EVALUATION OF THE MINERAL POTENTIAL (EXCLUDING HYDROCARBONS, POTASH, AND WATER) OF THE WASTE ISOLATION PILOT PLANT SITE, EDDY COUNTY, NEW MEXICO

Wm. Terry Siemers, John W. Hawley,
Christopher Rautman, and George Austin

Prepared for Sandia Laboratories by the
New Mexico Bureau of Mines and Mineral Resources
Campus Station
Socorro, New Mexico 87801

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ABSTRACT

The mineral potential of a proposed WIPP site, located 40 km east of Carlsbad, Eddy County, New Mexico, has been evaluated on the basis of information obtained from onsite field studies, the examination of records provided by Sandia Laboratories, and pertinent literature. The site is located near the northern edge of the Delaware Basin; the upper part of the stratigraphic section is comprised of marine and continental redbeds underlain by marine Ochoan evaporites.

Available data indicate that the only WIPP site-related commodities that may have any economic potential are (1) caliche, (2) salt, (3) gypsum, (4) lithium-bearing brines, (5) sulfur, and (6) uranium. A more detailed study however, indicates that for one or more of several reasons including (1) commodity abundance, (2) commodity accessibility, (3) low demand for the commodity, and (4) adequate supplies of the commodity elsewhere, these six commodities are uneconomic at present and for the foreseeable future.

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INTRODUCTION

New Mexico Bureau of Mines and Mineral Resources is providing technical assistance to Sandia Laboratories in the evaluation of the mineral potential of a proposed WIPP (Waste Isolation Pilot Plant) site east of Carlsbad, Eddy County, New Mexico. The results of this investigation, which center around information obtained from field studies of the area and from the examination of records provided by Sandia Laboratories, are contained in this report.

The proposed WIPP site is about 40 km (25 mi) east of Carlsbad, New Mexico (fig. 1) and includes four zones with a total area of about 93.7 km^2 (36 mi^2), centered at the common corner of sections 20, 21, 28, and 29, T. 22 S., R. 31 E. Approximately 90 percent of the area consists of federal owned surface and mineral rights; the remainder is owned by the State of New Mexico.

The WIPP site is on the eastern margin of the Pecos River Valley, and is part of the westward-sloping Los Medaños plain. Most of the plain is characterized by hummocky sand-dune topography with stable to semistable sand dunes that support a sparse flora of scruboak, mesquite, and grass.

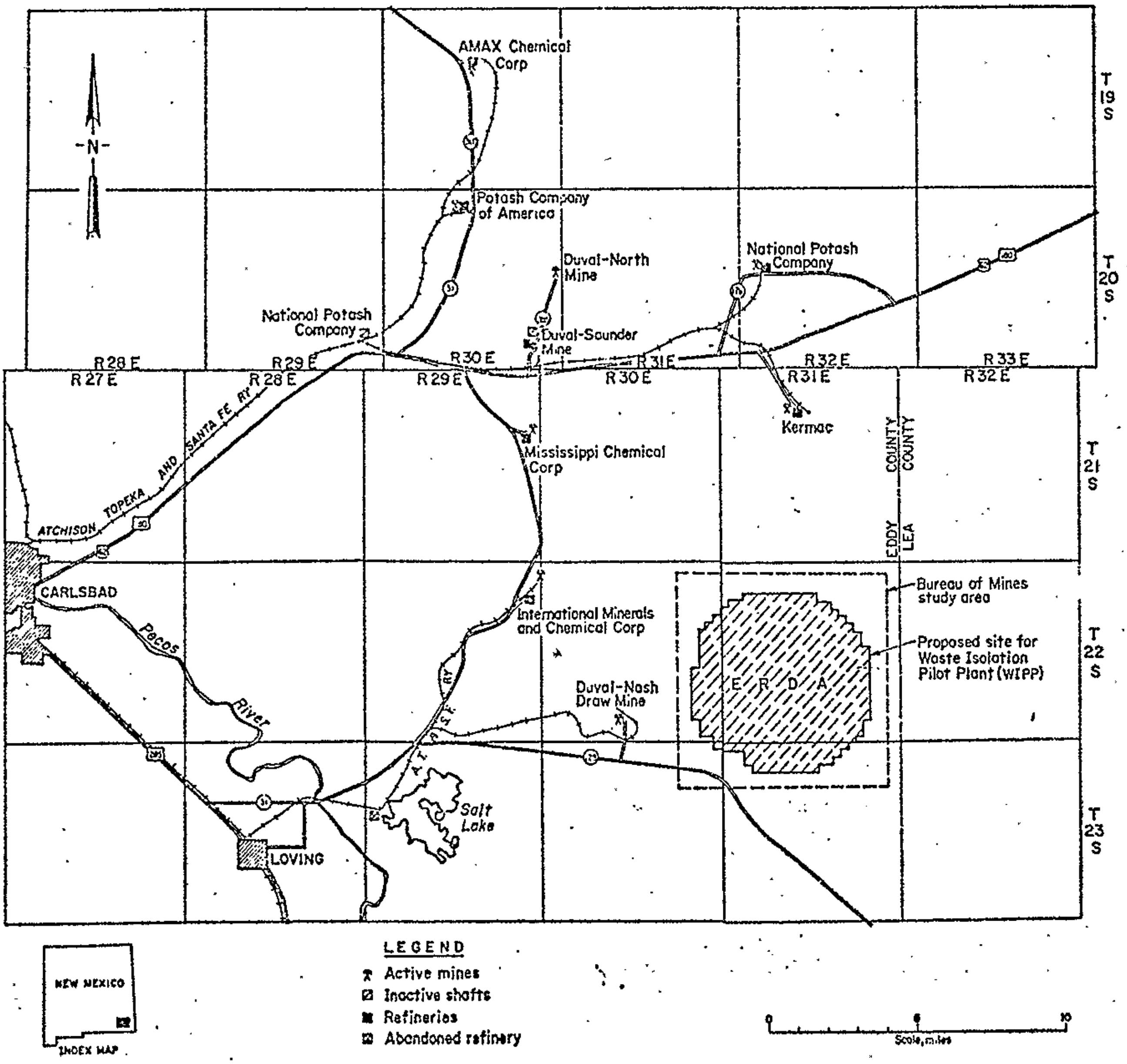

Figure 1. Location map of the WIPP site.

STRATIGRAPHIC SETTING

The proposed site is located near the northern border of the Delaware Basin, a deep structural feature in which the Precambrian surface lies 4,600 to 5,500 m (15,000-18,000 ft) below the surface. Paleozoic to Holocene units fill the basin, with Ochoan (Upper Permian) to Holocene units occupying the upper 1,200 m (4,000 ft); the sedimentary section is shown in table 1. With the exception of a linear dike or dike zone to the west of the proposed WIPP site, rocks within the area are exclusively sedimentary. From the base of the Castile Formation, marine Ochoan evaporites are overlain by marine and continental Ochoan to Quaternary redbeds.

Jones and others (1973) have described the sedimentary section in detail and much of their description has been incorporated into this report. Permian rocks, in ascending order from the base of the Ochoan Series, include the Castile Formation, Salado Formation, Rustler Formation, and Dewey Lake Redbeds.

