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# Mineral Resource Evaluation of State Lands in East-Central New Mexico (Area 7A)

by

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# INTRODUCTION

This report culminates more than six months of intensive investigation into the mineral resource potential of State lands in a selected part of east-central New Mexico. The study covers Ts. 1-12 N., Rs. 19-37 E., Ts. 1-5 S., Rs. 19-37 E., and T. 6 S., Rs. 20-38 E.; an area of more than 11,000 square miles. Included are all or parts of Quay, Guadalupe, DeBaca, San Miguel, Chaves, Roosevelt, Lincoln, and Curry counties.

Investigation of the mineral resources of the area began in the latter part of June 1970. On-site evaluations of State lands were conducted through the middle of September and the remainder of the time was spent in subsurface studies and preparation of final reports, tables, and illustrations.

Contained in the report is a summary of the data collected from on-site evaluation of State land parcels and regional subsurface studies; recommendations regarding the mineral resources of the area and future studies of this nature; basic geographic data necessary for economic studies; a discussion of the regional and economic geology; computerized data evaluation tables listing each tract of State land and the evaluation given for each mineral resource; and maps depicting on a regional basis, the geology and present or potential mineral resources.

The particular area selected for the investigation, although somewhat arbitrary, turned out to be a fortunate choice. It is believed that it represents a composite of the types of State land to be found elsewhere, and in particular the types of problems that are involved in the administration and study of these lands. In general, population is sparse, availability of water for multiple purposes is limited, and mineral production is almost totally restricted to aggregate for road construction. In addition there are large tracts of State lands that by virtue of unfortunate trades or the circumstances that existed when the lands were originally assigned to the State, are located in exceptionally poor areas from the standpoint of grazing, agriculture, or mining. It is not the purpose of this report to make a historical study of how the State came into possession of various tracts of land. It is instead to investigate the mineral resources the State now owns so that the lands can be administered from a base of existing knowledge.

## SUMMARY OF INVESTIGATIONS

Existing or potential mineral resources of east-central New Mexico (Area 7A) include copper, uranium, gypsum, anhydrite, clay, sand, gravel, dolomite, crushed and dimension stone, caliche, salt, potash, oil and gas, asphalt, and carbon dioxide. Other mineral commodities such as silver, molybdenum, vanadium, thorium, lead, coal, and diatomite either are known to occur or may occur in the area but the grade is such that they cannot be considered as part of the economic future of the area.

The greatest potential for economic growth in the mineral industry is from oil and gas. Of all the nonproducing areas of the State, east-central New Mexico has the greatest possibilities for the discovery of large reserves of petroleum. Oil is being produced from a small field in T. 6 S., R. 26 E., and recently there have been two important gas discoveries within the area, and a significant oil discovery a few miles to the south.

The potential for the discovery of commercial deposits of copper and uranium is considered fair. There are many known occurrences of uranium although none of commercial grade have been found thus far. There are several sedimentary-type copper deposits, and one, the Stauber mine, has yielded the greatest amount of copper from a deposit of this type in the State. Some silver was recovered as a by-product from this operation.

Huge reserves of common salt are present, and many beds occur at depths economically feasible for underground mining. Solution mining of deeper deposits is not presently practical because of the large quantities of fresh water required by this method. Some potential for the discovery of economic deposits of potash salts exists but is considered remote because of the geologic environment present during Permian time along the northern margins of the Permian Basin.

More than adequate reserves of aggregate for highway construction or concrete are available. Materials suitable for these purposes include widely distributed deposits of caliche, thick beds of dolomitic limestone in the southwestern part of the area, and good supplies of quality gravel in local areas.

Bedded deposits of gypsum and anhydrite underlie the entire area, but the utilization of this material depends on future expansion of population and growth of a local construction industry. Deposits that can be mined more economically occur in other parts of New Mexico, and these have greater potential for export.

Clay and shale that might be suitable for the production of structural clay products were unknown before this investigation. Two deposits with promise were discovered and additional work on these deposits is being conducted by the Bureau staff. If adequate reserves of strippable material can be blocked out, and firing properties remain fairly constant there exists a real opportunity for establishing a structural clay products industry.

Sand suitable for high-value products that could be exported from the area or that could form the base for a local industry were not discovered. Further investigation of a deposit with limited possibilities is planned. Sand that can be used for low-value uses, such as highway seal and for mortar is available in many parts of the area.

Dimension stone that could be exported or used locally for high quality construction does not appear to be available. Sandstones of Triassic age were widely used to build one or two room dwellings during the homesteading period. Some larger structures, such as the Catholic Church in Santa Rosa, also were built from these sandstones. For the most part, however, these stones are too weakly cemented and generally are not of an attractive color.

A large deposit of asphalt occurs in the Santa Rosa area. Future mining of this deposit and exploration for similar deposits depends to a large extent on development of additional uses for this material.

## RECOMMENDATIONS

With this report the State of New Mexico has a broader base of information on all present or potential mineral resources in east-central New Mexico than is presently available to any private industry or other governmental agency.

