonly are present in uranium deposits as daughters of U-238 decay and which may be transported with sediments away from mine and mill sites are Pb-210, Pb-214, Ra-226, and Th-234. Actinium-228, a long-lived daughter of Th-232 (Th is not regionally enriched) provides an independent measure of radionuclide behavior. Average radionuclide activities in surface samples compared to valley fill for various sections of the study region are shown in Table 1. In all cases, the recently deposited surface samples exhibit higher activities than the much older valley fill. The highest radionuclide activities were found in the Paguate Reservoir sediments which are trapped immediately downstream from the Jackpile mine. The surface samples from the lower Rio Puerco (downstream from the confluence with the Rio San Jose) exhibit higher activities than the upper Rio Puerco samples.

Variations in Pb-210 activity with sample depth at two contrasting sites are shown in figs. 2a and b. The Paguate Reservoir auger sample (fig. 2a) clearly shows enrichment at the upper end of the hole while activities in the hole from site 9 (fig. 2b), upstream of all mining and milling activity, are quite constant throughout (Popp and others,

Table 1. Activities in pCi/g of nuclides in surface (S), lower auger samples (before 1950) (L), and valley fill samples (V) for the upper Rio Puerco (URP), lower Rio Puerco (LRP), Rio San Jose (RSJ), and Paguate Reservoir (PR). Detailed tabulation of radionuclide activities may be found in Dehn (1983), Novo-Gradac (1983) and Popp and others (1983).

Radionuclide		URP	LRP	RSJ	PR*
Pb-210	S	1.26	2.00	2.15	5.39 (15.6)
	L	0.96	1.08	1.04	1.36
	V	0.88	1.03	—	1.44
Ra-226	S	1.19	2.84	3.29	11.5 (26.9)
	L	1.77	1.92	1.89	2.55
	V	1.63	1.89	—	2.74
Th-234	S	1.01	1.25	1.49	4.45 (9.35)
	L	0.85	0.94	0.96	1.30
	V	0.70	0.75	—	1.26
Pb-214	S	0.92	1.25	1.60	5.38 (13.6)
	L	0.89	0.94	1.01	1.29
	V	0.78	0.85	—	1.40
Ac-228	S	1.21	1.57	1.51 (2.31)	2.02
	L	1.04	1.13	1.03	1.41
	V	0.87	1.02	—	1.81

*Values in parentheses are highs for all samples and were found in Paguate Reservoir samples with the exception of Ac-228 (a Th-232 daughter). Th is not regionally enriched.

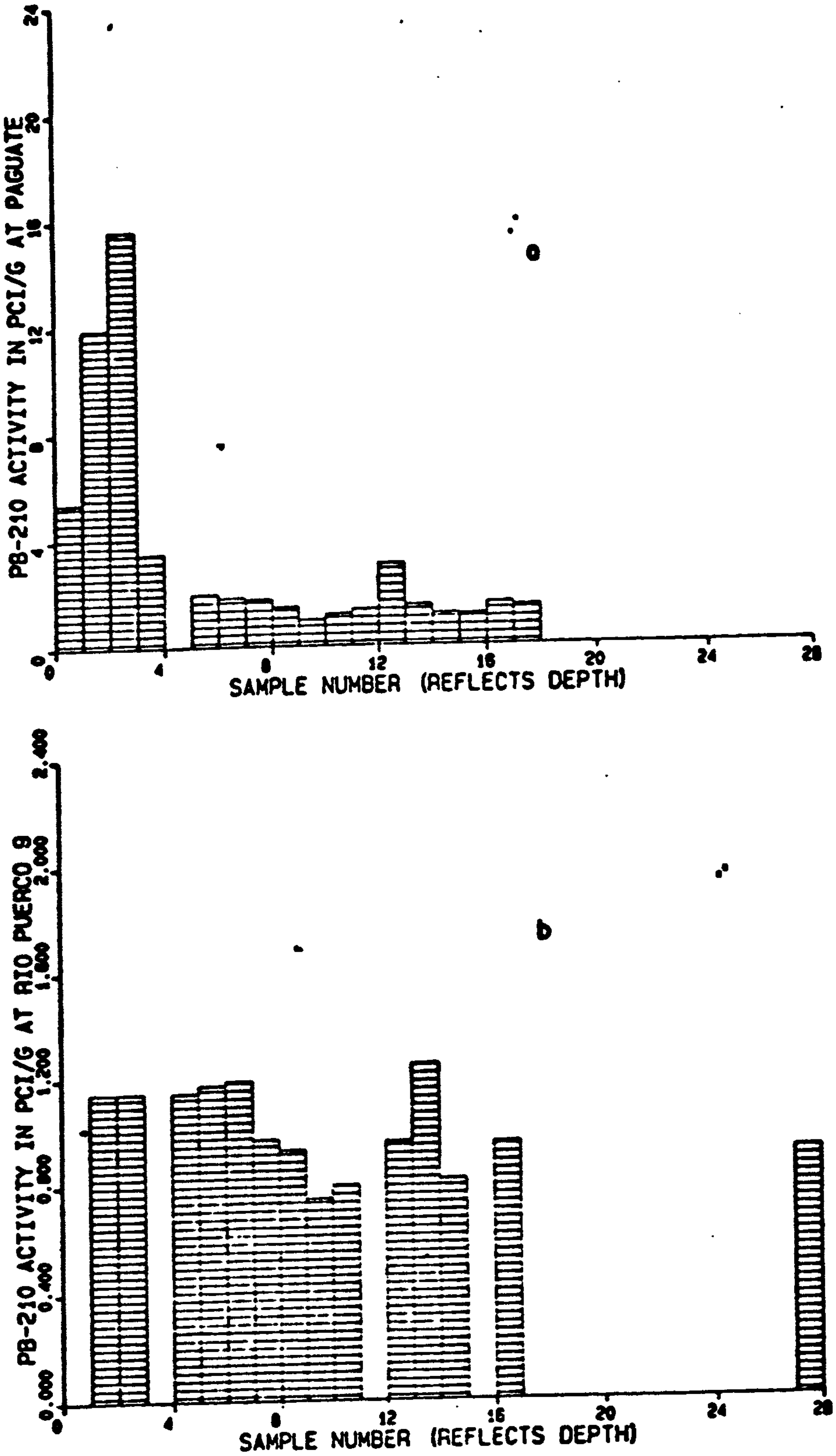

Figure 2. Pb-210 activity as a function of depth: a) Paguate Reservoir; b) Site 9, Rio Puerco (Popp and others, 1983).

1983). This behavior was mimicked by all the U-238 daughters measured.

A more typical auger sample in an oxbow is shown in fig. 3. The steady decline of Pb-210 activity is a function of larger grain size with depth. It should be noted that the deepest samples in fig. 3 have the same activities as all the samples from site 9.

DATING SEDIMENTS WITH Cs-137 AND Pb-210

Measured Cs-137 activities of the samples ranged from <0.0002 pCi/g to 0.73 pCi/g, with most samples ranging from 0.1 to 0.3 pCi/g. Uncertainties were typically 0.01-0.03 pCi/g. Profiles of normalized Cs-137 activity show a consistent pattern of a broad subsurface maximum. This is followed by a transition at a depth of a few meters to little or no detectable activity (see fig. 4). Dating the sediments using peaks in the Cs-137 profiles, the common procedure in previous studies, was not possible because relatively narrow and well defined maxima were not seen in any of the oxbow sites. The lack of sharp maxima may be due to dilution by sediments reworked from arroyo walls during times of peak Cs-137 fallout and/or later redistribution of the sediments. Several peaks were noted in the auger samples from Paguate Reservoir, but a more detailed analysis of a new core is needed to corroborate the data. In the absence of datable maxima in the profiles, the scope of Cs-137 dating is limited to determining whether or not significant levels of Cs-137 are present, and, therefore, whether or not the samples in question postdate 1950.

Pb-210 dating of the samples was not possible for several reasons, the most important of which is the variable amount of radon emanation. Additional factors include the variability of the initial unsupported Pb-210 activity among relatively similar surface samples, and the high amounts of supported (background) Pb-210. The non-atmospherically-derived Pb-214 typically reaches a maximum at some point below the surface, but, the Pb-210/Pb-214 ratio does not gradually decrease to unity with depth. Rather, it immediately drops from a value of about 2 to a value of approximately 0.8-0.9 and commonly remains between 0.8 and 1.0 throughout the rest of the core. This clearly indicates that the majority of the samples have not remained closed with respect to the immediate precursors of Pb-210 (presumably Rn-222) after deposition.

Both the ratio of Pb-210/Pb-214 and the Cs-137 activities showed large variations among samples with similar grain size, but, in general, the activities are highest in samples with large amounts of silt and clay. The variations among similar samples may be partially explained by fluctuations in the rates of Pb-210 and Cs-137 deposition over the course of years.

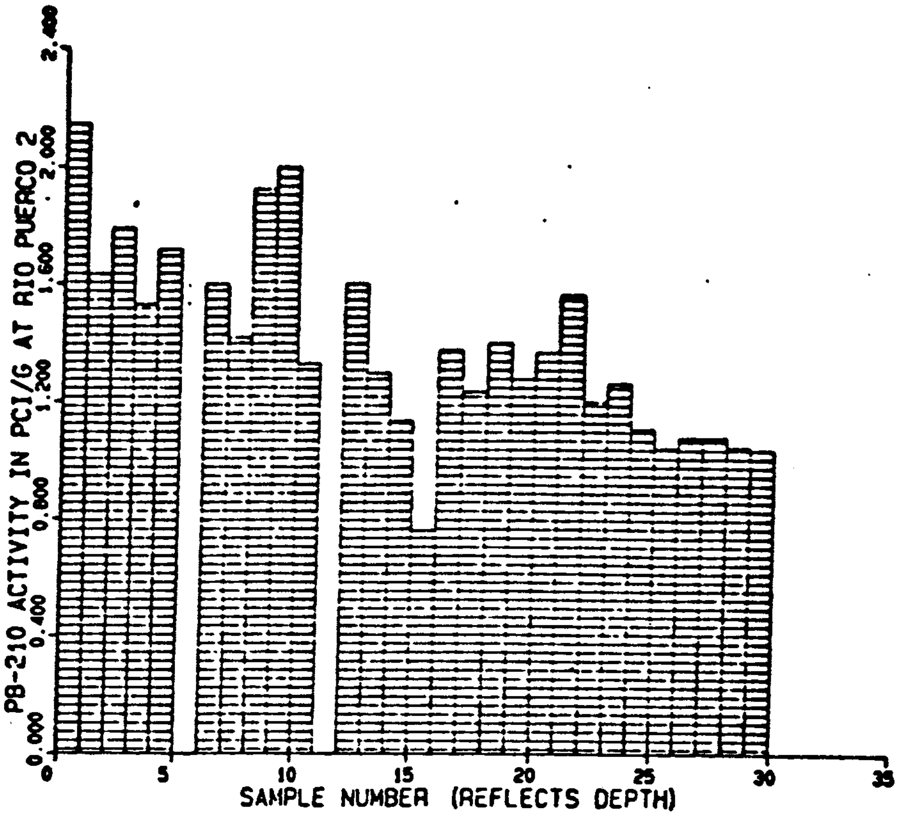

Figure 3. Pb-210 activity as a function of depth at site 2, Rio Puerco (Popp and others, 1983).

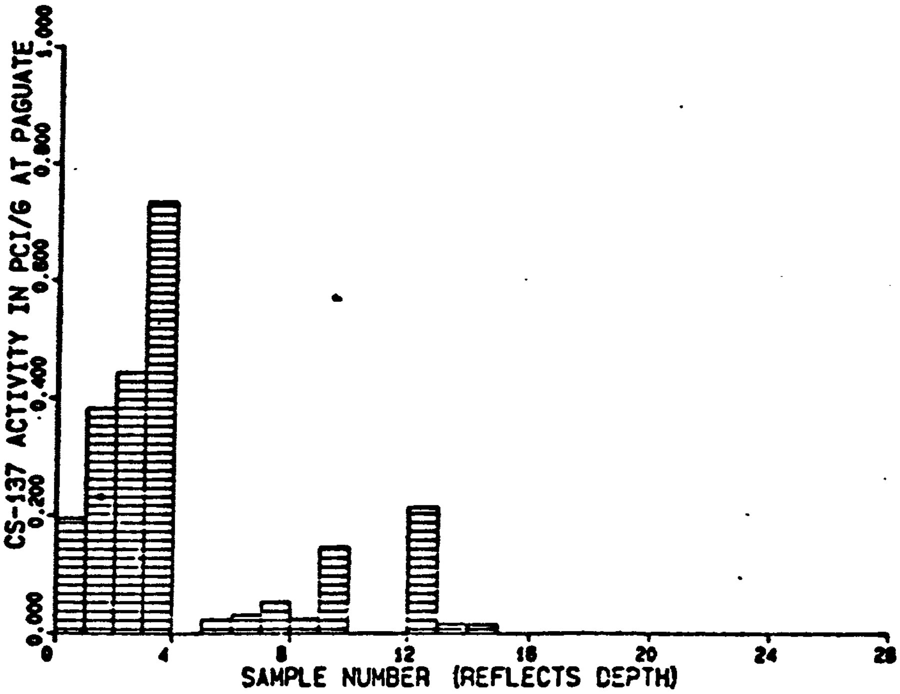

Figure 4. Cs-137 activity as a function of depth at Paguate Reservoir (Popp and others, 1983), measured to depth = 18. Zeros indicate no detectable activity. Sample 15 marks approximately 1950.

TRACE METAL DISTRIBUTION

The silt and clay fractions (<63 um) of sediments were analyzed for As, Cd, Cr, Cu, Hg, Mo, Pb, Se, V, and U. Previous studies (Brandvold and others, 1981; Popp and Laquer, 1981; Dreesen and others, 1982) indicate that concentrations of these trace metals are elevated in uranium mill tailings and in stream sediments in the Grants Mineral Region. Comparison of data from this study of fine-grained sediments to previous studies of suspended sediment from the Rio Puerco and Rio Grande and to average crustal abundances of the elements is shown in Table 2.

Both surface samples and subsurface samples show concentrations of As, Se, Cd, Hg, and U considerably elevated above average crustal abundances. Uranium concentrations are two orders of magnitude higher and Hg concentrations are an order of magnitude higher than crustal abundances. Along the Rio San Jose, Hg concentrations are even higher. The surface samples show trends similar to the older valley fill samples, suggesting long term regional elevation of these elements. The surface samples show concentrations consistent with previous work by Brandvold and others (1981) on suspended sediments in the Rio Puerco and Rio San Jose. Resuspension of surface sediments simply tranports the sediments and associated trace metals to an eventual sink in Elephant Butte Reservoir.

Paguate Reservoir has maximum U and V values at the surface, but only Se shows a significant trend with depth similar to the radionuclide concentrations. Apparently the solubilities of As, Cd, Hg, V, and U under oxidizing conditions are sufficiently high that they are eventually transported downstream while the radioactive species are less likely to be transported. Because most of the Pb is not radioactive, the overall Pb values may not be elevated even when radioactive Pb is high.

CONCLUSIONS

In the absence of historic geochemical baseline data for the Grants uranium region, environmental changes resulting from uranium mine-mill activities can only be determined by indirect methods. As summarized above, we developed a methodology for determining the age of recent sediments in streams draining the region, based on combined geomorphic, stratigraphic, and radiometric dating techniques. Because clay-sized and clay-mineral-rich sediments retain radionuclides and heavy metals derived from mineralization and mined sources, sample sites that contain fine-grained deposits that both predate and postdate mine-mill activity were located in abandoned-channel segments (oxbows) of major streams draining the eastern Grants uranium region. Aerial

Table 2. Surface (S), lower auger samples (L), and valley fill (V) averages for each stream reach. Upper Rio Puerco (URP), lower Rio Puerco (LRP), Rio San Jose (RSJ), Paguate Reservoir (PR); Rio Puerco Suspended Sediments (RP, Brandvold and others, 1981), Rio Grande Suspended Sediments (RG, Popp and Laquer, 1981) and average crustal abundance (CA). Values in ppm.

Trace Metal	Depth	URP	LRP	SJ	PR*	RP	RG	CA
		Sample Site						
As	S	8.0	14.7	17.2	4.6	16	-	1.8
	L	11.0	7.9	6.9	7.2			
	V	5.7	12.9	6.5	—			
Cd	S	0.29	0.31	1.10	0.31	0.15	4.8	0.15
	L	0.33	0.50	0.35	0.82			
	V	0.30	0.25	0.34	—			
Cr	S	56	46	33	26	26	73	100
	L	39	45	36	33			
	V	46	40	33	—			
Cu	S	62	69	21	20	87	41	50
	L	34	51	20	19			
	V	27	27	24	—			
Hg	S	0.31	0.22	1.02	0.06	0.05	0.72	0.02
	L	1.11	7.6	5.65	0.56			
	V	0.21	2.3	0.10	—			
Mo	S	2.9	11.1	1.2	2.4	0.58	19	1.5
	L	2.7	20.0	1.5	2.2			
	V	8.5	2.6	1.1	—			
Pb	S	17	36	32	16	37	20	13
	L	33	56	35	30			
	V	32	24	43	—			
Se	S	0.20	0.28	0.15	2.0	—	—	0.05
	L	0.20	0.32	0.26	0.48			
	V	0.48	0.26	0.37	—			
V	S	87	116	93	175	24	75	123
	L	103	87	98	91			
	V	103	107	111	—			
U	S	405	372	301	550	55	—	2.7
	L	139	265	176	412			
	V	500	275	125	—			

photographs and derivative maps made between 1935 and 1978 provided the historical and geomorphic documentation of approximate dates of oxbow formation and ages of alluvial fills in the abandoned-channel segments. Pits dug at these oxbow sites revealed the stratigraphy and composition of the deposits. Refinements in dating the sediments may be possible using dendrochronology and flood data to determine oxbow stratigraphy.

Samples collected from pit walls and auger holes below the pits were subjected to radiometric analysis by gamma ray spectrometry for the artificial radionuclide Cs-137 and the natural radionuclide Pb-210 as well as other U-238 and Th-232 daughters. Because of the dynamic nature of the system, absolute dating with Cs-137 was not possible but samples could be dated as either pre- or post-1950. The 1950 date is important because it marks the beginning of uranium mining activity in the region. Lead-210 dating was not possible because background Pb-210 was high relative to fallout Pb-210. It may be possible to separate effects of uranium mining and milling activity by comparing U-238 daughter accumulation to daughters in the Th-232 series.

Sediments dated by Cs-137, stratigraphic, and historic techniques were analyzed for radionuclides and trace metals which may be derived from uranium ores. The U-238 daughters are generally high in the region and little difference was found between present channels and past oxbow fills, except for the Paguate Reservoir site and surface samples. Recent sediments at Paguate Reservoir clearly show elevated levels of U-238 daughters in sediments dated after the mid-1950's. Sediments from the Jackpile uranium mine have been trapped in the reservoir fill.

Trace metals As, Se, Cd, Hg, and U show elevated values on a regional basis but no correlation with age (i.e. pre- or post-1950). These elevated trace metal values may simply be due to their association with the regionally mineralized rocks. Reworking of older sediments eroded from the arroyo walls apparently partially masks contributions of mine and mill-related trace metals and radionuclides in sediments.

ACKNOWLEDGMENTS

We are grateful to the Huning Land Trust, Westland Corporation, Benjamin Benavidez, and the Laguna Indian Tribe for permission to sample on their lands. The Office of Surface Mining, Department of the Interior, provided funding for the project. We thank Tom Lynch and George Austin for critically reviewing the manuscript. Virginia McLemore was very helpful in providing background data and production figures for the Grants uranium region. Several of the ideas and procedures discussed in this report, especially related to radioisotope dating, were initially pursued by Michael Dehn (1983). John Young, Jim Boyle, Doug Heath, Steve Rosen, Jack Purson, and Phil Coleman helped in surveying sample sites, digging pits, and compiling hydrologic and sedimentological data on the Rio Puerco drainage system. We are grateful to Lisa Zangara, Margo Moore, and Lois Devlin for typing the manuscript and to Teresa Mueller for drafting.

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[illegible] Mine Cleanup

Laguna [illegible] Anxious [illegible] Land To Use, But [illegible] May Bring More Delays

Laguna Gov. Chester Fernando: "We want to reclaim it."

A store in Paguate stands within site of the old mine.

[illegible] says in no uncertain terms.

Depressed market conditions, however, forced the Anaconda Minerals Corp. to close the mine in [illegible] 1982, sending the tribe's unemployment rate [illegible] from an estimated 25 percent to more than [illegible] percent.

The operation, consisting of three open pits and nine underground mines, also took a heavy toll on the landscape.

Spread over 2,656 acres, the operation produced almost 25 million tons of uranium ore. Close to 400 million tons of earth had to be moved.

The present day Jackpile is a lifeless gray mass of waste material piles, carved up mesa and abandoned roads winding their way down to the canyon bottoms. Chain link fencing lines the minesite perimeter to prevent would-be explorers from straying too close to the mine's steep-walled pits whose depths approach 250 feet. Scattered, padlocked metal buildings, once used as workshops, occupy multi-level sites throughout the mine.

Public safety requirements, cited in Anaconda's lease, along with federal environmental protection regulations require that the site be reclaimed.

Fernando said he is primarily concerned about the off-site effects — in the water supply or atmosphere — the mine might have on downstream communities.

Beyond that, Laguna is clearly not content to let the land remain unused.

What hasn't been settled is the best way to go about the project, a huge undertaking the Bureau of Land Management estimates could top $50 million.

On Tuesday and Wednesday, the BLM will conduct two public hearings — the first at the Albuquerque Convention Center, the second at Laguna Pueblo — on a draft environmental impact statement that addresses proposed reclamation plans prepared by Anaconda, the BLM staff, other technical experts in Department of the Interior, and

MORE: See MINE on PAGE C6

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Mine Cleanup $50 Million Headache

CONTINUED FROM PAGE C1

the pueblo itself, BLM project leader Mike Pool said.

Though none of the plans proposes the exceedingly expensive task of backfilling all the pits, each would restore the minesite, in varying degrees, for other land uses like grazing, and reduce its radiological and physical hazards.

The plans focus on revegetation, stabilizing highwalls, closing off underground entries, backfilling requirements and removing buildings that had been used for mining operations.

The EIS estimates the cost to carry out the Anaconda plan to be $54 million, the federal plan $55.5 million, and the Laguna plan $57 million. The bearer of the reclamation cost would be Anaconda.

The public comment period on the EIS, released in March, will end Oct. 4. After that, said Pool, a final EIS would be prepared and sent to the Interior secretary for approval.

Fernando said the tribe supports about 80 percent of the federal plan. A major difference is the tribe's proposal that the entire South Paguate Pit be returned to its original contour. Tribal attorney Bill Haltom added that the tribe actually hasn't been far apart on a meeting of minds on the Anaconda plan, originally drafted in 1982.

That meeting may have been temporary. Two weeks ago, the company withdrew its 1982 plan in favor of a new proposal Anaconda General Manager Meade Stirland says takes advantage of the latest reclamation technology and would expand the land use possibilities for the reclaimed area.

One new feature would be the conversion of the North Paguate Pit near the village of Paguate into a water reservoir that could be used for a variety of recreational purposes. The original plan called for partially backfilling the pit.

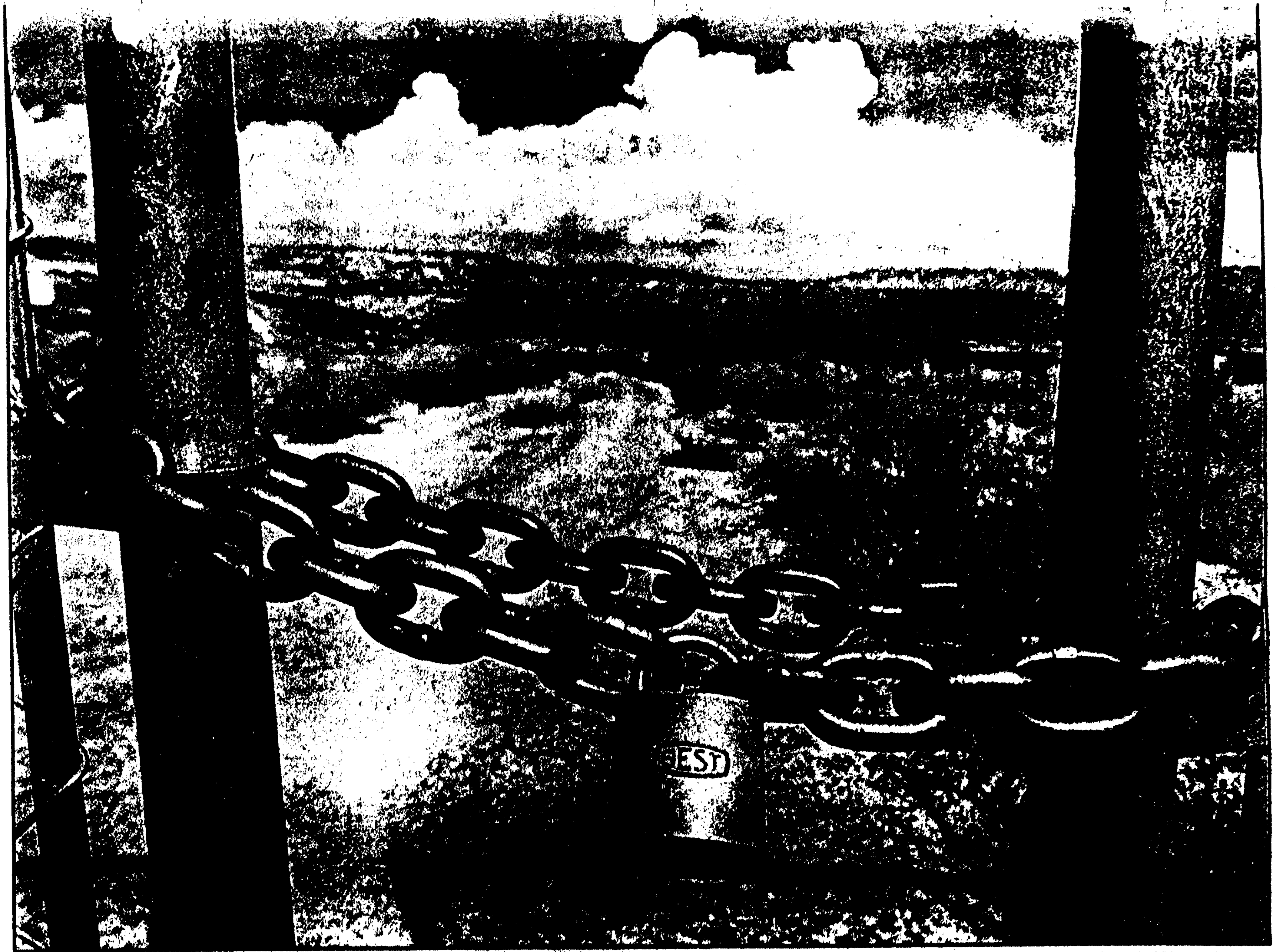
Instead of moving low grade ore piles left in the mine to the pits, the new plan calls for the piles to be moved away from streamways and stabilized where they would be available to be processed if the market improves. The savings in hauling costs would be considerable, Stirland said.

"We feel the willingness to perform a creditable reclamation but we want to use our money efficiently," he said.

Stirland said the modifications are so significant that the company has requested that a new draft EIS be prepared; Stirland also claims the draft EIS contains major factual errors.

But Fernando said the new plan is unacceptable. Haltom called it a "total disaster" that would leave the site essentially unchanged and that it sought only to save the company money.

Since the new Anaconda proposal was submitted during the public comment period, Pool said it likely will be integrated into the final impact statement.



JOURNAL PHOTOS / MARK HOLM

A heavy chain secured by a padlock blocks an access road leading to the Jackpile-Paguate mine's processing area.

▲ ▼ ▲ ▼ ▲ ▼

Evaluation for Post Reclamation Land Use at the Jackpile Mine Area

▲ ▼ ▲ ▼ ▲ ▼

by

Frances Andazola

and

CeCilia Sadler

for

Professor Wm. Paul Robinson

Independent Study
Community & Regional Planning
University of New Mexico
Albuquerque, New Mexico

December 16, 1993

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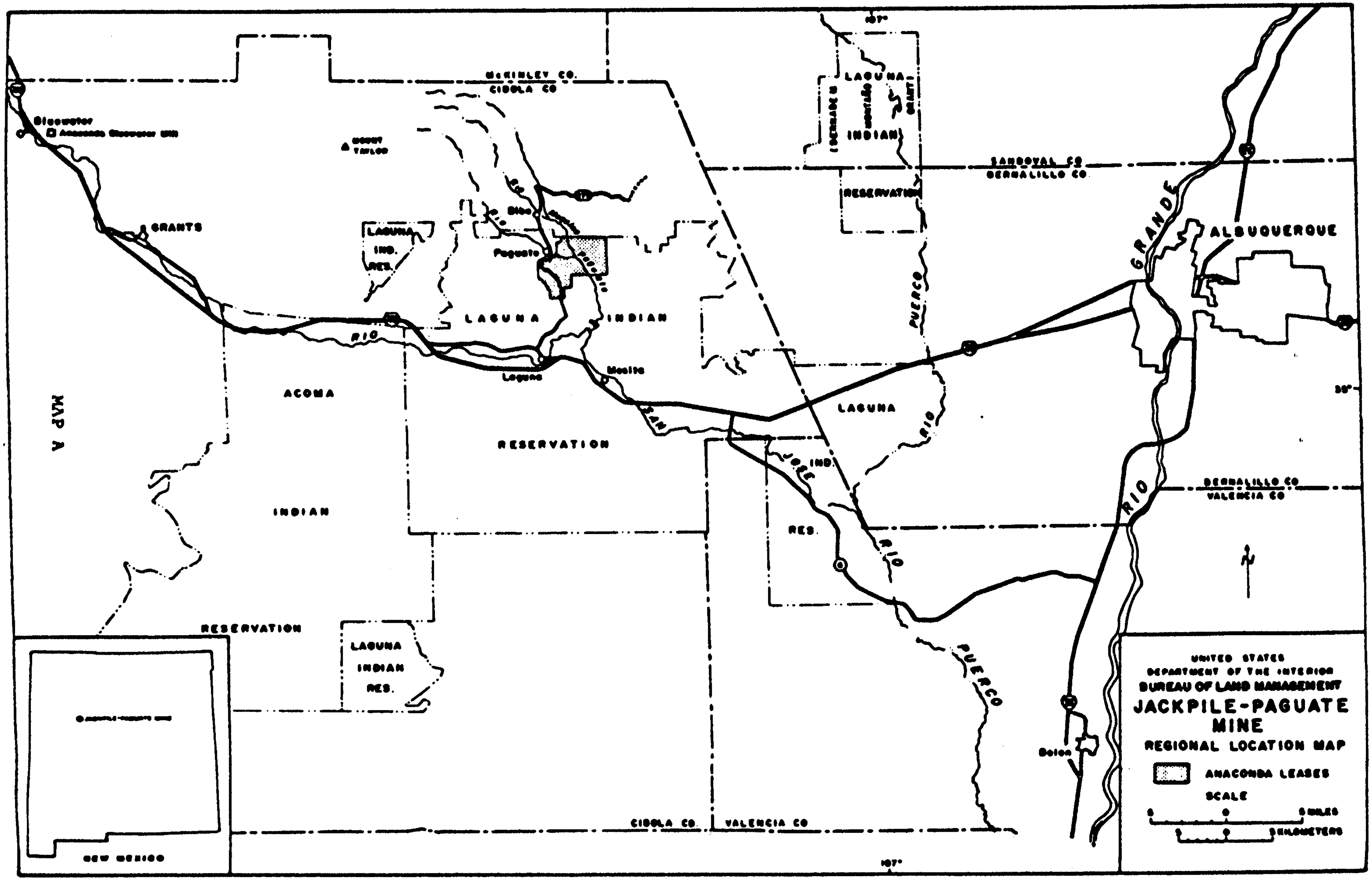
Acknowledgements

We would like to thank Governor Harry Early for permission to visit the Jackpile-Paguate mine-site, Jim Olsen, Reclamation Manager, for his time and patience in answering our questions, Allen Sedick, BIA, Rudy Lorenzo, Construction Supervisor, Nolen Duomo, Construction Foreman, Lloyd Pino Mesita Council Member, Elizabeth Waconda, Katherine Romero, Chuck Romero, Richard Luarke, Tribal Planner, Al Waconda, Mike Pool and Dave Sitzler, two of the three authors of the Final Environmental Impact Statement, Doyle Meadows of the Soil Conservation Service, Kim Ong, USGS, and the staff of the State Engineer's office.

Abstract

This report was prepared to meet requirements for an Environmental Evaluation class supervised by Professor Paul Robinson. The goal of the report is to organize information in an examination of possible land uses after the reclamation of the Jackpile-Paguate mine site has been completed. The reclamation process and the possible risks in the use of the reclaimed land are examined. This report is based on the Final Environmental Impact Statement (FEIS), Cost Optimization on the Jackpile-Paguate Reclamation Program by the Jacobs Engineering Group, Inc., a study requested by the Laguna Pueblo to assist in the development of a reclamation plan and the Record of Decision (ROD), the official plan for reclamation. Other studies include examinations of soil, vegetation, and livestock in areas contaminated by uranium mining and milling activities, fallout, and low level waste.

The use of reclaimed land by humankind and the possible health risks associated with its use cannot be fully explored under the time constraints of one semester. Few long term studies have been completed. Thus, this report only touches upon relevant information and clarifies the need for long term study and monitoring at the Jackpile-Paguate mine site and the Paguate Reservoir.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
JACKPILE-PAGUATE MINE
REGIONAL LOCATION MAP
ANACONDA LEASES
SCALE
MAP A
McKINLEY CO.
CIBOLA CO
SANDOVAL CO
BERNALILLO CO
VALENCIA CO
CIBOLA CO.
VALENCIA CO
Bluewater
GRANTS
LAGUNA IND. RES.
Paguate
Bibo
Laguna
Mesita
LAGUNA INDIAN
ACOMA INDIAN RESERVATION
LAGUNA RESERVATION
LAGUNA INDIAN RES.
LAGUNA IND. RES.
LAGUNA INDIAN RESERVATION
ALBUQUERQUE
Belen
RIO GRANDE
RIO PUERCO
RIO SAN JOSE
NEW MEXICO
107°
35°

Introduction

The Jackpile-Paguate mine site is located on the Laguna Pueblo, 40 miles west of Albuquerque (Map A). In a series of three leases with the Laguna Pueblo beginning in 1952, the Anaconda Minerals Company, a division of the Atlantic Richfield Company, expanded operations to include 7,868 acres of land. Mine operations included 1,015 acres of open pits, 1,266 acres of waste dumps, 103 acres of protore stockpiles, and 32 acres of topsoil stockpiles. 240 acres held support facilities and depleted ore stockpiles (FEIS, 1986, pg. 1'1.) When the mine closed in March of 1982 because of a depressed uranium market, it had expanded to the edge of the Village of Paguate. The terms of the mining lease and Federal regulations required that the mine be reclaimed.[1] A financial agreement between Anaconda and the Laguna Pueblo was made. Plans for the reclamation were made according to the funds available.

What follows is a brief description of the reclamation process and potential concerns associated with use of the reclaimed land. Traditional and current land use options are considered and an evaluation of the health risks associated with exposure to radiation and other contaminants. Finally, this report offers a few practical approaches to protection from radioactive contamination.

Section I

The Reclamation Process

Soil Cover

From 1987 through 1989, the Jacobs Engineering Group was employed by the Laguna Pueblo to develop a reclamation plan. As part of the reclamation plan prepared by the Jacobs Engineering Group, Inc., a minimum thickness of Mancos shale and topsoil was recommended to cover the waste dumps and pit bottoms of the Jackpile-Paguate mine site. Through the use of a computer model, it was determined that "one foot of Mancos shale and two feet of soil would provide the desired radon attenuation from ore-derived wastes inside pit areas. One foot of Mancos and 1.5 feet of soil would be adequate to cover ore-associated wastes outside the pit areas."[2] Again, through the use of a modeling system, these minimum cover thicknesses were predicted to meet the post-reclamation Record of Decision (ROD) standard. The standard required that radon measurements should be less than 3 picocuries per liter (pCi/l) of air plus the background level of .5 pCi/l when averaged over 3 principal areas of the mine site. This means that radon concentrations will vary over the minesite but will meet the average required by the ROD. In practice, 1 foot of Mancos shale and 1 1/2 feet of topsoil is used to cover the dumps and pit bottoms (Jim Olsen, Jackpile-Paguate Reclamation Manager).

A difference of a half-foot exists between what was recommended by Jacobs Engineering Group for the pit bottoms and what has been and is being done. Despite the discrepancy of a

Introduction

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What follows is a brief description of the reclamation process and potential concerns associated with use of the reclaimed land. Traditional and current land use options are considered and an evaluation of the health risks associated with exposure to radiation and other contaminants. Finally, this report offers a few practical approaches to protection from radioactive contamination.

half-foot of soil between what was recommended by the Jacobs Engineering Group for the pit bottoms and what has been and is being done, Mr. Olsen reports that radon measurements over the entire mine site average 1 pCi/l and range from .3-2.5 pCi/l (1 pCi = about 2 decays per minute) and that between the mine site and the village of Paguate there are 15 monitoring sites.

This average is below the 3 pCi/l average required by the ROD for radon gas. The gamma radiation standard set by the ROD is twice the background amount which at Laguna Pueblo adds up to 28 uR/hour (microroentgens per hour). Mr. Olsen reports these levels to be under standard as well. Measurements are made quarterly and verified by Eberline Analytical Company of Albuquerque. Any requests for information should be directed to Governor Harry Early of the Pueblo.

According to these measurements, the combination of 1 foot of Mancos shale and 1 1/2 feet of topsoil over mine pits and waste dumps seems to provide adequate protection for people and animals from exposure to direct gamma radiation and inhalation of radon gas. The possible effects of various erosive factors upon this layer of Mancos shale and Tres Hermanos sandstone will be discussed later in this report.

<u>Vegetative Cover</u>

The next step in reclamation is revegetation of the mine site. Revegetation is done in an effort to stabilize waste dumps from erosion, visually blend the mine site into its surroundings, and support the possibility of livestock grazing on the reclaimed land.[3] The ROD specifies that the vegetation reestablished on the mine site will "consist mainly of native plant species possessing qualities compatible with post-grazing use and adapted to local environment." There are two seed mixtures. One for fine-textured, sandy soils and the other for soils with 20-50% rock content. Mix 1 is composed of blue grama, sideoats grama, galleta, Western wheatgrass, alkali sacaton, fourwing saltbush, yellow sweetclover. Mix 2 contains alkali sacaton, sand dropseed, Indian ricegrass, sideoats grama, blue grama, little bluestern, fourwing saltbush, winterfat and yellow sweetclover. Additional vegetation known to grow in the area on mesa slopes and tops are woody plants like one-seed juniper, feather indigobush, soaptree yucca, winterfat, and rabbitbrush. Other grasses include feathergrass, red muhly, red threeawn, bottlebrush squirreltail and wolftail. Forbs include fleabane daisy, four 'o clocks and cutleaf primrose, wild buckwheat, pinque, plains blackfoot and stickleaf.[4] These other native plants, by the distribution of seeds by wind and animals, may become part of the revegetated surface.

The success of revegetation on the reclaimed area will be based on the percentage of plants present compared to undisturbed areas on the Pueblo. At least "90% of the density, frequency, foliar cover, basal cover, and production of undisturbed references areas" must be present. The ROD stipulates that a determination of the vegetation's success at reestablishing itself will not be made "sooner than 10 years following seeding" and "Livestock grazing will be prevented until 90 percent comparability values are met."

(ROD, 1986, pg. 7) According to Jim Olsen, the progress of revegetation will not be checked until after the third growing season.