Castile Formation is comprised of about 558 m (1,830 ft) of anhydrite, rock salt, and subordinate limestone. Three members are recognized: (1) a lower member of rhythmicly alternating laminae of gray anhydrite and brownish-gray limestone (2) a middle member of rocksalt and subordinate interlaminated anhydrite and limestone, 61 m to 221 m (200-400 ft) above the base of the formation, and (3) and upper member of anhydrite laminated by calcitic limestone, with subordinate massive anhydrite, rock salt, and limestone.
The top of the Castile underlies the WIPP site at a depth of

Age		Rock Unit	Thickness (feet)	Description
Quaternary	Holocene – Pleistocene	Mescalero Sand	0-15	Dune sand, uniformly fine-grained, light-brown to reddish-brown
				UNCONFORMITY
Quaternary	Holocene – Pleistocene	Caliche	0-5	Limestone, chalky, includes fragments of underlying rock
				UNCONFORMITY
Quaternary	Pleisto-cene(?)	Gatuna Formation	0-375	Sandstone and siltstone, poorly indurated, dominantly reddish-orange
				UNCONFORMITY
Terti-ary	Plio-cene	Ogallala Formation	20-60	Sandstone, fine- to medium-grained, tan, pink, and gray, locally conglomeratic, and typically has resistant cap of well-indurated caliche
				UNCONFORMITY
Triassic	Late Triassic	Chinle Formation	300-800	Mudstone shaly, reddish-brown and greenish-gray, interbedded lenses of conglomerate, and gray and reddish-brown sandstone
Triassic	Late Triassic	Santa Rosa Sandstone	212-245	Sandstone, medium- to coarse-grained, commonly cross-stratified, gray and yellowish-brown, contains conglomerate and reddish-brown mudstone
				UNCONFORMITY
Permian	Ochoan	Dewey Lake Redbeds	505-560	Siltstone and sandstone, very fine to fine-grained, reddish-orange to reddish-brown, contains interbedded reddish-brown claystone, small-scale lamination and cross-stratification common
				UNCONFORMITY
Permian	Ochoan	Rustler Formation	280-490	Anhydrite and rock salt with subordinate dolomite, sandstone, claystone, and polyhalite
Permian	Ochoan	Salado Formation	1200-2310	Rock salt with subordinate anhydrite, polyhalite, potassium ores, sandstone, and magnesite
Permian	Ochoan	Castile Formation	30-1830	Anhydrite and rock salt with subordinate limestone

Table 1. Summary of rock units of latest Permian (Ochoan) and younger in age, Los Medanos area, Eddy and Lea Counties, New Mexico (after Jones and others, 1973).

about 865 m (2,836 ft) in the ERDA 9 (sec. 20, T. 22 S., R. 31 E.) drill hole.

The Salado Formation rests conformably on the Castile Formation and is typically about 600 m (1,970 ft) thick in the WIPP site area. In the ERDA 9 drill hole the top of the formation lies about 262 m (860 ft) beneath the surface. The Salado is 85 to 90 percent rock salt with anhydrite as the next most abundant rock type; polyhalite, other potassium-rich rocks, sandstone, and claystone constitute the remainder of the formation. The rock salt contains halite and clayey halite in discrete layers ranging from 2.5 cm (1 in) to several meters in thickness. A threefold division of the Salado Formation includes: (1) a lower member characterized by alternating thick beds of rock salt and thinner beds of anhydrite and polyhalite, (2) the middle McNutt potash zone composed of potash-bearing rocks and hydrous evaporite minerals, and (3) an upper member containing rock salt, minor anhydrite and polyhalite, and two persistent halitic sandstone beds (Jones, 1973).

The Rustler Formation conformably overlies the Salado Formation and is 95 m (310 ft) thick in the ERDA 9 drill hole. The top of the formation lies about 168 m (550 ft) beneath the surface. The formation consists of anhydrite, and rock salt with subordinate gypsum, dolomite, sandstone, claystone, and polyhalite. Much of the gypsum that is so typical in outcrop gives way to anhydrite in the subsurface.

Dewey Lake Redbeds overlie the Rustler Formation in apparent unconformity and represent an abrupt change from evaporite deposition to deposition of terrigenous material. The Dewey Lake is about 160 m (525 ft) thick in the area and consists of interbedded reddish-orange to reddish-brown siltstone, sandstone and claystone. The contact between the Dewey Lake and the overlying Santa Rosa Sandstone is a low-angle angular unconformity.

Triassic rocks in the Los Medaños area include the Santa Rosa Sandstone and the Chinle Formation of Late Triassic age. The Santa Rosa Sandstone is about 70 m (230 ft) thick in the area and consists mostly of cross-stratified, medium- to coarse-grained, gray to yellowish-brown sandstone and subordinate conglomerate and mudstone. The overlying Chinle Formation is dominantly reddish-brown mudstone with minor lenses of sandstone and conglomerate.

The Ogallala Formation of Late Miocene to Pliocene age crops out in several High Plains outlines east of the site and consists of as much as 18 m (50 ft) of light-colored, fine- to medium-grained, calcareous sandstone interspersed with lenses of conglomerate and capped by a well-cemented caliche. The Gatuna Formation, primarily of early Pleistocene (Bachman, 1976), form a thin mantle of sediments on erosion surfaces cut below the High Plains (Ogallala) remnants. Gatuna sediments of the site form a thin veneer on lower Triassic rocks, but in nearby areas attain thicknesses of as much as 32 m (10 ft). The formation consists of poorly cemented reddish-orange sandstone and siltstone and some poorly consolidated conglomerate with some clasts derived from the Ogallala caprock caliche. The Gatuna Formation is overlain by as much as 1.5 m (5 ft) of caliche of the Mescalero Plain (Bachman, 1976). This caliche is covered by as much as 5 m (15 ft) of fine-grained, light-brown to reddish-brown dune sand, called the Mescalero Sand.

ECONOMIC GEOLOGY

Our field work and examination of existing records suggest that some consideration should be given to the economic potential of the following commodities: (1) caliche, (2) salt, (3) gypsum, (4) brine, (5) sulfur, and (6) uranium. The economic potential of most is evaluated below in terms of (1) their quality and abundance (2) present and future demand for the commodities, and (3) conditions that may make the commodities economic. The uranium potential is evaluated only in terms of its occurrence.

Caliche

Description of Deposits

Caliche is a general term for a zone of secondary carbonate accumulation in surficial materials, formed by both geologic and pedologic processes in warm, arid to subhumid regions. Finely crystalline calcium carbonate forms a nearly continuous void-filling and surface-coating medium in a variety of geologic materials. Cementation ranges from weak in nonindurated forms to very strong in "petrocalcic" or "calcrete" varieties. Caliches of the WIPP site formed by the pedologic (eluvial/illuvial) process of leaching of carbonates from sandy surface sediments by downward percolating soil water with precipitation of carbonate cement deep in the soil profile.

Caliche was measured, described, and sampled at four localities on the WIPP site (descriptions in the Appendix). Caliche covers about 74 km^2 of the 93 km^2 WIPP site with an average thickness of about 1.3 m, and it thus has a volume of about 96 million cubic meters (126 million cubic yds). The average density of caliche in the area is about 1.75 g/cm^3; therefore, about 168 billion Kg (185 million tons) of caliche occur within the boundaries of the proposed WIPP site.