The data supplied in this report should prove adequate in coverage for the administration of the mineral resources on State lands included in Area 7A. In some cases, as pointed out below, additional investigations in this area may be necessary. However, there is no reason these studies cannot be conducted by personnel of the State Land Office, providing this department maintains a staff of qualified geologists. Naturally, one of the tasks of the staff of the State Land Office is to incorporate any new information concerning mineral exploration and investigations within the area of the report.

The present investigation has convinced those of the Bureau staff who worked on this project that studies of this nature should be conducted on all State lands, and that these studies should be completed as soon as possible. However, once reports similar to this have been completed on the remaining State Trust lands in other areas, it should not be necessary for the Bureau to engage in additional investigations of this type for these areas.

Some recommendations and observations regarding the administration of the mineral resources of Area 7A are appropriate, even though the basic aim of the report is to supply the State Land Office with data for planning use.

It is strongly suggested that oil and gas rights be retained on all State lands in the area unless lands of equal potential are traded. This, essentially, would restrict any trading of oil and gas rights in Area 7A for lands favorably located in southeastern or northwestern

New Mexico. Until such time as studies are completed on these areas and other parts of the State there probably should be a limited moratorium on trading, not only of oil and gas but all mineral rights. Some trading could, of course, resume between areas where studies have been completed.

The Federal Government has retained varying degrees of mineral rights on certain lands. The tracts involved are given in Table 1. These retentions have resulted in a rather complex ownership of both surface and mineral rights. In addition, some lands are still carried on State records, although the State no longer has any ownership over these lands. These tracts and those where the State will no longer have ownership following completion of purchase contracts are given in Table 2.

From these tables it is obvious that land ownership could be greatly simplified by exchanges of lands that are of no particular value to the State. As an example, some of the lands included under the SSUSM heading could be traded or sold after an examination of their potential from the standpoint of grazing, agriculture, and industrial use.

Although some trades of this nature might be advantageous in administering State lands it should not be considered necessary to reduce levels of ownership to two or three classifications. With the use of computers, up-to-date retention and retrieval of data regarding ownership becomes a relatively simple task.

If it is desirable to trade some lands in Area 7A, there are abundant tracts that checkerboard the talus slopes bordering many of the mesas that could be relinquished. With the exception of oil and gas and possibly salt, they are virtually of no value to the State. This includes not only from a mineral standpoint but from any surface use as well. As an example, even if a high-grade deposit of uranium were found on one of these tracts the total tonnage of ore underlying the tract would be very small. This is because of the steep slopes, irregular outline of the mesa edge, and the nearly flat-lying nature of the potentially ore-bearing sedimentary intervals. The net result is that only a small part of the favorable sedimentary intervals are preserved. By contrast, tests for petroleum could be drilled on these slopes, and if successful the area of production would still include the total acreage of the state parcel.

Table 1. State Lands with Some or all Mineral Rights
Owned by U.S. Government

SSUSM*

T. 1N., R. 24E.
Sec. 32

T. 2N., R. 31E.
Sec. 29: SE

T. 2N., R. 32E.
Sec. 31: $S_2$SE

T. 3N., R. 24E.
Sec. 25: SW

T. 3N., R. 25E.
Sec. 19: $E_2E_2$

T. 4N., R. 24E.
Sec. 24: SWSE

T. 4N., R. 25E.
Sec. 7: Lot 4

T. 4N., R. 26E.
Sec. 1: Lots 1 to 4

T. 5N., R. 19E.
Sec. 22: $E_2$
Sec. 23: NW, $N_2$NE, $E_2$SE, $W_2$SW

T. 5N., R. 20E.
Sec. 2: $E_2$SE
Sec. 6: Lots 2, 3, 5, 6, 7, SWNE, SENW
Sec. 19: Lot 4, SESW, $S_2$SE
Sec. 20: $S_2N_2$, $S_2$

T. 5N., R. 22E.
Sec. 1: Lot 1, SWNW, NWSW
Sec. 3: Lot 2, SWNE
Sec. 4: Lots 1 to 4, SWNW, NWSW
Sec. 5: Lots 1 to 4, $S_2N_2$, NESE
Sec. 17: NWNW
Sec. 18: NENE
Sec. 19: SESE
Sec. 20: $W_2$SW, SESW
Sec. 21: NE, $E_2$NW
Sec. 29: NENE, NW, $N_2$SW, SWSW
Sec. 30: Lots 2 to 4, $E_2$SW, SENW, SE, $E_2$NE, SWNE

T. 5N., R. 23E.
Sec. 5: Lots 3 & 4
Sec. 6: Lots 3, 4, & 6, SENW, SWNE

T. 6N., R. 20E.
Sec. 21: SWSE
Sec. 28: $E_2$, SENW, NESW
Sec. 33: $E_2$
Sec. 34: $S_2$

* Explanation of abbreviations at end of table.

Table 1. State Lands with Some or all Mineral Rights
Owned by U.S. Government (cont.)