Erosion

The following description of weather conditions at Laguna Pueblo are summarized from the FEIS. The temperature range is from the mid-30s in winter averaging in the upper 80s with occasional maximums over 100 degrees in the summer. Mean precipitation in a year is 9.07 inches with 61% of precipitation occurring as rain from June to September from short, intense rainstorms. Wind speeds are light to moderate but strong winds may accompany thunderstorms and winter and spring storms. Winds are from the southeast and northwest with the stronger winds being northwesterly. In comparison to desert and even humid environments "erosion is relatively high in semiarid areas" because rainstorms are often of high intensity leading to flashfloods and erosion.[5] Thus, the comparatively high erosion of semiarid environments must be weighed when estimating the longevity of the protective cover. Other contributors to erosion include the displacement of soil caused by the movements of livestock herds over the topsoil and burrowing animals. In one study of pocket gophers at a low-level waste (LLW) site in Los Alamos, about 12,000 kilograms (kg) of soil per hectare (ha) was displaced during a fourteen-month period. This speeds up the erosion of the protective topsoil by wind but slows erosion by water runoff because of the rougher topsoil surface created by burrowing animals. At the same time, entrances to and tunnel systems created by burrowing animals provide voids or spaces where water can enter the topsoil and percolate downwards. Since evaporation at the site is great enough to result in a "net moisture deficit" (FEIS, 1986, pg. 2'62) the probability of the water percolating down and through the uranium ore-bearing waste and into ground water is limited.[6] Prairie dogs, rabbits, gophers, and other rodents and lizards are present on the Laguna Pueblo.(FEIS, 1986, pg. 2'74.) The ability of some of these animals to dig through the Mancos shale and possibly bring ore-bearing waste to the surface requires further study. At LLW sites, burrowing animals have excavated radionuclides and brought them to the surface just as they would soil.[7] Once on the surface redeposited contaminants have the potential of becoming airborne or transported by rain to areas where livestock and wildlife may drink (surface ponding, reservoirs) and heavy metals, uranium and its decay products can contaminate the water and accumulate as sediment. This is a possible radiation pathway to humans by consumption of livestock and wildlife using these water sources.

The elements of erosion discussed above reveal the dynamic nature of ecosystems and climates like that of Laguna Pueblo. The relative importance of one erosive factor over another and its overall impact upon an environment is not fully known. Yet, since protection from gamma radiation and radon gas is dependent upon the thickness and integrity of the protective cover at the Jackpile-Paguate mine site, very long-term monitoring of the effects of erosion on this cover is important.

Vegetation, Livestock, and Water Studies

While vegetation provides the benefits of erosion control and food for livestock, these benefits are tempered by the possible penetration of plant root systems through the shale cover, into the ore-bearing wastes, and the intake of radionuclides and heavy metals into the plant. It has been shown that "deep-rooted plants can access buried radionuclides and bring them to the surface of the site (Foxx et al., 1984).[8] In response to this possibility, the ROD requires that "Vegetation will be sampled annually for radionuclide and heavy metal uptake in the pit bottoms" (ROD, 1986, pg. 7). The specific capabilities of the Laguna native plant species to penetrate the protective Mancos shale cover on waste dumps and possibly take contaminants into their systems deserves monitoring as well. The intake of contaminants by plants also creates a means by which these substances can be redeposited onto the surface. When vegetation dies and decays substances contained in the plant will be left on surface soils exposed to erosion.[9] The possibility of affected vegetation being eaten by livestock, game, and wildlife creates a radiation and heavy metal pathway for anyone who consumes these animals.

A study of soil, vegetation, water, and cattle near uranium mining and milling facilities in Ambrosia Lake, New Mexico, just northwest of Laguna Pueblo, revealed elevated radionuclide levels in all four elements. The study was conducted because of the great number of uranium mines and mining related activities in the Grants Mineral Belt and concern about health risks to the region's population. According to the authors, "Few studies have addressed radionuclide concentrations in domestic animals raised near U mines or mills. Yet, evidence from two previous investigations indicates that there may be radionuclide contamination of the food chain leading to humans by the U mining and milling industry."[10] What has been learned from that study is applicable to livestock grazing on the Laguna Pueblo since land use, soil make up, vegetation type, and the type of radionuclides potentially present are identical.

In the Ambrosia Lake study, in addition to exposed samples, control samples of soil, plants, and water were collected. These control samples were not near nor had they been exposed to uranium mining and milling activities. Also, three groups of cattle were studied. The control group, consisting of 10 cows, was taken from an area near Crownpoint because it is most like the Ambrosia Lake area yet no above ground uranium mining has taken place there. Five cattle were designated as Group 1 and five as Group 2. The Group 1 cattle were taken from an area that had been frequently flooded by water pumped from the uranium bearing geological formations (dewatering effluent) of the mine site near Ambrosia Lake. Cattle from Group 2 grazed in a larger area and had access to both surface ponds as well as dewatering effluent. Analysis of the samples was done by Eberline Corporation in Albuquerque and for quality control purposes also by EPA-Environmental Monitoring Systems in Las Vegas, Nevada. Methods of measurement were guided by EPA and U.S. Department of Energy procedures. The results of the study showed that "cattle exposed to U mine and milling discharges and wastes had elevated tissue radionuclides, compared with controls" and that "findings support the conclusion that the elevated radionuclide levels found in cattle tissue from Ambrosia Lake resulted from the cattle's exposure to radionuclide byproducts of the U mining and milling industry." Although it is not possible to determine exactly what percentage of contamination was contributed to by each element in the cattle's environment, the authors of this study conclude that "Further environmental sampling and measurements of tissue radionuclide concentrations in animals exposed only to dewatering effluents, or to mill tailings, would be needed to identify the relative contribution from each source. Until these studies are completed, restricting access of livestock to U mine dewatering effluent and to land that has been irrigated with mine water--or is in proximity to mill tailing--would markedly reduce the probability of food chain contamination." All soil, vegetation, and water collected from the Ambrosia Lake area had elevated levels of radionuclides as well.

In the same study, cancer risks from ingestion of contaminated cattle over a one year period were estimated in an attempt to foresee health risks to residents of the area. Three possible situations were modeled in order to estimate these risks and considered the consumption of cattle from each area. Scenario One assumed that each individual in a family would eat 74 kg of meat (the average meat consumption in the United States per person) including the liver and kidneys. Scenario Two assumed that a person ingested 78 kg of muscle and no liver or kidney. Scenario Three, a worst case estimate, assumed that a person ate higher percentages of liver and kidney.

Deaths from cancer for Scenario One are - one chance in 1,640,000 from ingesting control beef, one chance in 1,180,000 from eating Ambrosia Lake Group 2 cattle, and one chance in 350,000 from eating Ambrosia Lake Group 1 cattle. Continued consumption of Group 1 cattle for 20 years would increase the cancer mortality risk to one chance in 18,000. In Scenario Two, where no liver and kidney were eaten, the risk of eating cattle from Group 1 decreased by 55%. Scenario Three revealed that eating a high percentage of liver and kidney raised the risk of death by cancer. Consumption of Group 1 cattle showed results of one chance in 150,000 and for Group 2 cattle, one chance in 500,000.

The authors conclude that "the health risk to the public from eating exposed cattle is minimal, unless large amounts of this tissue, especially liver and kidney, are ingested." Thus, if the liver and kidney is a staple of the Pueblo diet a significant risk exists. The liver and the kidney of cattle absorb greater amounts of radionuclides than other parts of the body. Generally, animals with multiple part stomachs such as cattle, goat, deer, and antelope will have higher levels of contamination than plant eating animals with single unit stomachs. When considering game, small mammals because of their rapid metabolic rate and carnivores because of their place in the food chain will have higher levels of contamination. Contaminants accumulate in the highest mammal in the food chain-humankind being at the top of the food chain.[11]

When comparing the results of this study to possible contamination of cattle at Laguna Pueblo, the following limitations and similarities must be considered. Understanding the limits of the study and the elements it shares with the Laguna Pueblo will be helpful in understanding the connection between the two situations and the possible radioactive contamination of livestock and game at Laguna Pueblo. Limitations include 1) only a small number of cattle were tested from each area; 2) the level of contamination in the soil, vegetation, and water collected may not have accurately reflected the level of contamination that the cattle were actually exposed to (the period of time study cattle grazed in this area varied from 2-7 years and the levels of contamination present may have varied too); 3) the study cattle may have actually drank water with much higher radionuclide levels than given in the report; 4) standard errors were large and; 5) the results of the split sample testing varied. For example, it is possible that levels of the uranium decay product Polonium 210 could be twice as high as the true values. Thus, the results of the study cannot be considered representative of the level of radionuclides present in all animals in the area. Also, Laguna Pueblo has had no uranium mill tailings stored on the mine site.

Important similarities are 1) land use, 2) soil and vegetation types, 3) contaminants identical to those potentially present in environmental elements at Laguna pueblo, and 4) livestock's (and game's) access to water from the mine site.

Since soil and vegetation types are alike we can reasonably expect contaminants to behave similarly in environmental elements and animals. For example, in 1979 radioactivity was measurable in vegetables at Laguna Pueblo (FEIS, 1986, pg. 2'46). However, the conditions existing then, during mining, and now with a great portion of the reclamation completed are different. Current studies of vegetation and livestock specifically from the area near the Jackpile-Paguate mine site would be helpful.

A closer examination of the environmental element, access to water from the mine site, that is shared by the affected livestock from the Ambrosia Lake area and possibly livestock from Laguna Pueblo is warranted. Over the lifetime of the mine site, the Rios Paguate and Moquino, in combination with natural erosive processes such as run off and arroyo headcutting, have carried soil downstream from the minesite to the Paguate Reservoir. The 1986 FEIS uses a conservative process to estimate that since 1952 the volume of deposited sediment in the reservoir is 620 acre-feet or 22 acre-feet per year (FEIS, 1986, pg. 2'58). Along with soil not associated with uranium, uranium ore (and, thus, its decay products) and heavy metals will have also been deposited. Tables 2-15 and 2-24, below, from the FEIS shows, respectively, 1981 gamma exposure rates at Paguate, 1983 radium and uranium levels at Paguate, and an 1982 aerial gamma radiation survey of the mine site and surrounding area.

TABLE 2-15

GAMMA EXPOSURE RATES AT PAGUATE PRESERVOIR
(microroentgens per hour)

Exposure Rate	Percentage of Reservoir
Less than 10	22
11-20	47
21-30	27
Greater than 30[a]	4

Source: Eberline Instrument Corporation 1981.
Note: [a]The maximum rate measured was 47 microroentgens per hour.

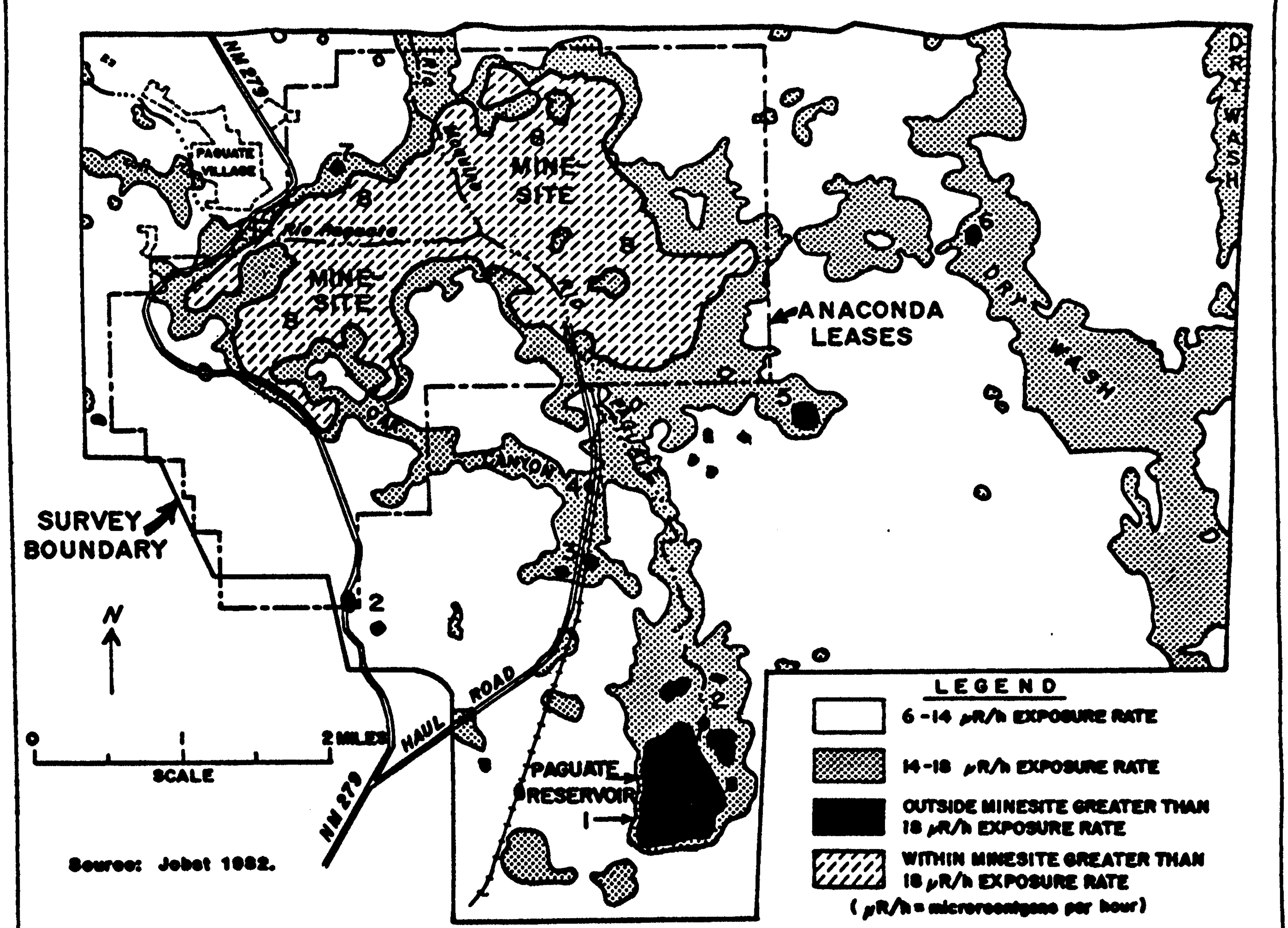
TABLE 2-24

RADIUM AND URANIUM IN SURFACE WATERS IN AND NEAR THE MINESITE

Location	Ra-226[a]	Natural Uranium[b]
Rio Paguate (upstream)	0.35	0.006
Rio Moquino (upstream)	0.28	0.008
Ford Crossing (downstream)	3.73	0.239
Paguate Reservoir	1.03	0.236

Source: Momeni, et al. 1983.

Notes: [a]Measured in picocuries per liter.
[b]Measured in milligrams per liter.



Aerial Gamma Survey of the Minesite and Surrounding Area

These charts are, at least, ten years old and change has occurred. Specifically, the gamma radiation readings represented by the aerial survey which surround the Paguate Reservoir will have decreased due to the positive efforts of the Jackpile-Paguate Reclamation staff and crew. However, long lived radioactive elements like uranium and radium and gamma radiation at Paguate Reservoir will have increased due to the continued build up of sediment.

The sedimentation at Paguate Reservoir which has caused a build up of uranium associated contamination, presents the clearest risk to animal and human health since ranching is one of several traditional occupations that remains in place. Currently, there are approximately 2500 head of cattle on the Laguna Pueblo-not all have access to Rio Paguate and Paguate Reservoir downstream from the mine site. There is one sheep rancher along the Concho Valley. The valley extends from the southern tip of the minesite, along the Paguate River and down to the Paguate Reservoir (per conversation with Nolen Duomo). The cattle and sheep that graze in the Concho Valley and the health of people that consume these cattle and sheep may be at risk.

Post-Reclamation Land Uses

The ROD summarizes possible land uses for the reclaimed mine site. They conclude that "Limited livestock grazing, light manufacturing, office space, mining and major equipment storage will be allowed. Specifically excluded are habitation and farming."[12] Although the ROD does not describe what is meant by limited livestock grazing, erosive factors contributed by cattle and sheep, burrowing animals, the natural erosive processes of a semiarid climate, and the consequent concerns about radioactive exposure places limits on how extensively the reclaimed land can be used.

Other options, the placement of light manufacturing, office space, or stored equipment on the land will require access to utilities, road improvements, and other investments in the physical structure of the site in order to make it functional. Currently, according to Richard Luarke, Tribal Planner, the pueblo does not possess the funds to make the necessary improvements. This does not necessarily close this option off to the Pueblo. Dependent upon the amount of investment required to make the site functional, any remaining reclamation funds could be applied to this purpose. Also, if the Pueblo desires, incentives such as low rent or other incentives can be offered to outside investors in exchange for their investment in the improvement of the site. This use of the reclaimed mine site would eliminate topsoil erosion due to livestock's movement on the surface of the land and paved roads would eliminate erosion due to vehicular traffic. Yet, people occupying these commercial spaces are still at risk to any exposure caused by the other erosive factors already discussed.

Currently, there is a moratorium on mining on the Laguna Pueblo (conversation with Lloyd Pino, Mesita Council Member). If the price of uranium increases to a profitable level, the incentives for mining the remaining uranium must again be measured against the impact on the environment as well as the social structure of the Pueblo. If this question arises again, the Pueblo now has a wealth of experience to base their decision on. Larry Chalis, speaking at the Southwest Indigenous Miner's Conference at Paguate Village[13] described some the social impacts of mining upon the village. For example, during mining, traditionally prepared fruits - sun dried - were exposed to uranium bearing dust from the mine site. That method of preparation had to stop. The traditional annual hunt was also effected by the retreat of game from mine activity. The structure of the hours of work required by Anaconda placed hardships on families and traditional methods of worship. Religious practices that required 4-5 days away from work were difficult to participate in since work hours conflicted with that amount of time away from work. Another hardship was experienced by families employed by the mine when shift hours did not match. For example, one parent may be arriving from work while the other was leaving. This left little time together with each other or children. Also, the generation that grew up working the mine lost opportunities to learn the once common practice of farming. Now, according to Richard Luarke, the current younger generation has little interest in farming.

At the conference, various village members expressed concern with the future possibility of mining. One village member asked if the Record of Decision could be amended to emphasize reclamation as opposed to future mine use. The sentiment expressed at this meeting does not seem to support the possibility of mining as a land-use option. However, the experience gained by the Pueblo will assist them in determining the social impacts of commercial development of the reclaimed mine site as well.

Due to the natural dynamic processes in the ecosystem of the mine site and surrounding areas, considerations for any future land use must examine change and how that might effect the reclamation. Another dynamic component is the culture. Any land use development in the area must consider the long history of cultural traditions.

Section II

Ground and Surface Water; A Closer Look

The purpose of this section of the report, is to assess the characteristics of the groundwater and surface water located in the Jackpile Mine and Mesita Reservoir area. Information presented here, is an evaluation of readily available literature regarding the Jackpile Mine area. Additionally, personal testimony gathered while interviewing Laguna Pueblo residents, is included where relevant to the subsection. The readily available information was accessed through several Federal Documents to include the Environmental Impact Statement Draft and Final, Water Resources on the Pueblo of Laguna, West-Central New Mexico, and Hydrology and Water-Quality Monitoring Considerations, Jackpile Uranium Mine, Northwestern New Mexico. Each of the documents reviewed is listed in the Bibliography. Since the goal of this section of the paper is to evaluate ground and surface water factors, one basic subsection within this section pertains to the geology of the area, with description of the water bearing units. It is necessary to include fundamental geological composition, which, in turn correlates to the amount of water and quality of water naturally occurring. These two points are critical in evaluating land use after the reclamation process has been finalized.

Topographical Features pertaining to Ground and Surface water

The area of the Jackpile Mine leases is an area situated along two perennial rivers and in the foothill region of the San Mateo

Mountains (refer to Map 1). Elevations within the mine lease boundary range in altitudes from 5,820 to 6,910 feet. Several prominent topographical features surround the Jackpile mine site. On the northwest side, the San Mateo Mountains frame the mine area. Mount Taylor is the highest peak, raising to 11,300 feet, and located 15 miles from the mine site. Wheat Mountain (7,140) is the highest feature on the southwest side of the mine site. Other topographically high areas contributing to the surface hydrology in close proximity to the mine area are the drainage divides located southeast of Mesa Chivato and west of the mine site. Gavilan Mesa is a prominent topographical feature located at the northeast corner. In the region south of the mine area are North and South Oak Canyon Mesas. Several unnamed mesas raise to prominent but undistinguished heights in the vast openness. From the village of Paguate, one can see jutting mountain peaks, contrasting mesas, and several piles of seemingly groomed earth. The "groomed" pilels are waste rock and stockpiled ore which range in height from 50 to 200 feet. From a high point, one can see two huge depressions in the earth's surface. These are pit areas which sink 200 - 300 feet below the surrounding land surface.

The Rio Moquino and the Rio Paguate are two perennial rivers meandering from the origin in the San Mateo Mountains. Rio Moquino enters the mine area on approximately the north side, the Rio Paguate enters on the northwest side. Rio Moquino joins the Rio Paguate in approximately the middle of the mine area. From the mine region, the Rio Paguate flows southeasterly into the Mesita Reservoir. Drainage area of the Rio Paguate above the Jackpile mine region is 107 square miles (EIS, final p2-46).

The Climate in northwestern New Mexico is characterized by minimal precipitation and significant evapotranspiration (USGS #85-4226). Climate classification is semiarid with an average annual rainfall in the area is 9.7 inches (EIS, final).

Rainfall has been more unpredictable then in the past in this semiarid climate. Three major storms carrying heavy precipitation have occurred since 1988. "We aren't sure which was the 50 year flood or the 100 year flood," commented Nolan Duermo, Reclamation Manager. Reportedly the storm of 1993, was localized directly over the mine area, with surrounding areas not receiving any rainfall (Rudy Lorenzo, Reclamation Project Crew Foreman, interview).

I. Geological Description of the Jackpile Mine Area

(The following information is summarized from the Risser and Lyford USGS Report 83-4038, section on 'Ground Water with Geology' from the EIS, final 1986).

The stratigraphy of formations in the area of the Jackpile Mine range in age from Late Cretaceous through to Triassic (Please refer to Figure 1 for this section).

SYSTEM	FORMATION OR GROUP	MEMBER OR TONGUE	THICKNESS (feet)
CRETACEOUS	Point Lookout Sandstone of Mesaverde Group	Hosta Tongue	100
	Crevasse Canyon Formation of Mesaverde Group	Gibson Coal and Dalton Sandstone Members	400
	Mancos Shale	Mulatto Tongue	400
	Crevasse Canyon Formation	Dilco Coal Member	85
	Gallup Sandstone of Mesaverde Group		80
	Mancos Shale		750
	Lower part of Mancos Shale	Includes three sandstone tongues of Mesaverde Group	270
	Dakota Sandstone		50
JURASSIC	Morrison Formation	Jackpile sandstone (economic use)	200
		Brushy Basin Member	270
		Westwater Canyon Member	50
		Recapture Member	40
	Bluff Sandstone		300
	Summerville Formation		90
	Todilto Formation		10
	Entrada Sandstone		120
TRIASSIC	Chinle Formation		

EXPLANATION

SANDSTONE

SHALE AND MUDSTONE

CARBONACEOUS MATERIAL

ANHYDRITE AND LIMESTONE

Source USGS #85-4226

Figure 1

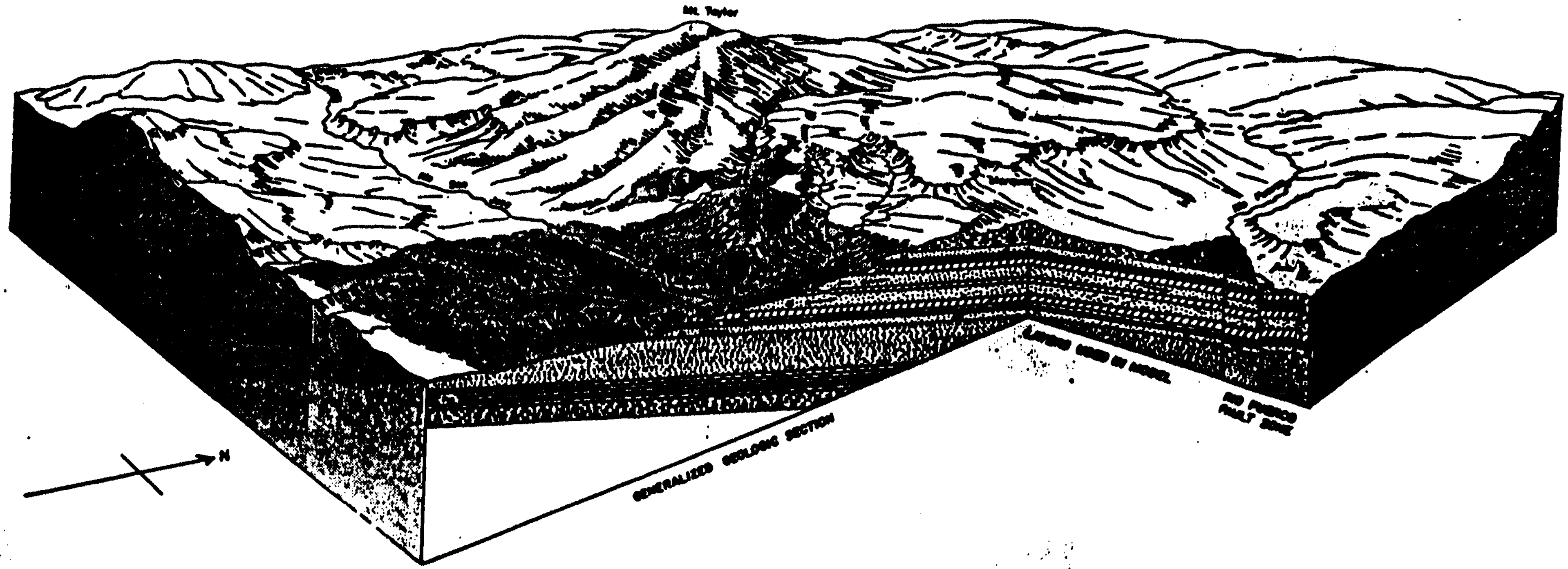


Figure 2

CONFINING BED

WATER BEARING BEDS

IMPERMEABLE BOUNDARIES

GENERAL DIRECTION OF GROUNDWATER FLOW

NOTE: NOT TO SCALE.

[DARKENED LAYER IS THE JACKPILE SANDSTONE]

Cretaceous

The Cretaceous Period in this area consists of inter woven layers of Dakota Sandstone, Mancos Shale and the Mesa Verde Sandstone. Water bearing units in the Cretaceous period are the Dakota and Mesa Verde Sandstone Groups. Units in the Cretaceous system with the greatest water bearing capacity are the Dakota and Mesa Verde Sandstone. Risser and Lyford describe Dakota Sandstone as four, fine - to coarse - grained, well consolidated sandstone beds separated by intertwining beds of Mancos Shale. Water from the Dakota Sandstone and Mesa Verde Formations yield approximately less than 15 gallons per minute (gpm). Wells pumped from this formation are generally used for stock consumption because of higher concentrations of dissolved solids and lower average gallons per minute retrieved.

Water recharge to the Cretaceous units is predominantly from stream flow and precipitation. Cretaceous units discharge to the Rio Moquino and the Rio Paguate through spring runoff. Seepage occurs to underlying geologic units.

Jurassic

The Jurassic Period (highlighted in Figure 1) in the area consists of Entrada Sandstone, Todilto Formation, Summerville Formation, Bluff Sandstone and Morrison Formation. For this section, the more significant water bearing units are summarized, those being units within the Morrison Formation.

The Morrison Formation in the mine area is divided into three members and one informal unit. The three members are the Recapture Member, Westwater Canyon Member and Brushy Basin Member, and the informal unit is the Jackpile Sandstone. Principal water bearing units in the Morrison Formation are the Westwater Canyon Member and sandstones in the Brushy Basin Member, which include the Jackpile sandstone. Water pumped from these members produce water for domestic, industrial, and stock uses at rates averaging 30 gpm.

Jurassic units in the area of the mine receive recharge by precipitation to exposed outcrops as well as leakage to from the overlying Cretaceous sandstones. Some discharge from this unit is released by seepage into the merging rivers, approximately at the mine site (Risser and Lyford, pg. 31). (Refer to figure 2, darkened area).

Triassic

The Triassic system in the area of the Jackpile Mine consists of siltstones and mudstones of the Chinle Formation (reddish-gray). This unit is reported to yield only occasional aquifers of local importance.

Recharge to units in the Triassic age are through precipitation on outcrop areas. Seepage occurs upward from the Permian rocks (Risser and Lyford, pg. 31).

Some Comments of Tertiary and Quaternary Deposits

The Tertiary member is compiled mainly of basalt flows from Mount Taylor. Sources of water located in this layer are from six springs located immediately in the area of Mount Taylor. Additionally, precipitation contributes to recharge within this unit. Water from this layer is hypothesized to contribute some recharge to Paguate Creek. Additionally, there are deposits of late or in the Quaternary period, in the alluvium fill of the Rio Paguate and the Rio Moquino. Relationship to water flow and recharge is shown in figure 3.

B. Pit Backfill

A more recent "formation" in the area of the Jackpile Mine is the pit back fill deposit. It consists of protore, waste dump material and excess material from waste dump re-sloping and stream channel clearing (Record of Decision, December 1986) Additionally, it was reported that the homes built to house the mine workers during mine operation were broken down and filled into the north pit.

The Record of Decision (ROD), states in the section titled "Pit Bottoms", the following:

> . . . "the pits will remain as closed basins. . . . Additional backfill will be added as necessary to

control ponded water. The duration of the monitoring program will be a minimum of ten years."

The two pits, North and South Pits are in the twice a year monitor phase (determined as by the EIS final and the ROD). Figure 4 is a photo looking east from the top west edge of the south pit. The monitor well is indicated by an arrow. Saturation into the fill by water is reportedly occurring at the north pit but not at the south pit (Jim Olsen, Nov. 93). Saturation is an indication of how water is refilling into the area after extensive dewatering and interruption of the water bearing units. Saturation is good in one aspect in that the water is returning to the area. However, saturation to the point of ponds developing in the pits is a potential health hazard. The backfill is placed a minimum of ten feet over the exposed ore to protect from ambient exposure. Also the backfill is put in place in an effort to prevent the groundwater to seep to the surface where it might begin collecting in ponds. The ponds would likely contain contaminants which would not meet federal regulations.

The north pit is located near the Rio Paguate and northeast of the south pit (refer to Map 1). Rio Paguate in the area of North Pit contributes seepage into the formations in that area. South pit is located northeast of the P-10 underground mine area. The slow recharge rate of water in the south pit is likely impacted by the extensive extraction of Jackpile Sandstone during underground

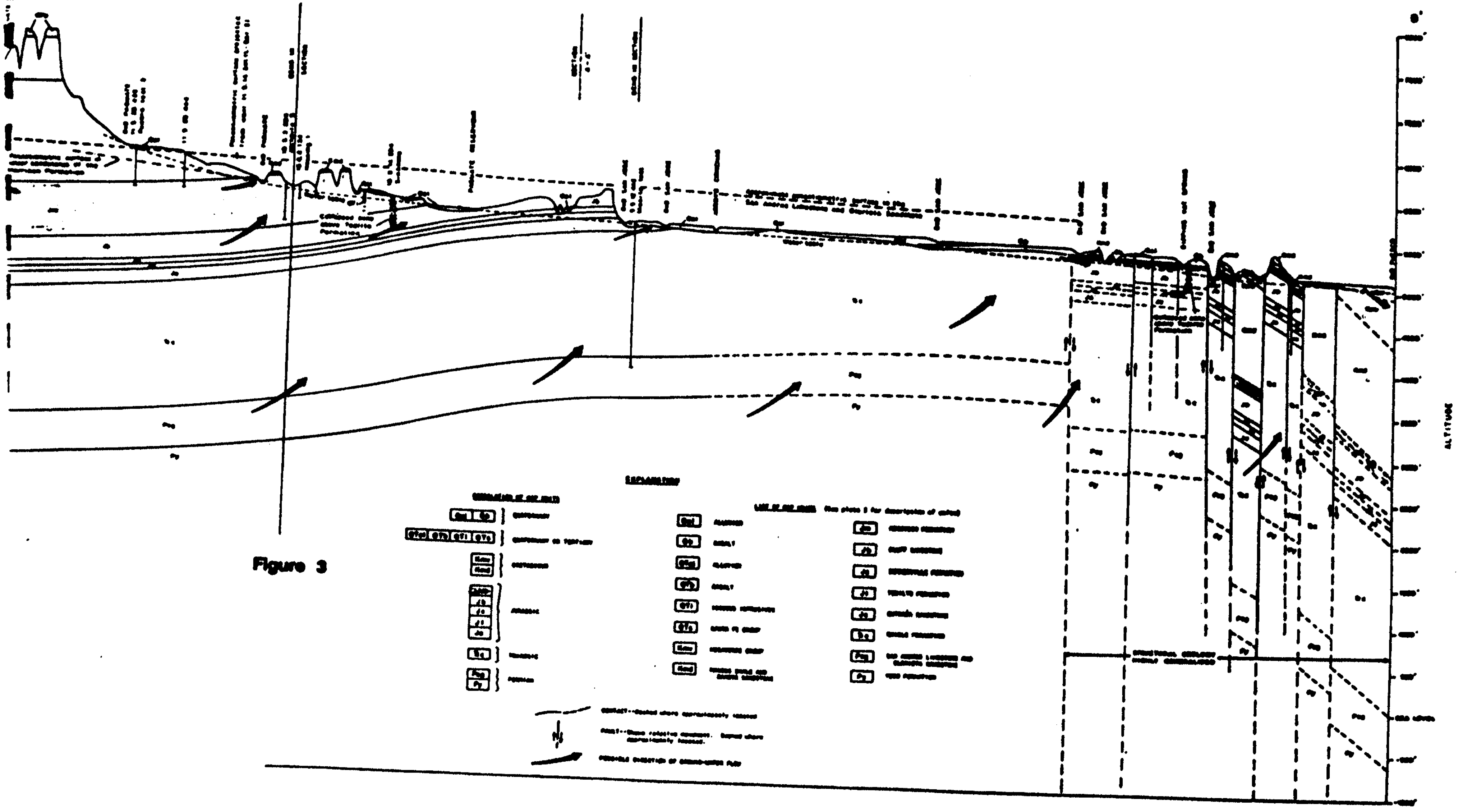


Figure 3

mining, this observation was confirmed by Reclamation Manager, Jim Olsen.

II. Discharge and Recharge

A. Dewatering with Impacts

An impact which caused loss of water in the Jackpile sandstone unit was dewatering for access into underground mines. Dewatering is the process of pumping water out of the ore layer to increase the strength of the rock. Drainage of the saturated ore body usually takes place before the uranium ore is recovered." (Water Quality Data Report, 1980, pg 8). Water was reported to have been extracted from the P-10 mine to an unlined holding pond directly east of the P-10 mine. The average rate of discharge in 1977 was reported as 150 gpm per day and in 1979 discharge declined to 104 gpm per day.

During 1978, discharge from the Jurassic aquifer averaged about 250,000 gallons per day during 1978 (Risser and Lyford).

Risser and Lyford also reported the following statement in their report:

> "The large open pits have permanently changed the geological composition of the area of the Jackpile mine. [One well] tested in the Jackpile sandstone, declined 25 feet from December 1974 to December 1977. Decline was partly in

FIGURE 4

combined rate of as much as 250 gpm might lower the water table and decrease the water lost to transpiration, which might dry up the marshy area and eliminate the wetland." (Lyford and Risser, 1984, p.41)

A natural wetlands was said to have existed in the alluvium of Rio Paguate near Chinatown by a local resident. Refer to map 1 in back flap for location of China Town).

> "Before the mine there was a marshy area over there near where Chinatown is (refering to a photo on file at the Laguna Library). We used to have fruit trees and the fruit was so delicious, so sweet. Since the mine, the marshy area dried up and the fruit trees died."
>
> -- Elizabeth Waconda, Village Paguate Native

III. Water Quality

This sub-section of the report will evaluate only uranium and radium levels in the ground and surface water of the Jackpile Mine and Mesita Reservoir area. "Concentrations of uranium and radium as well as other trace elements were generally less than permissible established in national drinking-water regulations or New Mexico ground-water regulations. Trace elements that could pose water problems because of their association with uranium ores are lead, selenium, iron, manganese, molybdenum, vanadium, radium and uranium." (Hydrology and Water Quality, BLM #854226) response to mine dewatering from Anaconda's underground workings. . . . The water level decline in the [same well] from 1959 to 1979 was about 102 feet. Apparently even before the start of underground mining in 1974, the water level had declined, probably as a result of ground water discharging into the pits excavated for the surface mining that began in the early 1950's (Risser and Lyford Report, pg. 17).

B. Wetlands

A wetlands area is present in the alluvium of the Rio Paguate, located just immediately west of the village of Paguate, between the village and the rio paguate. Wetlands generally are areas with rich soil and more concentrated water accumulation. Dry periods occur, usually in the winter. The significance of wetlands are characterized by unique vegetation that grows in the organically rich soil. Additionally, wetlands act as a filter for water seeping from higher elevations or from aquifers to a moving body of water.

"Groundwater of the alluvium along the Rio Paguate is hydraulically connected to streamflow in the Rio Paguate and the bedrock aquifers that bound the valley fill. . . . Groundwater is withdrawn for public supply in this area [between the Village of Paguate and the Rio Paguate on the southwest side of the village] at an average rate of 30 gallons per minute. More wells withdrawing water at a

FIGURE 5

RADIUM AND URANIUM IN SURFACE WATERS IN AND NEAR THE MINESITE

Location	Ra-226[a]	Natural Uranium[b]
Rio Paguate (upstream)	0.35	0.006
Rio Moquino (upstream)	0.28	0.008
Ford Crossing (downstream)	3.73	0.239
Paguate Reservoir	1.03	0.236

Source: Momeni, et al. 1983.

Notes: [a]Measured in picocuries per liter.
[b]Measured in milligrams per liter.

FIGURE 6

Sampling site	Uranium (milligrams per liter)	Radium-226 (picocuries per liter)
Rio Paguate upstream from mine area	0.008	0.36
Rio Paguate upstream from confluence with Rio Moquino	.160	3.89
Rio Moquino upstream from mine area	.007	.34
Rio Moquino upstream from confluence with Rio Paguate	.051	1.73
Rio Paguate at ford crossing downstream from mine area	.266	4.31
Paguate Reservoir	.210	1.18
Well 4	.005	.54
New shop well	.008	2.19
Old shop well	.112	2.13
Well P10	.0036	.82

The following table is the permissible limits for safe drinking water set by the Federal and State governments. There is not a Federal limit for Uranium, which would have jurisdiction for the permissible standards at Laguna Pueblo. The State standards have been considerably higher than the Federal standards in the other readings (only radium is shown). Notice in the example shown, permissable radium level is six times more than the federally agreed level.

Trace element	Federal Limit *(1)	State Limit *(2)
Radium (Ra), picocuries per liter	5.0	30
Uranium (U), milligrams per liter	No federal limits have been set for what is passable.	5

*(1) National Primary Drinking Water Regulations (US EPA, 1977).
*(2) New Mexico State Ground Water Regulations (NM Water Quality Control Commission, 1982).

Figure 5 and 6 are levels of radium and uranium concentrations found in and near the mine site. Figure 5 is from the Final Environmental Impact Statement and Figure 6 is from Hydrology and Water-Quality Monitoring Considerations, Jackpile Uranium Mine, Northwestern New Mexico, USGS Water-Resources Investigations Report 85-4226.

Each of the tables indicate that the uranium and radium levels in surface water are higher after passing through the mine site.

According to the State and Federal Limits, the samples show high levels, but are below the standards.