Sampling of representative caliche profiles was done on the basis of genetic soil morphologies using the system of horizon nomenclature developed by Gile and others (1965; 1966). Soil horizons that are so strongly carbonate-impregnated that their morphology is determined by the carbonate are designated "K horizons", with K_2 designating horizons of 90 percent or more (by volume) K-fabric, and K_1 and K_2 designating upper and lower transitional zones of 50 percent or more K-fabric (Gile and others, 1965). The subscript "m", e.g. K_{2m}, indicates induration and presence of a soil "petrocalcic" horizon. Soil horizons containing minor carbonate accumulations are noted by "ca" symbol in combination with a master horizon designation, e.g., Bca or Cca.

The thickness of the K_2 horizon on the WIPP site averages about 54.0 cm (1.8 ft) and ranges between 50 cm and 66 cm (1.6 and 2.2 ft). The K_2 horizon is mottled white in color and consists of angular, blocky to platy peds (2 to 6 cm in length) firmly cemented together by calcium carbonate. A few isolated angular fragments of Triassic Santa Rosa sandstone occur in the K_2 horizon at some localities. In the upper 10 to 20 cm, the horizon is often weakly laminated and the long axes of platy peds are often oriented parallel to the surface. Solution channels and pipes are observed in the K_2 horizon at most localities and are commonly filled with a red, sandy-loam consisting mainly of quartz grains with some feldspar and clay minerals.

The K_2 horizon grades downward into a K_3 horizon which ranges from 40 to 90 cm (1.3-3.1 ft) in thickness, and has an average thickness of about 64 cm (2.1 ft). The K_3 horizon consists of blocky to platy peds and angular, reddish-brown sandstone fragments weakly to moderately cemented together by calcium carbonate. In profiles sampled within the site the K_3 horizon grades downward into either a Cca horizon of scattered carbonate nodules embedded in Triassic sandstone, or into the basal zone of sandy surficial deposits tentatively correlated with the Gatuna Formation.

Chemical Data

Partial chemical analyses were made on 11 samples collected from 4 representative profiles from caliche pits within the site and 2 exposures adjacent to the site (Appendix A). Determinations were made for percent insoluble residues, loss on ignition, silicon, calcium, magnesium, aluminum, iron, sodium, potassium, titanium, and barium; and for parts per million of manganese, strontium, lithium, copper, uranium (U_3O_8), bromine, and iodine. The dominant soluble constitutent is low magnesium calcite, and the major insoluble mineral is quartz in the form of very fine to medium sand grains. Percent insoluble residue is given in table 2. Strontium and lithium contents are less than 10 ppm in all but one sample (#5B-K_3 horizon-30 ppm Sr). Uranium and iodine contents are less than 1 ppm, and bromine is less than 5 ppm in all samples. Copper contents ranges from 9 to 31 ppm, and potassium (K_2O) percentages are less than one.

TABLE 2. Percent insolubles in caliche

Profile No.	1	2	5	6	3[1/]	4[2/]
K_{2m}	32	26	15	37	28	21
K_3	65	60	34	51		
Cca		53	69	41		

1/similar profile outside site

2/Ogallala caprock caliche on "The Divide"

Uses, Supply, and Demand

The primary use of caliche in southeastern New Mexico is for crushed, road-surfacing and subgrade material (Lovelace 1972). Where market demand and transportation costs permit development of caliche deposits, values per cubic yard are in the one to two dollar range.[1] Current (1976) New Mexico production figures from the Sixty-fourth Annual Report of the State Inspector of Mines indicate that commercially utilized deposits annually produce only tens of thousands of cubic yards of caliche. Because reserves at the WIPP site alone exceed 100 million cubic yards and since caliche deposits of equal or better grade and greater thickness than those on the site are present throughout the southeastern New Mexico region (Lovelace, 1972), extensive utilization of onsite material is not foreseen. To date, caliche excavated from a small number of pits in or near the WIPP site has been used for surfacing of local roads. This type of limited resource utilization can be expected to continue.

Salt

Description of Deposits

"Salt" is used in this report to identify the mineral halite or sodium chloride. By weight, pure salt contains 39.34 percent sodium and 60.66 percent chloride, will depress the freezing point of water by 21.2°C or 38°F, and will melt at 800.8°C or, 1,473°F (Klingman, 1975). Salt is produced in three ways: (1) underground mining in which all presently operating salt mines in the United States use the room-and-pillar method, (2) solution mining of underground salt which makes use of wells that utilize much of the technology and equipment of the petroleum industry, and (3) solar evaporation or artificial evaporation of lacustrine brines.

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[1] February 1978 prices at Littlefield and Lubbock, Texas, caliche pits are $1.25 per cu. yd. pit grade, and $1.50 to $2.00 per cu. yd. crushed grade.

Descriptions of potash drill holes in the WIPP site (Jones, 1977) indicate that beds of halite and impure halite with an average total thickness of about 535 m (1,756 ft) occur in the Salado Formation. The top of the uppermost salt bed occurs about 165 m (542 ft) below the surface and the base of the lowest salt bed is about 865 m (2,836 ft) below the surface. Salado salt underlies the entire 93.5 km^2 (36 mi^2) proposed WIPP site. Assuming a specific gravity of about 2.15, an estimated 118 billion tons of salt occur in the Salado Formation beneath the proposed site.

The salt is interbedded with anhydrite polyhalite, sandstone, and claystone in a regular succession involving a change from claystone upward through anhydrite or polyhalite and halite to clayey halite capped by claystone; a change from halite to clayey halite to claystone is noted in other sequences (Jones, 1973). Salado salt is composed of halite and clayey halite in discrete layers that range from 2 cm to several meters in thickness. The clayey halite characteristically contains terrigenous quartz and clay minerals. The clay minerals include illite, chlorite, and a corrensite-type of swelling, regular mixed-layered clay mineral (Jones, 1973). Clayey halite is moderately crystalline, but somewhat porous with small cavities filled with clay and other terrigenous material. Traces of polyhalite and anhydrite, and locally glauberite, silvite, carnallite, kiesserite, and a few exotic evaporite minerals are common to both halite and clayey halite. Traces of brine and gas fill small, intergranular vacuoles.

Most drilling depths on the WIPP site are too shallow to provide much data on the Castile Formation. It was, therefore, necessary to rely mostly upon published regional stratigraphic studies to determine the nature salt in this lowermost Ochoan unit. The Castile contains a salt zone that is about 366 m (1,200 ft) thick in the Los Medaños area (Jones, 1973) with the top of the salt occurring at a depth of about 916 m (3,000 ft). The salt zone grades laterally into, and intertongues with anhydrite to the north. There are no published data regarding the lithologic character of Castile salt beneath the WIPP site.

Use, Supply, and Demand

Table 3 summarizes the various uses of salt; it should be noted that there are no substitutes for salt in any of its applications. Salt is the most abundant and least expensive source of sodium and chlorine used in the manufacture of caustic soda, soda ash, chlorine, and metallic sodium. The production of the intermediate chlor-alkali and soda ash chemicals consumes about 57 percent of the salt produced in the United States (LeFond, 1975). The portion of salt going to the making of other chemicals has been quite uniform at about 23 percent for the past 10 years (Klingman, 1975).

End use	1973	2000				
		Contingency forecast for United States				
		Forecast base	Forecast range		Probable
			Low	High	
Deicing compounds	6,729	21,200	18,000	22,000	20,000
Chemicals	10,655	30,100	28,000	35,000	31,000
Paper products	4,059	13,300	12,000	13,500	13,000
Ceramics and Glass	3,194	5,100	4,000	6,000	5,000
Food products	3,442	6,200	6,000	6,500	6,000
Plastics and Synthetics	3,174	11,800	10,000	14,000	12,500
Agricultural Chemicals	2,808	6,400	6,400	7,000	6,400
Soap and Detergents	2,452	5,500	5,000	6,000	5,500
Metal Production	1,843	7,700	7,000	8,500	8,000
Water and Sanitary Service	1,267	4,200	3,500	4,500	4,000
Petroleum refining	1,435	5,100	4,800	5,300	5,000
Other	5 808	17,500	17,000	22,000	20,000
Total	46,876	---	121,700	150,300	136,400

Table 3. U.S. salt demand by end use (after Klingman, 1975).

The next greatest demand for salt is for use in highway deicing. Such demand, however, is irregular and, depending on the weather, ranges from about 12 to 21 percent of the total salt consumed by the United States. The average for the last 10 years is about 15 percent of the total usage (Klingman, 1975). Environmentalist groups have claimed the excessive use of highway salt damages plants, animals and equipment along highways.

About 5 to 6 percent of salt production is used for agricultural purposes. Such salt is used as a soil stabilizer and pond sealer on many farms, and the cattle industry uses salt in feed formulations and for the production of salt blocks. Miscellaneous uses of salt are also found in the paper-pulp, ceramics, plastics, glass, soap and detergent, petroleum, and metal industries. Small quantities are used for water treatment and for medicinal purposes.

The demand for salt in the United States in 1976 was 45.1 million tons, with the five leading producers being Louisiana, Texas, New York, Ohio, and Indiana (Foster, 1977). Of the salt produced, salt in brine accounted for 53 percent, rock salt for 33 percent, and evaporated salt for 14 percent. Salt imports amounted to 4.1 million tons. The demand for salt in the United States is projected to rise to about 136 million tons by 2000 (Klingman, 1975). Plentiful supplies, an estimated 61 trillion tons (Klingman, 1975), exist underground as rock salt or as brine; moreover, seawater represents an almost inexhaustible source of salt. The United States salt resources are, therefore, virtually unlimited.

The salt mining industry in southeastern New Mexico produced about 110,000 tons of salt in 1977. Most of this production was from the Salt Lake Mine (United Salt Corporation) with an annual capacity of about 108,000 tons produced by dredging salt that has accumulated in Salt Lake (T. 22 S., R. 29 E.). Salt is also produced at the Zuni Salt Lake Mine in west-central New Mexico by solar evaporation at an annual capacity of about 100 tons. The nearest salt producing areas outside of the state are in Texas, Oklahoma, and Kansas.

About 50 percent of the salt produced in New Mexico is used for road (snow and ice) control within the state. As much as 15 percent of the total production is sent to Arizona for the same purpose. The remaining 35 percent is used in cattle feeds, with most being sent to nearby feedlots in western Texas. Salt shipment reports also show that New Mexico is a small salt-consumer (P. J. Foster, personal communication, 1977); furthermore, consumption is not likely to increase substantially unless there is a major influx of salt-consuming industries (chemical, paper, glass, plastics) into the state.

The major salt producer in New Mexico, United Salt Corporation, indicates that surface salt supplies, including brine lakes and potash tailing piles (which are predominantly halite) are large enough to meet all foreseeable demands for salt (personal communication, 1977). They believe that there is little likelihood of ever needing to mine underground salt in the WIPP site area.

Synthesis and Outlook

There are substantial salt reserves in the Salado and Castile Formations beneath the proposed WIPP site. However, considering that:

1. these salt reserves are more than 165 m below the surface,

2. there are virtually unlimited, readily available salt reserves on the regional and national levels,

3. substantial production of salt occurs between New Mexico and major consuming areas to the east,

4. there are plentiful surface supplies of salt in New Mexico that will meet all foreseeable future demands within the state,

the economic potential of salt in the subsurface beneath the WIPP site is small. Only if there is an influx of major salt-consuming industries into New Mexico is there a possibility that the demand for salt will increase enough for it to become economical to mine the deeply buried salt in the Salado and Castile Formations beneath the WIPP site by either underground or solution mining methods.

Gypsum

Description of Deposits

Gypsum is one of the principle constituents of most evaporite deposits and is the most commonly observed phase of calcium sulfate in outcrop. Pure gypsum contains 32.6 percent CaO, 46.5 percent SO_3, and 20.9 percent H_2O; however, because of metastable relationships between it and anhydrite, the anhydrous phase of calcium sulfate, pure gypsum deposits are seldom found. Most mine produced gypsum is, therefore, only about 85 to 95 percent pure, but in some cases the product can be upgraded by beneficiation.

Both open pit and underground methods are used to mine gypsum. Open pit employs conventional methods and equipment such as dragline and scrapers to remove the overburden and showels or front-end loaders to load the rock. Eighteen percent of the gypsum mines in the United States are underground. Most use the room-and-pillar method and total rock recovery ranges from 70 to 80 percent.

Although gypsum does not occur on the surface of the proposed WIPP site, as much as 30 m (100 ft) is present in the subsurface in the Rustler Formation. Considerable Rustler gypsum occurs to the west of the site, but the gypsum grades into anhydrite and polyhalite beneath the WIPP site (Jones, 1973).

Where Rustler gypsum occurs beneath the WIPP sites, it has an average total thickness of about 12 m (40 ft) distributed among one to five gypsum beds ranging from 1.5 to 18 m

(5 to 60 ft) thick. The top of the uppermost bed lies 102 m (335 ft) below the surface and the base of the lowermost bed occurs at a depth of 305 m (1,000 ft) below the surface. Rustler gypsum underlies about 44 km^2 (17 mi^2) of the proposed WIPP site. Pure gypsum has a specific gravity of 2.32; therefore, an estimated 1.3 billion tons of the commodity occur in the Rustler Formation within the boundaries of the proposed WIPP site. It should be noted, however, that the estimate is based on the specific gravity of pure gypsum, and that there is no data on the actual quality of the gypsum in the area.

Uses, Supply, and Demand

Most uses for gypsum (table 4) are based upon the unique property which calcium sulfate has of readily giving up, or taking on water of crystallization. With the application of a moderate amount of heat (a process known as calcining), gypsum is converted to a hemihydrate of calcium sulfate (plaster of Paris) which, when mixed with water, will set to harden as the calcium sulfate returns to the dihydrate form. This semifinished product is then manufactured into a large variety of plasters, wallboard and block for construction or industrial application. In 1972, about 70 percent of the gypsum used in the United States was calcined for these purposes (LeFond, 1975). The remaining 30 percent was marketed as uncalcined, crude gypsum, which was used as a retarder in portland cement, as a soil conditioner, and as a mineral filter. Gypsum also constitutes a large sulfur reserve, and it has been put to small scale use in the manufacturing of sulfuric acid and other sulfur compounds. Sulfur is, however, readily available at a lower cost from other sources here in the United States and such use occurs only outside of the country; consumption is, therefore, controlled by the construction industry. In 1976, for example, building activity improved and sales of prefabricated products increased 18 percent (Pressler, 1977). During the same time period, gypsum output increased from 9.8 to 11.5 million tons, or about 17 percent. Consumption of gypsum in 1976, however, amounted to 18.1 million tons, with net imports of 6.6 million tons making up the difference. Consumption is expected to increase at an annual average rate of about 2 percent through the year 2000 and reach a projected 35 million tons (Reed, 1975).