There are twenty two monitor wells currently in place checking the quality and recharge of water in the Jackpile Mine area. The monitor well sites are located through out the mine site area. The Final Environmental Impact Statement, October 1986, calls for twice annual checks on water quality and water recharge, for ten years after the start of reclamation and once a year after the ten year phase is completed. After the reclamation monitoring of twice a year is complete, then the mine site will be monitored once a year. Official samples are taken and recorded in November and May to fulfill the monitoring requirement.

According to the reclamation manager, Jim Olsen, there has been "no change" in the concentration of sediments checked. Presumably this means since the studies with findings reported in the Final Environmental Impact Statement, October 1986. Additionally, Mr. Olsen reported that the water analysis taken was "within standards." Since this is indian land, standard having jurisdication would be the federal standard.

Summary

There are several concerns regarding the ground and surface water after the reclamation phase is complete. A primary hydrologic concern is that oxidation may occur in the surface area of rock fragments in the backfill and waste piles. The studies reviewed of the mine site prove to display no data regarding the quality of water passing through the waste rock. Naturally, water from waste rock will discharge to adjacent streams and adjacent aquifers, principally the alluvium and the Jackpile sandstone.

The information reviewed and presented on water lead to the conclusion that the highest concentrations of radium and uranium are found in the water of the Mesita Reservoir. Use of the land other than to support agriculture or livestock is recommended as the uncertainty regarding potential health risks exists.

Summary Recommendations

This report examines potential land uses for the reclaimed Jackpile-Paguate uranium minesite, elements effecting the reclamation, and potential associated health risks. These aspects of land use at the mine site indicate the need to monitor the integrity of the protective shale and sandstone cover and identify and address contaminant levels downstream at the Mesita Reservoir. Currently, livestock are grazing in the area of the reservoir. Thus, a possible pathway for human consumption of radium and uranium is present. Activity which leads to consumption of water by livestock or wildlife at the reservoir is strongly discouraged. Immediate attention needs to be focused on lowering the risks associated with contaminated sediment in the Mesita reservoir. Based on conversations with Allen Sedik, BIA, there are current plans to remove the salt cedar and establish a wildlife refuge at the reservoir. Because of our research, we believe the Pueblo should consider the level of ionizing radionuclides deposited in the reservoir sediment and the associated health risks to anyone removing the salt cedar, to wildlife frequenting a refuge, and to area residents through possible consumption of ducks. It is reported that duck feathers are desirable by residents for ceremonial purposes (Conversation with Richard Luarke). The area of the reservoir might be reclaimed relatively inexpensively by constructing a wetlands. This could produce vegetation which would absorb the contaminants in the sediment. Yet, contaminated vegetation from the constructed wetlands can create a radiation pathway through ingestion.

Whatever decisions the Pueblo makes with regard to the land use of the Mesita Reservoir, considerations of how the reclaimed minesite will be used can now include the experience of the people of the Pueblo of Laguna, the physical aspects of land use presented in this paper, and the potential health hazardous due to long term exposure to ionizing radiation.

Endnotes for Section I

[1] Final Environmental Impact Statement, U.S. Department of the Interior, Bureau of Land Management, and Bureau of Indian Affairs, Albuquerque, New Mexico, October 1986, pg. 1'6. These regulations are published standards for Leasing of Tribal Lands for Mining, Surface Exploration, Mining and Reclamation of Lands, and Operating Regulations for Exploration, Development and Production.

[2] Cost Optimization on the Jackpile-Paguate Reclamation Program, Dr. Charles C. Reith, Mr. Raoul Portillo, Dr. Jere Millard, Dr. Douglas Gonzales, Jacobs Engineering Group, Inc., Albuquerque, New Mexico, 1989, pg. 3.

[3] Ibid., pg. 2.

[4] Final Environmental Impact Statement, U.S. Department of the Interior, Bureau of Land Management, and Bureau of Indian Affairs, Albuquerque, New Mexico, October 1986, pg. 2'69.

[5] Biotic and Abiotic Processes, T.E. Hakonson, L.J. Lane, E.P. Springer from Deserts as Dumps?, edited by Charles C. Reith & Bruce M. Thomson, University of New Mexico Press, Albuquerque, New Mexico, 1992, pp. 119 and 138.

[6] Ibid., pp. 112 and 113.

[7] Ibid., pg. 111.

[8] Ibid., pg. 107.

[9] Introduction to the Radioecology of Forest Ecosystems and Survey of Radioactive Contamination in Food Products from Forests, Andre Fraiture, Commission of the European Communities, Belgium, 1992.

[10] Health Implications of Radionuclide Levels in Cattle Raised Near U Mining and Milling Facilities In Ambrosia Lake, New Mexico, Sandra C. Lapham, M.D., M.P.H., Jere B. Millard, Ph.D., and Jonathan M. Samet, M.D., M.S., Pergamon Press, Health Physics Society, March 1989, Volume 56, Number 3, pg. 327.

[11] Introduction to the Radioecology of Forest Ecosystems and Survey of Radioactive Contamination in Food Products from Forests, Andre Fraiture, Commission of the European Communities, Belgium, 1992.

[12] Jackpile-Paguate, Uranium Mine Reclamation Project, Record of Decision, U.S. Department of the Interior, Bureau of Land Management, Bureau of Indian Affairs, Albuquerque, New Mexico, December 1986, pg. 8.

Endnotes for Section I (continued)

[13] Southwest Miners' Indigenous Conference, September 23rd and 24th, 1993, Village of Paguate, Laguna Pueblo.

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Cost Optimization on the Jackpile-Paguate Reclamation Program, Dr. Charles C. Reith, Mr. Raoul Portillo, Dr. Jere Millard, Dr. Douglas Gonzales, Jacobs Engineering Group, Inc., Albuquerque, New Mexico, 1989, pg. 3.

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Health Implications of Radionuclide Levels in Cattle Raised Near U Mining and Milling Facilities In Ambrosia Lake, New Mexico, Sandra C. Lapham, M.D., M.P.H., Jere B. Millard, Ph.D., and Jonathan M. Samet, M.D., M.S., Pergamon Press, Health Physics Society, March 1989, Volume 56, Number 3, pg. 327.

Introduction to the Radioecology of Forest Ecosystems and Survey of Radioactive Contamination in Food Products from Forests, Andre Fraiture, Commission of the European Communities, Belgium, 1992.

Jackpile-Paguate, Uranium Mine Reclamation Project, Record of Decision, U.S. Department of the Interior, Bureau of Land Management, Bureau of Indian Affairs, Albuquerque, New Mexico, December 1986, pg. 8.

Table IV-19

LUNG DOSES FROM RADON PROGENY INHALATION ESTIMATED FOR POPULATIONS IN THE YEARS 1990 AND 2000 AS A RESULT OF MODERATE URANIUM DEVELOPMENT

	1990			2000		
		Person-WLM/year			Person-WLM/year	
Communities	Population	Background	Uranium Develop.	Population	Background	Uranium Develop.
Municipalities (14) in the San Juan Basin	148,672	4,460	1,085	181,217	5,437	1,718
Navajo Reservation	126,209	3,786	533	155,815	4,674	1,443
Villages (14) in the Eastern Navajo Agency	27,356	821	337	33,779	1,013	574
Other residents of the San Juan Basin	71,981	2,159	236	91,189	2,736	640
Sub-Total, SJB	374,218	11,226	2,191	462,000	13,860	4,375
Albuquerque	461,772	13,853	793	568,202	17,046	1,459
TOTAL	835,990	25,079	2,984	1,030,202	30,906	5,834

Source: Schiager, 1979, No. 40, revised 1979.

Table IV-20

ESTIMATED LUNG CANCER RISK IN THE YEAR 2000 FROM MODERATE URANIUM DEVELOPMENT SAN JUAN BASIN

		Postulated lung cancer cases*		
Communities	Lung Dose Increase as % of Background	Annually from all causes ($4x10^{-4}$/person-yr)	Annually from nat. bkgd. radon conc. ($8x10^{-4}$/pers-WLM)	Commited from 1 yr of uranium develop. ($8x10^{-4}$/pers-WLM)
Municipalities (14) in the San Juan Basin	31.6%	72.49	4.35	1.37
Navajo Reservation	30.9%	62.33	3.74	1.15
Villages (14) in the Eastern Navajo Agency	56.7%	13.51	0.81	0.46
Other residents of the San Juan Basin	23.4%	36.48	2.18	0.51
Sub-total, SJB	-	184.81	11.08	3.49
Albuquerque	8.6%	227.28	24.72	1.17
TOTAL	-	412.09	35.80	4.66

* Calculations are based on national statistics; they provide a basis for comparisons but should not be construed as applying specifically to the population of the San Juan Basin.

Source: Schiager, 1979, No. 40, revised 1979.

and open a claim. The risks were mostly unsuspected by those who worked these mines. Shafts and drifts were small, tunnels often dry and dusty, and radiation monitoring practically nonexistent. As a result, the incidence of lung cancer was extremely high among the miners of these so-called "dog" or "coyote" holes.

The larger operations conducted by major corporations, by contrast, often monitored radiation and maintained records. Based on these records, a study covering the period from 1950 to 1968 compared the respiratory cancer deaths of uranium miners with those expected by other hard-rock miners. For the study sample of 3,366 non-uranium, hard rock Caucasian miners, 11.71 deaths caused by respiratory cancer could be expected. Among 3,366 Caucasian uranium miners, by contrast, 70 died of respiratory cancer, six times as many (Lundin, et al, 1971). Among non-Caucasian miners, the impact was less conclusive (1.76 deaths expected, 3 observed). The study also showed that the longer the exposure, the greater the chance of cancer. A related paper mentioned that most of the deaths occurred 10 years or more after exposure began (Lundin, et al, 1969). This report also contained the interesting observation that smoking uranium miners could expect to contract lung cancer at a rate of 10 times greater than that of non-smoking miners.

Ongoing studies of the cancer risks from radiation are expected to reduce the uncertainties in calculations of health effects.

The Impact on Health in the San Juan Basin

Cancer studies and statistics for isolated groups or population segments particular to the San Juan Basin are meager at best. Based on the available estimates of radon source terms and on lung cancer statistics from other population groups, a crude estimate of the general health impact is obtained. Cases of lung cancer may be postulated to result from uranium development at the Moderate level during the year 2000. These cases would not be expected to be manifested until many years later. However, they can be compared with natural incidence of cases that would occur in the year 2000. It must be remembered that the figures in the table* are for one year and the accumulative totals would be the sums of all years considered. Tables appear on the next page.

* Emanations from the Jackpile and the small St. Anthony open pit mines were not considered in this analysis of 1990 and 2000 regional effects. It is anticipated that they would add, at most, the equivalent of one additional mine's emissions.

Readings on Health Risks Associated with Uranium Mining

Specific to the Jackpile-Paguate Minesite
(Taken from the Final Environmental Impact Statement, 1986, pg. 3'9.)

The primary sources of radiation at the Jackpile-Paguate minesite are the radioactive isotopes formed by the decay of uranium-238 in the remaining ore and waste materials at the site. Specifically, these are: uranium-238, uranium-234, thorium-230, radium-226, radon-222, lead-210, polonium-210, bismuth-214, and lead-214. Although other sources of radiation exist, the amount of radiation emitted at the minesite from these other sources is so small in comparison with radiation from the uranium-238 series that the other sources need not be considered here.

The principal pathways by which people may be exposed to radiation from the minesite are: 1) external exposure which results from radiation emitted from airborne radioactive material in the air and ground deposited radionuclides and from gamma radiation emitted from residual ores on the minesite; 2) internal exposure to radiation from radioactive material inhaled into the lungs; and 3) internal exposure to radiation from radioactive material ingested with drinking water and foodstuffs. The major ingestion pathway for radionuclides would be the consumption of locally raised meat.

Health effects include somatic effects (diseases affecting an individual during his lifetime; primarily cancer) and genetic effects (disorders affecting offspring of the irradiated individual).

Regional

(Taken from Uranium Development in the San Juan Basin Region, Final Report, A Report on Environmental Issues by the San Juan Basin Regional Uranium Study, U.S. Department of the Interior, Albuquerque, New Mexico, 1980, pp. IV-53, IV-54, IV-38, IV-39, IV-42)

The Special Radiation Risks of Miners

Miners run a much greater potential health risk from exposure to radiation than does the general public. Two kinds exposure exist: 1) penetrating gamma radiation, and 2) alpha emitting radon daughters which are inhaled and enter the bronchial passages. The latter exposure is by far the more serious. Radon released from the ore decays through several short-lived nuclides to long-lived radioactive lead-210. Excessive accumulation of radioactive particulates in the lungs increases the risk of cancer.

In the early days of uranium mining, high grade ore was often found close to the surface. Small operations of 2 to 30 men proliferated; anybody with a Geiger counter or pickax could stake

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Glossary

Ambient; A term referring to conditions in the vicinity of a reference point, usually related to the physical environment (ex., the ambient temperature is the outdoor temperature).

Background level; In air pollution studies, the concentration of a pollutant that would exist in the absence of the particular source under study; a "standard" against which the contribution of the particular source can be compared.

Background radiation; The radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements.

Curie; A curie measures the radioactivity level of a substance; i.e., it is a measure of the number of unstable nuclei that are undergoing transformation in the process of radioactive decay. One curie equals the disintegration of 3.7×10^{10} (37 billion) nuclei per second or approximately the rate of decay of one gram of radium.

Depletion; as in water supply consumptively used and no longer available as a water source.

Detrital; made up of loose material resulting from disintegration or wearing away.

Discharge; rate of flow at a given instant in terms of volume per unit of time. With respect to water underground, the movement of water out of an aquifer.

Dissolved solids; chemical compounds in solution.

Dose; an amount of radiation absorbed.

Dose commitment; the total dose that an organism is expected to receive during its lifetime from a given quantity of radioactive material deposited in the body.

Ecology; the totality or pattern of relations between organisms and their environments.

Electron; an elementary particle consisting of a charge of negative electricity and having a mass when at rest, of 1/1837 that of a proton.

Element; any of more than 100 fundamental substances that consist of atoms of only one kind and that singly or in combination constitute all matter.

Energy; the capability of doing work.

Fugitive dust; a type of particulate emission made airborne by forces of wind, man's activities, or both, (ex. unpaved roads, construction sites, tilled land or windstorms).

Gamma radiation; short wavelength electromagnetic radiation emitted in the radioactive decay of certain nuclides. Gamma rays are released energy belonging to the same family of electromagnetic radiation as light, ultra violet, radio waves, etc.

Half-life; time required for a radioactive element to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

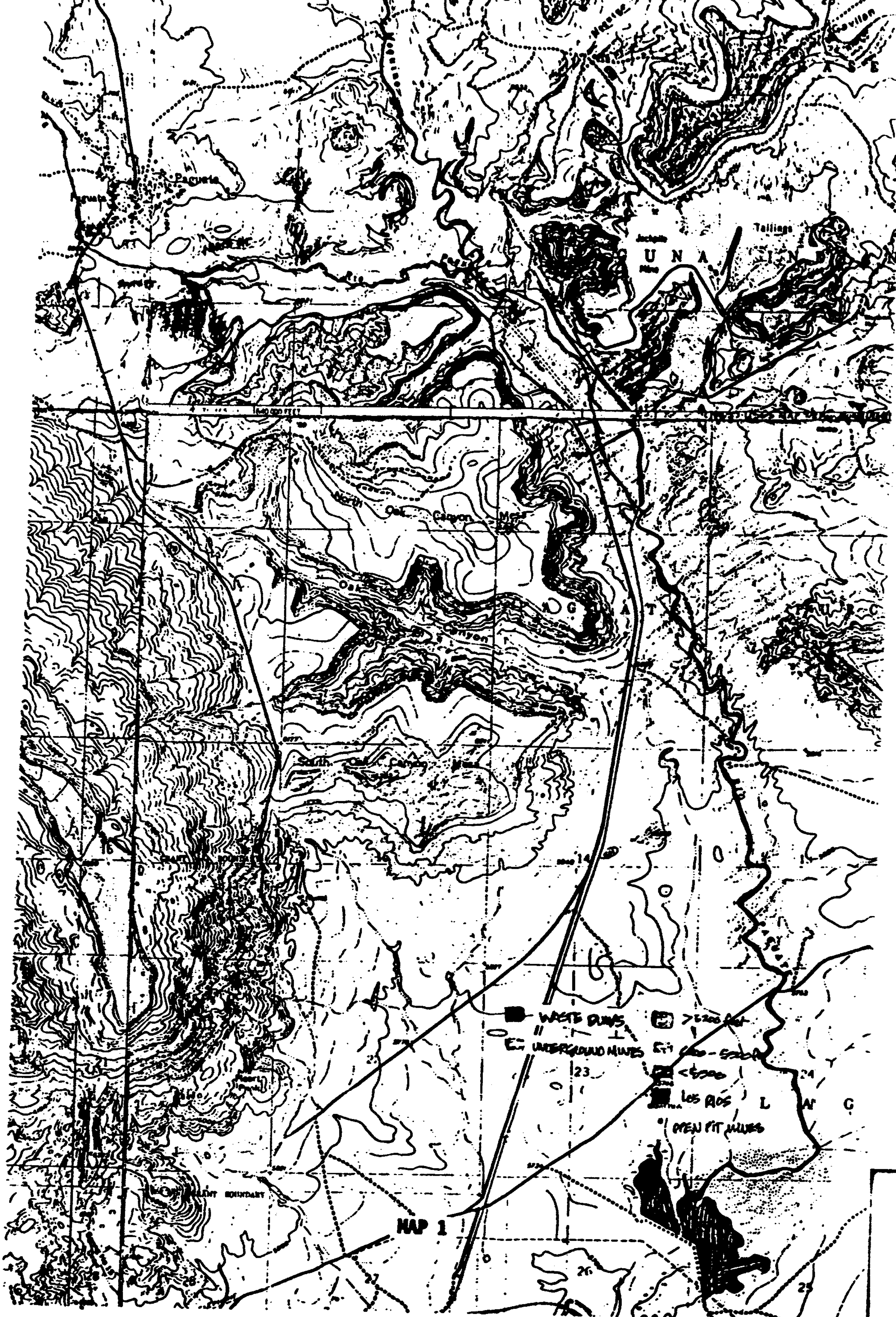
Ion; an atom or group of atoms that carries a positive or negative electric charge as a result of having lost or gained one or more electrons.

Ionization; the process by which a neutral atom or molecule acquires a positive or negative charge.

Nuclide; any species of atom that exists for a measurable length of time. A nuclide can be distinguished by its atomic weight, atomic number, and energy state. The term is used synonymously with isotope. A radionuclide is the same as a radioactive nuclide, a radioactive isotope, or a radioisotope.

Particulate; any liquid or solid particles suspended in or falling through the atmosphere.

Radon; a heavy, radioactive, zero-valent gaseous element, formed by the disintegration of radium. Radon-222 emanates from radium; half-life = 3.823 days; and an alpha particle emitter.



North Oak Canyon Mesa
South Oak Canyon Mesa
Tailings
WASTE DUMPS
UNDERGROUND MINES
LOS RIOS
OPEN PIT MINES
MAP 1

Facts about Radiation

(Taken from the <u>Final Jackpile-Paguate Environmental Impact Statement</u>, October, 1986).

Radiation is the transmission of energy through space. Many kinds of radiation exist -- including visible light, microwaves, radio and radar waves, and x-rays. All of these are electromagnetic radiations because they consist of a combined electrical and magnetic impulse traveling through space. Although much of this radiation (e.g., light) is vital to us, it can also be harmful; prolonged exposure to ultraviolet radiation from the sun can cause sunburn or even skin cancer.

Energy can also be transmitted through space by the motion of particulate radiations. These are either one of the fundamental particles of atoms (protons, neutrons, and electrons) or are a simple combination of the three fundamental particles.

The class of radiation of concern in evaluating the health risks of the material at the Jackpile-Paguate minesite is "ionizing" radiation. Ionizing radiation consists of either waves or particles with sufficient energy to knock electrons out of the atoms or molecules in matter. This disruption is termed "ionization."

The simplest example is the ionization of a single atom. The "nucleus," or center of the atom, is composed of particles called "protons" and "neutrons", the proton having a positive charge and the neutron having no charge. Negatively charged particles called "electrons" orbit the nucleus and are held in place by the attraction between the positive and negative charges. A neutral atom contains exactly the same number of electrons as protons, balancing the positive and negative charges.

When ionizing radiation knocks out an electron from an atom, the atom is left with a positive charge while the free electron is negatively charged. These parts of the atom are chemically active and react with neighboring atoms or molecules. The resulting chemical reactions are responsible for causing changes or damage to matter, including living tissue.

Types of Ionizing Radiation

Three common types of ionizing radiation are gamma rays, and alpha and beta particles.

Gamma rays are pure energy without any weight (or mass). Because they do not have any mass, they can pass through the free space in many atoms and through relatively thick materials before interacting. When gamma rays come into contact with living cells, they prove most destructive because of their high energy.

Beta particles are electrons moving at high speeds, some approaching the speed of light. They transmit energy as kinetic energy, and can travel up to 15 feet in air. Having comparatively small mass and a negative charge, their penetration through matter is intermediate between the alpha particle and the gamma ray.

Alpha particles are positively charged. Alpha particles have more mass than beta particles and gamma rays. Alpha particles do not easily pass through the spaces between atoms and lose energy quickly. If an alpha particle produced by radioactive material is inhaled or ingested into the body, it may cause many ionizations in more sensitive tissue.

Health Effects of Radiation

If molecules vital to the function of a cell are ionized by radiation, the cell may be destroyed; if enough cells are destroyed, an organ may be damaged. However, organ damage is usually associated with large doses and is generally referred to as a "short term" effect of radiation.

People who receive high radiation doses also increase their risk of developing cancer and producing genetic damage to their progeny; these are "long-term" effects. The risk is proportional to the dose. How low-level exposure to radiation results in cancer is not fully understood, and the relationship between the amount of exposure and the probability that cancer will develop depends on many variables.

Radiation levels around uranium mine sites are not generally considered to be high enough to cause short-term effects. Radiation levels may be significant enough to raise the risks of "long-term" effects, depending on conditions and length of exposure.

Background Radiation

"Background" is the term used to represent the natural levels of radiation (radioactivity) that are typical for an area. Naturally occurring radioactive elements are present in air, water and soil. Background radiation results from cosmic and terrestrial sources. Cosmic radiation originates in the cosmos and enters the earth's atmosphere, while terrestrial radiation originates from the naturally occurring radionuclides in the soil. The level of background radiation in any particular area depends on such factors as altitude, local geology and meteorological conditions.

Uranium Resources of Northwestern New Mexico

By LOWELL S. HILPERT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 603

Prepared on behalf of the
U.S. Atomic Energy Commission

A description of the stratigraphic and structural relations of the various types of uranium deposits in one of the world's great uranium-producing regions

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1969

holes were utilized for geologic information on the stratigraphic and structural relations of the deposits, and in some critical areas, stratigraphic sections were measured. During the 1955–56 field season and to some extent in 1957–58, the work was concentrated largely on abstracting the drilling records of the exploration companies in the Ambrosia Lake district.

Most of the data in this report are based on work done prior to 1959. Delay in completion of the report, however, made it desirable to update the mine production data to the end of 1964 and to locate and describe the pertinent features of deposits found after 1958. This information is shown on the illustrations as well as in the text. The text has been revised to benefit from the geologic literature published from 1959 to 1962.

GEOLOGIC NOMENCLATURE

Since this report was prepared, the age of the Ojo Alamo Sandstone has been changed from Late Cretaceous to Paleocene (Balz and others, 1966); the age of the Blanco Basin Formation has been changed from Oligocene(?) to Eocene (Steven and others, 1967); and the Potosi Volcanic Series has been changed to Potosi Volcanic Group, the name being used only near the type area in Colorado (Luedke and Burbank, 1963).

ACKNOWLEDGMENTS

It is not possible to give complete credit to the many companies and individuals whose interest and contributions make a synthesis of this type possible, and failure to acknowledge any assistance given is through oversight rather than through intent. I am especially grateful to the staffs and individuals in the following companies who were so generous in granting access to their records and properties:

American Metals Co., Ltd.
Anderson Development Co.
Calumet Hecla, Inc.
Colamer Corp.
E. J. Longyear Co.
Flat Top Mining Co.
Food Machinery & Chemical Corp. (Westvaco)
Four Corners Exploration Co.
Four Corners Uranium Corp.
Hanosh Mines, Inc.
Haystack Mountain and Development Co. (Santa Fe Railway)
Holly Minerals Corp.
Homestake Mining Co.
Homestake-Sapin Partners
Humble Oil & Refining Co.
Kermac Nuclear Fuels Corp.
Kerr-McGee Oil Industries, Inc.
L-Bar Cattle Co.
Mid-Continent Exploration Co.
Mid-Continent Uranium Corp.
National Lead Co.
New Jersey Zinc Co.
New Mexico & Arizona Land Co.
Pacific Uranium Mines Co.
Phillips Petroleum Co.
Rare Metals Corp. of America
Rimrock Mining Co.
Rio de Oro Uranium Mines, Inc.
Sabre-Pinon Corp.
Sabre Uranium Corp.
San Jacinto Petroleum Corp.
See Tee Mining Co.
The Anaconda Co.
Tidewater Oil Co.
United Nuclear Corp.
United Western Minerals Co.

Special thanks are also given the following individuals, who through their interest or involvement in the work contributed much of their time and assistance:

L. J. Reynolds and Ross Martinez, of Associated Uranium Producers; O. E. Manol and I. J. Rapaport, of Four Corners Exploration Co.; T. O. Evans, of Haystack Mountain and Development Co. (Santa Fe Railway); Paul Melancon, of Holly Minerals Corp.; E. E. Jones, of Kerr-McGee Oil Industries, Inc.; C. N. Holmes, of Phillips Petroleum Co.; J. W. Knaebel and R. D. Lynn, of The Anaconda Co.; and E. G. Robinson and Helge Laursen, of Tidewater Oil Co.

Thanks are also extended to the following individuals for their courtesy in contributing geologic information and (or) granting access to their properties:

Richard Bokum; E. P. Chapman, Jr., and J. A. Wood, of Chapman and Wood; Henry Elkins; Thomas Hyde; Malcolm Larson; Howard Major; Robert Sayre; and J. Q. St. Clair. Thanks are also extended to the Council of the Ácoma Pueblo for granting access to the Ácoma Reservation.

V. L. Freeman assisted in the work from July 1954 to June 1955, and A. F. Corey assisted from July 1955 to April 1958. H. C. Granger provided much assistance in his technical review of the manuscript. To these individuals and my other colleagues in the U.S. Geological Survey, I wish to express my appreciation for the assistance given. Special thanks are also due the many individuals on the staff of the U.S. Atomic Energy Commission, Grand Junction Operations Office, for their generous assistance. The work was done by the U.S. Geological Survey on behalf of the Divi-

sion of Raw Materials, U.S. Atomic Energy Commission.

HISTORY OF MINING AND ORE PRODUCTION

Uranium minerals have been known in northwestern New Mexico for many years, but were little more than curiosities until carnotite deposits were discovered west of Shiprock in 1918. Little ore was produced from these deposits until the 1942–44 period, when several thousand tons was mined for vanadium content. In 1948, prospecting was stimulated by the U.S. Atomic Energy Commission's ore-buying schedule announced in Circulars 1 and 2 and, subsequently, by additional incentives.[1] New deposits were found in the Shiprock area and west of Sanostee, San Juan County. Discoveries of these deposits were followed by those near Grants and Laguna, in McKinley and Valencia Counties, respectively (pl. 1). Exploration for uranium in northwestern New Mexico, however, received little stimulus until the discovery of uranium in limestone in 1950 and the discovery of large uranium deposits in sandstone in 1955. Earlier discoveries were considered unimportant and were largely forgotten (Smith, 1954; Kelley, 1963). A résumé of the 1950 and 1955 discoveries and closely related events is of interest because of the effects they had on subsequent developments and the importance of these developments to the uranium industry of the United States.

In the early spring of 1950, Paddy Martinez, a Navajo Indian, found yellow coatings on the Todilto Limestone outcrop in sec. 19, T. 13 N., R. 10 W., McKinley County. He subsequently learned that the discovery site was on Santa Fe Railway Co. property, and brought the matter to the attention of T.O. Evans, a Santa Fe Railway mining engineer. Evans examined the site on September 20, and thereafter recommended an exploratory drilling program which was initiated on November 15, 1950 (T.O. Evans, written commun., 1959). The exploration shortly resulted in the development of an important ore body, later worked as the Haystack mine, which at the end of 1958 had yielded more ore than any other deposit in the Todilto Limestone. The discovery of the Haystack deposit stimulated prospecting in the region, and led to the discovery of many other deposits in the Todilto Limestone and in sandstone along the outcrop of the Morrison Formation.

The first significant discovery of uranium in sandstone in the general area was made a few miles north of Grants at Poison Canyon on the outcrop of the Morrison Formation on January 4, 1951, by T.O. Evans. This deposit was later identified by the name Poison Canyon mine.

Two later discoveries in the Morrison Formation were of outstanding significance, the Jackpile deposit near Laguna, Valencia County, and the Dysart deposit near Ambrosia Lake, McKinley County. The Jackpile deposit was discovered on November 8, 1951, from a radioactive anomaly picked up by an Anaconda Copper Mining Co. plane in which Dale Terry was the observer and Woodrow House the pilot. The anomaly was confirmed the same day by a ground check made by Terry, and the following day, House and Terry returned to the site with J.D. "Jack" Knaebel, manager of Anaconda's New Mexico operations. During the examination of the outcrop, Terry referred to the discovery as "Jack's pile," later contracted to Jackpile (R.D. Lynn, oral commun., 1958.)

Discovery of the Jackpile did not have the impact on the industry that other discoveries had, although the Jackpile by 1958 had been developed to become the largest uranium mine in the United States from the standpoint of ore produced, reserves, and magnitude of operations. The lack of impact may seem surprising, because the Jackpile was discovered nearly 8 months before Charles Steen's discovery of the Mi Vida and more than a year before Vernon Pick's discovery of the Delta deposit in southeastern Utah. The Jackpile discovery, however, was made by the employees of a large company and was not publicized; also much time elapsed before development drilling revealed the great size of the deposit.

Discovery of the Dysart deposit, however, had a great and almost immediate effect on the uranium industry, although it was found more than 3 years after the Jackpile. Early in 1955, Louis Lothman reportedly found radioactive cuttings at the site of the M. K. Wadley's Dysart well, drilled in 1952 near the SW. cor. sec. 11, T. 14 N., R. 10 W., McKinley County. Lothman and Ellis Dunn then undertook a joint drilling venture in the ground just north of the Wadley-Dysart well, where the second drill hole penetrated mineralized ground about mid-April 1955. This discovery caught the public's fancy, just as had Steen's and Pick's discoveries, because each resulted from the efforts of an individual prospector. The resulting publicity stimulated intensive exploration in the area and led to the discovery and development of several multimillion-ton deposits. By the end of 1958, a mining and milling industry of national importance flourished in the area.

Five principal uranium mining areas, or districts, in northwestern New Mexico justify description. Two

[1] See Atomic Energy Commission Regulations, pt. 60, Domestic Uranium Program Circulars 1 to 6, inclusive, April 9, 1948; June 15, 1948; February 7, 1949; and June 27, 1951.

of these, the Shiprock and Chuska districts, are defined by the boundaries used by the U.S. Atomic Energy Commission, and extend into adjoining parts of Arizona, Utah, and Colorado. The other three, the Gallup, Ambrosia Lake, and Laguna districts, are in the central part of the area and are the most productive parts of the larger Grants mining district as defined by the Commission. The boundaries of these five districts are shown in figure 1.

A relatively small amount of mining for uranium has been done in other metal-mining districts or areas that do not require description.

From 1950 through 1964, more than 23 million tons of ore averaging 0.22 percent U_3O_8 was produced from northwestern New Mexico (table 1). This yield came from about 175 mines and largely from the Ambrosia Lake and Laguna districts (fig. 2). The area was not an important producer of uranium ore until 1956, however, when the Jackpile mine attained large-scale operation. The ore produced by this mine in 1956–57 dwarfed the combined tonnage from all other mines, but in 1958 the Ambrosia Lake district started yielding large tonnages, and in that year northwestern New Mexico yielded about 1.9 million tons of ore—36 percent of the tonnage mined in the United States. The output continued to climb, reaching a peak in 1960 of about 3.7 million tons, after which it declined; yield was about 2.1 million tons in 1964. During the 1956–64 period, however, the output was 42 percent of that of the United States. The decline after 1960 stemmed largely from the saturated market, which resulted in the government's reduction and stretchout of mine quotas and reduction in the price offered for mill concentrates.

The district production is briefly reviewed in table 2 in order of total output. The greatest yield has been from the Ambrosia Lake district. Initial mine output in the district was in 1950, after which it progressively increased, with two minor dips, until it peaked in 1962 with an output of about 2.9 million tons. (See fig. Through 1964, the district yielded 15.3 million tons of ore, which averaged 0.22 percent U_3O_8 and 0.15 percent V_2O_5 (table 2). This tonnage was 66 percent of the total output of northwestern New Mexico. The ore came from 64 mines, of which 43 were in limestone and 21 were in sandstone. The sandstone ores, however, constituted 94 percent of the total output and averaged 0.22 percent U_3O_8, 0.15 percent V_2O_5, and about 5 percent $CaCO_3$, generally referred to in the industry as lime. Through 1964, the output of limestone ores totaled about 939,000 tons, and had the same average grade for uranium and vanadium as the sandstone ores. At least one mine, the Zia, yielded a small mixed tonnage of sandstone-limestone ore.

Mining started in the Laguna district in 1952, and by the end of 1958 the district had produced about 3.3 million tons of ore (fig. 2), which was about 70 percent of the total production in northwestern New Mexico. By the end of 1964, the total output of about 7.3 million tons, which came from nine mines, was about 32 percent of the total for northwestern New Mexico. This ore averaged 0.21 percent U_3O_8 (table 2). Most of it came from the Jackpile mine, and all but about 1,000 tons was ore from sandstone; this ore during the 1952–57 period had an average content of 0.13 percent V_2O_5, and during the 1954–58 period had an average lime content of about 1 percent. Three mines in the district produced ores from limestone; one of the mines, the Sandy, yielded mixed sandstone-limestone ore. The ore from these three mines averaged 0.13 percent U_3O_8; the vanadium content probably was low, but the average content is not known.

Output in the Gallup district started in 1952, and by the end of 1964 totaled about 384,000 tons of ore that averaged 0.22 percent U_3O_8 (table 2). This yield came from 13 mines, of which 10 produced ore from sandstone and 3 produced ore from carbonaceous shale. The

TABLE 1.—*Uranium ore produced from northwestern New Mexico, 1950–64*

[All data furnished by courtesy of the U.S. Atomic Energy Commission. Data for the 1950–58 period were compiled by the author from records in the Commission's files, Grand Junction, Colo. Prior to 1950, and principally during World War II, about 10,000 tons of ore was produced from the Eastside Lease, Vanadium Corp. of America. Most of this ore, however, came from Arizona; it averaged about 0.30 percent U_3O_8 and 2.50 percent V_2O_5, and during 1942–43 was mined for vanadium only]

Year	Tons	U_3O_8 Grade (weight percent)
1950	5,813	0.21
1951	1,011	.24
1952	22,998	.22
1953	84,598	.25
1954	196,161	.36
1955	262,113	.25
1956	1,105,655	.26
1957	1,185,975	.21
1958	1,888,459	.21
1959	3,200,779	0.21
1960	3,730,905	.21
1961	3,575,589	.22
1962	3,450,791	.23
1963	2,294,892	.22
1964	2,093,355	.2
Total and weighted average	23,099,094	0.2

ore from sandstone constituted 98 percent of the total output and had the same average grade as that of the district. Vanadium and lime assays are available only for the 1952–58 period, during which the sandstone ores averaged 0.11 percent V_2O_5 and 0.6 percent lime. The carbonaceous shale ores totaled about 6,500 tons and averaged 0.19 percent U_3O_8. About 4,400 tons of this ore averaged 0.03 percent V_2O_5, and 2,400 tons averaged 0.7 percent lime.

For the 1950–64 period, the Shiprock district yielded about 27,000 tons of ore having an average grade of 0.24 percent U_3O_8 and 2.6 percent V_2O_5 (table 2). This ore, which was entirely in sandstone, came from about 30 mines and was the only ore in northwestern New Mexico that ran consistently high in vanadium. For the 1954–58 period, about 5,000 tons had an average content of 9 percent lime. A small amount of ore was mined prior to 1950, but there are no detailed records.

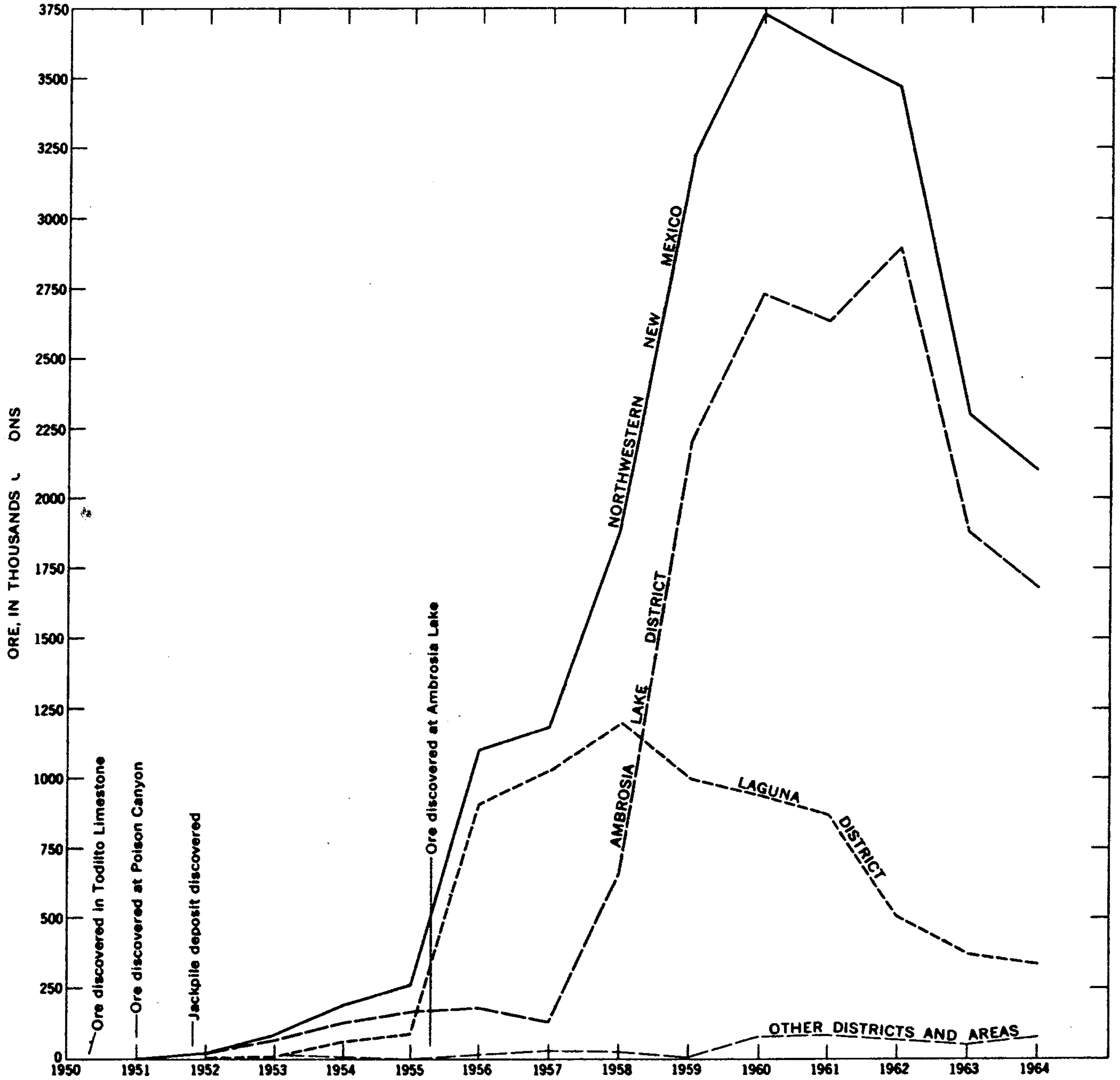


FIGURE 2.—Yearly production of uranium ores produced in the Ambrosia Lake, Laguna, and other districts and areas, and the totals for all districts and areas in northwestern New Mexico, 1950–64.