Domestic resources and reserves of gypsum are adequate for any foreseeable period of time but are unevenly distributed. Large deposits occur in the Great Lakes region, midcontinent region, California, and a few other states. Leading producers are California, Michigan, Iowa, Texas and Oklahoma, which together account for 62 percent of the total production in the United States (Pressler, 1977). There are no gypsum deposits, however, on the eastern seaboard of the United States, and large imports from Canada are used to augment domestic supplies in this area. In some cases other construction materials can be used in place of gypsum, but there is no substitute for the commodity in portland cement.

U.S. demand pattern:	65	66	67	68	69	70	71	72	73	74
Construction:										
Plasters, building (includes prefabricated products)	11,137	9,703	9,274	10,333	10,763	9,790	12,028	13,920	14,565	12,515
Cement retarder	3,152	3,372	3,154	3,439	3,464	3,358	3,386	3,924	4,148	4,058
Total	14,289	13,075	12,428	13,772	14,227	13,148	15,414	17,844	18,713	16,573
Agriculture	1,359	1,240	1,280	1,388	1,100	805	1,124	1,146	1,453	1,671
Other:										
Plasters, industrial	378	382	347	357	374	284	263	298	353	326
Miscellaneous	66	81	77	108	117	97	113	124	117	123
Total	444	463	424	465	491	381	376	422	470	449
Total U.S. demand	16,092	14,778	14,132	15,625	15,818	14,334	16,914	19,412	20,636	18,693

Table 4 . U.S. demand pattern for gypsum 1965-1974 (after Reed, 1975).

New Mexico produced 255,000 tons of gypsum in 1973 and 157,000 tons of gypsum in 1974 from mines located in Sandoval and Santa Fe counties (Craig, 1974). Three gypsum mines (1) White Mesa, sec. 11-15, T. 15 N., R. 1 E.; (2) San Felipe, sec. 35 and 36, T. 4 N., R. 5 E., and (3) Rosario, sec. 5 and 32, T. 14 & 15 N., R. 7 E., are currently operating in New Mexico. Production from these three operations is uncertain, but we estimate it to be about 250,000 tons per year. Virtually all of the crude gypsum is used to manufacture construction products; very small quantities are used for agricultural purposes. Estimates of the quantity of gypsum products consumed in New Mexico and those shipped out of state could not be obtained from American Gypsum Company, the largest consumer of raw gypsum in New Mexico. Ideal Cement Company, which consumes about 25,000 tons of gypsum annually, however, reported that only about 5 percent of the cement products they produce are shipped to destinations outside of New Mexico.

Deposits of rock gypsum and gypsite are widely distributed throughout a large part of New Mexico in rocks ranging in age from Pennsylvanian to Pleistocene, with local gypsum dune sands of Recent age. Reserves are substantial. The one gypsum deposit at White Mesa contains measured reserves of 98 million tons and an estimated additional 123 million tons available by stripping relatively thin overburden (Weber and Kottlowski, 1959). At present production rates, the White Mesa deposit alone would supply New Mexico with gypsum for about 885 years. Gus Palmeroy of the White Mesa Gypsum Company cannot foresee the need to ever mine the gypsum beneath the surface of the proposed WIPP site (Gus Palmeroy, personal communication, 1978).

Synthesis and Outlook

About 12 m (40 ft) of gypsum, distributed between one to five beds, buried 102 to 305 m (355-1000 ft), occur in the Rustler Formation beneath the surface of the proposed WIPP site. We conclude, however, that because there are adequate gypsum reserves in the Great Lakes, midcontinent, and West Coast regions--closer to large consuming areas, and because New Mexico has large known reserves that will meet its future demands, there is little likelihood of it being necessary to mine the gypsum in the Rustler Formation beneath the proposed WIPP site to meet a demand for gypsum.

Brine

Description of Deposits

Brine pockets, saturated in Na, K, Ca, and Mg chlorides and sulfates occur frequently in the McNutt member of the Salado Formation. Such pockets are encountered routinely in the course of potash mining. There are no quantitative data on total brine volume. Griswold (1977) reported that the largest known pocket contained an estimated 100,000 gal of brine; the average pocket is much smaller (10 to 100 gal).

On July 30, 1975, borehole ERDA No. 6 (sec. 35, T. 21 S., R. 31 E.) produced saturated brine and H_2S gas from a fractured, gray, laminated Castile anhydrite unit, 626.5 m (2,711 ft) below the surface. Oil companies report similar phenomena in the Castile (Lambert, 1977). A chemical analysis (New Mexico Bureau of Mines and Mineral Resources Laboratory, 1976) indicates the brine contains 140 g/ml lithium. Economic concentrations of other commodities were not found in the brine.

Use, Supply, and Demand

Lithium is the lightest of all the metals, having an atomic weight of 6.938. Major uses for lithium are for the production of primary aluminum, ceramics and glass, lubricants, fluxes, and air conditioning. American firms, mostly located in the central and Atlantic states, consumed 3,100 tons of lithium in 1977 (Quan, 1977). Table 5 shows that demand expected to increase at an annual rate of 5 percent and approach 14,400 tons by 2000 (Singleton and Wood, 1975). Singleton (1977) believed that most of increasing demand for lithium will be for small batteries and lithium catalysts for organic chemicals. Lithium, however, is still a developing commodity and its implications are expanding rapidly. Its application in various phases of the metallurgical and chemical industries are diversifying and expanding rapidly. A potential application for lithium also exists in nuclear power as an absorption blanket in fusion generation. In thermonuclear reactions, the most likely fuel will be a deuterium-tritium

(Short tons)

End use	1973	2000 Contingency forecasts for United States: Forecast base	Forecast range: Low	Forecast range: High	Probable
Aluminum production	1,400	5,000	3,500	6,200	6,200
Ceramics and glass	1,000	2,500	1,800	3,100	2,700
Lubricants	480	600	520	780	660
Air conditioning	250	510	400	700	700
Other	720	2,000	2,000	20,000	4,140
Total	3,850	10,610	8,220	30,780	14,400

Table 5 . U.S. projections and forecasts for lithium demand by end use, 1973-2000 (after Singleton and Wood, 1975).

mixture because of its very large reaction rate (Holden, 1971). Tritium is naturally scarce but can be artificially generated within a reactor itself by bombarding a lithium-6 isotope in the blanket with neutrons created by the fusion reaction.

Production of lithium in 1977 was about 4,000 tons (Quan, 1977); therefore an oversupply prevailed at the close of 1977. Most of the world's lithium reserves are in the United States, the U.S.S.R., Canada, and southern Rhodesia. Approximately 36 percent (270,000 tons) of the world's reserves are in subsurface brines, mainly in Nevada. United States total reserves are estimated to be about 3.2 million tons and will meet demand through 2000 and well into the next century, assuming the average growth rate (5 percent discussed earlier (Singleton and Wood, 1975; Singleton, 1977).