TABLE 2.—*Uranium ore produced, by district, from northwestern New Mexico, 1950–64*

[Leaders (...) indicate no production or no assay. Data furnished by courtesy of the U.S. Atomic Energy Commission; the data for 1950–58 were compiled from records . the Commission's files, Grand Junction, Colo.]

Year	Ambrosia Lake district: Tons	Grade (weight percent): U_3O_8	V_2O_5 [1]	$CaCO_3$ [2]	Laguna district: Tons	Grade (weight percent): U_3O_8	V_2O_5 [3]	$CaCO_3$ [2]	Gallup district: Tons	Grade (weight percent): U_3O_8	V_2O_5 [4]	$CaCO_3$ [5]
1950	10	0.35	0.19 (10)	...	...	...	...	...	...	...	...	...
1951	779	.36	.16 (779)	...	...	...	...	...	...	...	...	...
1952	14,562	.21	.20 (14,562)	1.8 (810)	1,125	0.32	0.27 (1,126)	...	309	0.27	0.17 (309)	...
1953	66,248	.25	.17 (66,248)	1.6 (369)	10,063	.30	.20 (10,063)	...	3,136	.20	.14 (3,136)	5.7 (195)
1954	129,202	.26	.17 (129,202)	3.9 (36,702)	57,474	.61	.29 (57,474)	3.1 (56,574)	1,491	.17	.12 (1,491)	1.3 (625)
1955	166,859	.22	.15 (166,859)	5.0 (52,549)	86,748	.26	.16 (82,595)	2.9 (84,795)	4,428	.19	.15 (4,428)	.7 (4,408)
1956	181,593	.22	.16 (181,527)	4.8 (66,913)	906,397	.27	.14 (906,397)	.8 (906,737)	12,588	.21	.07 (12,588)	.6 (12,588)
1957	131,921	.23	.12 (118,463)	5.8 (50,453)	1,027,262	.21	.10 (1,026,815)	.8 (1,026,815)	19,421	.24	.08 (8,525)	.5 (19,421)
1958	670,035	.24	.16 (22,506)	4.0 (15,749)	1,198,291	.20	...	.6 (271,578)	17,459	.24	.18 (17,340)	1.0 (3,810)
1959	2,196,335	.22	...	...	1,001,650	.19	...	...	1,916	.19	...	...
1960	2,719,065	.22	...	...	935,649	.19	...	...	75,584	.23	...	...
1961	2,623,718	.23	...	...	868,141	.19	...	...	81,955	.21	...	...
1962	2,883,676	.22	...	...	503,654	.24	...	...	55,880	.21	...	...
1963	1,872,512	.22	...	...	371,381	.21	...	...	40,042	.23	...	...
1964	1,677,285	.22	...	...	399,266	.24	...	...	69,960	.22	...	...
Totals and weighted averages	15,333,800	0.22	0.15 (700,156)	4.8 (223,545)	7,307,081	0.21	0.13 (2,084,469)	0.9 (2,346,494)	384,169	0.22	0.11 (47,817)	0.6 (41,047)

Year	Shiprock district: Tons	Grade (weight percent): U_3O_8	V_2O_5 [3]	$CaCO_3$ [2]	Chuska district: Tons	Grade (weight percent): U_3O_8	V_2O_5 [3]	$CaCO_3$ [2]	Other districts and areas: Tons	Grade (weight percent): U_3O_8	V_2O_5 [3]	$CaCO_3$ [2]
1950	5,803	0.21	2.34 (5,803)	...	...	...	...	...	...	...	...	...
1951	232	.18	2.36 (232)	...	...	...	...	...	...	...	...	...
1952	5,374	.32	3.12 (5,374)	...	1,628	0.12	0.15 (1,628)	...	...	...	...	...
1953	3,285	.25	2.71 (3,285)	...	1,866	.20	.23 (1,866)	3.6 (415)	...	...	...	...
1954	3,868	.23	2.41 (3,868)	7.7 (1,828)	4,014	.15	.17 (4,014)	3.7 (3,509)	112	0.22	0.12 (98)	6.5 (90)
1955	1,656	.25	3.17 (1,656)	11.5 (1,634)	1,832	.22	.21 (1,832)	5.6 (1,832)	590	.19	.12 (57)	11.9 (57)
1956	1,195	.22	2.44 (1,195)	10.0 (920)	987	.19	.16 (987)	5.7 (987)	2,945	.21	.03 (2,446)	1.6 (592)
1957	719	.20	1.98 (719)	7.6 (698)	...	...	...	...	6,652	.37	.06 (4,782)	1.2 (6,556)
1958	480	.21	1.55 (480)	7.9 (206)	1,955	.18	.14 (1,955)	3.7 (1,955)	239	.18	...	2.0 (239)
1959	82	.37	2.17 (82)	...	444	.17	...	...	322	.14	1.29 (13)	...
1960	480	.22	1.28 (480)	...	...	...	...	...	127	.14	...	...
1961	136	.28	2.99 (136)	...	1,565	.22	...	...	74	.18	...	...
1962	1,718	.22	1.98 (126)	...	4,062	.21	.12 (4,062)	...	1,801	.16	...	...
1963	1,303	.20	1.49 (591)	...	4,214	.23	.12 (4,214)	...	5,490	.14	...	...
1964	726	.12	...	...	3,996	.20	...	...	2,122	.14	...	...
Totals and weighted averages	[6] 27,067	0.24	2.56 (24,027)	9.2 (5,286)	26,513	0.19	0.15 (20,508)	4.3 (8,738)	20,474	0.23	0.05 (7,396)	1.4 (7,534

[1] Numbers in parentheses are tons of sandstone and limestone ores assayed for V_2O_5.
[2] Numbers in parentheses are tons of sandstone ore assayed for $CaCO_3$.
[3] Numbers in parentheses are tons of sandstone ore assayed for V_2O_5.
[4] Numbers in parentheses are tons of sandstone and carbonaceous shale ores assayed for V_2O_5.
[5] Numbers in parentheses are tons of sandstone and carbonaceous shale ores assayed for $CaCO_3$.
[6] Prior to 1950, and principally during World War II, about 10,000 tons of ore was produced from the Eastside Lease, Vanadium Corp. of America. Most of this ore, however, came from Arizona; it averaged about 0.30 percent U_3O_8 and 2.50 percent V_2O_5 and during 1942–43 was mined for vanadium only.

Of a total of about 10,000 tons mined from the Eastside Lease, Vanadium Corp. of America, about 9,000 tons was mined during 1942–43 for vanadium only and about 1,000 tons was mined in 1948 for uranium and vanadium. Most of this output, however, came from Arizona; it averaged about 0.30 percent U_3O_8 and 2.50 percent V_2O_5.

The Chuska district started production in 1952, and by the end of 1964 had yielded about 26,500 tons of ore having an average grade of 0.19 percent U_3O_8 and 0.15 percent V_2O_5 (table 2). This output came from 15 mines and was ore from sandstone. Assays of about 8,700 tons mined during the 1953–58 period averaged about 4 percent lime.

In addition to the ore mined from the above-mentioned districts, about 20,500 tons was mined from other scattered districts and areas during the 1954–64 period. This ore, which averaged 0.23 percent U_3O_8 (table 2), was principally in sandstone and volcanic rocks; some was in limestone, and a small amount was in coaly shale. These ores were low in vanadium except for a 13-ton shipment of sandstone ore which was reported to have averaged 1.29 percent V_2O_5. During the 1954–57 period, about 7,400 tons of the sandstone ores had an average content of 0.05 percent V_2O_5. The lime content of the sandstone ores varied rather widely between deposits, as would be expected for the relatively small and spotty occurrences. During the 1954–58 period, the lime content ranged from about 1 to 12 percent and averaged about 1.5 percent.

The ores in northwestern New Mexico occur in sandstone, limestone, carbonaceous shale and coal, and in igneous rock—in rocks that range in age from Pennsylvanian to Tertiary. Ores that occur in sandstone a the most economically important, constituting mc than 95 percent of the tonnage yielded from 1950 to

TABLE 4.—*Uranium deposits, by county, in northwestern New Mexico*—Continued

Name of deposit	Location Sec.	T.	R.	Description of deposit and sample	Source of data
				Socorro, County—Continued	
Rattlesnake	NW¼SE¼ 15	3 N.	5 E.	Radioactive zone in red and gray sandstone and conglomerate of Abo Formation. Yellow-green uranium mineral also occurs in surficial float.	G. E. Collins (WC, 1954).
Abo	SE¼ 22	3 N.	5 E.	A yellow-green uranium mineral occurs in seam about 2 in. thick along wall of short adit for distance of about 5 ft. Seam is in siliceous conglomerate lens in Abo Formation. Sample of seam, 13.0 percent U_3O_8.	H. D. Wolfe and G. E. Collins (WC, 1954).
Pioneer	23(?)	3 N.	5 E.	Yellow and green uranium minerals are visible along walls of 20-ft adit in several podlike zones and associated with carbonaceous layers in conglomeratic sandstone in lower part of Abo Formation. Podlike zones are generally an inch or less thick and traceable for few feet along bedding. Selected sample, 2.15 percent U_3O_8. This deposit may be in sec. 22 in same general zone as Abo deposit (above).	J. P. Hadfield, Jr., and H. E. Geslin (WC, 1953).
				Valencia County	
Brownlow-Heath	N½N½N½ 4	6 N.	4 W.	Radioactive zone in conglomeratic sandstone about 100 ft above base of Chinle Formation, possibly in Shinarump Member.	AEC.
Sonora	1 and 12	7 N.	5 W.	Yellow uranium minerals occur along fracture surfaces in impure nodular limestone and dark-gray shale of San Andres Limestone which is intruded with numerous igneous dikes and sills and is mineralized by copper, lead, and possibly silver and nickel minerals.	W. A. Carlson (WC, 1954).
Crackpot (*7*)	NW¼NW¼ 8	8 N.	5 W.	Medium deposit in elongate domelike fold in Todilto Limestone. The fold, which has closure of about 3–5 ft on underlying Entrada Sandstone contact, trends northwestward and is constituted in part by several minor folds that radiate from central part of dome. Deposit was concentrated in lower part of limestone, where it was about 15 ft thick near center of dome and from where it tapered and thinned irregularly toward margins near periphery of dome. Mineralogy is similar to other deposits in Todilto Limestone. (See text.) Other small deposits occur in vicinity. Ore mined from open pit in 1955.	FN, April 1955; J. M. Elias (OC, April 1955); AEC.
Unnamed	NW¼NW¼ 5	8 N.	6 W.	Small deposit exposed at outcrop of Todilto Limestone.	R. H. Moench (WC, 1960).
Do	SW¼SW¼NW¼ 5.	8 N.	6 W.	do	Do.
Do	CW½NW¼ 5	8 N.	6 W.	do	Do.
Do	SW¼SW¼ 10	8 N.	6 W.	do	Do.
Do	CW½ 11	8 N.	6 W.	do	Do.
Paisano (*23*)	SE¼NW¼ 16	8 N.	6 W.	Small deposit at outcrop of Todilto Limestone. Ore mined from open pit in 1957.	AEC.
Balo	S½ 18	8 N.	6 W.	Spotty occurrences of tyuyamunite and uraninite occur along bedding at outcrop of Todilto Limestone for distance of about 1 mile. Sample, 0.16 percent eU.	J. W. Allison (WC, 1954).
Sandy (*76*)	SE¼ 22	9 N.	5 W.	The Sandy is a cluster of several small deposits within upper 15 ft of Entrada Sandstone and, locally, in base of overlying Todilto Limestone. Cluster is more or less continuous body, roughly parallel to the bedding, elongate eastward, roughly 5–10 ft thick, 10–25 ft wide, and about 600 ft long. A diabase sill, about 25 ft thick, intrudes and displaces the upper part of deposit. The uranium is largely in finely disseminated coffinite and uraninite. Deposit was mined in 1955.	FN, 1955; The Anaconda Co., 1955; Hilpert and Moench (1960, p. 457–459); Moench (1962, p. B 67–B 69).
Unnamed	CS½N½ 27	9 N.	5 W.	Several, generally small, deposits associated with intraformational folds in Todilto Limestone. Folds are sinuous, have amplitudes as great as 15 ft, and are displaced in places by diabasic dikes and sills, which are younger than primary uranium minerals.	FN, April 1954; Hilpert and Moench (1960, p. 459 and fig. 17).

TABLE 4.—*Uranium deposits, by county, in northwestern New Mexico*—Continued

Name of deposit	Location			Description of deposit and sample	Source of data
	Sec.	T.	R.		
				Valencia County—Continued	
Unnamed	CW½ 27	9 N.	5 W.	Several, generally small, deposits associated with intraformational folds in Todilto Limestone. Geology similar to other deposits in sec. 27 (above).	FN, April 1954.
Paraje	NW¼ 17	9 N.	6 W.	Conglomeratic sandstone at top of Jmb is mineralized just beneath northern flank of channel scour, exposed along mesa rim by bulldozer cut. Scour is at base of Dakota Sandstone. About 1,500 ft down slope a fragment of this deposit is exposed in landslide block.	FN, September 1954.
Section 4 prospect	CE½ 4	10 N.	3 W.	Deposit exposed in short adit in sandstone in Jmr	Moench and Puffett (1963b).
Chaves (*18*)	SE¼ 22	10 N.	3 W.	Deposit in medium- to coarse-grained sandstone with pockets of carbonized plant debris in Jmr in area marked by landslides and several faults. Ore was mined from shallow opencut and adit in 1955.	FN, 1955.
Unnamed	SE¼NE¼ 27	10 N.	3 W.	Two small deposits in Jmw at outcrop	Moench and Puffett (1963b).
Do	NW¼ 34	10 N.	3 W.	Small deposit in sandstone in Jmb	R. H. Moench (WC, 1960).
Do	NW¼ 34	10 N.	3 W.	do	Do.
Townsite	CE½ 3	10 N.	5 W.	Roughly tabular deposit in Jmj	The Anaconda Co., DH, 1957.
Paguate (*63*)	NW¼ 4, E½ 5, and SE¼ 33.	10–11 N.	5 W.	Very large, elongate deposit that trends northeastward, in Jmj.	The Anaconda Co., 1957; Kittel (1963, p. 174).
Oak Creek Canyon	NE¼ 10 and NW¼ 11.	10 N.	5 W.	Roughly tabular deposit in Jmj. Exposed in face of of bulldozer cut on north slope of Oak Creek Canyon.	The Anaconda Co., 1955; FN, 1955.
Unnamed	NW¼ 14	10 N.	5 W.	Small deposit at outcrop of Jmj	R. H. Moench (WC, 1960).
Horace and Quemason.	NW¼NW¼SE¼ 4.	10 N.	9 W.	Yellow uranium minerals occur along fracture and bedding surfaces in lower part of Todilto Limestone. Mineralized zone at outcrop is several tens of feet long, a few feet wide, and several feet thick. Sample, 0.11 percent U.	Forrest Fincher (WC, 1954).
Wilcox Ranch	NE¼ 14	10 N.	15 W.	Deposit possibly in Shinarump Member of Chinle Formation. Located by drill hole. Sample assayed 0.14 percent U_3O_8.	David Carter (OC, 1956).
Unnamed	*SW¼ 18	11 N.	4 W.	Two or more small deposits near top of Jmj	The Anaconda Co., undated.
M–6 (*66*)	SW¼ 19 and NW¼ 30.	11 N.	4 W.	Large, tabular deposit near top of Jmj. Ore mined through vertical shaft, 1957–58.	Climax Uranium Corp., March 1957; AEC.
St. Anthony (Bibo).	NE¼NW¼ 29	11 N.	4 W.	One or more tabular deposits at top of Jmj	Climax Uranium Corp., March 1957.
Hanosh (M–1, M–2, and M–3).	N½ 30	11 N.	4 W.	Cluster of small and medium tabular deposits 0–100 ft below top of Jmj.	Do.
Unnamed	N½SE¼ 31	11 N.	4 W.	Tabular deposit near top of Jmj	R. H. Moench (WC, 1960).
L-Bar	*SW¼ 13 and NW¼ 24.	11 N.	5 W.	Two medium to large tabular deposits in Jmj	The Anaconda Co., DH, 1957; Kittel (1963, p. 168, 171, 174).
Unnamed	SE¼ 23 and SW¼ 24.	11 N.	5 W.	Small and medium deposits near top of Jmj	Climax Uranium Corp., March 1957.
Do	S½S½ 24	11 N.	5 W.	Several small and medium deposits near top of Jmj	Do.
Do	SE¼ 24	11 N.	5 W.	Small and medium deposits near top of Jmj	R. H. Moench (WC, 1960); Climax Uranium Corp., March 1957.
Do	NE¼ 25	11 N.	5 W.	Several small deposits near top of Jmj	R. H. Moench (WC, 1960).
Windwhip (*101*)	SW¼NW¼ 35	11 N.	5 W.	A roughly tabular deposit about 15 ft below top of Jmj. Western edge exposed at outcrop, where mined from opencut in 1954.	Hilpert and Moench (1960, p. 454).

TABLE 4.—*Uranium deposits, by county, in northwestern New Mexico*—Continued

Name of deposit	Location Sec.	T.	R.	Description of deposit and sample	Source of data
				Valencia County—Continued	
Woodrow (*102*)	S½SE¼ 36 and N½NE¼ 1.	11 N. 10 N.	5 W. 5 W.	This deposit is in immediate periphery and in core of near-vertical pipelike structure that extends from surface to unknown depth. At least upper part is in Jmb and top 50 ft or so is in the Jmj. Pipe structure is roughly cylindrical, about 30 ft in diameter, and has known length of at least 200 and possibly more than 300 ft. The core is breccia-like and has slumped downward 30–45 ft, with respect to wallrock, along a ring fault. In upper part of structure the deposit is fairly high in grade and is mostly in fault zone and in favorable beds of the core; in lower part, deposit is mainly in core and is lower in grade. Mineralogy is similar to other deposits in the Morrison Formation in the vicinity, except principal ore mineral, coffinite, is coarse grained and the uranium and the general suite of associated elements, excepting vanadium, are roughly tenfold as abundant; the vanadium is about one-tenth as abundant. Deposit was mined in 1953–56.	FN; The Anaconda Co.; Hilpert and Moench (1960, p. 456–457); Wylie (1963).
Jackpile (*43*)	Parts of 26 and 35 and CN½ 2.	11 N. 10 N.	5 W. 5 W.	Very large, roughly tabular, multilayered deposit in upper part of Jmj. Deposit is in thickest part of sandstone, is roughly elongate northward, and is coextensive with black carbonaceous material. Deposit is closely related to sedimentary structures and may also be partly controlled by broad pre-Dakota folds. Principal ore mineral is finely disseminated coffinite. Since 1952 deposit has yielded several million tons of ore.	The Anaconda Co., 1955–57; Hilpert and Moench (1960, p. 450–454); Kittel (1963); Moench (1963c).
Tom 13 (*47*)	NW¼SE¼ 4	11 N.	9 W.	Small deposit 2–3 ft thick, in Todilto Limestone. Some ore mined 1954–55.	AEC.
Lone Pine 3 (*21*)	NE¼ 8	11 N.	9 W.	Small deposit in Todilto Limestone. Ore mined from adit, 1954–55.	Do.
Cedar 1 (Section 20; Yucca) (*5*).	NW¼SE¼ 20	11 N.	9 W.	Medium, elongate deposit, associated with east-trending intraformational fold in Todilto Limestone. Deposit mined from open pit, 1952–57. Other small deposits in vicinity.	FN, 1954–55; AEC.
Ingerson	NW¼SW¼ 7	11 N.	12 W.	Radioactive zone in basal conglomerate of Abo Formation immediately above contact with Precambrian granite. Zone contains copper carbonates, carbonaceous fossil logs, and macerated plant debris and is 1,500 ft long and 200 ft wide. Deposit has been worked for copper. Chip sample 2½ ft thick, 0.03 percent eU_3O_8.	L. H. Baumgardner (WC, 1954).
Unnamed	*Approx. CE½ 23.	12 N.	4 W.	Deposit, located by drill hole, possibly in, and near, west pinchout of Jmj.	R. D. Lynn (OC, undated); R. H. Moench (WC, 1960).
Do	*W½ 30	12 N.	4 W.	Deposit in Jmj	R. D. Lynn (OC, undated).
Do	*SE¼ 30	12 N.	4 W.	do	Do.
Do	*N½ 35	12 N.	5 W.	do	Do.
Do	*E½ 36	12 N.	5 W.	do	Do.
Double Jerry (Vallejo; Farris 1) (*9*).	NW¼NW¼ NW¼ 3.	12 N.	9 W.	Small and medium deposits occur at northeast end of stringlike cluster in the Todilto Limestone and are associated with set of intraformational folds that generally trend southwestward through sec. 4 into sec. 9. Ore mined from incline shaft, 1957–62; entry is in SW. cor. sec. 34, T. 13 N., R. 9 W.	FN, 1957; Gabelman (1956b, p. 391–399): AEC.
Red Bluff 3 (*24*)	CNE¼ 4	12 N.	9 W.	Small deposit in Todilto Limestone immediately north of Red Bluff 9. Deposit mined from open pit, 1952–56.	FN, 1954; AEC.
Red Bluff 5 (*25*)	CNE¼ 4	12 N.	9 W.	Small deposit in Todilto Limestone immediately west of Red Bluff 3. Ore mined from open pit in 1954.	Do.
Christmas Day (*6*)	SE¼NE¼ 4	12 N.	9 W.	Elongate cluster of small to medium deposits, in lower part of Todilto Limestone, that trends northeasterly, extends through area about 1,500 ft long, ranges from few feet to about 200 ft wide, and averages several feet thick. Deposits mined from open pit, 1954–56.	FN, 1955; Colamer Corp., DH, 1954; AEC.

TABLE 4.—*Uranium deposits, by county, in northwestern New Mexico*—Continued

Name of deposit	Location Sec.	T.	R.	Description of deposit and sample	Source of data
				Valencia County—Continued	
Red Bluff 9 (*27*)	CNE¼ 4	12 N.	9 W.	Small deposit in Todilto Limestone immediately west of Christmas Day (above). Small amount of ore mined from open pit in 1955.	FN, 1954; AEC.
Red Bluff 7 (*26*)	SE¼SW¼ 4	12 N.	9 W.	Two or more small, elongate, westerly trending deposits in Todilto Limestone. Ore mined from open pit, 1953–58.	Gabelman (1956b, pl. 10); AEC.
Black Hawk-Bunney (*4*).	CSE¼ 4	12 N.	9 W.	Elongate, medium, and small deposits in middle of Todilto Limestone. This cluster of deposits generally trends northwesterly from the Gay Eagle. Ore mined from opencut, 1952–63.	FN, 1954; Malcolm Larson, DH, July 1954; AEC.
UDC 5 (*49*)	CSE¼ 4	12 N.	9 W.	This deposit is southern extension of adjoining Black Hawk (above). Deposit mined from opencut, 1953–54.	FN, July 1954; AEC.
Gay Eagle (*13*)	SW¼SE¼ 4	12 N.	9 W.	Elongate, rather discontinuous, medium deposit in middle of Todilto Limestone. Deposit trends northerly, is about 400–500 ft long, a few feet to several tens of feet wide, about 5–20 ft thick, and generally follows a rather complex northerly trending, intraformational fold. Deposit mined from opencut, along with Red Bluff 8 and 10, 1952–64.	FN, July 1954; Gabelman (1956b, p. 397–399); AEC.
Red Bluff 10 (*13*)	SE¼SW¼SE¼ 4	12 N.	9 W.	Southward extension of Gay Eagle deposit. (See above.)	FN, July 1954.
Red Bluff 8 (*13*)	SW¼SW¼SE¼ 4	12 N.	9 W.	Medium deposit or cluster of small deposits in Todilto Limestone immediately west of, and similar to, Red Bluff 10 (above).	Do.
UDC 1	SE¼SE¼SE¼ 4	12 N.	9 W.	Small deposit, defined by drill holes, in middle of Todilto Limestone. Highest radiometric reading about 0.10 percent eU_3O_8.	Do.
Last Chance (*19*)	NE¼NE¼ 8	12 N.	9 W.	Several small and medium deposits in Todilto Limestone. Generally irregular in outline. Ore mined from opencuts, 1952–56.	The Anaconda Co. and FN, 1954–55.
Section 9 (*30*)	NW¼ 9	12 N.	9 W.	Many small and medium deposits largely clustered and irregular in outline. Deposits are associated with intraformational folds in Todilto Limestone that have diverse trends and that range in size from folds with amplitudes of only a few inches to several feet and in length from a few feet to several hundred feet. One deposit about 1,000 ft south of north ¼ cor. is C-shaped, 300 ft in diameter, and open to west. Deposits mined from open pits, 1953–62.	The Anaconda Co., 1955.
Section 9	Near SW. cor. NE¼ 9.	12 N.	9 W.	Tabular, doughnut-shaped deposit, about 150 ft in diameter, exposed at rim in Todilto Limestone.	The Anaconda Co., DH, 1955.
Do	CW¼NE¼ 9	12 N.	9 W.	Cluster of deposits, irregular in outline, in Todilto Limestone.	Do.
Do	NW¼SW¼ 9	12 N.	9 W.	Cluster of small deposits in Todilto Limestone. Generally are elongate easterly to northeasterly.	Do.
Taffy (*98*)	SW¼SW¼ 11	12 N.	9 W.	Small deposit in sandstone in Jmpc. Ore is associated with carbonized plant debris and clay galls. Some ore mined in 1961.	Eugene Berkoff (WC, 1961); AEC.
Zia (*52*)	CE¼SW¼ 15	12 N.	9 W.	Deposit in lower part of Todilto Limestone and upper part of Entrada Sandstone.	AEC.
La Jara (*18*)	NW¼SE¼ 15	12 N.	9 W.	One or more small deposits in Todilto Limestone. Deposit mined with Zia, 1952–60.	Do.
F-33 (*10*)	SE¼ 33 and SW¼ 34.	12 N.	9 W.	A cluster of deposits mostly in middle and upper part of Todilto Limestone. Principal deposit is stringlike, trends about N. 70° E. along intraformational fold, is about 100 ft wide, as much as 15 ft thick, and more than 1,200 ft long. Ore mined from adit, 1954–59.	The Anaconda Co., 1957; Hilpert and Moench (1960, p. 460–461); AEC.
Unnamed	CW½ 16	13 N.	8 W.	Deposit in the Jmw	AEC, DH.
Section 30 (San Mateo) (*88*).	30	13 N.	8 W.	Several large and medium deposits in Jmpc. Deposits are generally elongate southeastward.	Rare Metals Corp., October 1957; Rapaport (1963, fig. 1).

to faults in many places, and strongly jointed areas contain bodies that merge with prefault bodies away from the jointed areas (Granger and others, 1961, p. 1190; Hazlett and Kreek, 1963, p. 87). Examples of such deposits are the Section 15, Section 22, Section 23, Section 24, and Black Jack 1 mines. The deposit of the Hogan mine occurs along the flank of a northeastward-trending anticlinal fold and in close association with two fracture sets, and is apparently controlled at least in part by both the fold and the fractures (Rapaport, 1963, p. 131–133). The age of these deposits is younger than that of the fractures and that of the prefault deposits, from which they apparently were derived. Their exact age, however, has not been determined; they could range from early Tertiary to Quaternary, but Pb:U ratios suggest that these deposits are post-Miocene in age (H. C. Granger, written commun., 1966).

The oxidized suite of deposits is characterized by the high-valent uranyl vanadates, by their association with fractures as well as with sedimentary structures, their irregular form, and by their general tendency to occur near the outcrop and above the water table. They postdate the prefault and postfault unoxidized deposits from which they were derived, and some or parts of some deposits are in the process of oxidation. Examples of such deposits are in the Blue Peak and Dog mines (Rapaport, 1963, p. 123, 128) and in parts of the Black Jack 1 and Section 15, Section 22, and Section 23 mines.

COLOR RELATIONS OF THE HOST ROCKS

The color relations of the host rocks to the uranium deposits in this district and others along the southern part of the San Juan Basin is incompletely understood, but a brief summary of present information may be useful.

For sandstone host rocks associated with deposits in the Morrison Formation in the Colorado Plateau, the colors have generally been considered to be gray or light brown and away from deposits to be dominantly reddish gray. These colors also have been considered "favorable" or "unfavorable" in the search for hidden deposits in the sandstone of the Westwater Canyon and Brushy Basin Members in the Ambrosia Lake district, but with notable exceptions.

In a progress report (Granger and others, 1961) the favorable colors listed for unoxidized rocks were white to light gray (*N9*–*N7*), and for weathered rocks were very pale orange to dark yellowish orange (10*YR* 8/2, 10*YR* 8/6, 10*YR* 7/4, 10*YR* 6/6). Rocks colors are from the National Research Council "Rock-Color Chart" (Goddard and others, 1948). For the gray rocks, finely disseminated pyrite was noted, but was found to be largely destroyed in the weathered rocks and replaced by films of limonite on the sand grains. These observations of color were in general agreement with earlier findings of Konigsmark (1955) and Young and Ealy (1956), except that Granger, Santos, Dean, and Moore (1961) found that the colors of some red, as well as of limonitic, sandstones are epigenetic and not necessarily original with the host rock. They noted that both colors, in association with ore, occur well below the surface and below the water table along fractured zones. The epigenetic red colors were listed as generally moderate to dusky red (5*R* 5/4–5*R* 3/4) and moderate orange pink to moderate reddish brown (10*R* 7/4, 10*R* 5/4, 10*R* 6/6, 10*R* 4/6), and the coloring agent was identified as hematite film on the sand grains. Near the outcrop they also noted moderate-red to very dark red (5*R* 4/6, 5*R* 3/4, 5*R* 2/6) sandstone closely associated with low-grade redistributed oxidized ores. The association of hematitic colors with deposits has also been noted by others (Hoskins, 1963; Gould and others, 1963; Rapaport, 1963, p. 131–133).

Gray shades may possibly not always bear a favorable relation to deposits. In some drill holes in the district, as much as 10–15 miles from the outcrop and where the host rock is as much as 3,000 feet deep, the rock is dominantly gray. These holes are more than 10 miles from a known deposit, but it is not known, of course, whether hidden deposits are in the vicinity.

Present information indicates that gray unoxidized sandstone and limonitic oxidized sandstone generally occur in the vicinity of uranium deposits, but that locally, especially along fractured zones and in close proximity to deposits, hematitic oxidized sandstone also occurs. Before more specific conclusions can be drawn, more work must be done to determine the history of the oxidation and reduction that has taken place in the host rocks before, during, and after mineralization.

LAGUNA DISTRICT

In the Laguna district 33 deposits or clusters of deposits are listed in the Morrison Formation (pl. 2 and fig. 7). Of these, 30 are in the Brushy Basin Member, 1 is in the Westwater Canyon Member, and 2 are in the Recapture Member. Of those in the Brushy Basin, 27 are in the Jackpile sandstone of economic usage. Five mines have yielded ore, and two of them, the large open-pit operations of the Jackpile and Paguate, have yielded 99 percent of all ore produced in the district. The Woodrow deposit also is in the Morrison Formation, but is discussed later with the vein deposits.

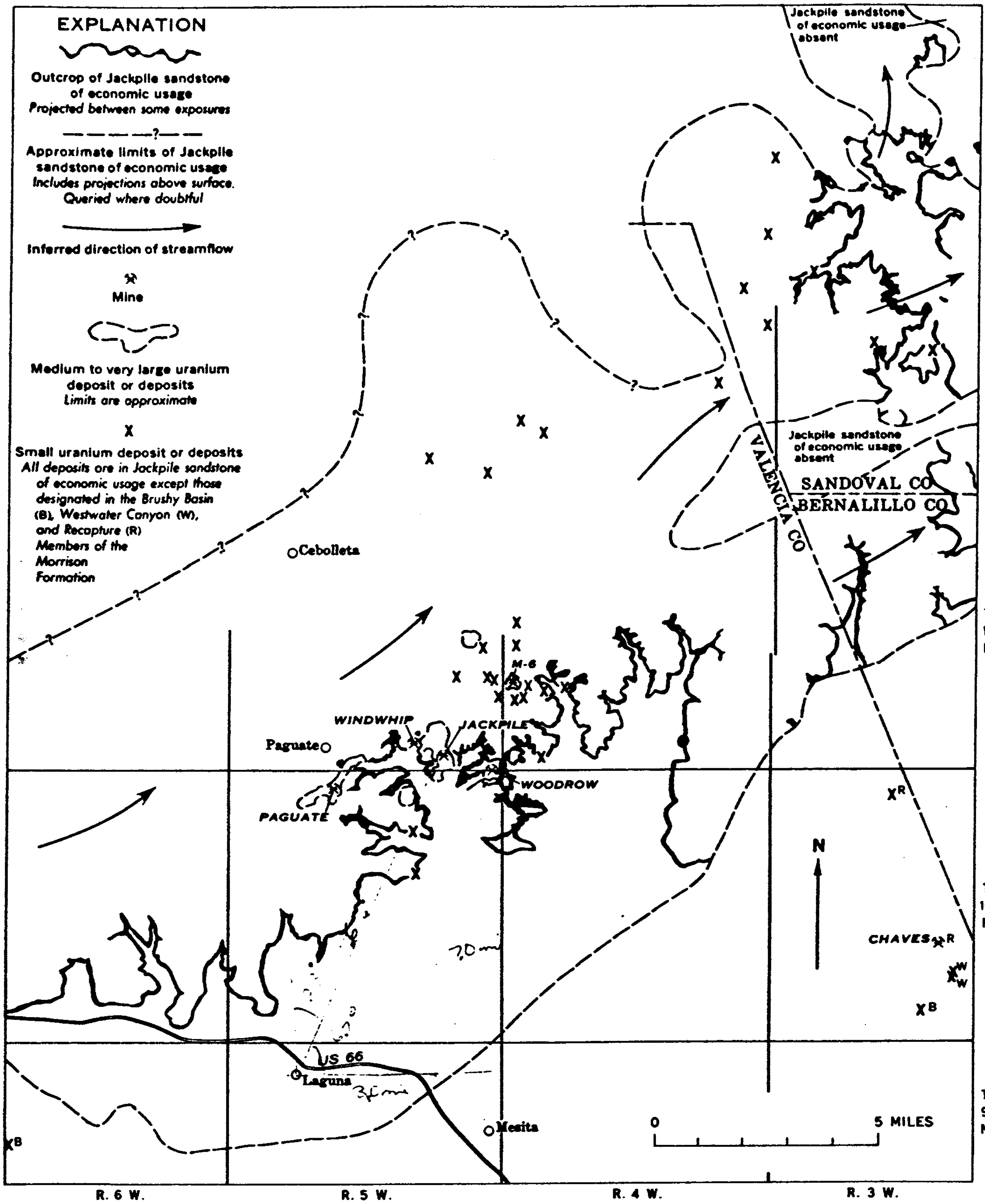


FIGURE 7.—Part of Laguna district showing the uranium deposits in the Morrison Formation. Modified from Schlee and Moench (1961, figs. 4, 10) and R. H. Moench (written commun., 1960).

The U : V ratio of about 2 million tons of ore shipped from three properties averaged 5 : 2 and ranged from 3 : 1 to 1 : 2. Except for a few thousand tons, this ore came from the Jackpile mine. During the 1954–58 period about 2.3 million tons of ore shipped from four properties averaged 0.9 percent and ranged from 0.6 to 10 percent lime. Except for a few hundred tons from one property that averaged 9 percent lime, nearly all shipments averaged less than 2 percent.

STRATIGRAPHY

Between the Ambrosia Lake and Laguna districts, the Morrison Formation is deeply buried in the McCartys syncline. Where it crops out immediately north of Laguna it has about the same thickness as in the Ambrosia Lake district, but is composed mostly of a relatively thick Brushy Basin Member and markedly thinner Westwater Canyon and Recapture Members. The stratigraphic relations of the members between the two districts are shown in figure 8. The Morrison attains its maximum thickness of about 600 feet in the central part of the Laguna district from where it thins laterally. Southward it is beveled under the pre-Dakota erosion surface, and it is missing from the southern part of the district. (See Moench, 1963a, b; 1964a, b; Moench and Puffet, 1963a, b; Moench and others, 1965; Schlee and Moench, 1963a, b.)

The lowermost member, the Recapture, ranges in thickness from 0 to about 100 feet and probably averages about 25 feet. It consists of alternating grayish-red and greenish-gray mudstone, siltstone, sandstone, and a few thin beds of limestone. It is lithologically similar to the Recapture in the Ambrosia Lake district. Locally, in the eastern part of the district, it contains two uranium deposits in a sandstone bed in close association with a pocket of coalified plant debris.

The overlying Westwater Canyon Member ranges in thickness from 0 to more than 100 feet and averages about 50 feet. It is thickest in the northern part of the district from where it thins southward. Locally it grades into the Recapture Member. It consists of grayish-yellow to very pale orange fine- to coarse-grained friable sandstone, structurally similar to the Westwater Canyon in the Ambrosia Lake district. It contains two small deposits at the outcrop.

Overlying the Westwater Canyon is the Brushy Basin Member, which composes most of the Morrison. From the central part of the district, where it is more than 300 feet thick, it thins laterally, but most markedly southward, and is cut out in the southern part of the district under the pre-Dakota erosion surface. It consists of grayish-green bentonitic mudstone and some sparse thin beds of clay-rich sandstone. In the lower part it contains lenses of sandstone similar to that of the Westwater Canyon. These are generally less than 20 feet thick, but are locally as much as 85 feet thick. In the central part of the district, it contains, in its upper part, the Jackpile sandstone of economic usage (Hilpert and Freeman, 1956), which is the main ore-bearing unit. The following description of it is largely taken from Schlee and Moench (1961).

It is a tabular body about 15 miles wide and 35 miles long that extends from the vicinity of Laguna, northeastern Valencia County, northeastward to the vicinity of Mesa Prieta, southwestern Sandoval County fig. 7). From a maximum thickness of about 200 feet a few miles north of Laguna, it tapers to its margins and, to the northeast, splits into two fingers.

The Jackpile is a yellowish-gray to white friable fine- to medium-grained fluvial sandstone that generally grades from coarser grained subarkosic material at the base to finer material at the top. The cementing material is principally calcite in the lower part and clay in the upper part. At the top the interstices of the sandstone are filled with white clay which is mostly kaolinite and probably a product of weathering of interstitial debris under the pre-Dakota erosion surface prior to Dakota deposition (Leopold, 1943;

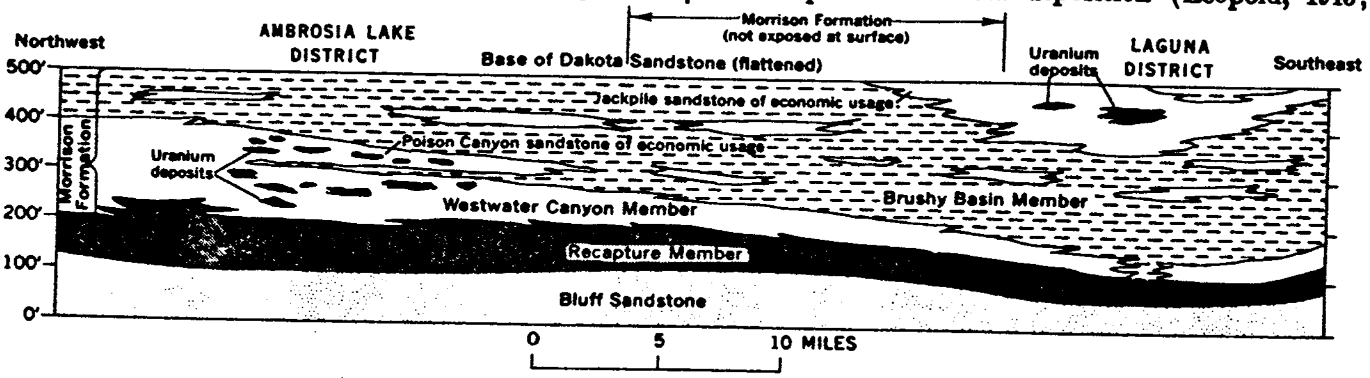


FIGURE 8.—Relations of the principal stratigraphic units of the Morrison Formation between the Ambrosia Lake and Laguna districts.

Schlee and Moench, 1961). The unit is generally thin to thick bedded and massive, but festoon crossbedding is well formed in sets as much as 4 feet thick. The crossbedding planes indicate that the sediments were transported northeastward parallel to the long axis of the unit. The truncation of the unit at the top under an unconformity indicates that former dimensions were larger than at present, but the former extent may not have been much greater, as indicated by the apparent thinning by loss of beds at the base as well as by the wedging out of the unit in places below the unconformity. The Jackpile sandstone contains nearly all the known deposits in the Brushy Basin Member and all the principal deposits in the Morrison Formation in the district (fig. 7).

STRUCTURE

The Laguna district is mainly on the east limb of the McCartys syncline, which dips gently northwestward into the San Juan Basin (fig. 3). On the east flank of the district the beds are downdropped along a north-trending faulted monocline into the Rio Grande trough. The volcanic rocks of Mount Taylor cover the western side of the district, and numerous volcanic centers, flows, dikes, and sills are distributed throughout the district and mark the northern part of the Datil volcanic field. As in the Ambrosia Lake district, three periods of deformation are recognized: Late Jurassic to Early Cretaceous, Late Cretaceous to middle Tertiary, and middle Tertiary to late Tertiary or Quaternary. The Jurassic deformation produced broad gentle folds, associated pipelike structural features, and a structural basin, all similar to those in the Ambrosia Lake district. These structural features, which are described by Moench (1963c, p. 159), are shown in figure 9.

"The Jurassic deformation produced two sets of folds of low amplitude, one trending east to northeast, the other trending north-northwest * * *. These folds are known to predate the Early Cretaceous Dakota sedimentation because folded Jurassic rocks are unconformably overlain by less-deformed beds of the Dakota. Jurassic folding was accompanied by lateral flowage of unconsolidated limestone of the Todilto Formation into the synclines, producing the variety of intraformational flowage folds that are characteristic of that unit and accounting for the thickening of limestone in the synclines. Folding was also accompanied by slumping and internal faulting of unconsolidated clastic sediments and by the formation of peculiar cylindrical subsidence structures or sandstone pipes (Hilpert and Moench [1960], p. 437-443). Folding also markedly influenced sedimentation. The fluvial Jackpile sandstone, for example, seems to have accumulated in a broad, east- to northeast-trending syncline that deepened and expanded during sedimentation (Schlee and Moench [1961], p. 147-150)."

The Late Cretaceous to middle Tertiary tilting is dated from outside the district by the same evidence as listed under the Ambrosia Lake district (p. 62). This deformation caused the tilting of the beds to the northwest.

The third period of deformation, from middle to late Tertiary time, and possibly extending into Quaternary time, marked the subsidence and sedimentation of the Rio Grande trough and produced the north-trending normal faults, the faulted monocline along the west margin of the trough, and the joints in the sedimentary rocks (Moench, 1963c). The fracturing was accompanied by the emplacement of numerous dikes and sills, for these intrusives occupy joints of the fracture system and sills are cut by joints and faults of the same system (Moench, 1963c, p. 159).

The fracture system in the main part of the Laguna district probably is younger than that in the Ambrosia Lake district. In the latter district the fractures are closely associated with the formation of the west limb of the McCartys syncline, a structural feature that probably formed early in the history of the San Juan Basin. The fractures in the Laguna district are apparently younger and occurred during formation of the Rio Grande trough, a Basin and Range structural feature.

MINERALOGY AND FORM

Most deposits in the district occur above the water table and most are oxidized to some extent, possibly more so than most descriptions have implied, for metallurgical tests of the ores from the Jackpile and Paguate deposits indicate about 75 percent of the uranium is oxidized (Kittel, 1963, p. 170).

Coffinite is the principal uranium mineral that is primary and certainly unoxidized. It is associated with the oxidized minerals, with sparsely disseminated pyrite and some marcasite, and with minute quantities of other metallic sulfides. The coffinite-bearing material contains uraninite, which might be primary, but could also be secondary after oxidized coffinite (Granger, 1963, p. 31). Vanadium generally occurs with the uranium in the ratio of about 1:2 in the ores, but few primary or unoxidized vanadium minerals have been identified, probably because of their extreme fineness. Most of the vanadium probably occurs in the unoxidized state in vanadium-bearing mica and clay.

The principal oxidized uranium minerals are the vanadates tyuyamunite and metatyuyamunite, the phosphate autunite, and the silicate uranophane

$(Ca(UO_2)_2SiO_3(OH)_2 \cdot 5H_2O)$. The vanadates occur chiefly as tabular bodies and small concretionary masses within the partly oxidized ore bodies and locally as fracture fillings in silicified fossil logs and in a diabase dike that intrudes the Jackpile deposit. Autunite and less common phosphates also coat fracture faces; the autunite is most abundant in the borders of the diabase intrusive. A more complete list of the uranium-bearing minerals and associated gangue minerals is given by Granger (1963, p. 32), and additional identified uranium-bearing minerals are listed by Kittel (1963, p. 170). Most deposits are closely associated with coextensive fine-grained carbonaceous material similar to that associated with the deposits in the Ambrosia Lake district. A few small deposits are associated with coalified plant debris.

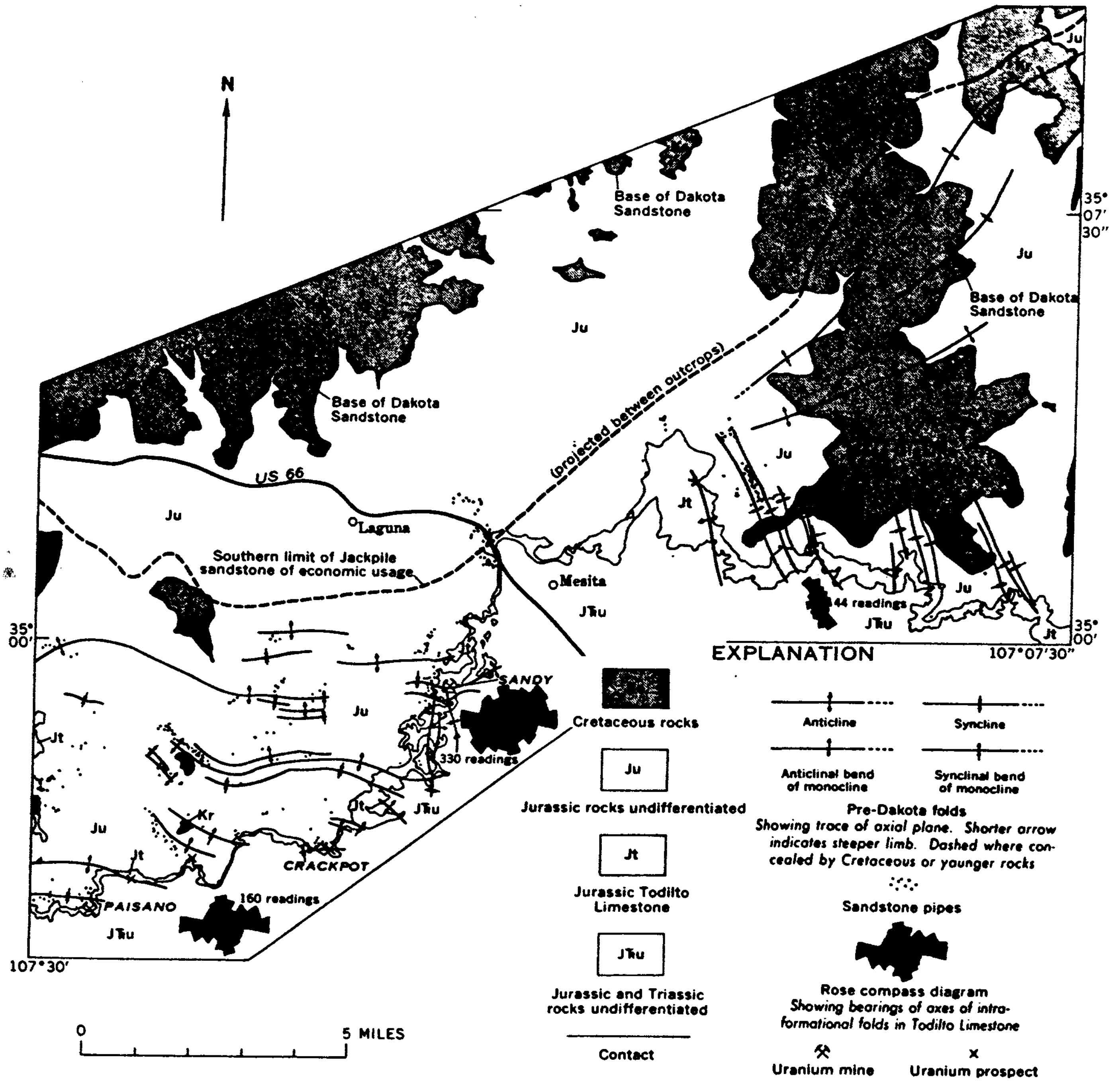


FIGURE 9.—Pre-Dakota structural features and south limit of Jackpile sandstone of economic usage, Laguna area. Simplified from R. H. Moench (written commun., 1959).

Most of the deposits are crudely tabular and have a tendency to occur in one or more layers, as elsewhere, but are generally more irregular in outline; only the larger ones are notably elongate. The layers range in thickness from only a few inches to as much as 20 feet and occur in multiple units that are as much as 50 feet thick. In lateral dimensions they range from a few feet to several thousand feet. The two largest, the Jackpile and Paguate, are elongate, the Jackpile averaging about 2,000 feet in width and having a length of about 7,000 feet, and the Paguate averaging about 1,500 feet in width and having a length of about 2 miles (fig. 7). Peculiar to the lower grade parts of some of the deposits are rodlike structures composed of uraniferous carbonaceous material, which coats sand grains and locally thoroughly impregnates the sandstone. These rods are roughly normal to bedding (Hilpert and Moench, 1960, p. 453; Moench, 1963c, p. 162, and figs. 4, 5).

STRATIGRAPHIC RELATIONS OF THE DEPOSITS

Most of the deposits, including all the larger ones, are in the Jackpile sandstone and largely concentrated within the thicker part where it ranges in thickness from about 100 to 200 feet. The margins of the deposits locally are controlled by mudstone contacts, bedding planes, diastems, and other sedimentary features, but in general the deposits figuratively float in the sandstone units within the lower and middle parts of the host sandstone (Hilpert and Moench, 1960, p. 451; Kittel, 1963, p. 170), and the Paguate extends from the lower two-thirds at the southeast end of the deposit to the upper third at the northeast end where it apparently is beveled under the pre-Dakota erosion surface (Kittel, 1963, p. 170 and fig. 4). The principal cluster of deposits in the Jackpile sandstone is elongate northeastward (fig. 7) and conforms to the dominant dip direction of the crossbedding and to the axial trends of the Jackpile sandstone body. Thus, the deposits show a direction relation to both broad and detailed stratigraphic features.

STRUCTURAL RELATIONS OF THE DEPOSITS

The uranium deposits were both indirectly and directly controlled by structures formed during Late Jurassic deformation, but obviously were not controlled by structures formed during Tertiary or later deformation, except for the oxidized material.

Indirect control is shown by clustering of the deposits in the central part of the Jackpile sandstone (fig. 7). The Jackpile occupies a structural trough that formed before, during, and after sedimentation, as evidenced by the abnormal thickness of the Morrison Formation along the axis of the Jackpile sandstone, by the pre-Dakota folds along the southeast margin, one set of which is parallel to the axis of the Jackpile sandstone (fig. 9), and by the beveled southeast and northwest flanks of the Jackpile sandstone under the pre-Dakota erosion surface (Schlee and Moench, 1961, figs. 3, 4, 11).

Direct control is shown by the occurrence of black ore in the boundary ring fault of a sandstone pipe in the Jackpile mine (Hilpert and Moench, 1960, fig. 8; Moench, 1963c, fig. 2 and p. 163). Ore also occurred in the Woodrow pipe, but the genesis of this deposit is controversial; it is discussed with the vein deposits. Locally there is evidence that the Juriassic folds mav have exerted some direct control on localization of deposits. The northern part of the Jackpile ore body apparently trends northward along the axis of a pre-Dakota anticline, which is one of a set of such folds. As this trend is almost normal to the axis of the northeastward-trending sedimentary structures and to the northeastward elongation of the Paguate deposit, probably the pre-Dakota anticline exerted some control on the localization of the Jackpile deposit (Hilpert and Moench, 1960, p. 450–451, and fig. 9; Moench, 1963c, p. 163–164).

The Tertiary structures show no obvious contrc over the primary uranium deposits, and are apparently younger than the deposits. This is demonstrated by the relations of the deposits to the diabasic dikes and sills and to the fracture systems.

The diabasic dikes and sills, which probably are the oldest recognized intrusives in the district (Hilpert and Moench, 1960, p. 444), intrude and displace the Jackpile deposit (fig. 10) and other nearby deposits in the Todilto Limestone. If these intrusives are the same age as the fracture system, as indicated, both the fracture system and the intrusives are younger than the deposits and could not have influenced their emplacement. This relation is confirmed by the lack of any convincing alinement of the deposits with nearby fractures (Moench, 1963c, p. 161).

Oxidized uranium minerals occur along joint faces and in the chilled borders of diabasic intrusives, but the field evidence indicates that the minerals were derived from earlier black ores (Moench, 1963c, p. 161). No postfault unoxidized ores similar to those described by Granger, Santos, Dean, and Moore (1961) (see p. 63) have been recognized in the Laguna district.

Available evidence indicates that the deposits in the Laguna district were emplaced closely following c during Jurassic deformation, prior to development ot the Late Cretaceous erosion surface, and prior to Late

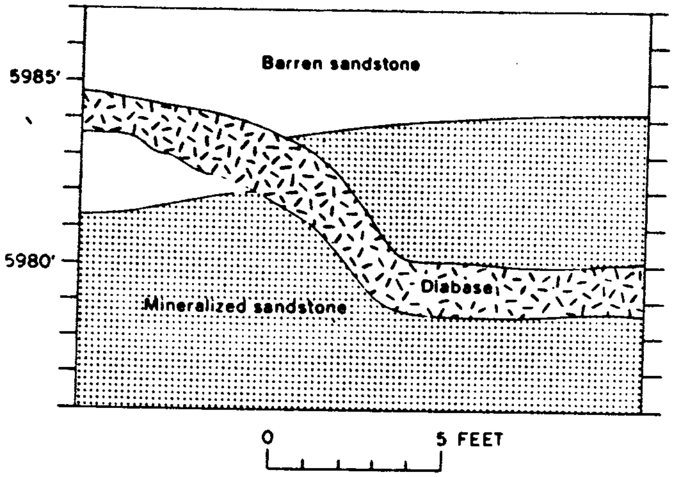


FIGURE 10.—Displacement of Jackpile uranium deposit by diabase sill. Geology by R. H. Moench. Datum is approximate mean sea level.

Cretaceous or early Tertiary tilting of the southern part of the San Juan Basin. As the deposits are generally widespread and show little or no obvious relation to fractures, the assumption is that they were emplaced from solutions that moved laterally and perhaps under a water table. If so, the local transection of deposits across the Jurassic folds (Hilpert and Moench, 1960, fig. 15) can be explained by emplacement during or after folding. Their pre-Cretaceous age also is supported by the apparent beveling of the Paguate deposit under the pre-Dakota, or Late Cretaceous, erosion surface (see p. 74) and by the absence of known uranium mineralization of the rocks of Cretaceous age in the district. Moreover, if the rodlike ore structures in the Jackpile sandstone ore bodies were formed by gravity control of the mineralizing solutions, as determined by Moench (1963c, p. 161–162), they would be expected originally to have had a vertical orientation. As they appear to be approximately normal to the bedding of the Dakota Sandstone, a relation confirmed by one measurement, and as the ore layers of the Jackpile conform to the dip of the Dakota Sandstone, the uranium deposits apparently were emplaced prior to tilting of the Dakota Sandstone.

Conclusions are that Late Jurassic (pre-Dakota) deformation indirectly controlled the emplacement of the deposits and likely caused some direct control on their emplacement. The emplacement probably occurred during or shortly after the Jurassic deformation and before the deposition and tilting of the Dakota Sandstone. Post-Dakota structures exerted no control on the primary deposits, but did localize some secondary minerals.

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COLOR RELATIONS OF THE HOST ROCKS

Except for the Jackpile sandstone, the colors of the ore-bearing sandstones in the Morrison Formation in the district are generally light gray (*N*7) in the proximity of deposits, and range from light gray to very pale orange (10*YR* 8/2) to locally dusky yellow (5*Y* 6/4) away from deposits. The Jackpile sandstone mostly is very light gray to white (*N* 7–*N* 9). The lighter shades are at the top, the result of kaolinization by weathering of feldspar minerals under the pre-Dakota erosion surface (Leopold, 1943; Schlee and Moench, 1961; Moench, 1963c, p. 165). Darker shades, medium light gray (*N*6) to dark gray (*N*3), generally are closely associated with the deposits and result largely from the presence of carbonaceous material (Hilpert and Moench, 1960, p. 446).

Reddish hues, which generally have been found away from deposits (p. 69), occur only sparsely in the Laguna district.

GALLUP DISTRICT

About 30 deposits or clusters of deposits in sandstone are listed in the Gallup district (pl. 1). Most of them are in the Westwater Canyon Member, many are in the Brushy Basin Member, and two are recorded in the Recapture Member. Seven of the deposits or clusters have been mined, five of them are partly or entirely in the Westwater Canyon and two of them are in the Brushy Basin. Most of the ore from the Church Rock mine was produced from a body in the Dakota Sandstone, and a relatively small part was obtained from bodies in the Westwater Canyon Member.

The ore shipments made in the 1953–58 period totaled about 3,800 tons and had an average U:V ratio of 1:1 and a range among mining properties of from 1:1 to 1:2. Also, from four properties, about 3,500 tons of ore averaged 1.6 percent lime content and ranged from 0.8 to 17 percent. The 17-percent lime content represents only a few tons of ore. All the ores were partly oxidized.

STRATIGRAPHY

In the district the Morrison Formation crops out around the west and north flanks of the Zuni uplift from about 30 miles south of Gallup, where it pinches out, northward and eastward to the Continental Divide, at the east side of the district. In the western part of the district, the Recapture Member grades and intertongues with the Cow Springs Sandstone. From the general vicinity north of Thoreau the Recapture shows an increasing amount of light-gray Cow Springs material westward until it "sands up" and loses its

GUIDEBOOK OF

Defiance--Zuni--Mt. Taylor Region Arizona and New Mexico

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Editor

NEW MEXICO GEOLOGICAL SOCIETY

[EIG]HTEENTH FIELD CONFERENCE — OCTOBER 19, 20, AND 21, 1967

URANIUM DEPOSITS OF THE GRANTS REGION

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Editor's Note:

This contribution to the Guidebook was written in 1966 for publication in the forthcoming Graton-Sales Volume, which will be published early in 1968 by the American Institute of Mining, Metallurgical and Petroleum Engineers as a sequel to the well known classic "Ore Deposits of the Western States," published by AIME in 1933. Coauthor Kittel has condensed and updated the article for publication at this time.

INTRODUCTION

The Grants uranium region comprises several contiguous mining districts that contain a belt of uranium occurrences more than 85 miles in length. For the most part the uranium mineralization occurs in the Jurassic sandstones and limestones that comprise part of the southern edge of the San Juan Basin of northwestern New Mexico.

The districts have been designated Grants, Gallup, and Laguna (Kelley, 1963), and comprise the Gallup, Churchrock, Smith Lake, Ambrosia Lake, Grants, North Laguna, and South Laguna mining areas. The districts are separated physiographically by Mount Taylor, a late Tertiary volcano that rises from basalt-capped Mesa Chivato to an elevation of 11,389 feet above sea level. (fig 1). The Laguna district lies east of Mesa Chivato and the Grants and Gallup districts lie generally west of it.

Mining areas within the Grants and Gallup districts lie along a series of southward-facing cliffs, cuestas, mesas, and soft-rock valleys. The Ambrosia Lake area is the major producer of the two districts; it is in a valley that was formed by erosion down to lower Cretaceous sandstones and shale. The valley is about 12 miles long, three miles wide, and is at about 7,000 feet elevation. Ore from the two districts is processed at mills, operated by Kerr-McGee Corporation and Homestake-Sapin Partners.

At present all production from the Laguna district comes from Anaconda's large Paguate open pit mine. It is shipped by rail to Anaconda's mill near Bluewater, where it is treated by an acid leach process.

* Now with Humble Oil & Refining Co., Denver, Colorado.

DISCOVERY, EXPLORATION, AND MINING

The occurrence of uranium minerals in outcrops in the Grants districts was known as early as 1920. No mining of them was done until after 1950, however, following a well publicized find by Paddy Martinez of yellow carnotite-type ores in the Todilto Limestone near Haystack Mountain.

The first production was small tonnage mined from outcrops of the Todilto limestone and the Poison Canyon sandstone tongue of the upper Morrison and shipped to the AEC buying station at Monticello, Utah. Later intense exploration and development of these outcrop ore bodies brought about the establishment in 1952 of an AEC buying station in conjunction with Anaconda's mill that was being built near Bluewater. The mill, designed to treat limestone ores, was completed in 1953, and was followed two years later by the completion of a second mill to treat sandstone ores.

Many types of equipment were used to explore for new deposits and to outline and delineate the known ones. Among them were geiger counters, scintillation counters, either handcarried or mounted in ground or airborne vehicles, various types of drilling, and electric-gamma ray logging.

Nearly all of the first ore produced came from open pit mines. Maximum production up to 1954 amounted to about 300 tons per day from the Haystack operation owned by the AT&SF Railway. The first underground mines in the Grants districts produced about 20 to 200 tons per day, and gradually became larger operations as discoveries were made by drilling back from the uranium-bearing outcrops. Late in 1954 the Jackpile mine (later to become the world's largest open pit uranium mine) was brought into large-scale production.

The first discovery of uranium in the Ambrosia Lake area was made by Louis Lothman early in 1955. About a year and a half later more than 50 drills were exploring in that area, resulting in the outlining of the largest single deposit, or closely related group of deposits, known in the world. Later smaller discoveries were made in the Smith Lake and Churchrock areas between Ambrosia Lake and Gallup.

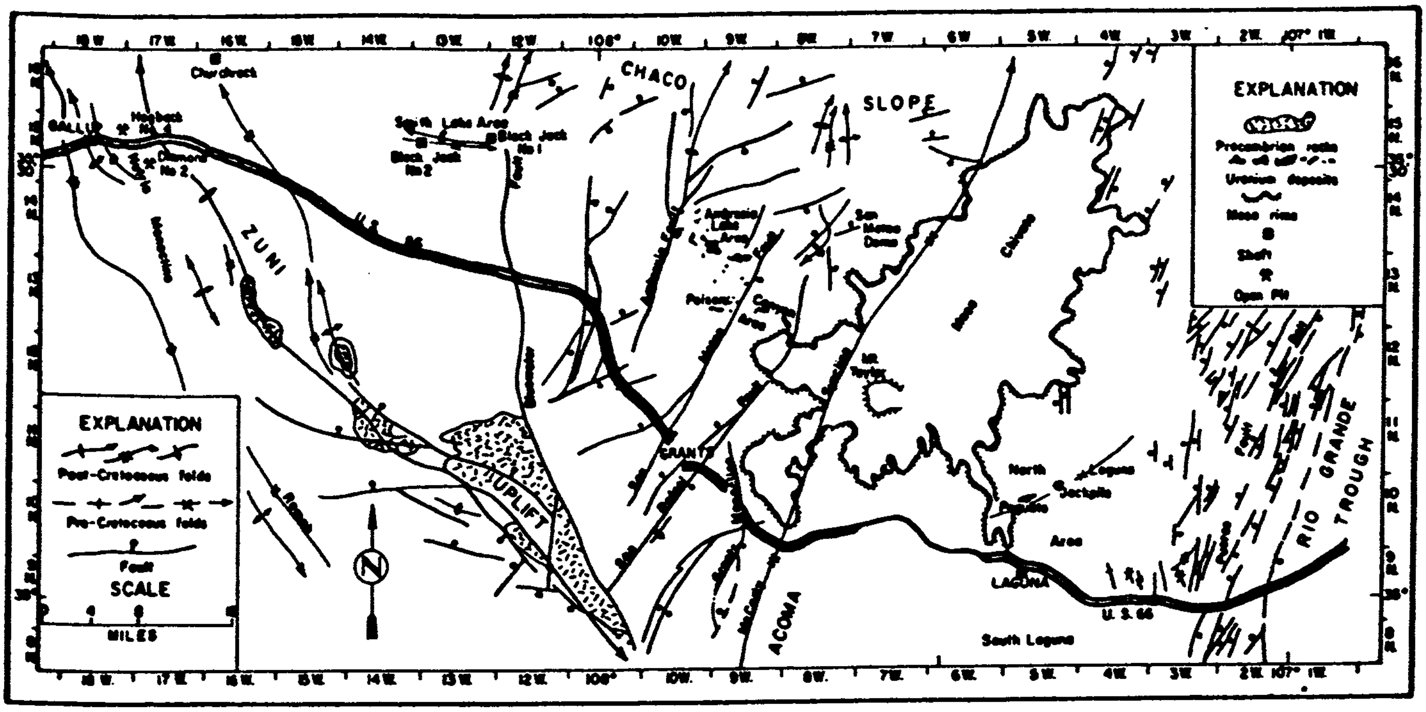

FIGURE 1.

Geologic features of the Grants uranium region.

Prior to the uranium discoveries in the Grants districts the United States was for the most part dependent upon foreign sources of uranium to meet its defense needs. During the years that followed, and up to the start of 1967, a little over one billion dollars worth of concentrates has been produced from mills operated by Anaconda, Homestake-New Mexico Partners, Homestake-Sapin Partners (now idle), and Kerr-McGee Industries.

STRATIGRAPHY

The sedimentary rocks of the Grants districts range in age from Pennsylvanian to Cretaceous. Precambrian gneiss, schist, and granite are exposed in the core of the Zuni Mountains, and overlying these rocks, on the flanks of the Zunis, are the Pennsylvanian Magdalena Formation (125 feet), Permian Abo, Yeso, and San Andres Formations (650, 900, 300 feet), and Triassic Dockum Group (1600 feet) (Smith, 1957). Uranium deposits of consequence are almost entirely in the Jurassic, but a few small deposits have been mined from the lowermost beds of the Cretaceous. The currently prevailing stratigraphic nomenclature of the significant units in the Grants districts is as follows:

SYSTEM	UNITS	THICKNESS
Cretaceous:	Hosta Sandstone	150+
	Crevasse Canyon Formation	800-1000
	Gallup Sandstone Member	180- 250
	Mancos Shale (including Tres Hermanos)	800-1000
	Dakota Sandstone (sandstone, shale)	10- 150
Jurassic:	Morrison Formation	100- 600
	Brushy Basin Shale Member including Jackpile sandstone	20- 350
	Westwater Canyon Sandstone Member including "Poison Canyon" tongue	0- 300
	Recapture Shale Member	50- 175
	Bluff Sandstone	130- 400
	Summerville Formation (mudstone, sandstone)	50- 220
	Todilto Formation (gypsum, limestone)	0- 125
	Entrada Sandstone	150- 250
Triassic:	Chinle Formation	1000-1600

The Todilto Limestone has accounted for about 4.2 percent of the uranium produced to date in the Grants districts. In the Laguna district it is up to 125 feet thick and consists of 5 to 35 feet of fetid gray laminated limestone overlain by as much as 90 feet of gypsum and anhydrite. The basal limestone consists of laminated to massive beds, and the upper part is massive. The gypsum zone pinches out southward and is only locally present south of U.S. Highway 66. In the Grants and Ambrosia Lake area the limestone only is present, and this commonly is a tripartite unit 15 to 30 feet thick consisting of parallel laminated limestone and some siltstone at the base, a middle unit of crinkled thin limestone beds, and an upper massive, often coarsely crystalline, limestone. The upper unit is locally absent.

The basal platy zone is up to 15 feet thick, thin-bedded, and light gray to grayish-brown. This carbonaceous partings commonly occur along bedding planes, and recrystallization has occurred along joint planes and in folds. The medial limestone zone is up to six feet thick, extremely crenulated, usually recrystallized, and of the

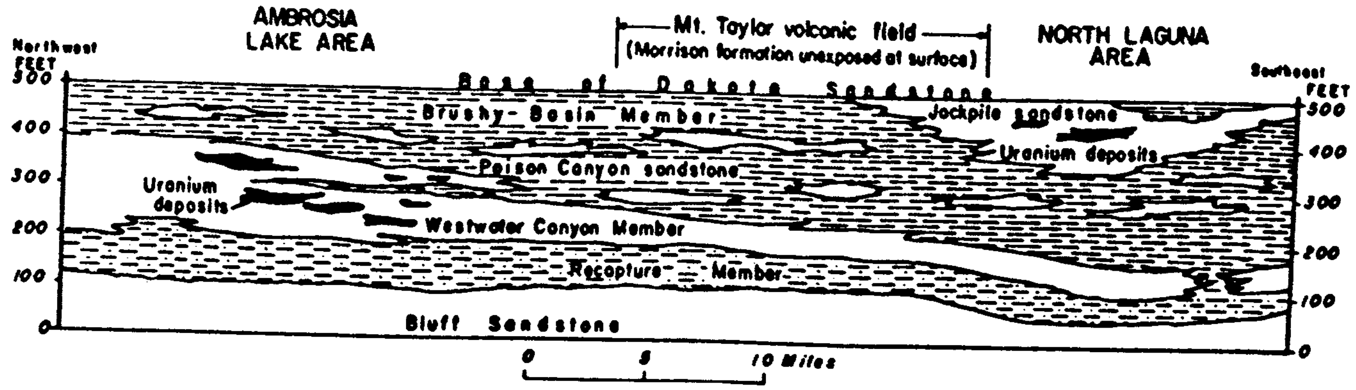

FIGURE 2.

Stratigraphic diagram of the Morrison Formation in the Grants region, showing the relationship of its members between the Ambrosia Lake and North Laguna areas.

same colors as the platy part. Because of these crenulated bedding planes, this middle unit is locally referred to as the "crinkly" zone. The upper massive limestone is usually assigned to the Todilto although some assign it to a transition zone between the Todilto and Summerville formations.

The Westwater Canyon sandstone is quite irregular in thickness owing to lensing and lateral gradations into Brushy Basin or Recapture type mudstone and claystone. The "Poison Canyon" sandstone, which is up to 85 feet thick, is a tongue of Westwater Canyon sandstone in the Brushy Basin Member. The Westwater averages about 150 feet thick in the Ambrosia Lake area, but locally it may reach 300 feet or thin and disappear into zones of arenaceous mudstone. Its sandstone beds vary from parallel-bedded to irregularly cross-bedded. The color may be light gray, yellow-brown, red-brown, or grayish black, depending on proximity to the surface, mineralization, or content of organic material. The sand is fine to coarse, poorly sorted, and locally conglomeratic. The composition is feldspathic with considerable sanidine (Austin, 1963). Locally the quartz fraction contains slightly corroded, high-temperature, biypramidal phenocrysts. In general the composition indicates an acidic tuffaceous derivation for many of the beds.

The Brushy Basin resembles the Recapture and consists of greenish gray and reddish brown mudstones with numerous Westwater-type sandstone lenses, channel fills, or arenaceous zones. It is as much as 500 feet thick, but may be much less, owing partly to intertonguing with the underlying Westwater Canyon and Bluff sandstone tongues, but principally to plication at the extensive pre-Dakota erosion surface.

In the Laguna district the Westwater and Recapture units are thought to have thinned markedly, and both are relegated by Hilpert (1963) to about the lower 100 feet of the Morrison (fig. 2). On the other hand, the overlying Brushy Basin is thought to have thickened to about 500 feet (Hilpert and Moench, 1960). In the vicinity of the Jackpile mine as much as 220 feet of the uppermost part of this thickness consists of a large sandstone channel deposit (Jackpile sandstone) preserved in a broad pre-Dakota structural downwarp that was more or less parallel to the northeasterly depositional trend.

Over 94 percent of the uranium production from the Grants districts has come from the Morrison sandstones.

IGNEOUS ROCKS

A variety of shallow intrusive rocks and rather extensive basaltic flows constitute the principal igneous rocks found in the region. Diabase dikes and sills are common in the Laguna district; most of these are less than 10 feet wide, but a few that branch from plugs are several tens of feet wide. Dike trends are principally northerly and northwesterly (the maximum known length is about 10 miles), and sills are found in many stratigraphic horizons in the district.

Numerous basaltic necks occur in or adjacent to the Mount Taylor valcanic field. Most of these fed volcanos, and several sections of partly dissected cones and feeder necks are exposed along the edge of Mesa Chivato and lesser volcanic-capped mesas. These necks may consist of solid lava, lava breccia, or lava-sedimentary mixed breccias.

About seven miles northeast of Grants, in what is referred to as East Grants Ridge, there is an elliptically shaped dome one to one and one-half miles in diameter. The central part is aphanitic, lithophysaical, flow-banded rhyolite surrounded by a peripheral-chilled sheath of obsidian and perlite.

STRUCTURE

The principal regional structures of the area are the Zuni uplift and the Acoma sag. The Zuni uplift is a broad northwest-trending upwarp asymmetrical to the southwest, and the Acoma sag is a broad, flat, little deformed downwarp that slopes very gently northward between the Zuni uplift on the west and the Lucero uplift and Puerco fault belt. McCartys syncline near the margin of the Zuni uplift forms the axis of the sag. Deposits at Ambrosia Lake line alone the northeastern corner of the Zuni uplift in the Chaco slope into the San Juan Basin. The Laguna depsoits lie along the eastern side of the Acoma sag.

The eastern and northeastern parts of the Zuni uplift are broken by numerous faults. Mapping by Thaden and Santos (1963) has more clearly delineated the pattern of these faults and in particular the San Rafael, San Mateo, and Ambrosia fault zones. As shown on Figure 1, the Ambrosia Lake area deposits are generally bounded by the San Mateo and Ambrosia fault zones.

The Zuni uplift and McCartys syncline together with the associated major faults and folds such as the Ambrosia anticline are considered to be Laramide. The Puerco fault belt is probably largely Pliocene, and its development considerably modified the eastern side of the Acoma sag during subsidence of the Rio Grande trough. Some faults that dislocate the volcanics capping Mesa Chivato around Mount Taylor may be late Pliocene or early Pleistocene.

Structures of most importance to ore localization consist of (1) fractures in the host sandstone; (2) folds in the Todilto Limestone; and (3) broad gently flexures of pre-Dakota age.

Both tectonic and gravity flow folds are present in the Todilto Limestone, and seem to have localized ore deposits in numerous places. The tectonic folds affect the adjacent formations and are in general larger than the minor disharmonic flow folds. As a consequence somewhat larger deposits may be found associated with the tectonic folds. The flow folds are intraformational and in many places range down to minute crenulations.

In the Ambrosia Lake and South Laguna areas most of the folds trend either northerly or westerly, and commonly follow the flanks and troughs of pre-Dakota folds. A second group of folds is late Jurassic or early Cretaceous and probably related to northward regional tilt of a broad east-west upwarp which extended across central New Mexico and Arizona during and following Morrison time.

About 300 collapse structures in the Bluff and Summerville formations have been mapped in the South Laguna area. They range up to 200 feet in diameter and from a few feet to possibly 300 feet in height. None of these South Laguna structures is known to penetrate into either the Morrison or the Todilto.

OCCURRENCES

The main host rocks for the ore bodies in the Grants districts are limestone and sandstone of continental origin. The deposits in the limestone are replacements and disseminations that form tabular to elongate bodies ranging from a few hundred to more than 200,000 tons. The deposits in the sandstone are grain coatings, interstitial fillings, replacements, and fracture coatings that form runs (Emmons, 1940) ranging from a few hundred to several million tons. A few deposits have been found in the Dakota carbonaceous shale as submicroscopic disseminations that form thin runs of only a few thousand tons. Although about 20 unranium minerals have been identified, coffinite, $U(SiO_4)_{1-x}(OH)_{4x}$; uraninite, UO_2; tyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}10H_2O$; and uraniferous carbonaceous material are predominant.

LIMESTONE DEPOSITS

Discoveries in the Todilto Limestone resulted in approximately 200 workable uranium deposits, varying considerably in size, all occurring within the major belt of of uranium mineralization that constitutes the Grants districts. Although these occurrences have provided the only appreciable production from a limestone host in the United States, it is relatively insignificant when compared to that from the Morrison sandstones. By the end of 1966 the limestone production amounted to about 4 percent of the total from the Grants districts.

The Todlito uranium deposits lie principally in two areas; those generally along the Todilto outcrop from the Haystack mine area to the F-33 mine (fig. 3), called the Todilto bench, and those in the South Laguna area. A few small deposits have been also mined in an area a few miles east of Grants.

The Todilto bench is transected by three fault sets; north-south, east-west, and N. 20° E. Displacements of the F-33 deposit indicate that the N. 20° E. set is postore.

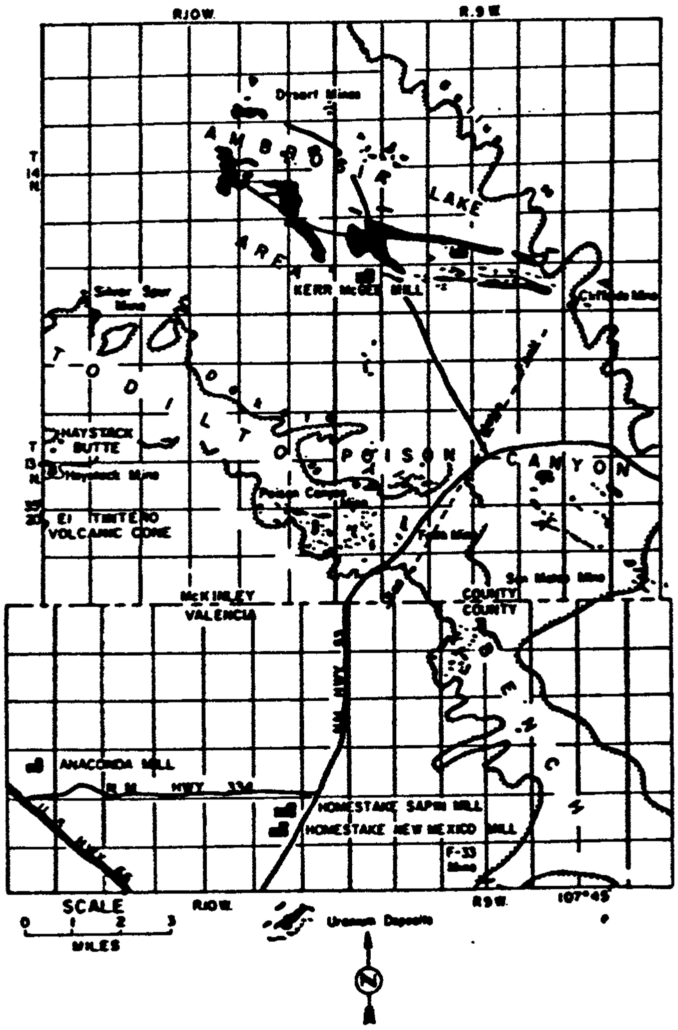

FIGURE 3.
Uranium deposits in the Grants district.