There is no information concerning the consumption of lithium in New Mexico. However, more than 13,000 tons of lepidolite and several hundred tons of spodumene (two principle lithium-bearing minerals) have been produced in New Mexico since 1920 (Lesure, 1965). Most of this production, representing nearly 10 percent of the total U.S. production between 1920 and 1950, came from the Harding mine in Taos County. Small amounts came from the Pidlite mine in Mora County. No lithium production has been recorded in New Mexico since 1950 (Lesure, 1965).

Jahns (1953) estimated the amount of lepidolite and spodumene in the Pidlite mines to be 530 tons in 1947, but how much of this has been mined since then is uncertain.

Large quantities of the two minerals still remain in the Harding pegnatite (Lesure, 1965), but no reserve data have been published.

Synthesis and Outlook

Economic grade lithium-bearing brines do occur within the boundaries of the proposed WIPP site, but there are insufficient data to determine the quantity of the brine that occurs there. Furthermore, the brines seem to occur in small, local, isolated pockets containing 10 to 100 gal of brine that occur at least 400 m below the surface.

With spodumene reserves in North Carolina and lithium-bearing brine reserves in California and Nevada that are substantial enough to meet all demands for lithium well into the next century, it is inconceivable that it will be economic to drill wells to depths in excess of 400 m to pump less than 100 gals of brine. It is, therefore, concluded that the economic potential of WIPP site-related brines is very small.

Sulfur

Sulfur is one of the most important industrial raw materials with importance in every sector of the fertilizer and industrial complexes of the world. Sulfur, constituting 0.06 percent of the earth's crust (Gittinger, 1975), is one of the most abundant elements in the earth, and is one of the few that occurs in the native state. By far the greatest quantity however, is combined with other elements. Various mining methods are used to mine sulfur including: (1) the Frasch Process, (2) tunneling, (3) room-and-pillar, (4) cut-and-fill systems, (5) open pits, and (6) various forms of stoping. Processing ore to separate sulfur is by various combinations of melting, distillation, agglomeration, flotation and solvent extraction.

No sulfur was observed on the WIPP site during the course of our field work, nor was any sulfur encountered in any of the potash drill holes on the WIPP site. Smith (1978), nevertheless, reported that sulfur is common in gypsum and gypsiferous rocks of Ochoan (Late Permian) age in Eddy County, New Mexico, but his work centered around control points in Culberson and Reeves counties, Texas, and his maps barely extend across the New Mexico border. The sulfur of the main ore body occurs along faults and joints in the Castile Formation, usually near the base, and as irregular masses and lenses in the Salado residum. Hinds and Cunningham (1970) found that the Castile Formation, in the central Delaware Basin, contains several thick halite beds. Along the west and south sides of the basin, however, the Castile halite beds were never deposited or have been removed by subsurface solution. All of the sulfur deposits lie west or south of the southern and western edges of the Castile halite (Hinds, and Cunningham, 1970). The WIPP site is located east of the edge of the Castile halite (fig. 2); therefore, an onsite occurrence of a sulfur deposit that is large enough to be economic is unlikely.

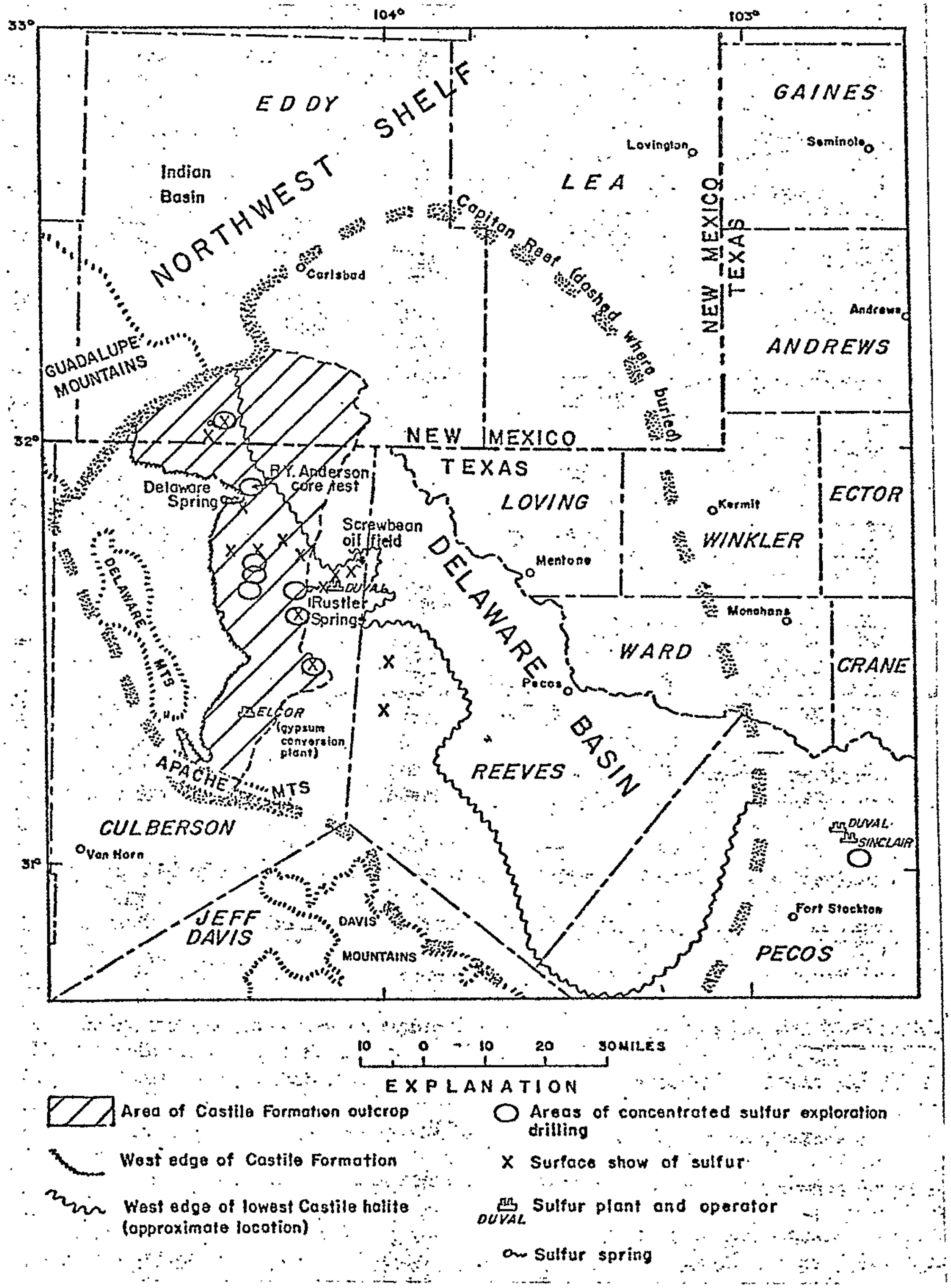

Figure 2 . Location of sulfur recovery plants, surface occurrences, areas of concentrated exploratory drilling, Castile Formation outcrop, and approximate position of the edge of the Castile halite (after Hinds and Cunningham, 1970).