Folds in the Todilto are both harmonic and disharmonic with respect to the adjacent beds. The harmonic folds are part of the regional structure, and their distribution is incompletely known. The disharmonic intraformational consistently localized uranium deposits.
folds are small, irregular, and may be confined to any unit of the Todilto or lower Summerville. They vary from gentle arches to tight and recumbent forms. Considerable fracturing and occasional brecciation are associated with these intraformational folds. Both types of folds have

Very few of the Todilto uranium deposits have yielded more than 5,000 tons of ore. One exception that produced more than 100,000 tons of ore before its depletion in 1961 was the Haystack Mountain Development Company's open-pit mine in sec. 19, T. 13 N., R. 10 W. It was in a northwest-trending ore body about 1,150 feet long and 100 to 500 feet wide. The deposit was in a harmonic northwesterly plunging syncline, and the ore occurred chiefly in the platy member of the Todilto as disseminated yellow secondary uranium vanadates.

Another large deposit in secs. 33 and 34, T. 12 N., R. 9 W., has been worked from the underground F-33 mine. The ore body trends N. 70° E. for a developed distance of about 1,500 feet with an average width of about 70 feet. In the main ore zone the massive unit forms a bulbous lens immediately above the crinkly zone and is up to 20 feet thick. Most of the uranium is concentrated as uraninite in intraformational folds in this thickened lens of the massive unit. With the ore are very minor amounts of pyrite, fluorite, and barite. Some areas in the mine contain numerous solution channels and cavities in which the uranium vanadates, tyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}10H_2O$ and carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 3\text{-}5H_2O$; the vanadium oxides; haggite, $V_2O_3 \cdot V_2O_4 \cdot 3H_2O$ and paramontroseite, V_2O_4; and the rare calcium vanadate, metahewettite have been deposited. Substantial reserves of uranium ore remain at the mine, where underground operations were suspended in 1959 because of the curtailment of the uranium market.

The Faith mine in sec. 29, T. 13 N., R. 9 W., has also produced more than 50,000 tons of uranium ore. Its shaft was sunk for Food Machinery Corporation to below the 450-foot level, where the ore was mined from a series of about 30 disconnected ore shoots that ranged up to 250 feet long, 60 feet wide, and 15 feet thick. Mining was terminated in 1963 when the ore was depleted. Most of the ore shoots were oriented northsouth along intraformational folds, but an abrupt change to an east-west orientation occurs in the extreme southern part of the trend. The largest ore shoot occurred on a broad intraformational fold upon which were several superimposed closed folds. The major uranium mineral was uraninite, and with it were gummite, fluorite, barite, pyrite, calcite, iron oxides, and manganese oxides.

Section 25, T. 13 N., R. 10 W., and section 30, T. 13 N., R. 9 W., together contain approximately one hundred uranium deposits that have produced more than two million pounds of U_3O_8 from both open-pit and underground operations. The individual deposits ranged considerably in size and shape but for the most part were small, and are now mined out. They comprised a few hundred to a few thousand tons of randomly oriented localizations of disseminated uraninite distributed in any or all of the limestone units. In the northern part of section 25, where some relatively large ore bodies occurred, an easterly trend is evident. In section 30 many of the relatively large ore bodies were oriented north-south. Apparent structural ore controls were chiefly intraformational folds and related joints. The supergene ore minerals included tyuyamunite, carnotite, gummite and uranophane, and calcite, pyrite, hematite, fluorite, and barite gangue.

Another area from which more than 50,000 tons of Todilto ore were produced is in secs. 4 and 9, T. 12 N., R. 9 W., where 50 small deposits, ranging in size up to 2,000 tons, were mined by open-pit methods and from adits driven into the walls of the pits. Control of the deposits by folds was often evident during mining. The ore occurred in all Todilto Limestone units and consisted mostly of uraninite in association with minor amounts of yellow uranium vanadates and uranophane, and with barite, calcite, fluorite, and iron oxides. Locally fluorite massively replaced the limestone.

The South Laguna area, about 30 miles east-southeast of Grants, comprises T. 8 N., R. 4 W., T. 8 and 9 N., R. 5 and 6 W., and the eastern part of T. 8 and 9 N., R. 7 W.; all of which is Laguna Pueblo land. The dominant structural features in the normally flat-lying beds of the South Laguna area are a series of broad and gentle pre-Dakota folds which trend both westerly and northerly across the general area. Innumerable small harmonic and intraformational Todilto folds are inconsistently oriented. In conjunction with joints they often exerted significant controls on the emplacement of the uranium mineralization. However, numerous intraformational folds are barren of uranium mineralization. Only a few faults of much displacement are known to occur in the South Laguna area; most of them are in the eastern half of T. 9 N., R. 5 W., and are oriented generally north-south. No relationship has been noted between faults and uranium mineralization.

Extending for about 15 miles from southwest corner of the area in a northeasterly direction is an outcrop zone of Todilto Limestone in which numerous radiometric anomalies were discovered in the mid-1950's by scintillation-equipment surveys and conventional foot prospecting. Although much close-spaced shallow drilling was done in the anomalous areas by The Anaconda Company, only two anomalous areas were sufficiently mineralized to warrant mining operations. One was the Crackpot mine near the center of the northwest quarter of sec. 8, T. 8 N., R. 5 W.; the other was the Sandy mine in the north-central part of sec. 27, T. 9 N., R. 5 W.

Nearly all Crackpot ore occurred in the crinkly and platy zones of the Todilto; the upper massive unit was virtually barren of uranium. Intraformational folds were the chief ore control. The minerals consisted mainly of uraninite and yellow uranium vanadates that were irregularly disseminated in a small fold. Accessory minerals other than calcite and limonite were not in evidence.

The Sandy deposit consisted of several small pods in Todilto Limestone and upper bleached Entrada Sandstone on a gentle south-facing moncline. Several small harmonic and intraformational folds provided some ore control, but the ore cutting across the tilted Todilto-Entrada contact indicated that folds were not the only control. The ore was similar mineralogically to that in the Crackpot deposit. Less than 5,000 tons of ore were produced from the Sandy and Crackpot open-pit mines, and no ore has been produced from either mine since 1955.

SANDSTONE DEPOSITS

Uranium deposits have been found in the Entrada Sandstone, Morrison Formation, and the Dakota Sandstone, in addition to the Todilto Limestone. The deposits in the Morrison are by far the largest and most continuous known to date, while those in the Entrada and Dakota are small, isolated, and widely scattered.

Entrada Sandstone

Deposits in the Entrada occur just below the Todilto Limestone contact in the bleached part of the upper sandy member. This member is 80 to 250 feet thick, reddish orange to light-gray, moderately well-cemented and well-sorted fine- to medium-grained quartz sandstone. The upper 5 to 30 feet is generally bleached to light gray; this is thought to be the result of weathering of the pre-Todilto surface.

The principal Entrada uranium deposits were at the Haystack mine (sec. 19, T. 13 N., R. 10 W.), the Zia mine (sec. 15, T. 12 N., R. 9 W.), and the Sandy mine (sec. 27, T. 9 N., R. 5 W.) in the South Laguna area. These and all other known deposits in the districts appear to be supergene occurrences derived from overlying Todilto ore bodies. Field observations of the present terrain indicate that the overlying impermeable formations were eroded away making it possible for meteoric waters to reach the Todilto, and tension fractures associated with ore-localizing intraformational folds provided the permeability necessary to allow the waters to leach the uranium from the limestone. The uranium was reprecipitated in the Entrada in the form of uraninite, coffinite, and tyuyamunite.

Morrison Formation

More than 95 percent of the uranium ore produced in the Grants districts has been mined from the Westwater Canyon and Brushy Basin members. The Westwater Canyon is the principal host rock west of Mount Taylor in the Ambrosia Lake, Smith Lake, Churchrock, and Poison Canyon areas. In the Laguna district the Jackpile sandstone is the principal host.

Special terms are in use locally to describe recognizable variations in the occurrences of black Westwater deposits west of Mount Taylor.

OLDER ORES	YOUNGER ORES
prefault	postfault
trend	redistributed
primary	secondary
roll	stack

The term stack is intended to refer to thick postfault, redistributed occurrence, but the superposition of two or more runs has the appearance of, and is sometimes erroneously termed, a stack.

Prefault or trend ore bodies are properly termed runs. They are usually elongate in a west-northwesterly direction. In the lower Westwater, they are generally a part of a larger, elongate, thin layer of mineralization in which the grade, thickness, and width of mineralization have been observed to increase at predictable intervals into runs.

In places the ore changes elevation abruptly, crosses the bedding, and thickens to form a roll. It has been observed that when this change in elevation occurs across the west-northewesterly trend direction, the higher elevation is consistently to the north and up-section.

In the upper Westwater the mineralization is not as wide-spread, and the deposit generally forms a single wide run that is lenticular in cross section, and may have small satellitic prefault ore bodies along its north and south edges. Here again the northern ore bodies have a higher stratigraphic elevation than those to the south, although the regional dip is northward.

A direct relationship has not been established between prefault ores and specific structural features. Faults observed in the older ore bodies throughout the district indicate post-ore movement inasmuch as the ore and bedding planes are displaced the same amount. An indirect relationship exists between the uranium deposits and regional deformation which controlled the original linear features in the Morrison sandstone host beds.

Redistributed or postfault uranium deposits are generally associated with, and quite often engulf, an older prefault deposit. These deposits tend to be more equidimensional horizontally and considerably thicker (up to 100 feet) than the prefault occurrences. Their direction of elongation is commonly related to an increase in fracture density along which the redistribution has taken place. Changes in grain size and sorting, intraformational mudstone layers, gouge in fault zones, and the amount of fracturing are all features that have influenced the shape, position, and grade of the redistributed deposits.

The redistributioan process, which has apparently been in progress since the earliest Laramide tectonic activity, changed the hydrodynamics and set formation waters in motion. Redistribution is accomplished by circulation of aerated ground water through an area of older mineralization. These solutions change the uranium from a plus four to a plus six valence state that can form complexes with bicarbonate and sulfate ions present in the waters. These uranium-rich solutions proceed down dip until their oxidizing capability lessens to the point where precipitation takes place in a favorable (reducing) environment.

Oxidation, solution, and reprecipitation are well illustrated by the presence of high-grade redistributed ore in a zone along the contact between oxidized and unoxidizd sandstone. From this contact zone the grade decreases and finally feathers out into the unoxidized sandstone. Remnants of prefault ore that may have provided the uranium for redistribution have been observed in oxidized sandstone through which redistributing solutions have passed.

The uranium minerals that make up the deposits have been chemically precipitated as sand grain coatings, interstitial cement, fracture fillings, and replacements of carbonaceous material. The minute grain size makes megascopic mineral identification nearly impossible and microscopic study difficult. The most reliable identifications have been made using X-ray equipment.

Coffinite, uraninite, and uraniferous carbonaceous material are the principal uranium-bearing materials found throughout the districts in the unoxidized sandstone deposits. Granger (1963) describes the carbonaceous material as..." an authigenic organic matter that seems to have introduced in a fluid state and has remained as a precipitate or residue to form grain coatings, interstitial cement, and fracture fillings". It is coextensive with prefault ore and seems to be the matrix or gangue in which many of the prefault ore metals occur. Carbonaceous material in the sandstone host is generally uraniferous and contains coffinite, but where it is oxidized, such as in shallow deposits exposed at the surface, the coffinite may be destroyed and the uranium leached. Coalified fossil trunks, limbs, and fragments of wood and grasses may also be uranium-bearing. Numerous uranium-bearing dinosaur bones have been found in the Morrison.

The most common secondary minerals are tyuyamunite, metatuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 3\text{-}5H_2O$, and carnotite. Zippeite, $2UO_3 \cdot SO_3 \cdot 5H_2O$, andersonite, $Na_2Ca(UO_2)(CO_3)_3 \cdot 6H_2O$, and bayleyite, $Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$, are commonly found as post-mining efflorescent deposits on the mine walls.

Commonly occurring interstitial gangue minerals are pyrite, marcasite, calcite, jordisite, ilsemannite, and ferroselite ($FeSe_2$). Native selenium, barite, calcite, and pyrite occur as fracture fillings, and pascoite is a common post-mining efflorescent occurrence.

Molybdenum in the mineral jordisite, MoS_2, is a common accessory in both the upper and lower deposits where it is found as a halo or fringe on the edges as well as within the ore. The mineral montroseite is also an included accessory mineral.

The most significant deposits in the Westwater Canyon Member are found in T. 14 N., R. 9 and 10 W. (the Ambrosia Lake area). The minable uranium ore bodies (those containing more than two pounds of U_3O_8 per ton) form a nearly continuous west-northewesterly striking deposit that extends some eight miles from the southeast corner of T. 14 N., R. 9 W. to the northeast quarter of T. 14 N., R. 10 W. along the southern edge of the Ambrosia Lake trend these deposits occur throughout the entire thickness of the member, including the "Poison Canyon" tongue. Santos (1963) noted that this stratigraphic range gradually lessens to the north as follows: "Through the center of the belt, ore deposits occur from near the middle to the top of the Westwater Canyon, and along the northern margin of the belt, they occur at the top only."

The subdivision of the 250-foot thick Westwater into distinguishable sandstone units, separated by discontinuous mudstone layers and beds, has been a practical necessity for correlating the ore bodies. These ore-bearing units range in thickness from 12 to 60 feet, and the ore ranges in thickness from less than two feet in runs to more than 100 feet in redistributed stacks.

The localization of the uranium deposits within the various sandstone units occurred in at least two phases. The first deposition occurred in reducing environments created when areas of dense vegetation were rapidly buried and later converted into carbonaceous material. During this time sedimentary features controlling porosity and permeability had their most important effect. Interstitial and interbedded mudstones controlled the flow of and trapped the carbonaceous fluids and uranium-bearing solutions. Large areas of unoxidized clean sandstone that contain little interstitial mudstone are barren even though geologic evidence indicates that uranium-bearing solutions passed through the sandstones.

The second and posssible succeeding phase of localization occurred when the uranium in older prefault runs was redistributed by moving ground waters. The effectiveness of the redistribution process along zones of increased permeability is well demonstrated in the Poison Canyon trend where prefault uranium deposits in the San Mateo fault zone and associated syncline were completely removed and were probably reprecipitated down dip to form the Hogan and the Cliffside deposits.

The permeability that allowed deposits to be destroyed was also necessary for the formation of the characteristic Ambrosia Lake stack ore bodies. Examples of stack ore bodies that have been localized in fault zones and areas of increased fracture density are found in secs. 10, 11, 22, 23, 24, and 25, T. 14 N., R. 10 W., and secs. 29, 30, 35 and 36, T. 14 N., R. 9 W. Carbonaceous material is generally present but less abundant in redistributed deposits.

Production from individual Ambrosia Lake mines has ranged from less than 100 tons to more than 1,000 tons per day. At the end of 1966 production from the larger mines averaged about 600 tons per day, but with an expanding market in sight production is increasing accordingly.

The first discoveries in the Westwater were made in runs that form the "Poison Canyon ore trend". The occurrences in this trend also span some eight miles from the Blue Peak mine (sec. 24, T. 13 N., R. 10 W.) where uranium ore occurs at the surface, southeasterly to the San Mateo mine, where ore lies at a depth of about 1,400 feet (fig. 3).

Most of the ore occurs in typical upper Westwater runs that are found where "Poison Canyon" sandstone exceeds 40 feet in thickness. Although most of the ore is localized near the base of the unit, the changes in thickness do not reflect channeling or thickening at the base, but are the result of the accumulation of stray sandstone lenses at the top of the unit (Rapaport, 1963).

The southern edge of the "Poison Canyon" trend is marked by a straight sharp boundary between ore and barren rock that more or less parallels the long axis of the sandstone lenses. In comparison the northern edge is irregular, and the transition from ore to waste is gradual;

this irregularity is the result of redistribution down dip along northeasterly striking fracture systems. Uranium in the ore bodies in secs. 7 and 8, T. 13 N., R. 9 W., was almost certainly dissolved from runs in the trend and carried more than 2 miles down dip along a fault system before being redeposited. The San Mateo fault zone is an area where removal of pre-existing ore bodies was complete.

All production from the "Poison Canyon" trend has been from underground mines except for that from the rim at the Blue Peak mine, and from the Poison Canyon open pit. Daily production from individual mines along the trend varied from a few tons to several hundred tons.

The Smith Lake area is about 20 miles north-northwest of Ambrosia Lake in T. 15 N., R. 13 W., (fig. 1). The Homestake-Sapin Partners' Black Jack No. 1 and No. 2 mines are the only producers and deposits in this area.

The Black Jack No. 1 deposit, in sec. 12, T. 15 N., R. 13 W., is a J-shaped easterly trending ore body that hooks south and west, and lies on the east end of the Mariano Lake anticline. This ore deposit of more than one million tons occurs in the middle and upper Westwater, in seven zones (Fitch, 1961). The lower three intertongue and form an east-west prefault run nearly 3,600 feet long. The upper four zones appear to be redistributed deposits that have formed in areas of increased fracture density along both normal dip-slip and strike-slip faults (McRae, 1963). Shorter northeasterly prefault runs that have been partly removed are found in the southern part of the deposit. In this ore body, the sharp ore-waste cutoff occurs along the north edge of the run. The reason for the apparent redistribution from north to south is not clear. The mine has produced more than 1,000 tons per day and now averages about 750 tons per day.

The Black Jack No. 2 deposit was in the north-central part of sec. 18, T. 15 N., R. 13 W., (fig. 1), at the southwest end of the Mariano Lake anticline. It occurred in the "Poison Canyon tongue" of the Westwater Sandstone. This sandstone lens is a very local occurrence and ranges in thickness from 18 to 60 feet in the mine area. More than 200,000 tons of ore were produced from the deposit before it was mined out in 1964. Daily production ranged from 100 to 200 tons. There were three zones of ore; the lowermost zone near the base of the sandstone was the most prevalent. Observations in the mine indicate that the ore was prefault and deposited in a sand-filled channel where shapes of the ore pods were controlled by changes in permeability related to interbedded mudstone.

The westernmost Westwater occurrences have been found in T. 15, 16, and 17 N., R. 16 W., in the Churchrock area (fig. 1). Ore production from the area has been limited. A few small mines along the rim produced a few thousand tons each, and the Churchrock mine operated by United Nuclear Corporation produced less than 50,000 tons from the Westwater before it was closed. A substantial tonnage of low-grade reserves remains.

In the Churchrock area uranium mineralization has been found throughout the Westwater, with the bulk occurring in the middle of the member. Deposition and apparently later leaching of the deposit occurred along a northeasterly striking fracture zone. Natural radioactivity logs of widely spaced drill holes in the above-mentioned three townships indicate that uranium-carrying solutions ranged widely in the Churchrock area.

A new deposit has been discovered north-northeast of the Churchrock mine, and several drills are presently being employed by local operators to develop it. Drill holes in this Northeast Churchrock deposit have cut minable thicknesses of ore grade mineralization throughout the member. The best concentrations are near the base and in the upper part of the member. The configuration of the deposit suggests that the lower ores are prefault and the upper ores redistributed.

The North Laguna area is about 30 miles east of Grants and includes the Jackpile, Paguate (pronounced Pah wah' tee), St. Anthony, L-Bar, and Woodrow ore bodies (fig. 4). The Jackpile and Woodrow deposits were discovered in November, 1951, with airborne scintillation equipment; an outcrop of the St. Anthony deposit was discovered in early 1954, and the Paguate and L-Bar deposits, neither of which are exposed at the surface, were discovered in 1956 as a result of systematic exploration drilling.

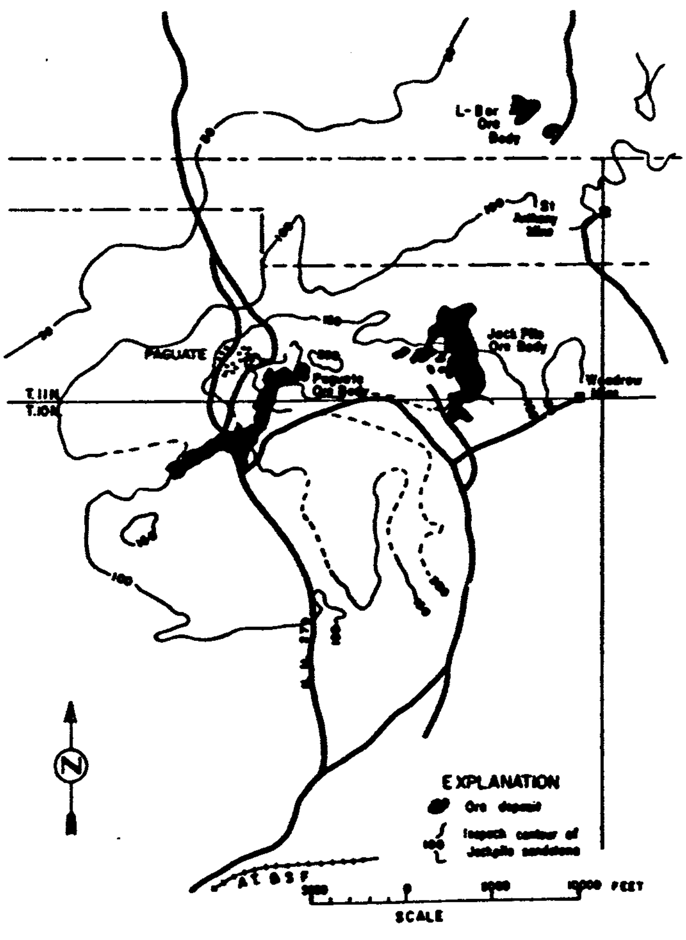

FIGURE 4.

North Laguna area, showing the relationship of the ore bodies to Jackpile sandstone thicknesses.

The Jackpile sandstone is the host rock for all economically important uranium deposits in the North Laguna area. It is thought that this unit was derived from the southwest; it was deposited in a northeasterly-trending downwarp known to be at least 35 miles long, 15 miles wide, and 220 feet deep. The Jackpile and Paguate ore bodies are in the thicker part of the Jackpile sandstone.

There are practically no faults in the area, and those that are present are small and have no apparent control over primary ore localization. Mineralization was influenced in different degrees by such controlling factors as cross-bedding, carbonaceous material, mudstone layers and lenses, bedding planes, lithologic changes, weak intraformational faults, and thickness of host rock.

The Jackpile deposit has a known length of about 1.5 miles, and an average width of about one-half mile. The Paguate deposit has a known length of over 2 miles and an average width of a few hundred feet. In the Jackpile mine nearly all the uranium mineralization occurs in the lower half of the host sandstone. The ore ranges in thickness from 20 to 50 feet and is locally separated by various thickness of barren sandstone of similar lithology. Uranium mineralization in the eastern part of the Paguate deposit normally occurs in the upper one-third of the Jackpile sandstone; locally, mineralized lenses have been truncated by the overlying Dakota Sandstone. In the western part of the deposit ore normally occurs in the lower two-thirds of the host sandstone. To date the following minerals from the Jackpile and Paguant mines have been identified:

Autunite, $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$
Becquerelite, $7UO_3 \cdot 11H_2O$
Carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$
Coffinite, $U(SiO_4)_{1-x}(OH)_{4x}$
Hydrogen-autunite, $HUO_2PO_4 \cdot 4H_2O$
Metatorbernite, $Cu(UO_2)_2(PO_4)_2 \cdot {}_nH_2O_n = 4$ to 8.
Metatyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}7H_2O$
Phosphuranylite, Ca. $(UO_2)_4(PO_4)_2(OH)_4 \cdot 7H_2O$
Schoepite, $4UO_3 \cdot 9H_2O$
Sklodowskite, $Mg(UO_2)_2(SiO_3)_2(OH)_2 \cdot 6H_2O$
Soddyite, $(UO_2)_5(SiO_4)_2(OH)_2 \cdot 5H_2O$
Tyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}10H_2O$
Uraninite, UO_2
Uranophane, $Ca(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$

Noncommercial quantities of selenium, molybdenum, and vanadium also occur in association with the uranium. Metallurgical studies show the normal mill feed from the Jackpile and Paguate deposits to be about as follows:

Black oxidized uranium complexes	80%
Uraninite	15%
Black organo-uranium complexes	3%
Coffinite	2%

Coffinite and uraninite are relatively more abundant in the high-grade ores. The uranium minerals are intimately mixed with and replace carbonaceous material, or occur as the cement in the sandstone.

Production from the Jackpile and Paguate mines averaged more than 4,000 tons per day prior to May, 1959, when the AEC curtailed its purchases of uranium concentrate. Since then production has been reduced to about 950 tons per day, but it is anticipated that it will soon increase as market demands increase.

The St. Anthony deposit is about two miles northeast of the Jackpile mine. It occurred in the Jackpile sandstone and was mined from the 250 level of a vertical shaft by Climax Uranium (a subsidiary of Climax Molybdenum) during the period 1957-60. The ore body was about 1000 feet long, 50 to 300 feet wide, and up to 30 feet thick. The mineralogy of the deposit was essentially the same as that of the Jackpile and Paguate ore bodies, being for the most part a complex of black uranium oxides in which the higher grade portions comprised coffinite to a large extent, with some associated uraninite. Normal production amounted to somewhat less than 200 tons per day of ore with a grade of about 0.20 per cent U_3O_8, most of it mined by a pillar-retreat stoping.

The L-Bar deposit is a partially developed ore body located about a mile northwest of the St. Anthony deposit on land belonging to the L-Bar Cattle Company. Its shape as developed to date is roughly a square about 2,000 feet on a side, but drill-hole data indicate that the mineralization may extend for another 2,000 feet southeasterly. The deposit is made up of numerous, fairly discontinuous thin lenses of uranium mineralization that occur throughout the entire section of Jackpile sandstone. The ore composition is the same as that found in the Jackpile and Paguate mines.

The Woodrow mine is about a mile east of the Jackpile mine. The deposit occurred in a nearly vertical breccia pipe of Jackpile sandstone. the pipe is for the most part bounded by strong ring faults that penetrate into Brushy Basin mudstone near the surface, and which continue downward into the Morrison Formation beyond a known depth of 272 feet. The core of the pipe has been downthrown approximately 40 feet, and relatively thick, black clay-gouge was formed along the fault. Most of the mineralization occurred in this core, and in the interval from 31 to 51 feet below the surface small quantities of ore assaying as high as 20 per cent U_3O_8 were found. In this same interval of depth the mineralization extended up to 10 feet outside the ring fault, along minor fractures. (Wylie, 1963). The following minerals have been identified from the Woodrow pipe:

*Autunite, Ca $(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$
Barite, $BaSO_4$
*Becquerelite, $7UO_3 \cdot 11H_2O$
Chalcopyrite, $CuFeS_2$
Coffinite, $U(SiO_4)_{1-x}(OH)_{4x}$
Galena, PbS
Jarosite, $KFe_3(OH)_6(SO_4)_2$
Johannite, $Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$
Marcasite, FeS_2
*Meta-autunite, $Ca(UO_2)_2(PO_4)_2 \cdot 8H_2O$
*Metatorbernite, $Cu(UO_2)_2(PO_4)_2 \cdot nH_2O_n = 4$ to 8
*Pyrite, FeS_2
Sabugalite, $HAl(UO_2)_4(PO_4)_4 \cdot 16H_2O$
Torbernite, $Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$

* known to occur also in the Jackpile deposit.

*Uraninite, UO_2
Uranopilite, $(UO_2)_6(SO_4)(OH)_{10}\cdot 12H_2O$
*Zippeite, $2UO_3\cdot SO_3\cdot 5H_2O$

The Woodrow pipe is without question a unique uranium host that has certain geologic characteristics otherwise unknown except at the Orphan pipe on the south rim of the Grand Canyon. The strong ring faults, the breccia, and sulfides suggest that the mineralization in the pipe may be hydrothermal.

The Woodrow deposit was mined from the 100-foot level to the surface in 1954, and from the 200-foot to the 100-foot level in 1956. The first mining phase produced ore with an average grade of 1.53 per cent U_3O_8 and 0.05 per cent V_2O_5, whereas the second phase produced ore with an average grade of 0.32 per cent U_3O_8 and 0.03 per cent V_2O_5.

Dakota Sandstone

Uranium occurs in basal interbedded sandstones and shales of the Dakota. The deposits have been found in the Gallup area along the hogback formed by the Nutria monocline, in the Churchrock area, and in the southwestern corner of the Ambrosia Lake area. The first mine in the Dakota Sandstone and one of the first in the district was the small open-pit Silver Spur mine in sec. 31, T. 14 N., R 10 W. fig. 3). The largest producers, about 40,000 tons each, have been the Diamond No. 2 mine south of U.S. Highway 66 on the Nutria monocline (fig. 1) and the Dakota level of the Churchrock mine. At the end of 1966 the Diamond No. 2 was still producing a few hundred tons per month and was the only Dakota deposit being worked. The total production from the Dakota deposits has been about 100,000 tons containing four pounds of U_3O_8 per ton.

The uranium has been concentrated in fine- to coarse-grained sandstone and interbedded carbonaceous shale that in places contain enough carbonized vegetal remains to form thick peat beds. The Hogback No. 4 deposits occurred entirely within a shaly carbonaceous bed.

Primary uranium minerals, uraninite and coffinite, are found in deposits that lie below the water table. On the outcrop and in near surface deposits these have been oxidized to form carnotite and other secondary minerals. These primary and secondary minerals impregnate the host rock as sand grain coatings and interstitial fillings, and the secondary minerals commonly fill fractures.

The deposits are nearly equidimensional in the horizontal plane, and their thickness has been limited to less than 20 feet by the thickness of the sandstone units in which they occur. The elongation of the deposits generally is parallel to northerly trending fractures associated with the ore bodies.

The occurrence of several of the ore bodies in folded, faulted, and fractured areas suggests that the uranium in the Dakota deposits may be post-Laramide and has been derived from eroded updip or underlying Morrison deposits and redistributed along the fractures where the favorable carbonaceous environment was encountered.

* known to occur also in the Jackpile deposit.

ORIGIN

Theories of the origin of the Grants deposits, as with most others of the Colorado Plateau, have fallen into the following genetic types:

(1) Syngenetic-sandstone, mudstone, tuff, carbonaceous shale
(2) Ground water
  (a) Lateral secretions
  (b) Supergene
(3) Hydrothermal

Some theories are combinations of the above or are multiple variations of one of them, such as a penesyngenetic category. To evaluate the genesis of the deposits properly it is absolutely essential to know as nearly as possible the geologic history beginning with the source and deposition of the sedimentary materials. It is therefore fitting to begin with the nature and source of the Morrison beds.

The Morrison sediments are markedly tuffaceous and clearly indicate a volcanic provenance in which there may have been flow, pyroclastic, geyser, and hot spring eruptions. Significant quantities of uranium may have been associated with these eruptions. If this were true the uranium could have been brought to the sites of the Morrison deposition by surface and subsurface waters, fluvial debris, and fallout. The surface and subsurface waters moving toward the Morrison depositional sites could have continued to extract uranium from unstable rock debris during transportation. Associated with the rocky sediment was also considerable organic debris or trash which accumulated in irregular deposits that eventually became instrumental in localizing many of the ore deposits. Diagenetic redistribution of uranium may have continued during burial, compaction and cementation. These were the conditions and environments during the earliest stage of possible uranium accumulation by sedimentary syngenetic or pensyngenetic processes.

The sedimentary stage of late Jurassic was brought to a halt in most of the area by the rise of the Mogollon highland with its broad gentle tilt to the north (Kelley, 1955). Some gentle folding accompanied the tilting while widespread stripping reworked the upper sediments to the north. Channel sands such as the Jackpile and other post Brushy Basin deposits farther to the north may have formed during this episode. Water tables, ground-water dynamics, and water chemistry were undoubtedly modified considerably during this rejuvenaion. Previous uranium deposits could have been weathered, leached, eroded mechanically, and redeposited several times. To many geologist this has been a favored time for formation of the older runs west of Mount Taylor and the Jackpile and Paguate deposits.

This second state was terminated with marine encroachments which accompanied regional subsidence of subcontinental dimensions and eventually buried the Grants region to nearly 5,000 feet in late Cretaceous and possibly 7,000 by Paleocene time. Although temperatures and pressures were increased during this stage, ground-water circulation essentially ceased and modifications of deposits would have been local and slight.

The next stage of potential ore formation began with Laramide deformation and continued through the Tertiary. For the Grants region the rise of the Zuni uplift and the subsidence of the San Juan Basin and its subsidiary Gallup and Acoma embayments were the predominating tectonic influences. In addition to the Zuni dome all the folds and most of the faults that are so prevalent in the vicinity of Ambrosia Lake were formed during this time. Metallizing porphyry intrusions may have occurred at this time in the more than 300 square mile area between Ambrosia Lake and Laguna that is covered by the Mount Taylor volcanic field. The obvious effects upon the deposits beyond deformation included general decline of pressure and temperature and increased mobility of the ground water. Additionally, hydrothermal alteration and introduction of uranium is a possibility at this stage.

Continued regional uplift probably resulted in first re-exposure of the Morrison along the Zuni uplift by middle Tertiary. By the end of the period the uranium-bearing horizons had been stripped and truncated well off the crest of the uplift where the Precambrian was exposed in a wide erosion surface. During all this time and into the present, oxidation and solution by meteoric water progressively modified and "worked" the deposits down dip, to their present positions, especially to the north and northeast of the uplift. Some of this downward migration of the uranium-bearing solutions is thought also to have crossed the formations downard to be precipitated in the Todilto Limestone.

The history of exposure and modification at Laguna was quite different, as these great deposits lay in the Acoma embayment well removed from the energizing effects of the Zuni uplift. Exposure came later, slower, and along a much broader area owing to the low dips. As a result supergene buildup was not shifted so much down the dip as in the redistributed stacks which characterize the Ambrosia Lake and Gallup areas.

The foregoing outline of the geologic history since late Jurassic furnishes a framework of conditions which must have controlled the formation of the deposits regardless of the specifics of their origin. The source of the metal, whether from sedimentary debris, ground-water introductions, or hydrothermal additions is the principal genetic problem along with timing of deposition.

In order to decide upon these problems, petrographic, spectrographic, paragenetic, geochemical, isotopic, and radiometric studies are pursued. These appear to raise additional subsidiary problems such as the chemistry of the transporting fluids, precipitation or concentration, the significance of the widespread alteration in the Morrison sands, etc. Nevertheless, some conclusions appear to have reached near unanimity. One of these is recognition at Ambrosia Lake of two stages (prefault and postfault) of ore body development associated with down dip oxidation, solution, and enrichment. If an early derivation of the ore deposits is agreed upon, then later modification and redistribution energized by the Laramide disturbances and erosion, become more or less logical, corollary, sequential steps that would accompany the known geologic history.

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THE AEC AND THE GRANTS MINERAL BELT

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THE AEC AND THE DEVELOPMENT OF THE URANIUM INDUSTRY

With the passage of the Atomic Energy Act of 1946, the Congress of the United States placed the responsibility for the control and development of nuclear energy in a civilian agency, the Atomic Energy Commission. The atomic bomb, whose power was so awesomely demonstrated at Hiroshima and Nagasaki, had been developed in remarkable wartime secrecy by the Manhattan Project, a division of the Army. While recognizing the paramount importance of the new energy source to national defense, the Act enjoined the Commission to develop atomic power for the promotion of world peace, improvement of the general welfare, and strengthening of free competition in private enterprise. These objectives were retained in the revised Atomic Energy Act of 1954, which relaxed certain restrictions of the earlier act to permit easier participation in nuclear power development and international cooperation for peaceful purposes.

The most critical situation facing the Commission in 1946 was the pitifully small amount of atomic fuel available. It seems incredible now, but the bombs which ended the war with Japan were made possible only by the fortuitous presence on a Manhattan dock of 2500 tons of high grade uranium ore from the Belgian Congo.

The Webber report of Union Mines Development, compiled for the Manhattan Project, estimated the known and indicated minable uranium ore reserves of the United States in 1947 at less than 1,000,000 tons, containing about 2,000 tons of U_3O_8. The total domestic mine production in fiscal year 1948, two years after establishment of the Commission, was only 54,000 tons of ore, from which the Commissionn obtained but 110 tons of U_3O_8. The responsibility for alleviating this condition was placed in the AEC's Division of Raw Materials, which had to be organized and staffed from scratch.

The first contract for purchase of U_3O_8 concentrate was executed with the Vanadium Corporation of America in May 1947 for its Naturita, Colorado plant. A few months later the second contract was signed with the U. S. Vanadium Co., a subsidiary of Union Carbide, for the Rifle mill. Both of these plants had been vanadium producers and the first deliveries to the AEC took place in late 1947. In view of the fact that all of the domestic uranium reserves known at the time were located in southwestern Colorado and southeastern Utah, the Colorado Raw Materials Office was established in December of 1947 at Grand Junction, Colorado.

In considering the most effective means of relieving the critical shortage of U_3O_8, the AEC early decided to leave the mining and processing of uranium ores almost entirely to private enterprise, the wisdom of which was later to be amply demonstrated. The basic requirement for this purpose was to provide a market for ores and concentrates at prices which would encourage the prospector, miner, and miller to put in the tremendous effort and investment needed to build up the industry. To this end, the AEC issued a number of offers for uranium ores culminating in the well-known Domestic Uranium Program Circular 5, Revised, of March, 1951, which has remained the basic ore buying schedule to this day. Aside from the Government-owned mill at Monticello, Utah, which was shut down in late 1959, all processing plants were built by private operators under negotiated contracts with the Commission.

In addition to the fundamental requirement of a market, the AEC instituted a large number of other incentives and stimulants to uranium production. Approximately \$17,000,000 was paid out, chiefly to small miners, as a bonus for initial and certain other production of uranium ores.

Between 1948 and 1956, over 5.5 million feet of drilling was done by the USGS and the AEC and extensive geological studies were made and published. Over 1,200 miles of access roads were built and improved in Arizona, Colorado, New Mexico, South Dakota, Utah, and Wyoming at a cost of \$17,000,000. Sixteen ore buying stations were established in promising districts, before mills were built, and were operated for the AEC by its contractors, principally the American Smelting and Refining Co. and Lucius Pitkin. Forty nine leases were issued to private firms and individuals between 1949 and 1954 on withdrawn lands.

Many other assisting programs were carried out such as airborne reconnaissance and posting of anomalies, development of geophysical instruments and techniques, improvement of ore sampling practices, and free examination and assay of radioactive minerals for prospectors.

Less known than the help given to prospectors and miners was the extensive research performed and initiated by the Commission in the then primitive art of extracting uranium from its ores. Uranium extractive metallurgy in 1947 was confined to a crude separation of yellow cake, primarily as a byproduct, from the vanadate ores of the Uravan Mineral Belt. Recoveries were poor and costs were high. With American Cyanimide and National Lead as the principal contractors, the AEC established the Raw Materials Development Laboratory at Winchester, Massachusetts and, in 1953, the pilot plant at Grand Junction.

Numerous research contracts were concluded with

* Publication authorized by the Atomic Energy Commission.