Uranium

Associations

Numerous small uranium occurrences belonging to the redbed copper-uranium association are known throughout eastern New Mexico (Finch, 1972). These deposits occur in rocks that range in age from Pennsylvanian to Pleistocene, and may be characterized briefly as occurring in fluvial sandstones intimately associated with abundant carbonaceous plant matter (organic "trash"). Rock units containing uranium deposits are invariably brownish to black in color. Red and maroon colored units seem to be conspicuously barren (Tschanz and other, 1958). Scours cut into underlying fine-grained rocks that are backfilled by carbonaceous sandstone contain the highest uranium concentrations; however, overall grade of mineralization is low. Channel samples of deposits typically contain 0.001 to 0.05 percent U_3O_8, although selected samples may contain 0.10 percent U_3O_8 or more.

The uranium potential of the WIPP site caliches has been previously examined in the section of this report on caliches (p. 7-11) and in Appendix A.

Dewey Lake Redbeds

The Dewey Lake Redbeds of Permian age are exposed or are present in the subsurface throughout the entire study area and in adjacent regions. The redbeds are 148 m (487 ft) thick in ERDA 9 and consist of reddish-brown siltstone and mudstone with greenish-gray reduction spots (Griswold, 1977). Several thin (less that 1.5 m thick) very fine-grained reddish-brown silty sandstone beds are present. The Dewey Lake Redbeds are 62 m (202 ft) thick in the Project Gnome shaft southeast of the WIPP site (sec. 34, T. 23 S., R. 30 E.) and consist almost exclusively of thinly bedded reddish-brown siltstone with small greenish-gray reduction spots (Gard, 1968). Sandstone is rare, and occurs as units less than 0.3 m thick. Carbonaceous material is essentially absent. Elsewhere is the Nash Draw 15' Quadrangle, Vine (1963) reports that the Dewey Lake Redbeds consist of red-orange to red-brown thinly laminated siltstone and fine sandstone. Lenses of cross-bedded fine sandstone in the upper part of the unit may have formed in a fluvial environment.

No evidence of uranium favorability is found in the Dewey Lake Redbeds. The unit contains mostly fine-grained deposits, and lacks carbonaceous matter. Colors are exclusively reddish, in contrast to known redbed uranium occurrences. No elevated uranium concentrations are indicated from examination of gamma ray logs from potash evaluation holes penetrating the redbeds. Most gamma logs show only moderate variability at approximately 100 cps throughout the Dewey Lake interval. A spectral gamma log for K, U, and Th, in ERDA 9 indicates a uniformly low uranium concentration of less than 13 ppm.

Santa Rosa Sandstone

The Triassic Santa Rosa Sandstone is present in the study area only northeast of a north-northwest trending line located slightly west of the ERDA 9 drill site. Southwest of this line the unit has been removed by erosion. Maximum thickness is in excess of 76 m (250 ft) on the northeast margin of the study area. Vine (1963) described the Santa Rosa from outcrops in the northeast part of the Nash Draw 15' Quadrangle; a thin wedge of the unit is present in the ERDA 9 drill hole (Griswold, 1977).

In the Nash Draw region, the Santa Rosa consists of reddish-brown, large-scale trough cross-bedded sandstone of probable fluvial origin. Cross sets are 1-5 m (3-15 ft) thick, and are separated from adjacent sets by thin partings of reddish siltstone and mudstone. The sand is dominantly fine-grained, poorly sorted, and contains 15-20 percent feldspar. Local conglomeratic beds occur. Vine reports the rare occurrence of fossil plant impressions and other carbonaceous material Secondary bleaching has occurred locally at the base of the unit and in some of the coarser sandstone beds, indicating post depositional movement of fluids.

Despite the local occurrence of carbonaceous trash in a thick, arkosic fluvial sandstone, the Santa Rosa of the WIPP site is considered to be unfavorable for uranium concentrations. The colors are dominantly reddish, whereas known uranium deposits in the Santa Rosa occur in dark brown sandstones (Finch, 1972).

Gamma logs show no evidence of elevated count rates, and frequently show lower radioactivity than the underlying Dewey Lake Redbeds. Some lowered radiation zones may correspond to bleached (leached) zones noted in the published descriptions. The spectral gamma log from hole ERDA 9, although penetrating less than 3 m (10 ft) of Santa Rosa, indicates less than 13 ppm uranium. While the fluid movement that produced the bleached zones noted above may have leached uranium from the near surface rocks and reconcentrated it down dip, no evidence for such reconcentration can be observed in the available data. A spectral gamma log from drill hole AEC 8, located outside the WIPP site boundary to the northeast indicates a maximum uranium content of approximately 65 ppm locally.

Gatuna Formation

Radioactive anomalies have been described from the Gatuna Formation in Lea County (Finch, 1972), some tens of miles east of the WIPP site. These occurrences are in dark red, gypsiferous clay as exposed in oil well mud pits. Maximum uranium content reported is 0.006 percent U_3O_2 (60 ppm) (Waltman, 1954). No evidence of such radioactive zones could be detected in gamma logs from the WIPP site.

SUMMARY AND CONCLUSIONS

The proposed WIPP site is located about 40 km (25 mi) east of Carlsbad, New Mexico, near the northern border of the Delaware Basin. From the base of the Castile Formation, the stratigraphic section includes marine Ochoan (Late Permian) evaporites that are overlain by marine and continental Ochoan to Quarternary redbeds. Our field observations and examination of existing records indicated that (1) caliche, (2) salt, (3) gypsum, (4) lithium-bearing brines, (5) sulfur, (6) uranium are the only WIPP site-related commodities that may have any economic potential. A more detailed study of WIPP site reserves and national, state, and local supply-demand relationships indicates that the economic potential of onsite reserves of the first five commodities is minimal. Uranium is present only in concentrations far below economic levels and therefore is not considered to be of potential importance.

Caliche reserves of the proposed WIPP site are about 96 m^3 (126 yds^3); however, because of the low local demand for caliche (about 10,000 yds^3) and extensive caliche deposits of higher quality throughout southeastern New Mexico, we cannot foresee the utilization of WIPP site reserves.

There are about 118 billion tons of salt in the Salado and Castile formations beneath the WIPP site. We conclude that because of the depth of the salt (greater than 165 m) the low demand for New Mexico salt, and virtually unlimited and readily available salt reserves on the regional and national level, the economic potential of WIPP site salt reserves are also very small.

About 1.3 billion tons of gypsum occurs within the boundaries of the proposed WIPP site. In our opinion the economic potential of this gypsum is very small because there are substantial gypsum reserves in the Great Lakes, midcontinent, and West Coast regions, closer to large consumer areas. Furthermore, New Mexico has other large, widely distributed gypsum reserves that will meet all of its foreseeable demand for gypsum.

Pockets (10 to 100 gal) of economic grade (140 ppm), lithium-bearing brines occur in the WIPP site subsurface. However, because of the small, isolated nature of the pockets, and the presence of adequate lithium reserves in North Carolina, Nevada, and California, we cannot foresee the utilization of onsite brines to meet a demand for lithium.

Sulfur deposits in the Los Medanos area may be economically important, but the WIPP site is located east of the edge of the Castile halite, and all known sulfur deposits lie to the west of the Castile halite edge. Any occurrence of onsite sulfur is unlikely.

There is no evidence that economic or subeconomic concentrations of uranium exist in the redbed units of the WIPP site study area, despite the fact that certain units (Santa Rosa Sandstone and Gatuna Formation) are known to contain subeconomic deposits elsewhere. The dominant red coloration, and corresponding lack of carbonaceous material in the sediment (reducing agent for uranium), indicates regional unfavorability. Gamma ray logs for 21 potash test holes, and spectral gamma logs for 2 additional holes (AEC 8 and ERDA 9) also indicate uniformly low uranium content (less than 100 ppm max).

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APPENDIX A

Description of Sampled Soil-Caliche Profiles in or near the WIPP Site, Eddy County, New Mexico

Profiles described and collected by W. T. Siemers, G. O. Bachman (USGS) and C. Rautman. Sample notes reviewed and appendix prepared by J. W. Hawley.

General Setting and Comments on Sampled Profiles:

Surface geology of the part of the Site on Nash Draw (15 minute) Quadrangle has been mapped by Vine (1963). A low intensity soil survey (scale 1:31,680) of the entire site area has been published by the U.S. Soil Conservation Service (Chugg and others, 1971). General aggregate-resource inventory and geologic mapping of the area (scale 1:190,080 was also done by the New Mexico Highway Department (Lovelace, 1972), Quad. 119). Recent reconnaissance maps (scale 1:250,000) of the Site region have been prepared by Bachman (1976) and C. C. Reeves (Texas Bur. Econ. Geology, 1976).

Sampled profiles 1, 2, 5, and 6 are located in the 93 square km (36 square mile) WIPP site area. Profiles 3 and 4 are located, respectively, about 4 and 7 miles northeast of site center. All profiles except no. 4 (Ogallala Fm. caprock caliche on "The Divide") are in materials representative of caliches on the site. Surface soil materials (Chugg and others, 1971) above caliches at profiles 1, 2, 3 and 6 are representative of the Soil Survey "Berino complex" that comprises 1 to 1.5 meters of reddish, fine sand to sandy clay-loam with a basal zone of soft caliche. Low stabilized sand dunes are locally present in this mapping unit. Soil materials above caliche at profile 5 are representative of the "Kermit-Berino fine sands". This soil Survey mapping-unit complex comprises soils of the "Berino complex" with common overlays, up to 1.5 meters thick, of stabilized and active dune sand. Field investigations indicate that 75 to 80 percent of Site area is underlain by materials like those described at profiles 1, 2, 3, 5, and 6. Samples selected for laboratory analyses are denoted with an asterisk (*).

Profile 1:

Sampled in caliche pit, NE¼,NE¼, Sec. 32, T. 22 S., R. 31 E. Surface soil material in pit area: SCS Soil Survey Mapping Unit BB (Berino Complex). Estimated depth range to caliche near pit is 1 to 1.5 m; overlying reddish soil material poorly exposed.

0-66 cm; K_{2m} horizon, indurated caliche, blocky ped structure, angular peds 2-6 cm, firmly cemented; sandy, cemented zones in joints; weakly-developed, subhorizontal laminar structure in upper 17 cm. Dry colors: very pale brown (10YR8/3), with pink (5YR8/4) mottles (2 cm diameter). Channel Sample Wc-1a*.

66-134 cm; K_3; caliche, with scattered fragments of Triassic sandstone engulfed by $CaCO_3$; carbonate-plugged nodular fabric in upper 45 cm; lower part nodular, but loosely cemented. Channel Sample Wc-1b*.

below 134 cm; Triassic sandstone

Profile 2:

Sampled in caliche pit, NW¼,NW¼, sec. 22, T. 22 S., R. 31 E. Surface soil material: SCS Soil Survey Mapping Unit BB (Berino Complex). Estimated depth range to caliche near pit is 1 to 1.5 m; tongues of overlying reddish soil material are present in solution channels and pipes that penetrate the K_{2m} horizon (Sample Wc-2a).

0-48 cm; K_{2m} horizon, indurated caliche, well-cemented; upper 10 cm hard under hammer, weakly laminated; platy ped structure, peds up to 5 cm long and 1 cm thick. Channel Sample Wc-2b*.

48-102 cm; K_3; caliche, with moderately-cemented platy peds; basal 15 cm loosely cemented. Channel Sample Wc-2c*.

102-127 cm; Cca horizon, scattered carbonate nodules in Triassic sandstone. Sample Wc-2e*.

below 127 cm; sandstone. Grab Sample Wc-2d.

Profile 3:

Sampled in caliche pit, NE¼,SW¼, sec. 12, T. 22 S., R. 31 E. Surface soil material: SCS Soil Survey Mapping Unit BB (Berino Complex). Estimated depth range to caliche near pit is 1 to 1.5 meters; overlay of reddish soil material sampled (Grab Sample Wc-3a).

0-160 cm; Km; indurated caliche; platy ped structure, well cemented throughout; engulfs Triassic sandstone at base; numerous pipes and incipient pipes at this locality. Grab Sample Wc-3b*.

Profile 4:

Sampled in west-facing scarp of "The Divide" SW¼,SW¼, sec. 4, T. 22 S., R. 32 E. Outcrop of Ogallala caprock caliche; well-indurated, dense, with zones of pisolotic structure. Grab Sample Wc-4*.

Profile 5:

Sampled in caliche pit; SW¼NE¼, sec. 5, T. 23 S., R. 31 E. Surface material: Pit spoil; SCS soil mapping unit in pit area is "Kermit-Berino fine sand (Unit KM)." Estimated depth to caliche near pit is from 0.5 to 2.5 m; fine dune sand forms the upper part of thicker zones of overlying soil material (Kermit soils), and reddish sandy clay loams (similar to surface soils at profiles 1, 2, 3 and 6) make up the basal part.

0-20 cm; K_{22m} horizon, indurated caliche; blocky ped structure, angular peds with subhorizontal long axes; moderately to firmly cemented. Channel Sample Wc-5a* (upper).

20-50 cm; K_{23m}; indurated caliche; blocky ped structure, with prismatic peds; moderately cemented. Channel Sample Wc-5a* (lower).

50-145 cm; K_3 horizon; blocky peds; moderately to poorly cemented. Channel Sample Wc-5b*.

below 145 cm; Cca horizon; carbonate nodules with sandy earth matrix, some coalesced nodules. Channel Sample Wc-5c*.

Profile 6:

Sampled in caliche pit, SE¼, sec. 17, T. 22 S., R. 31 E. Surface soil material in pit area: SCS Soil Survey Mapping Unit BB (Berino Complex). Estimated depth range to caliche near pit is 1 to 1.5 m; overlay of reddish soil material sampled (Grab Sample Wc-6a).

0-52 cm; K_{2m} horizon, indurated caliche, block to platy ped structure; well cemented; angular fragments of Triassic sandstone sparsely scattered in caliche matrix. Channel Sample Wc-6b*.

52-92 cm: K_3, caliche, blocky ped structure, moderately cemented with some well-cemented layers. Common Triassic sandstone fragments. Channel Sample Wc-6c*.

92-117 cm; Cca horizon; nodules and platy masses of carbonate-impregnated sandy material. Bulk of unit composed of Triassic sandstone. Channel Sample Wc-6d*.

below 117 cm; Triassic sandstone, Sample Wc-6c.