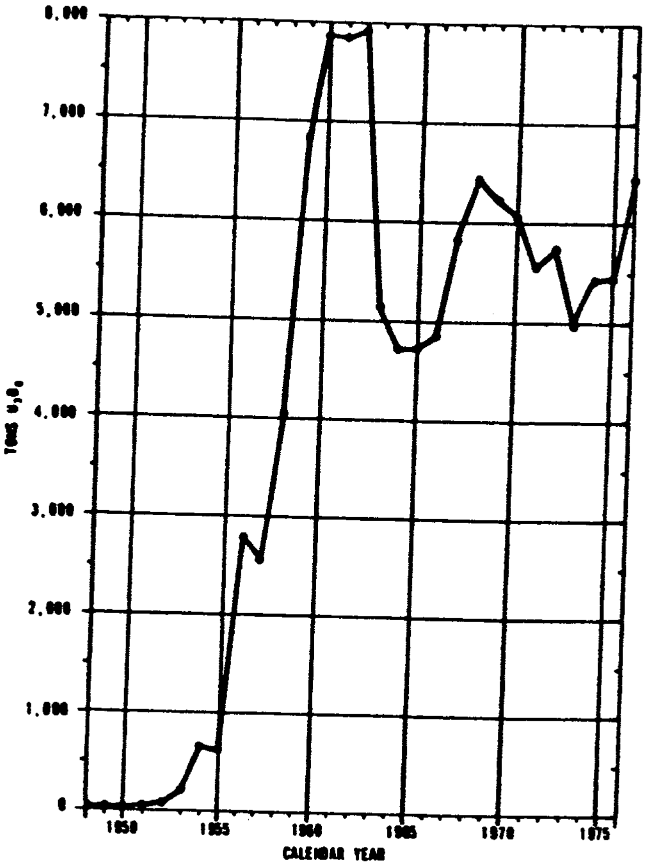

Figure 4. San Juan Basin uranium production, 1948 through 1976.

the nuclear electrical power industry. The decline in uranium sales in the early 1970s was due to a saturated market and was accentuated in 1973 by a long strike against Kerr-McGee. The rise in production in recent years reflects increased demand by the electric-power utility companies.

Recent large increases in spot prices being paid for uranium have had little affect on the production in the Grants mineral belt during 1976. In a recent survey by ERDA, U.S. producers reported that the prices for uranium delivered in 1976 ranged from slightly over $6 to nearly $42 per pound. The average price of uranium reported for actual deliveries in 1976 was $16.10 per pound. This is due to the fact that most of the current production is tied to long-term contracts that were negotiated before the sharp rise occurred. The price of uranium sold by the producers in the Grants area in 1976 probably is near the national average.

PROCESSING FACILITIES

Early output from the eastern Carrizo Mountains was shipped to the Vanadium Corporation of America's (VCA) mill at Durango, Colorado. Shipments continued to the Durango mill until it closed in March 1963. In January 1952, the AEC opened an ore-buying station at Shiprock, New Mexico, and closed it in 1954 when Kerr-McGee Oil Industries began operating a mill at Shiprock. Although this mill was built to treat ore from the Lukachukai Mountains in northeastern Arizona, it also treated ore from non-VCA properties in the eastern Carrizo Mountains. VCA acquired the Shiprock mill in March 1963, and operated it until it closed in 1968.

At first, limestone and sandstone ores from the Grants area were shipped to the AEC buying station at Monticello, Utah. In June 1952, an AEC buying station was established at Bluewater, New Mexico, and closed when the Anaconda mill went on-stream at Bluewater in mid-1953. This mill, using a carbonate-leaching circuit, was constructed to treat limestone ores and operated until May 1959. In 1955, Anaconda constructed a second mill to treat sandstone ores derived chiefly from its Jackpile mine.

Following the discovery of the Ambrosia Lake ore bodies, the AEC established a buying station at Milan, New Mexico, in mid-1956. In late-1956, the AEC contracted to purchase uranium concentrate from Homestake-New Mexico Partners. During 1957, additional purchase contracts were signed with Homestake-Sapin Partners, Kermac Nuclear Fuels and Phillips Petroleum Company. The four uranium mills required to fulfill these contracts began operating in 1958.

After the consolidation of the two Homestake mills in November 1961, the Homestake-New Mexico Partners mill was shut down in April 1962. When Phillips sold its interests to United Nuclear Corporation in March 1963, the Phillips mill was shut down and United Nuclear began shipping its ore for processing, on a toll basis, to the Homestake-Sapin Partners' mill. This is the only remaining carbonate-leach mill in the Grants area, and it is now operated by United Nuclear in partnership with Homestake Mining Company.

In 1973, Sohio Petroleum Company and Reserve Oil and Minerals Corporation announced their intention to build a 1,600-tons-per-day mill on their property near Cebolleta, New Mexico. Construction of this facility began in 1974, and the mill became operational in August 1976.

In early 1977, the four mills operating in New Mexico had a combined nominal operating capacity of 15,100 tons of ore per day, which is nearly half of the total daily national capacity. These mills and operating capacities are as follows:

	Tons of Ore Per Day
The Anaconda Company	3,000
Kerr-McGee Nuclear Corporation	7,000
Sohio Petroleum Co.-Reserve Oil and Minerals Corp.	1,600
United Nuclear-Homestake Partners	3,500
Total	15,100

United Nuclear announced plans to build a mill in the northeast Church Rock area in the early 1970s. In November 1975, ground was broken and the construction of this 3,000 TPD mill commenced; the target date for operations is the summer of 1977. United Nuclear and the Sohio-Reserve mills are the first to be constructed in New Mexico without benefit of government concentrate-purchase contracts.

During the latter part of 1976, Phillips Petroleum announced plans for a mill on its Nose Rock property and the Anaconda Company announced plans to enlarge its plant to a capacity of 6,000 TPD.

RESOURCES

Uranium resources consist of reserves and potential resources. Reserves are the firmest element of resources, comprising deposits that have been delineated by drilling or other direct sampling methods. Potential resources are the quantities of uranium estimated to be present in deposits that are incompletely defined or undiscovered. By declining order of reliability, potential resources are divided into three categories: probable, possible and speculative.

The relationship of reserves to potential resources is illustrated below.

<table>
<tr><td colspan="4">URANIUM RESOURCES</td></tr>
<tr><td>DEFINED</td><td colspan="3">INCOMPLETELY DEFINED OR UNDISCOVERED</td></tr>
<tr><td rowspan="2">RESERVES</td><td colspan="3">POTENTIAL RESOURCES</td></tr>
<tr><td>PROBABLE</td><td>POSSIBLE</td><td>SPECULATIVE</td></tr>
</table>

Table 2. Uranium resources of the San Juan Basin.

Tons U_3O_8

$/lb. U_3O_8 Cost Category	Discovered Ore Reserves	Undiscovered (Potential) Probable	Undiscovered (Potential) Possible	Undiscovered (Potential) Speculative
$15	225,800	230,000	250,000	50,000
$30*	356,400	395,000	455,000	65,000

*Includes $15

Ore reserves are calculated from drill hole data and other engineering sources which are made available to the Grand Junction Office voluntarily by the uranium companies. Separate evaluations are made of the amounts of uranium that could be exploited at maximum forward costs of $15 and $30 per pound U_3O_8, using established engineering, geologic and economic techniques and criteria.

Forward costs are those operating and capital costs yet to be incurred at the time an estimate is made. Profit and "sunk" costs, such as prior expenditures for property acquisition, exploration and mine development, are not included. Therefore, the forward costs are independent of the market price at which the estimated resources would be sold.

Potential resources, as used by ERDA, are estimates based on geological judgment of the undiscovered tons of U_3O_8 present in minable amounts in areas that are relatively unexplored in detail, but about which enough is known of the uranium geology to permit prediction of the nature and extent of favorable geologic environments. The geographic locations of potential deposits may be definable only within broad limits. Providing the subjective nature of potential is recognized and taken into account, potential plus reserves provide a more useful base for long-range predictions of domestic supply than do reserves alone.

The reliability of potential estimates varies with the classes. It is greatest in the probable class where there has been extensive exploration and where mines have been developed, thus defining ore habits, the nature and extent of the favorable host rocks, etc. The reliability is least in the speculative class where areas of favorability must be inferred solely from literature surveys, geological reconnaissance of formation outcrops and/or the examination of the logs and cuttings of wells drilled for petroleum or other purposes.

The uranium resources of the San Juan Basin as estimated by ERDA, as of January 1, 1977, are given in Table 2.

Nearly all of the reserves in both cost categories are in the Grants mineral belt, and most are associated with operating mines. The $15 reserves represent 55 percent of the total domestic $15 reserves, and the $30 reserves represent 52 percent of the total $30 reserves of the nation.

Probable potential resources in the San Juan Basin are estimated to occur in the uranium areas as extensions of known deposits, or as new deposits in trends or areas of mineralization that have been identified by exploration. Possible potential resources are estimated to occur as new deposits within the Morrison Formation in areas of the basin which are not yet completely explored. Subsurface data, largely from oil and gas wells (Sears and others, 1972) have been used to determine the extent of the favorable ground. Speculative potential resources are restricted to Upper Cretaceous and Tertiary rocks which have not been productive, yet contain uranium occurrences and favorable geology for larger deposits.

Potential estimates are revised as new information becomes available. Recent increases in both the probable and possible classes are the result of new exploration which increased the size of the areas considered favorable. Speculative potential estimates are currently under review and will probably be decreased due to unfavorable exploration results. The extensive exploration currently underway within the basin is expected to convert a large population of the potential resources into reserves in the foreseeable future.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of Harlen K. Holen of the Albuquerque field office for his contribution of the potential resource estimates, and the help of Bette Learned for compiling the statistics.

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universities, companies, and such organizations as the Bureau of Mines, the Battelle Memorial Institute, and the Oak Ridge National Laboratory. Approximately $27,000,-000 was spent in this work but the improvement to uranium ore processing was tremendous.

The results of all this were successful beyond the fondest hopes and are a credit to the energy and competence of the American mining industry. Between 1948 and 1961, urainum ore production soared from 54,000 to 8,000,000 tons, concentrate production from 110 to 17,600 tons, and minable reserves from less than 1,000,000 to over 74,000,-000 tons. From the carnotite rim deposits of the Uravan Mineral Belt and adjoining Utah areas, uranium discoveries spread to the Black Hills, Big Indian Wash, the Jackpile and Ambrosia Lake, the Gas Hills and Shirley Basin, the Colorado Front Range, the Texas Gulf Coast, and even to the Spokane Indian Reservation and Prince of Wales Island in Alaska.

By 1956 it was becoming evident that the AEC might be faced with an embarrassment of riches. In October, 1957, the AEC announced that it was "no longer in the interest of the Government to expand the production of uranium concentrate" and on November 24, 1958, modified the procurement program by limiting concentrate purchases in the 1962-1966 period to those derived from reserves developed prior to that date.

However, the Commission became increasingly concerned with the necessity of maintaining a viable uranium industry during the period following expiration of the procurement program in 1966, and up to the time a significant private market for nuclear power fuel might develop. Consequently, a stretchout program was announced on November 17, 1962 whereby mill operators could defer delivery of part of the concentrates contracted for purchase by the AEC in the 1963-1966 period until 1967 and 1968. In return, the AEC offered to purchase during 1969 and 1970 a quantity of U_3O_8 equal to the amount deferred, thus providing the industry with an assured, albeit reduced, market for four more years.

At the time the stretchout program was offered, it was estimated that a sizable private market for U_3O_8 would not develop much before 1975. However, the spectacular success of power reactor technology in lowering delivered power costs has accelerated the utility industry's trend to nuclear power plant construction, and consequently the estimates of nuclear fuel requirements are constantly being revised upwards and earlier. It now appears that, far from facing a few lean years, the uranium industry will have to make an unprecedented effort to meet future needs for raw materials.

In retrospect, the AEC's primary function during the first decade of its existence, from 1947 to 1957, might be described as creating and stimulating with every possible means the production of a new element from the earth's crust. The second decade, from 1957 to 1967, was one of restraining the snowballing growth of the new industry while keeping it in a healthy condition for the needs of the future. The third decade begins with the expectation that the industry faces a new and greater expansion if man's ever-increasing needs for energy are to be satisfied.

THE AEC AT GRANTS

Who first recognized the presence of uranium in what was to become the world's most productive district is unrecorded, but for practical purposes the story starts with the discovery of tyuyamunite near the base of Haystack Butte by a Navajo Indian, Paddy Martinez, in the spring of 1950. A few years before, his find would have elicited nothing but idle curiosity, but the uranium rush had started and the land on which the discovery was made belonged to the Santa Fe Railway Co. Exploration work was started that summer by the Santa Fe, and by fall most of the open Todilto Limestone bench around Haystack Butte had been staked by local individuals. The first major mining company, the Anaconda Copper Mining Company—later called simply—"The Anaconda Company," set up an office in Grants in January of 1951, leased extensive tracts, and started trenching and wagon drilling on the Todilto bench east of the San Mateo road.

News of the new discovery was of particular interest to the AEC's Colorado Raw Materials Office at Grand Junction; first, because of its location outside of the known productive districts of the Colorado Plateau, and second, because it was the first known occurrence of commercial uranium ore in limestone. AEC and USGS geologists examined the occurrences in November of 1950 and the first AEC office was established in the railway station at Prewitt in January, 1951, staffed by two geologists of the Denver Exploration Branch. In view of the almost complete lack of local geological information on the area, early efforts were directed to geologic mapping and detailed stratigraphic studies of the ore-bearing region. The first report incorporating the results of this work, "The Jurassic Rocks of the Zuni Uplift," was published in March, 1952.

During the same period, ore occurrences were evaluated, geologic advice was given to prospectors and miners, and free examination and assay of radioactive samples was offered.

In August, 1951, a Supai Indian brought some ore samples to the office that came from the Lucero Uplift in the Laguna Indian Reservation, and field examination disclosed uranium mineralization. The locality was approximately 25 miles east of the previously known occurrences. An agreement for prospecting and leasing was concluded shortly after between the Laguna Tribal Council and Anaconda, and in November, 1951 the outcrop of the famed Jackpile deposit was found by ground checking of an airborne radiometric anomaly.

Probably the AEC's greatest contribution to the early development of the Grants district was the establishment of an ore buying station. Most of the known ore showings in 1951 were owned by individuals or small companies and income from sale of ore was vital to the development of their properties. At the time there was no market for the Todilto limestone ores and the newly discovered sandstone deposits faced a haul of 250 miles to Monticello, Utah.

In December, 1951, the AEC signed a contract with Anaconda for the construction of a mill at Bluewater to treat Todilto limestone ores with a carbonate leach. As an addendum to the contract, Anaconda's sampling plant, the first mill unit to be built, was utilized by AEC as an ore buying station, and a buying schedule was announced in June, 1952. In addition to the customary provisions for carnotite-type ores to be purchased under Domestic Uranium Program Circular 5, Revised, the schedule announced that limestone gangue ores would be purchased without penalty for lime content. Anaconda operated the station as AEC contractor.

The bulk of the early ore reserves at Grants were in the Todilto Limestone. The original Anaconda mill was designed primarily for these ores and the mill feed was predicted chiefly on the developed Haystack Butte deposits of the Santa Fe Pacific Railway Co. in sec. 19, T. 13 N., R. 10 W. However, it was natural that the Morrison Formation would be investigated in view of its reputation as the host rock for the Colorado Plateau deposits. In early 1951 the first sandstone discovery was made in the Morrison Formation in Poison Canyon in sec. 19, T. 13 N., R. 9 W. The Blue Peak deposit, to the west, was found shortly after and developed into the first underground mine in the Grants district. As more Morrison discoveries were made and realization of the size of the Jackpile deposit developed from Anaconda's drilling, the relative importance of the limestone ores began to diminish.

As the Grants district developed, the Exploration Branch of the AEC expanded its geologic studies to encompass the entire northern flank of the Zuni Uplift from northeast of Gallup to west of Mt. Taylor. Trailer camps were set up to facilitate the field work, the last and most permanent being at Smith Lake. In 1953, two access roads were built under the AEC program, the first being six miles from the Bluewater mill east to the San Mateo road and the second seven miles northeast from U.S. 66 near Laguna to the vicinity of the Jackpile deposit. In the same year, an office was established in downtown Grants for a representative of the Mining Division to maintain liaison with mining operators and give as much assistance to the burgeoning industry as possible.

The Grants office became the most permanent AEC installation in the Grants district, one representative having a continuous record of service from 1954 to the present. In the meantime, the increasing development of sandstone ore reserves resulted in the execution of contracts between the AEC and Anaconda for the addition of an acid circuit to the Bluewater mill and a major increase in capacity, both in 1954.

In April, 1955, an independent wildcatter, Louis Lothman, drilled two holes in the Mancos shale about six miles northeast of the Dakota rim and the known deposits of the Poison Canyon trend. Location of the holes in sec. 11, T. 14 N., R. 10 W was reportedly influenced by the shallow depth to the Morrison as revealed in an oil test near the crest of Ambrosia Lake dome. The second hole struck ore in the Westwater Canyon member of the Morrison at about 300 feet and the great Ambrosia Lake trend was discovered. The first major underground mine in the Grants district, the Stella Dysart #1, was developed on the site of the discovery.

Within a year over 50 drilling rigs were operating in the Ambrosia Lake area and the tremendous scope of the deposits was being realized. The AEC's truck-mounted logging units were swamped with requests to log drill holes and the engineers and geologists calculating ore reserves were flooded with data. State Highway 53, the old San Mateo road, was improved and the nine-mile branch to Ambrosia Lake was built under the AEC's access road program. In 1956, the Commission contractor, Lucius Pitkin, built a new ore buying station near the junction of the San Mateo road and U. S. 66 which began receiving ore in July.

The AEC executed a contract in December, 1956 with Homestake-New Mexico Partners for the first processing plant to treat Ambrosia Lake ores and the second plant in the Grants district. In 1957, three additional mills were authorized, one for Homestake-Sapin Partners adjoining the Homestake-New Mexico Partners site, one for Phillips Petroleum, and one with Kermac Nuclear Fuels which has the largest capacity in the United States.

The discoveries at Ambrosia Lake, together with those in the Gas Hills of Wyoming, filled the cup of domestic raw materials to overflowing, at least so far as requirements at the time were concerned. The growth of the uranium industry, particularly at Grants, had developed to a point where many incentives or stimuli were no longer needed. Government exploration was terminated in 1956 and in the following two years most of the lands withdrawn by the AEC for this purpose were restored to the public domain. The access road program was terminated in 1957 and the Grants ore buying station was shut down in the fall of 1958.

In January, 1958 the Grand Junction Operations Office had been reorganized to reflect the retrenchment of procurement activities. The Exploration and Mining Divisions were combined into a Production Evaluation Division and the Grants office became a Field Branch of the Division. The consolidated Branch was moved to larger quarters at the present location in Milan during the summer of 1958.

Although the AEC was no longer interested in increasing the production of uranium, the industry continued to grow for some time because of pre-existing commitments obligatory on the AEC. The peak of both uranium ore and concentrate production occurred in 1961, of which the Grants district contributed the lion's share.

The AEC in 1961 modified the contract with Homestake-Sapin Partners to replace the prior contracts with Sapin and Homestake-New Mexico Partners, and the latter mill was shut down in April, 1962. The Phillips mill was closed in March, 1963 after transfer of its contract to United Nuclear. United Nuclear ores were subsequently tolled through the Homestake-Sapin plant. All of the remaining mills in the Grants area executed stretch-out contracts with the Commission, thus assuring a government market through 1970.

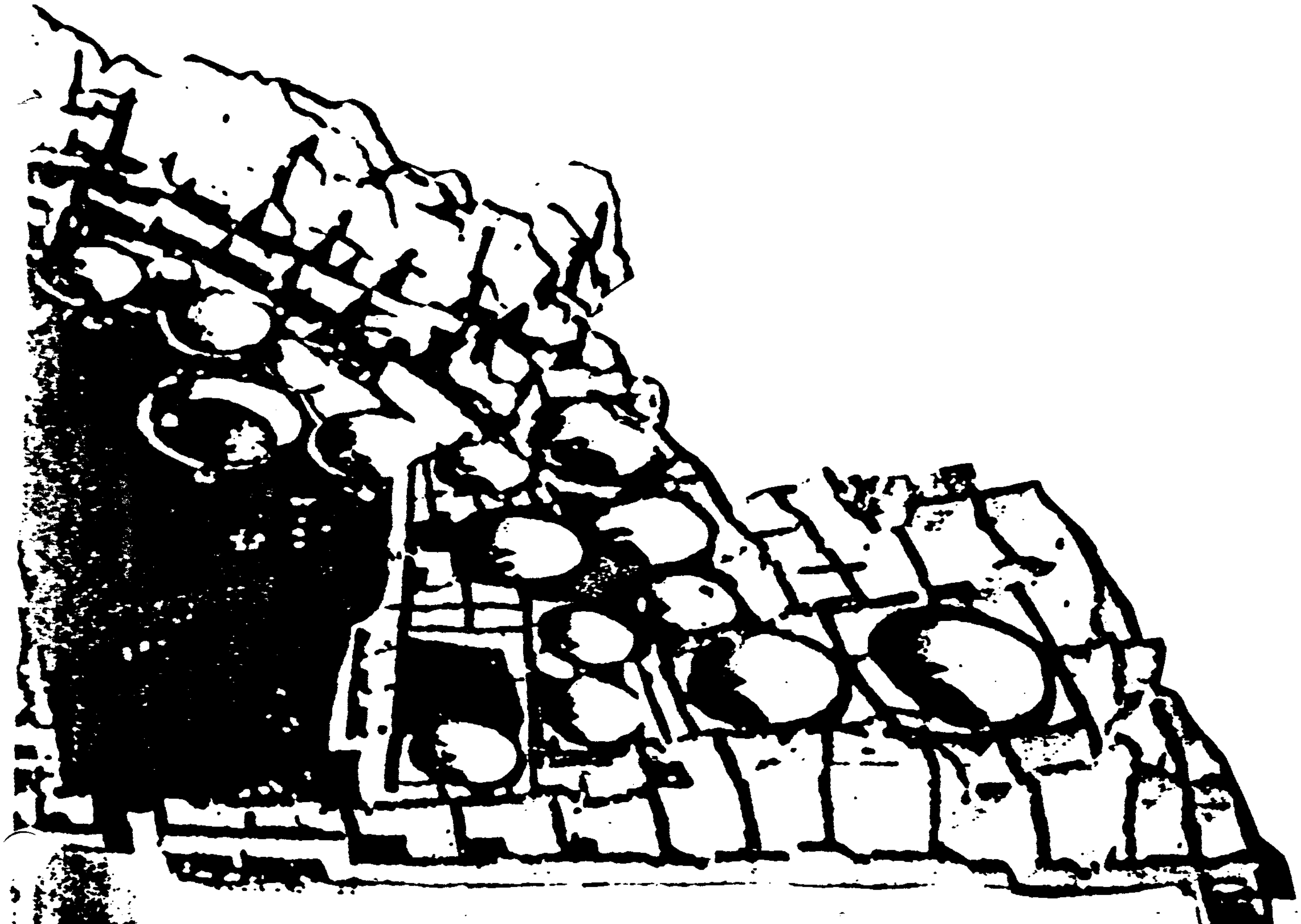
Now, in mid-1967, the pendulum of uranium demand is again changing direction and the function of the AEC is changing with it. The size and complexity attained by the industry, particularly as affected by the inevitable new growth, require a greater effort than before on the part of the Commission to keep abreast of developments and, figuratively speaking, its finger on the industry's pulse.

The continuing determination of mine and mill productive capability and of uranium ore reserves is vital to any planning for nuclear power and will need the full cooperation of the industry from whom the basic data must come. A recent reorganization of the Grand Junction and Grants offices is designed to aid these objectives in addition to placing new emphasis on the exploration and development of potential uranium bearing areas. As the only comprehensive source of information on the uranium industry, deposits, and technology, the AEC must continue to supply the answers for nuclear development as well as assist the industry to meet the greater goals of the future.

The immediate factor that is stimulating the rejuvenation of the Grants district, along with the rest of the uranium producing areas, is the rapid rise in estimates of fuel requirements for nuclear power plants. The Grants mills have already contracted the sale of substantial amounts of U_3O_8 concentrates through commercial channels, aside from their continuing sales to the AEC, and this outlet is expected to grow as demand increases.

Exploration and development drilling, a good yardstick of the industry's future plans, is rising rapidly and land acquisition activity is reaching a high level. This healthy condition of the uranium industry is very gratifying to the AEC and is reassuring evidence that the infant was not nourished to maturity in vain.

New Mexico Geological Society
Twenty-Eighth Field Conference
September 15-17, 1977



Guidebook of
San Juan Basin III
NORTHWESTERN NEW MEXICO

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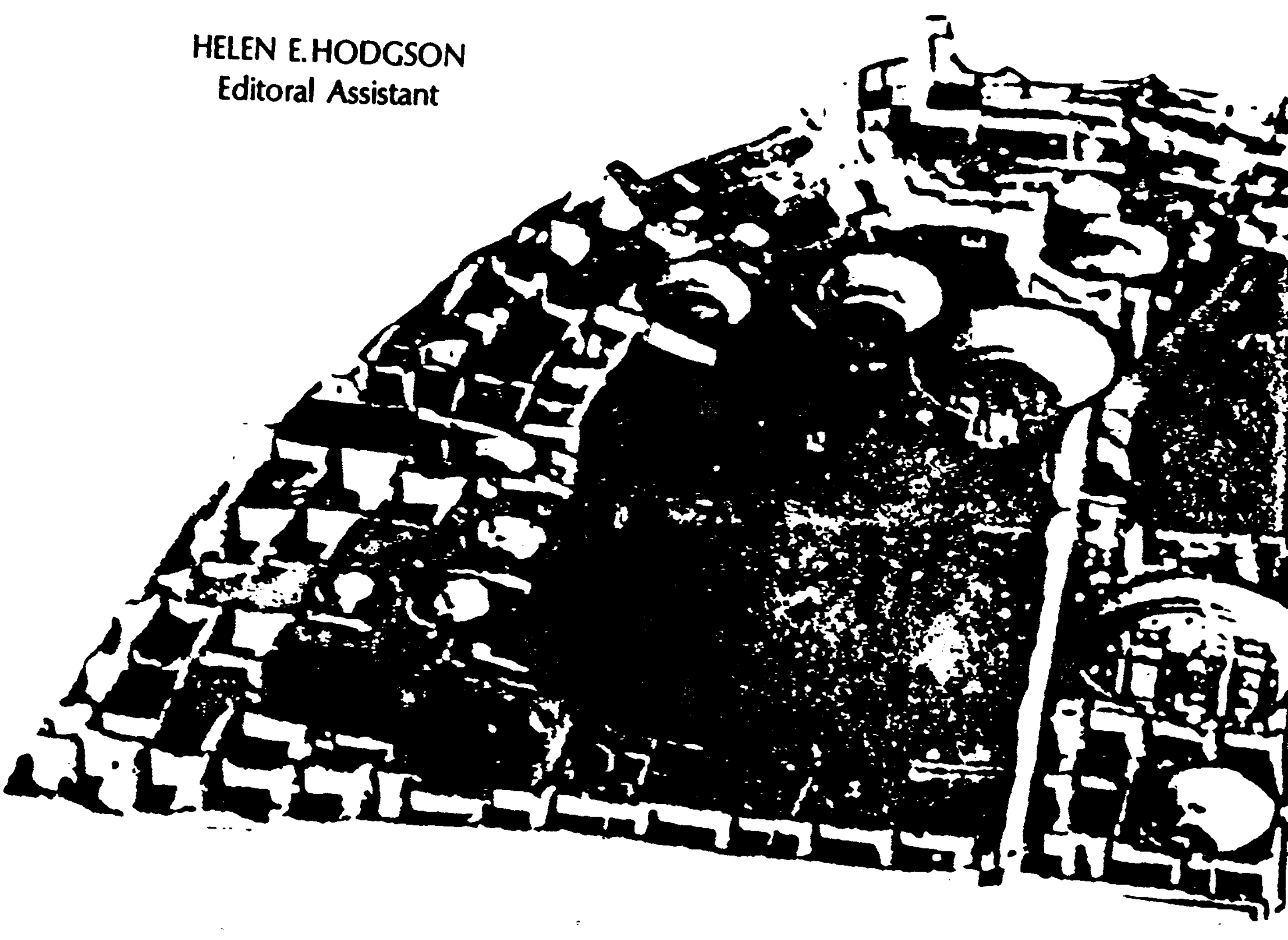

New Mexico Geol. Soc. Guidebook, 28th Field Conf., San Juan Basin III, 1977

URANIUM IN THE SAN JUAN BASIN—AN OVERVIEW*

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INTRODUCTION

The San Juan Basin of northwest New Mexico has been the source of more uranium production than any other area in the United States. Nearly all of the production has come from the Grants mineral belt (fig. 1). This paper describes the geologic setting of the ore deposits in the San Juan Basin, summarizes the growth of the uranium raw materials industry, and reviews the resource base.

GEOLOGIC SETTING

In the San Juan Basin, bedded and vein uranium deposits are in several different rock-types of Mesozoic and Tertiary age. Tabular deposits, which occur primarily in continental, fluvial sandstone of Jurassic age, are the most important. Only the more significant occurrences are discussed in this paper.

Most uranium deposits are in the Grants mineral belt in McKinley, Sandoval and Valencia counties. This cluster of large deposits extends for nearly 100 miles across the southern flank of the San Juan Basin. Although poorly defined, the belt is 10 to 20 miles wide. The four principal mining areas in the belt are Gallup, Smith Lake, Ambrosia Lake and Laguna (fig. 1). Ore deposits occur from the surface to depths greater than 4,000 feet, although to date all production has come from deposits shallower than 2,000 feet. Deposits in the Grants mineral belt have been described in detail by Kelley (1963) and by Hilpert (1969).

The Todilto Limestone of Jurassic age contains uranium ore bodies along the southern margin of the Grants mineral belt, where the limestone has been deformed by intraformational folding and faulting. Some 2,718 tons of U_3O_8 have been produced from 42 properties, mainly in the Ambrosia Lake area, accounting for two percent of the total output of the mineral belt. At a few places in the Todilto, ore also has been mined from the underlying Entrada Sandstone of Jurassic age where the ore bodies cross the contact between the two formations. Uranium also occurs in the Todilto in the Sanostee area of San Juan County, where small trial shipments have been made from two properties.

The Morrison Formation of Jurassic age was deposited in a continental environment. It consists of interbedded fluvial sandstone, claystone and mudstone. In the southern San Juan Basin, the Morrison consists of three members, all of which contain ore deposits. In ascending order, they are the Recapture, Westwater Canyon and Brushy Basin members. In the Ambrosia Lake and Laguna areas, the Recapture contains minor sandstone beds that are hosts for small uranium deposits.

The Westwater Canyon Member consists of thick sandstones with interbedded lenses of relatively thin discontinuous claystone. This member contains large uranium deposits in the Ambrosia Lake and Gallup areas. The Brushy Basin Member consists of greenish-gray mudstone and claystone with interbedded sandstone and a few thin beds of limestone. A thick lens of sandstone, the Jackpile sandstone, occurs in the upper part of the Brushy Basin in the Laguna area, where it contains large ore deposits. The Brushy Basin also is host for deposits in the Smith Lake area, although these are smaller than those at Laguna.

Uranium deposits of the Grants mineral belt are irregular in shape and generally are parallel to paleostream channels (fig. 2). The deposits range in size from thin pods a few feet in width and length to large masses of ore several thousand feet long, several hundred feet wide and several tens of feet thick.

The deposits are in many different sandstone beds and form clusters along distinct trends. Some ore has been redistributed, generally in areas of faulting (fig. 3). The principal ore mineral in the Grants sandstone deposits is coffinite, a uranium silicate $(U(SiO_4)_1 - _x(OH)_{4x})$, which is intimately associated with grayish-black to brown carbonaceous humate, which impregnates the sandstone. Production from the Morrison Formation in the Grants mineral belt has amounted to 114,795 tons U_3O_8.

In the northwestern San Juan Basin, uranium-vanadium deposits occur in the Salt Wash Member of the Morrison Formation on the eastern side of the Carrizo Mountains. This member, composed of interbedded mudstones and fluvial sandstones, is the lowermost member of the Morrison and is present nowhere else in the basin. Mines in the eastern Carrizo Mountains, astride the New Mexico-Arizona line, have produced 110 tons U_3O_8.

South of the Carrizo Mountains, in the Chuska Mountains near Sanostee, both the Salt Wash and Recapture members have yielded ore. Sandstones in the Recapture have been the most productive host rock, from which 80 tons of U_3O_8 have been obtained.

On the eastern flank of the San Juan Basin, the Morrison Formation has yielded 395 tons of ore, averaging 0.13 percent U_3O_8, from two properties on the Ojo del Espiritu Santo Grant, northwest of San Ysidro.

The Dakota Sandstone of Cretaceous age has yielded 246 tons of U_3O_8 from nine properties in the Gallup and Ambrosia Lake areas. The Dakota host rocks are carbonaceous sandstone, carbonaceous shale and lignite. On the eastern flank of the basin, south of Cuba, New Mexico, 23 tons containing 0.63 percent U_3O_8, have been mined from carbonaceous shale and lignite at one property in the Dakota Sandstone.

Uranium occurs in rocks of the Mesaverde Group of Cretaceous age, at various locations in the San Juan Basin. The most significant area is near La Ventana on the eastern flank of the basin. Here, uranium-bearing coal, carbonaceous shale and carbonaceous sandstone form a mineralized zone several feet thick in the upper part of the Menefee Formation immediately below the La Ventana Tongue. Studies by Bachman and others (1959), suggest that a resource of 132,000 tons, averaging 0.10 percent uranium is present; principally on North Butte.

A small amount of ore has been produced from a sandstone

*Publication authorized by the U.S. Energy Research and Development Administration, Grand Junction Office.

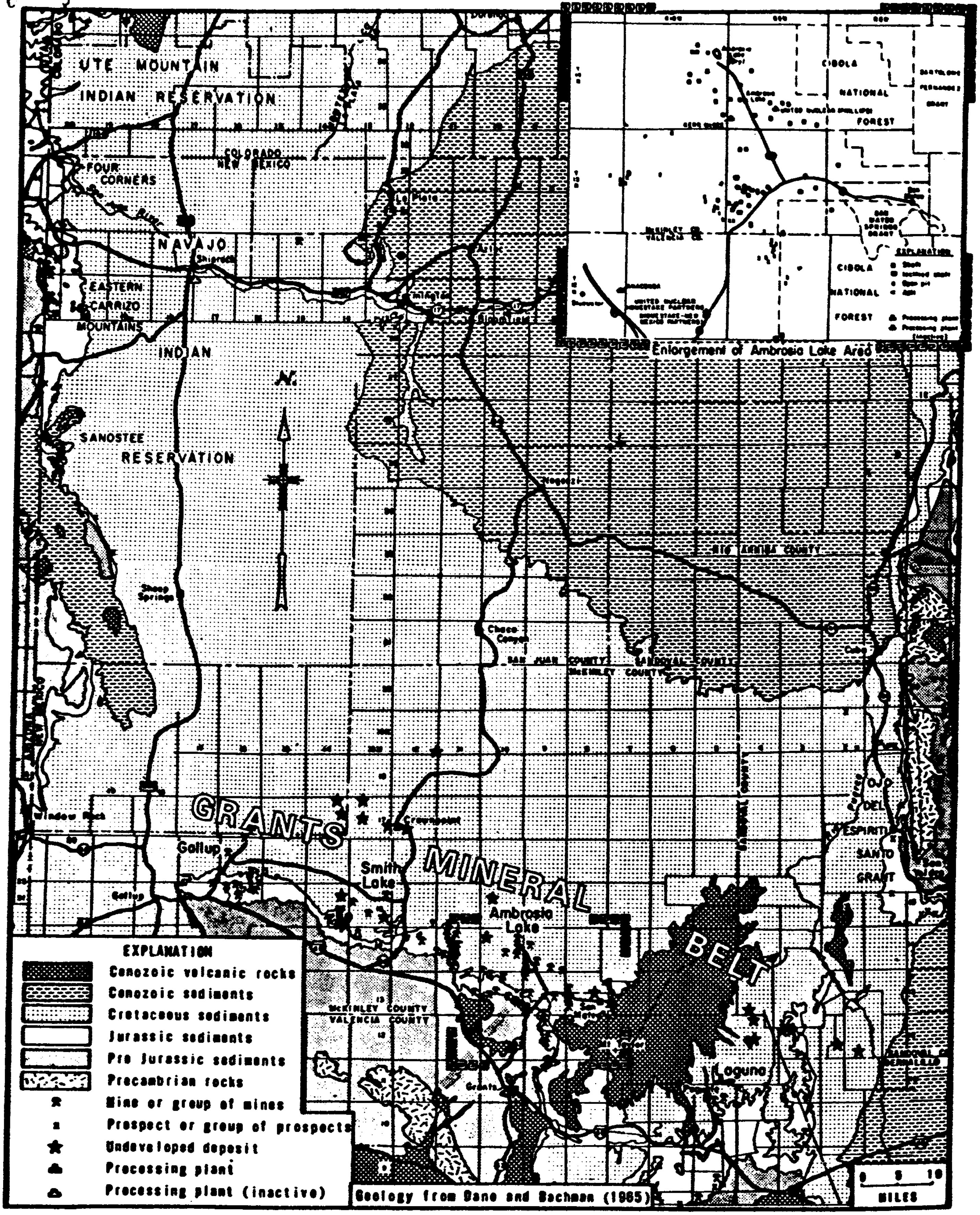

Figure 1. Uranium occurrences, mines and mills, San Juan Basin.

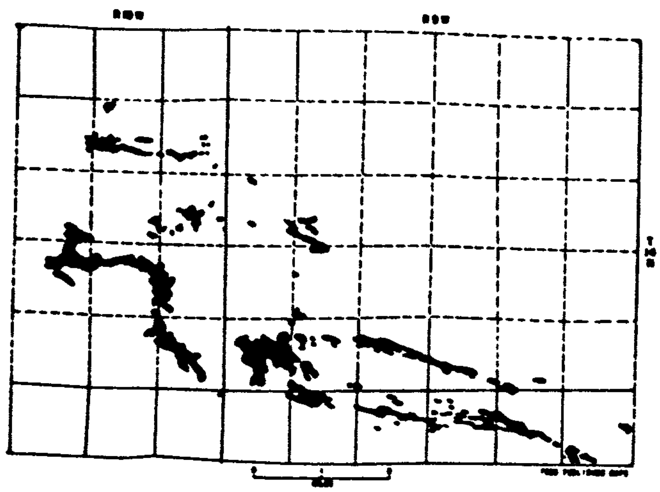

Figure 2. Plan map of ore bodies, Ambrosia Lake area.

in the lower part of the Fruitland Formation of Cretaceous age, northwest of Farmington.

The Ojo Alamo Sandstone of Paleocene age and the San Jose Formation of Eocene age contain uranium in Rio Arriba and San Juan counties. To date, no commercial deposits have been developed.

In the San Juan Basin, vein-type deposits occur in collapsed pipe structures in the mineral belt. The most significant structure is that exploited by the Woodrow mine, north of Laguna. This mine yielded 67 tons U_3O_8 during the middle 1950s.

HISTORY OF EXPLORATION

The first significant discovery of uranium in the San Juan Basin was in vanadium-bearing carnotite ores in the eastern Carrizo Mountains west of Shiprock by John Wade in 1918. By 1920, Wade had 41 claims in various parts of the Carrizo Mountains (personal communication, 1955), including the eastern flank. No ore was mined then, due to lack of demand for either vanadium or uranium.

On of the earliest observations of uranium minerals in the Grants area was made in 1937 when V. C. Kelley (1963, p. 1) noted carnotite in a hand specimen which had been collected by Mr. Whiteside, a local prospector. Since Kelley's observation was unrecorded, the occurrence of uranium minerals of the Grants area was overlooked for many years.

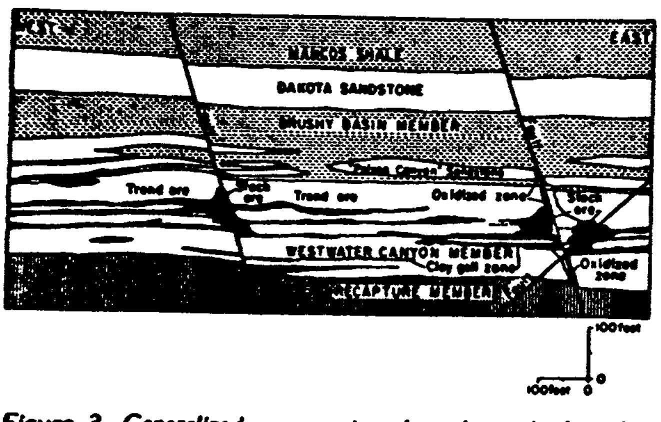

Figure 3. Generalized cross section through ore bodies, Ambrosia Lake area.

World War II increased the demand for vanadium. Early in 1942, Wade, Curran and Company leased a few plots in the east Carrizos. In July 1942, the Vanadium Corporation of America (VCA) leased 12 plots in the east Carrizo area. From 1942 to 1944, these two companies mined carnotite ore from surface exposures in the Salt Wash Member of the Morrison Formation. Although these ores were mined for their vanadium content, uranium was later recovered from the mill tailings. Following the termination of vanadium mining in 1944, the Union Mines Development Corporation systematically studied the vanadium-uranium deposits in the Morrison Formation in the Carrizo Mountains as part of a general uranium resource appraisal of the Colorado Plateau by the federal government's Manhattan Engineer District. Their work was very thorough and few surface exposures of uranium known today were overlooked. Coleman (1944) and Webber (1947) of Union Mines estimated the early ore production for the eastern Carrizo Mountains as 12,000 tons, averaging 0.27 percent U_3O_8 and 3.00 percent V_2O_5.

In 1948, prospecting for uranium was stimulated by the ore-buying schedules and other incentives of the U.S. Atomic Energy Commission (AEC). In the years that followed, uranium deposits were discovered in the Sanostee area, south of the Carrizo Mountains, and in the Cuba-San Ysidro area on the eastern side of the basin. The well publicized uranium discovery by Paddy Martinez in the Todilto Limestone near Haystack Butte in Valencia County in the fall of 1950 brought a wave of prospectors into the Grants area. In January 1951, uranium was discovered nearby in the Morrison Formation in Poison Canyon. This discovery led to the subsequent delineation of the Poison Canyon trend deposits. In November 1951, an airborne radioactive anomaly was detected north of Laguna in Valencia County, by the Anaconda Copper Mining Company, which led to the development of the Jackpile mine. Prospecting continued throughout the San Juan Basin, and by 1956 all surface occurrences had been discovered.

Using the cuttings of an oil well on the nearby Ambrosia dome to ascertain the drilling depths to the Morrison Formation, Louis Lothman began a wildcat uranium drilling project in April 1955, in sec. 11, T. 14 N., R. 10 W. (Louis Lothman, 1956, written communication). The second hold penetrated uranium-bearing sandstone in the Westwater Canyon Member. The discovery stimulated an intensive exploration effort and led to eventual development of the multi-million-ton deposits in the Ambrosia Lake area.

During the extensive prospecting that followed the initial discoveries in the Grants area in late 1951 and early 1952, several small ore bodies were discovered in outcrops of the Morrison and Dakota formations in the Gallup and Thoreau areas. Drilling downdip from these deposits led to the discovery of the larger Blackjack and Church Rock ore bodies in 1958 by the Lance Corporation and Phillips Petroleum, respectively.

In 1962, an ore body was found by Sabre Pinon Corporation in the northeast Church Rock area, where previous drilling had penetrated ore-grade material at a depth of about 1,875 feet in the Westwater Canyon Member. Exploration by Kerr-McGee on adjacent Navajo Tribal lands led to the discovery of its northeast Church Rock ore body in 1966. Following the competitive sale of Navajo leases in 1971, exploration efforts have continued in the northeast Church Rock area and have been extended eastward into the Crownpoint area, where large ore bodies are currently being developed by several companies.

The discovery of ore at a depth of 2,700 feet in the Westwater Canyon Member near San Mateo by the Fernandez Joint Venture in the fall of 1968, led to the eastward extension of the Ambrosia Lake area. Nearly a year later, ore-grade intercepts were found at a depth of 4,000 feet in a hole drilled by the Bokum Corporation on the flanks of Mt. Taylor. By early 1971, Gulf Oil had purchased the San Mateo and Mt. Taylor ore bodies to consolidate its holdings in the east Ambrosia area. At about the same time, exploration on the eastern side of Mt. Taylor, especially in the Marquez area, identified ore in the Westwater Canyon Member in an area previously explored only for ore in the Jackpile sandstone of the overlying Brushy Basin Member. In August 1976, Continental Oil Company announced a major find at the extreme eastern end of the mineral belt on the Bernabe Montano Grant.

In January 1974, the Exxon Company signed an agreement with the Navajo Tribe to explore 400,000 acres of tribal land in the western San Juan Basin. This agreement was approved by the Secretary of the Interior in January 1977. As a part of the agreement, the Navajo Tribe received a $6,327,300 bonus from Exxon.

In December 1975, the Phillips Petroleum Company announced the discovery of a large deposit, approximately 25 million pounds U_3O_8, 12 miles north of Crownpoint in McKinley County at depths of 3,000 to 3,500 feet. Since this discovery is considerably north of the present concept of the Grants mineral belt, it has revived deeper exploration in the San Juan Basin.

The Mobil Oil Corporation entered into an exploration agreement with the Ute Mountain Tribe in January 1976, for uranium exploration on 162,176 acres of tribal land in southwestern Colorado. This agreement brought the Ute Mountain Tribe a bonus of $2,432,640.

The magnitude of the exploration efforts expended in the San Juan Basin can be measured by the amount of surface drilling that has taken place. Records of ERDA's Grand Junction Office show that from 1964 to 1977, there were 12,622 holes, having a total footage of 16,002,368 feet, drilled in the search for new deposits. In addition, 10,991 holes having a total footage of 13,059,300 feet were drilled for the development of deposits. The San Juan Basin had its peak year in 1976 when 7,104 holes having a total footage of 10,916,302 feet were drilled. This footage represents 32 percent of the total U.S. surface drilling for uranium in 1976.

PRODUCTION

ERDA records indicate that during 1948-1976, the San Juan Basin produced 55,649,500 tons of ore averaging 0.21 percent U_3O_8, and containing 118,018 tons U_3O_8. In addition, 1,145 tons U_3O_8 have been recovered from mine water. These totals constitute 40 percent of the domestic production through 1976. Details of this production are summarized in Table 1. The most productive area is Ambrosia Lake, where the mines, shown in Figure 2, have produced 62,760 tons U_3O_8 or 53 percent of the basin's total production.

When AEC buying schedules for uranium went into effect in 1948, mining commenced in the King Tutt Mesa area of the eastern Carrizo Mountains and uranium production in the San Juan Basin began. The yearly production is shown graphically in Figure 4.

As the mines in the Ambrosia Lake area came into production, the amount of uranium ore produced increased rapidly (fig. 4). Production reached an all-time high of slightly more than 7,900 tons of U_3O_8 in 1962, but declined sharply in 1963 during the AEC's stretchout program. This program, announced November 17, 1962, extended the government's procurement program from January 1, 1967, to December 31, 1970. It deferred delivery to 1967 and 1968 of some uranium concentrates which were originally contracted for delivery before 1967, and provided for purchase of additional amounts of concentrates in 1969 and 1970 equal to the amounts deferred to 1967 and 1968.

Since January 1, 1971, when the AEC ceased its procurement program, most uranium purchases have been made by

Table 1. Summary of uranium production, San Juan Basin.

Area and Source	Member	Number Of Properties	Type Of Mines	Years Of Production	Production Tons U_3O_8	Remarks
Grants Mineral Belt						
Morrison Formation	Westwater Canyon, Brushy Basin minor Recapture	129	Underground, Two large open pits	1951 to present	114,795	Molybdenum and vanadium recovered as by-products
Todilto Limestone	–	42	Underground and open pit	1951 to present	2,718	
Dakota Sandstone	–	9	Underground	1951 thru 1970	246	
Mine water	–	–	–	1963 to present	1,145	
Breccia pipe	–	1	Underground	1953 thru 1956	67	
East Carrizo Mountains						
Morrison Formation	Salt Wash	45	Underground	1948 thru 1968	110	1,141 tons V_2O_5 produced as a co-product
Sanostee						
Morrison Formation	Recapture, minor Salt Wash	11	Underground	1951 thru 1971, 1976	81	
Todilto Limestone		2	Open pit	1954		
Nacimiento						
Morrison Formation	Brushy Basin	2	Open pit	1957, 1959	1	
Dakota Sandstone		1	Open pit	1954, 1957		
Farmington						
Fruitland Formation		1	Open pit	1955		
				TOTAL	119,163	

"Review of Recent Uranium Production and Market Trends"

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for presentation to:

Joint Federal Provincial Panel on Uranium Mining Developments in
Northern Saskatchewan
Saskatoon, Saskatchewan
June 13-14, 1996

This memo has been prepared by Wm. Paul Robinson, Research Director at Southwest Research and Information Center. A resume of my experience is attached this memo. This review was conducted at the request of the Saskatchewan Uranium Committee, Saskatoon, Saskatchewan in May 1996. The memo responds to specific questions identified by Saskatchewan Uranium Committee participants.

I. Q: Why has uranium experienced an increase in its world spot market price?

A: Uranium market conditions have changed dramatically in the past six months as the spot market price for uranium has risen from $12.20 to $16.15/lb between January and April 1996. This new price range results in a near doubling of the price for uranium since 1994 when low price milestones were set for CIS uranium at $7.00 - 7.20/lb and for non-CIS uranium at $9.00-9.60/lb. (EMJ 1996 and EMJ 1995).

A review of recent trade literature provides four major reasons for the 1996 prices changes:

1. The gap between uranium production and estimated reactor requirements of more than 70 million pounds, the largest in history and associated rapid depletion of overhanging inventories for future reactor use. (EMJ March 1996);

2. The default of uranium trader Nuexco occurred February 1995 and the associated disruption of historic trading networks centered on litigation and unfulfilled contracts of involving that long-time uranium broker and its primary owner Oren Benton. As a result utilities have sought open market supplies to replace those affected by Nuexco/Benton; (NF May 20, 1996)

3. Dramatic reduction in uranium supplies and projected supplies, from CIS nations which have been a source of the lowest spot market price uranium, as a result of factors such as generally identified "economic pressures" in the producing country and continuing limits on CIS uranium in European and North American markets; and (NF May 20, 1996)

4. Increasing clarity of policy regarding conversion of highly enriched uranium, including US congressional action regarding dismantling of Russian and US weapons for commercial reactors in May 1996 and recognition that significantly lower levels of diluted HEU are likely over the next twenty years. (NF, May 20, 1996)

II. Q: What uranium market conditions have changed since 1993 and why?

A: Conditions in 1993 included a maximum contribution of former CIS and Eastern European uranium to a relatively stagnant demand market. World uranium production reached a new low of 82.3 million pounds in 1994, but rebounded slightly to 85.3 million pounds, approximately 1 million pounds higher than 1993 production. 1993 was a period of declining uranium activity in terms of transactions and overall volume of uranium traded, a trend which bottomed out in 1994. 1993 showed 25 transactions totaling 29.5 million pounds and 1994 showing 86 transactions totaling 29.2 million pounds.

In 1993, uranium production from Eastern European countries appears to have been approximately 24.9 million pounds, exceeded that of Canada, the largest single producing nation, which produced a relatively steady 23.8 million pounds. For comparison, roughly 6 million pounds each was produced in Russia, Kazakhstan and Uzbekistan. (EMJ, March 1995)

Since then, projected production through 1996 from Eastern European and Asian sources has reduced rapidly, though less rapidly than predicted in 1995. Previous, 1995, projections predicted Eastern European production would be down to16.2 million pounds in 1996, lower than the more recent, 1996, production estimates in from a projected 17.40 million pounds for the current year, 1996. If Asian supplies are stay in the 6.2 - 7.2 million pound range through 1998, Eastern European and Asian production will have dropped from a 1993 high of approximately 24.9 million pounds to a projected 17.4 million pounds, a drop of greater than 25%, with further reduction projected down to 14.1 million pounds in 1998. If these projections are accurate, Eastern Europe sources will be producing 10.8 million pounds per year less in 1998 than they did in 1993.

The sharp decrease in projected Eastern European uranium supplies is in direct contrast to the rising production forecast of other producers world-wide which were steady-state or rising. . During this period the Australian production forecasts for 1998 ranged from 6.3 million pounds in 1995 to 10.30 million pounds in a 1996 forecast and Canada's 1998 forecast rose from 22.1 million pounds, in 1995, to 35 million pounds, in 1996. African and Other Nations forecasts remained relatively steady with Africa ranging from 18.0 in the 1995 forecast to 17.95 million pounds in 1996 and other producing nations projections for 1998 at 6.2 million pounds in 1995 and 7.2 million pounds in 1995. The US was also projected for a major statistical increase, though small in world production terms with 1998 project production rising from 3.6 million pounds in 1995 to 5.25 million pounds in 1996, an increase of nearly 50%. (EMJ March 1995 and EMJ March 1996).

III. Q: Where is current and future uranium production anticipated to come from?

A: 1995 Uranium Production Sites are lead by the large Canadian facilities: (EMJ, 1996a and 1995a)

	Name	Prod. Rate - Est. 1995	Est. 1994
Canada	Key Lake	13.7 (million lb./yr.)	12.5
	Rabbit Lake	8.5	7.4
	Cluff Lake	3.0	2.1
Russia	Krasnokmensk	5.0	6.5
Australia	Olympic Dam	3.1	3.1
	Ranger		3.2
US	White Mesa	2.0	0.0
	Miscellaneous	4.2	3.4
Africa	Akouta/Niger	5.0	5.0
	Arlit/Niger	2.6	2.6
	Rossing/Nam	5.0	5.0
	Gabon		1.4
	Vaal Reefs/S Af	2.6	2.8
	Miscellaneous		1.7
Other	Zafarabad/Uzb		2.2

Changes in production could come from the start-up of new producers, shutdown of aging facilities, or new production from existing un-used uranium production. Noted developments recently projected include but not limited to (EMJ, 1996):

	Name	Prod. Rate (Est.1996)	Key Dates
Canada	McClean Lake Mill	+ 6 million lb./yr.	1997-2009
	Cigar Lake	+18	2000-2009
	Key Lake - existing deposits exhausted	-14	ceasing 2000
	Key Lake - Production from MacArthur Lake	+18	Start-up 2001
	Rabbit Lake	+ 3.5	Start-up 1997
	Baker Lake	+ 3.2	as soon as 2000
Australia	Ranger	+ 2.0	add'l capacity
	Jabiluka/NT	+ 9.0	as soon as 2000
	Yeerlirie/WA	+ 5.0	as soon as 2000
US	Additional production capacity available at increased prices		add'l capacity
Africa	Rossing	+ 5.0	
Other	Miscellaneous available Capacity - Argentina, Brazil, China, India, Mongolia, Pakistan, Portugal, Spain, France	+ 6.5	production used in 1989

Total potential production + 63.7 million pounds/yr.

These projected production rates will result in significantly great uranium producer income due to the recent rise in spot market price to the $15-16 US/lb range. This increase represents a greater than 50% increase in non-CIS spot market from prices in the $9.20-9.60 range in 1994. This increases means that a 1 million pound per year production rate would be worth $15 million at 1996 prices, versus $10 million at 1994 prices. The 24 million pounds per year anticipated from the McClean Mill would increase in value to $360 million per year at $15/lb, versus $240 million at $10/lb. Similarly the 18 million pounds per year anticipated from the MacArthur Lake deposits would increase in value to $270 million per year at $15/lb versus $180 million per year at $10/lb. No increased costs associated with production or distribution of the uranium from these sites has been identified during the period of this 50% increase in spot market prices. Specific contracts involving the uranium production from these sites are not specifically set at the spot market level, the projections of uranium value estimates based on spot market prices are presented to demonstrate the enormous income projected, and increase in value, from these Saskatchewan sites based the available spot market price.

IV. Q: What are the current sources of uranium demand and what are the likely sources in the future?

A: 1996 world uranium consumption projections were relatively steady, projecting demand in the 150 million pound range through the year 2000. The EMJ, 1996 projection shows 153.20 in 1996; a peak of 159.80 million pounds in 1997; 156.90 in 1998; a low of 149.10 in 1999 and 153.40 in 2000. These figures are approximately 10 million pounds higher than the same publication's projection the previous year, 1995, which showed demand at projected consumption of 143.1 in 1996, 143.8 in 1997 and 149.1 in 1998.

Regarding potential future demand, projected changes in consumption by region showed Western Europe as the only significantly gaining region moving from 46.30 million pounds projected consumption in 1996 to 50.30 in 2000 and Eastern Europe as the only significantly dropping region falling from 26.30 in 1996 to 23.00 in 2000. Anticipated demand from growth in the reactor market in eastern Asia is not identified for the period prior to the year 2000.

Little demand in terms of new reactors or weapons use is projected while a long-term decrease in uranium demand is likely due to reactor shutdowns. US-based projections anticipate essentially flat uranium demand through 2010, followed by a sharp drop off as reactors continue to age and replacements are not being planned. (EMJ, 1996)

As a result of this flat uranium demand picture, uranium supplies are being made up from current or future production supplemented by potential reactor fuel from "diluted" highly enriched uranium. The addition of the identified potential production of 63.7 million pounds to existing 1995 production of 85 million pounds, for a total of 148.7 provides to leaves little or no room in the market for the addition of other potential sources of uranium, unless listed potential sources are delayed or are never realized.

Additional reactor fuel uranium available from HEU has been projected at as high as 8 million pounds from 1995-2000 and 24 million pounds from 2000-2015. Recent analyses support a potential maximum level for Russian production rate at only 10 million pounds per year. (EMJ, March 1996). These decreased expectations reduce the anticipated supply of diluted HEU by more than 200 million from previously projected levels.

Analysts anticipate an avalanche of low cost Canadian uranium resulting in Canada increasingly dominating the uranium supply sector at the expense of other producers including those in Central Africa and Eastern Europe. Australia production from new deposits potentially available if the "three mines" policy ceases may provide alternatives Canadian for a portion of the utilities seeking uranium before 2010. This production, as well as increased in-situ leaching and conventional production in the US and other countries will have uranium cost challenges to compete with the new high grade Canadian deposits.

Projections for uranium demand beyond 2010 are not presented in the analyses reviewed, though a sharp drop off in demand is anticipated if no new reactors are ordered. (EMJ, March 1996)

V. Reference List:

EMJ, 1996 Pool, T.C., "Uranium: A Widening Supply-Demand Gap", Engineering and Mining Journal, March 1996

EMJ, 1996a "Annual Project Survey, 1996", EMJ, January 1996

EMJ, 1995 Pool, T. C., "Uranium: A Lackluster Year", Engineering and Mining Journal, March 1995

EMJ, 1995a "Annual Project Survey 1995", EMJ, January 1995

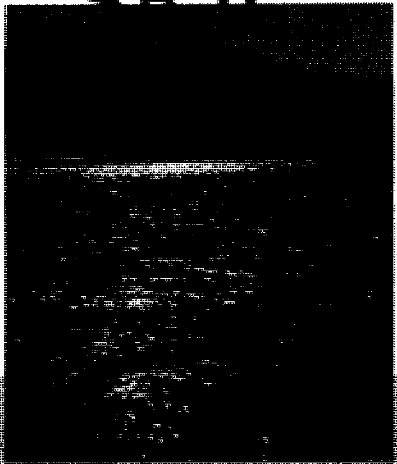
NF, May 20, 1996 "Cameco's Michel Gives Shareholders Bullish Report About Uranium Market", Nuclear Fuel, May 20, 1996

— helping people and communities fight pollution, protect resources, and promote citizen participation

Southwest Research and Information Center

P.O. Box 4524 • Albuquerque, New Mexico 87106
(505) 262-1862 • fax: (505) 262-1864

Southwest Research and Information Center



— helping people and communities fight pollution, protect resources, and promote citizen participation

Since Southwest Research and Information Center was founded in Albuquerque in 1971, it has focused on effective citizen action as the means to a healthy environment and social, racial, and economic justice.

SRIC's mission is

"to provide timely, accurate information to the public on matters that affect the environment, human health, and communities in order to protect natural resources, promote citizen participation, and ensure environmental and social justice now and for future generations."

We work to fulfill SRIC's mission by

- providing technical and organizational assistance to communities affected or threatened by pollution or resource exploitation
- empowering people with information
- conducting research and advocating in the public interest

SRIC

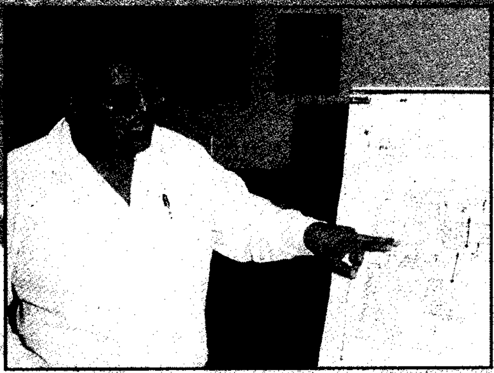
- assists hundreds of community groups throughout New Mexico and the Southwest, the nation, and the world.
- answers dozens of information requests every month, from community activists, students, educators, health professionals, business people, regulators and lawmakers, and news media

- maintains a 20,000-volume reference library, tens of thousands of news articles and technical reports, and scores of alternative press publications and organizational newsletters addressing environmental, consumer, economic, and social concerns

- publishes *The Workbook*, a [illegible]-year-old "alternative" quarterly with a national readership, respected as an important and unique information resource on the environment and social change
- furthers environmental education through [illegible]

For 25 years, SRIC has framed and supported enactment of laws and regulations that force polluters to clean up contamination and that open decision making to public scrutiny and participation. We have promoted sustainable, locally controlled economies and have helped form and develop community action groups in Albuquerque, Santa Fe, on the Navajo Nation and throughout northern New Mexico. SRIC's work with citizens and other organizations has also accomplished:

• the decade-long delay in bringing nuclear wastes to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, because health and safety standards have not been met.



• regulation of more than 50 uranium mill waste sites in the U.S., mandated by laws enacted by Congress in 1978

• the first-ever reclamation requirements for existing and new hardrock mines, under the New Mexico Mining Act of 1990

• federal compensation for Navajo uranium miners [illegible] lung cancer and other respiratory [illegible] through the Radiation Exposure Compensation Act of 1990

• shutdown of a medical waste incinerator whose uontrolled emissions threatened people's health in a Mexican-American community in southern New Mexico

• a comprehensive study of pollution from oil and gas production and other mineral extraction in Navajo communities in southeastern Utah

• major improvements in how New Mexico protects its groundwater and in state and federal regulation of oil-field wastes

• national networks of activists sharing information on mining sites and oil-field wastes

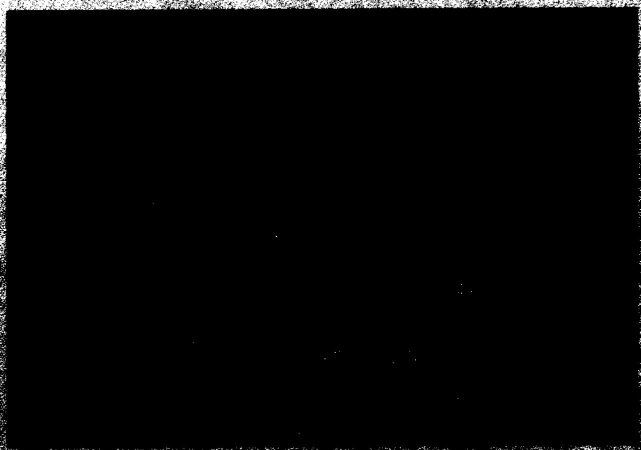


Photo Courtesy of Lighthawk

SRIC is the only nonprofit organization in New Mexico dedicated to providing free technical services to communities affected or threatened by pollution. We plan to expand these services while continuing our work with other progressive groups throughout New Mexico, the Southwest, and the nation to

- oppose efforts to store commercial spent nuclear fuel on the Mescalero Reservation or at WIPP
- advocate for environmental cleanup and sustainable development along the U.S.-Mexico border and for citizen participation in decisions affecting border communities
- help Navajos in northwestern New Mexico stop the threat to their drinking water supplies posed by uranium solution mining
- ensure state-of-the-art cleanup and reclamation of area mine and oil field sites throughout New Mexico

In an era of shrinking public resources, growing corporate power and influence, and increasing racial and economic division, the need for SRIC's work is greater than ever.

If you want to join the battle for environmental and social justice in the next 25 years, please write or call us

SRIC

Who we are...

The Staff

With nearly 100 years of collective service to SRIC, our experienced, professional staff maintains a long-term commitment to working with citizens and communities.

Annette Aguayo
Don Hancock
Frances Ortega
Janna Rolland
Lynda Taylor
Kathy Cone
Raymond Morgan
Wm. Paul Robinson
Chris Shuey

The Board

SRIC's board of directors reflects the geographic and ethnic diversity of the state and region as well as long and close involvement with the organization and its mission.

Anne Albrink
attorney, Santa Fe, New Mexico

David Benavides
attorney, Northern New Mexico Legal Services, Santa Fe

Katherine Montague
New York City, SRIC co-founder

Peter Montague
Environmental Research Foundation, Annapolis, Maryland
SRIC co-founder

Wilfred Rael
community water administrator, Questa, New Mexico

Gauven Rajen
consulting environmental engineer, Albuquerque

Mary Ann Tsosie
Lupton (Arizona) Chapter, Navajo Nation

Linda Velarde
Western Environmental Law Center, Taos, New Mexico

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SOUTHWEST RESEARCH AND INFORMATION CENTER
P.O. Box 4524 Albuquerque, NM 87106 505-262-1862 FAX: 505-262-1864

ORGANIZATIONAL OVERVIEW — 1997

Purpose/Mission: Southwest Research and Information Center (SRIC) exists to provide timely, accurate information to the public on matters that affect the environment, human health, and communities in order to protect natural resources, promote citizen participation, and ensure environmental and social justice now and for future generations.

Scope of Work: Now in its 26th year, SRIC works both locally and nationally. Locally, we provide site-specific technical assistance on issues ranging from water pollution to solid wastes to nuclear wastes. We provide training to empower citizens to act on their own behalf in local, state, and national forums. Nationally, we are actively involved in oil and gas, mining, and nuclear weapons and waste issues with citizens' networks. *The Workbook*, now in its 23rd year, is published quarterly and is used by citizens nationwide.

Staff and Board: An experienced staff that has a combined total of more than 100 years with the organization is able both to carry out long-range programs and to respond effectively to new requests for information and assistance. The board of directors is actively involved in all aspects of the organization. Its members are predominantly New Mexicans and represent diverse cultures and occupations.

Financial Support: SRIC's financial support primarily comes from foundations and individuals. For the last four years, we have increased our income from consulting fees. The 1997 budget is $555,000.

Programs: SRIC's work can be described in two ways: First, we provide various services — technical assistance, networking, public information, policy analysis, environmental analysis, and skills development. Second, we integrate those services into our four active, ongoing programs:

- Border Environment
- Community Water, Wastes and Toxics
- Environmental Information and Education
- Nuclear Waste Safety

The Future: SRIC will continue to play an active role in the economic and environmental issues of New Mexico, the Southwest, and the nation. Our programs will continue to reflect our focus on fundamental, long-term problems, while we also respond effectively to new emerging issues and public concerns.

For more than 25 years a continuing tradition of effective citizen action
printed on kenaf paper

SRIC BOARD OF DIRECTORS

Anne Albrink, Santa Fe, N.M. Attorney and mediator.
LaLora Charles, Crownpoint, N.M. Executive Director of Navajo Education and Scholarship Foundation.
Gregory Green, Santa Fe, N.M. Political consultant and lobbyist, working on environmental issues.
Fred Griego, Albuquerque, N.M. Youth Synergy Project Coordinator with New Mexico Advocates for Children and Families.
Katherine Montague, New York, N.Y. Administrator of the Department of Statistical Genetics at the Research Foundation for Mental Hygiene; cofounder of SRIC.
Peter Montague, Ph.D., Annapolis, Md. Editor of *Rachel's Hazardous Waste News* of the Environmental Research Foundation; cofounder of SRIC.
Wilfred Rael, Questa, N.M. Community activist, emphasizing community empowerment, mining, and water issues.
Gaurav Rajen, Ph.D., Albuquerque, N.M. Consulting environmental engineer, formerly with Navajo EPA and All-Indian Pueblo Council.
Mary Ann Tsosie, Lupton, Ariz. Community activist in the Lupton Chapter of the Navajo Nation.

SRIC STAFF

Kathy Cone, editor, *The Workbook*.
Don Hancock, director, Nuclear Waste Safety Program; SRIC Administrator.
Ray Morgan, Navajo community liaison, based near Gallup, N.M.
Ellie Ortiz, Development Coordinator.
Frances Ortega, community liaison and director of Environment 2000.
Paul Robinson, Research Director.
Chris Shuey, director, Community Water, Wastes and Toxics Program.
Lynda Taylor, director, Border Environment Program.
Annette Velasquez-Aguayo, Office Manager.

1997 BUDGET

INCOME

Foundation grants	$360,000
EPA grant*	3,000
Individual donations	35,000
Rent and other	10,000
Consulting fees	139,000
Publications	8,000
Total	$555,000

EXPENSES

Salaries & benefits	$393,844
Travel	40,000
Office supplies/equipment	20,000
Occupancy	20,000
Reproduction & postage	20,000
Telephone	20,000
Miscellaneous	41,156
Total	$555,000

* An EPA grant provides an additional $15,000 to SRIC to support citizen participation in oil and gas waste issues.

SRIC News

26 Years — Southwest Research and Information Center

Fall 1997

SRIC's Work in Diné Bikeyáh

By Chris Shuey

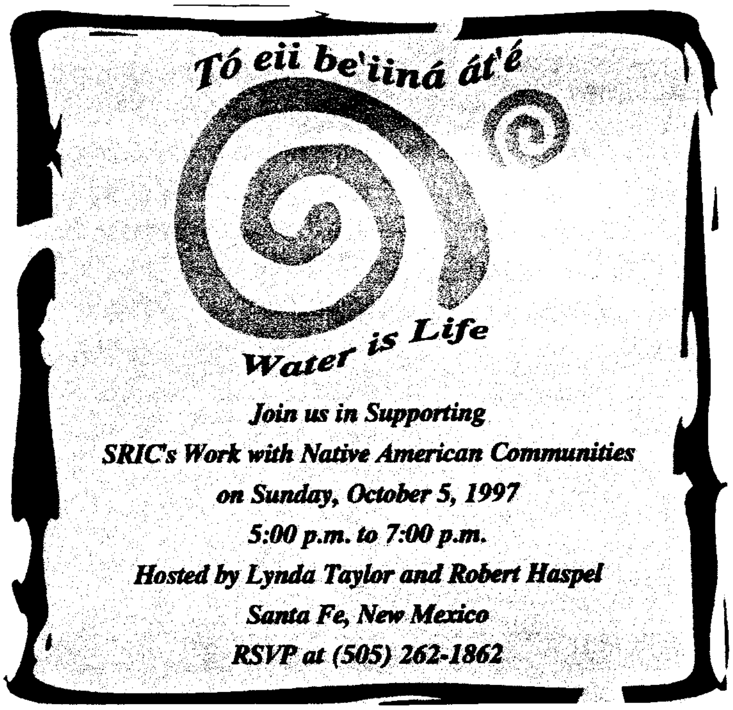
For more than 20 years, SRIC's staff and board have had the privilege of working with many Diné communities on a wide range of resource development and pollution concerns. From our efforts on federal compensation for Navajo uranium miners to our ongoing partnership with residents of Crownpoint, New Mexico, opposed to new uranium mining in their community, SRIC's work in Diné Bikeyáh ("The people, their land") has been largely at the request and in support of grass-roots Navajos, who desire to address the health and environmental damages of the past while participating in decisions that will affect them today and for generations to come.

Toward that goal, SRIC staff provides virtually daily support to Eastern Navajo Diné Against Uranium Mining (ENDAUM) in its quest to stop construction of three new uranium solution mines near Crownpoint and Church Rock. SRIC's work for ENDAUM entails administrative support, review and interpretation of the mining proposal, and assistance in meetings with tribal and federal decision makers. SRIC staffers Ray Morgan, Paul Robinson and Chris Shuey contribute more than 1.5 full-time equivalent staff positions to this effort. Board member LaLora Charles, a landowner in the Crownpoint area, recently filed a sworn affidavit with the U.S. Nuclear Regulatory Commission, attesting to how the mines would directly affect her health, lands, livestock and religious practices. (SRIC and ENDAUM are represented before the NRC by attorneys with the New Mexico Environmental Law Center.)

Another current Navajo project is SRIC's participation in a multiagency effort to assess health conditions in the Aneth Chapter in southeastern Utah where oil and natural gas have been produced and processed for more than 40 years. The current health-assessment work is an outgrowth of a study of contaminant sources and water quality impairment in the Aneth area that SRIC staff conducted in 1994 and 1995.

For four years SRIC has provided consulting services to a federal agency in support of the Navajo Nation's selection of federal mineral-producing lands located in northwestern New Mexico. SRIC staff and Navajo Nation officials have identified lands with existing mineral production

(continued on page 2)



SRIC Work . . .

so that the Nation may receive royalty revenues that are critical to its ability to address infrastructure needs.

And finally, SRIC's historic work on the impacts of uranium mining and milling on Navajo lands and water has helped forge lasting professional and personal relationships with Navajo community leaders, one of whom, Mary Ann Tsosie, the long-time secretary of the Lupton (Arizona) Chapter, is now the president of SRIC's board of directors and an invaluable contributor to the work of the organization. SRIC's association with Diné people like Mary Ann Tsosie, LaLora Charles and Ray Morgan demonstrates the organization's continued commitment to and support for Navajo concerns for years to come.

You Made A Difference!

Dorie Bunting hosted our Albuquerque "Making a Difference for Future Generations" fundraiser at her lovely north valley home. Special guests State Senator Dede Feldman, State Representative Mimi Stewart, and SRIC co-founder Katherine Montague spoke passionately about the work SRIC has been doing and what it means to future generations. Special thanks to the following businesses who provided silent auction items and food: Borders Books & Music, John Brooks Supermarket, Bueno Food Products, Jane Butel Cooking School, Classique Hair Trends, Gary Diggs Argentine Tango Classes, El Patio Restaurant, The Frontier Restaurant, the Hyatt Hotel, Marimann Gallery, The Range Restaurant, artist Carla Reed, Schlotsky's, UNM Lobo Football, Women's Workout Company, and Wolfe's Bagels. Please support these businesses. A most special thanks to all who came and those who couldn't come but helped with a gift. The event was great fun!

Sustainability for the World

By Lynda Taylor

My U.S./Mexico environmental work keeps me traveling to numerous border communities to ensure effective public involvement in the NAFTA-created Border Environment Cooperation Commission (I serve as a U.S. Board member) in addressing infrastructure needs (water/wastewater/solid waste management, etc.) with projects that are environmentally sound, community-supported, and achieve sustainable development for the long-term. I am also working with border and national groups to ensure that any future trade agreements between the U.S. and other countries meaningfully incorporate environmental and social issues on an equal footing with the economics of international trade. The "greening" of any trade agreement is the single most important way to guarantee protection and sustainability of the world's natural resources and people. Without "fair trade agreements," economics (cheapest labor, including forced child labor, lax or nonexistent environmental/health laws and enforcement) — propelled principally by multinational corporations — will continue to exploit poor and developing countries and drive trade and development at the expense of global social and environmental goals.

On a more local front, I am working with New Mexico groups to challenge a proposed weakening of our state's Air Quality Act, and have started working on legislative initiatives we expect out of the Governor's Office to weaken many of the state's environmental laws next January.

SRIC STAFF

Annette Aguayo
Office Manager

Kathy Cone
The Workbook Editor

Don Hancock
Nuclear Waste Safety

Ray Morgan
Navajo Community Liaison

Frances Ortega
Community Liaison

Ellie Ortiz
Development Coordinator

Paul Robinson
Research Director

Chris Shuey
Community Water Wastes and Toxics Program

Lynda Taylor
Border Environment Program, Legislative Liaison

Kristin Linkugel, Tara Martin, Barbara Ritter, Mari Simbaña, and Mavis Smith
Research Assistants

Environment 2000 Note Cards for Sale!

Help support the
Environment 2000 Scholarship Contest,
open to kids K-12 in New Mexico, the Navajo Nation, and El Paso, Texas.

Cards are $1.25 each or
8 Cards for $10.00/4 Cards for $6.00
To order please send a check or money order to:
SRIC, P.O. Box 4524, Albuquerque, NM 87106

Youth & the Planet

Planet Earth's limited resources will be addressed in SRIC's upcoming Environment 2000 poster and essay scholarship competition. Elementary, middle and high schools throughout New Mexico, the Navajo Nation, and El Paso, Texas will be sent lesson plans filled with easy the understand information, fun hands-on activities, and rules for the scholarship contest in January 1998.

Certainly the most exciting part about Environment 2000 is how *you* can help. We need *you* to promote Environment 2000 at *your* local schools by going into the classrooms and assisting teachers with the easy to follow lessons and assist students with their posters or essays. This is an incredible opportunity for *you* to impact kids and teens understanding of the Earth's resources and the affect human populations have on the planets limited resources. Ellie Ortiz is the Director of Environment 2000 and is waiting for your call at (505) 262-1862.

Why We Support SRIC

by Kris Kron and Ted Davis

In the seventies both of us became increasingly aware and concerned about governmental agencies and industry's propensity for making poor decisions with profound negative results regarding resource use, land use, and health & safety issues. Both of us have been active as volunteers or professionally in various arenas regarding these issues.

We look to SRIC as the ultimate resource for information and support on environmental, economic, and social issues. SRIC is truly a watchdog for the public, gleaning all the information available on a particular issue, analyzing and disseminating it in a manner that a lay person can understand and utilize, thus arming the public with the most compelling ammunition: the truth.

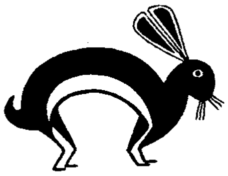
There are many important and viable organizations out there clamoring for donations, we support a number of them, however there are one or two that the majority of our charitable funds go to and SRIC is at the top of the list. We know every dollar we donate is utilized in the most frugal and direct manner; supporting SRIC's fact/truth finding team and producing the informative magazine *The Workbook*. In addition to this we have also donated equipment to SRIC.

We have seen the experts/scholars of SRIC in action; their efforts and effectiveness are recognized and highly respected even by the opposition. SRIC is a crucial component in the ongoing dialogues and battles regarding vital issues that effect all of us and those who come after.

SRIC Needs Your Help!

* We are asking for your old computers or laptops (386 or higher), WordPerfect 6.0 for Mac, file cabinets, office chairs, bookshelves, carpet, and window blinds.

Please use the enclosed envelope to make a tax-deductible contribution to SRIC. Thank you!



Molycorp Update

By Paul Robinson

I am providing technical assistance to Amigos Bravos, a rapidly growing community-based organization in Taos, related to its effort to address pollution associated with the Molycorp molybdenum mine upstream of Questa in the Red River watershed.

For a November 1996 hearing in Questa on Molycorp's proposed groundwater discharge plan for its tailings piles, I reviewed company and New Mexico Environmental Department evidence, provided expert witness testimony, developed cross examination of company and state witnesses, and drafted proposed permit conditions. Currently, I am reviewing Molycorp's documents related to permanent tailings cover and seepage plans, which are required by the discharge permit. Regarding Amigos' Clean Water Act suit on Molycorp mine-related pollution sources, I have reviewed technical documents in the company's office for several days to identify material for Amigos' out-of-state experts.

This exciting and critical work continues a 18-year effort of technical oversight and support of community advocacy related to environmental effects of the Molycorp mine on its downstream neighbors in Taos County.

Special Thanks to representatives from the Albuquerque Financial Service Center, Department of Energy, Wellborn Paint, Denise Gonzales from Little Caesar's Pizza, Cheryl Goeltsch, and McDonald's for helping us out during United Way's Day of Caring!

SRIC Needs Your Help!

* Volunteers are needed to help out on Special Events, provide educational outreach to the youth and teachers across the state, and help with building maintenance.

***You can find us at:* (505) 262-1862; fax: (505) 262-1864; e-mail: sric@igc.org**

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