SSUSM*

Sec. 35: $W_2$

T. 6N., R. 22E.
Sec. 33
Sec. 35: NESE

T. 6N., R. 23E.
Sec. 31: $W_2$SE

T. 8N., R. 28E.
Sec. 3: NWSW
Sec. 6: Lots 4 & 5
Sec. 7: Lots 3 & 4
Sec. 10: NENW
Sec. 11: NWNE
Sec. 29: SWNW
Sec. 30: NWNE, $S_2N_2$

T. 8N., R. 29E.
Sec. 35: SWSW

T. 8N., R. 30 E.
Sec. 4: Lots 3 & 4

T. 8N., R. 31 E.
Sec. 35: SESW, $S_2$SE

T. 8N., R. 32E.
Sec. 19: SESE
Sec. 20: NWSE
Sec. 24: NWNE, SENW
Sec. 26: NWSW
Sec. 27: SWNW
Sec. 31: Lots 3 & 4, SESW, SWSE
Sec. 34: $E_2$NW, SWNW, NWSW
Sec. 35: $S_2$NE

T. 8N., R. 33E.
Sec. 3: Lot 4
Sec. 8: NESE
Sec. 9: SENW, NESE
Sec. 18: Lot 2

T. 9N., R. 27E.
Sec. 18: Lots 1 to 4, $E_2W_2$, $E_2$
Sec. 19: $N_2$NE, NENW, Lot 1
Sec. 25: SENE
Sec. 34: NWNE
Sec. 35: $E_2$NE, $S_2S_2$

T. 9N., R. 28E.
Sec. 13: SWNE
Sec. 25: $S_2S_2$
Sec. 27: NESW
Sec. 29: $S_2$NW, SWNE
Sec. 30: $S_2$NE, SENW, Lots 2 & 4
Sec. 31: Lots 1 & 2, NWNE
Sec. 34: NWSW
Sec. 35: $E_2$NW, NESW, NWSE

T. 9N., R. 29E.
Sec. 1: Lot 4
Sec. 2: SWNW
Sec. 3: SENE, SE, $S_2$SW
Sec. 4: $S_2$SE
Sec. 9: NENE
Sec. 17: SENW
Sec. 18: $N_2$SE, NESW
Sec. 21: SENW
Sec. 31: $E_2$NE
Sec. 35: NWNE

T. 9N., R. 30E.
Sec. 2: SWNE, SENW, $E_2$SE
Sec. 12: NWNE
Sec. 13: SE, SENW, NESW
Sec. 15: $S_2$NW
Sec. 24: $N_2$NE, SWNE, $S_2$NW, $E_2$SW
Sec. 35: SWNW

T. 9N. R. 31E.

Table 1. State Lands with Some or all Mineral Rights Owned by U.S. Government (cont.)

SSUSM*

Sec. 7: SWSE
Sec. 8: SWNW, NWSW
Sec. 17: NESW, SWSW
Sec. 18: Lots 1 & 2, W$_2$SE
Sec. 19: Lots 1 to 4, E$_2$SW, W$_2$E$_2$
Sec. 20: N$_2$NW
Sec. 26: W$_2$SW
Sec. 27: S$_2$NE, NW, S$_2$
Sec. 28: E$_2$E$_2$, SWSE, S$_2$SW
Sec. 30: Lot 1, NENW, NWNE, SENE, SESW
Sec. 33: W$_2$NW, SW, S$_2$SE
Sec. 34: NE, N$_2$SE, SESE
Sec. 35: NWNW

T. 9N., R. 33E.
Sec. 13: NWNW
Sec. 14: NESE
Sec. 21: E$_2$NE
Sec. 22: NW, NWSW
Sec. 23: W$_2$NE, NWSE
Sec. 33: W$_2$W$_2$, NENW, SESW

T. 9N., R. 34E.
Sec. 20: NWNE
Sec. 26: W$_2$SW
Sec. 27: SWNW
Sec. 28: S$_2$NE, NW, N$_2$SW, N$_2$SE, SESE
Sec. 29: SENE
Sec. 34: N$_2$NW, SWNE, N$_2$SW, SESW

T. 9N., R. 37E.
Sec. 29: Lots 3 & 4
Sec. 30: W$_2$SE

T. 10N., R. 27E.
Sec. 19: Lot 2
Sec. 26: S$_2$SE
Sec. 34: SWNE

T. 10N., R. 28E.
Sec. 15: NWNE, W$_2$SE, SESW
Sec. 22: NWNE

T. 10N., R. 29E.
Sec. 1: SWSW
Sec. 2: S$_2$SE, NWSE
Sec. 9: NWNE
Sec. 10: NENW
Sec. 14: SWNE, SWSW
Sec. 21: SENW
Sec. 24: S$_2$SW
Sec. 25: NENE, NWNW, SWSE
Sec. 27: SENE, SENW
Sec. 29: SENW

Table 1. State Lands with Some or all Mineral Rights
Owned by U.S. Government (cont.)

SSUSM*

Sec. 34: NESE
Sec. 35: $E_2$NE, SWNE, NW, NWSW, $S_2$SW, SESE

T. 10N., R. 30E.
Sec. 19: Lot 1
Sec. 25: SESE

T. 10N., R. 32E.
Sec. 1: Lots 1 to 4, $S_2N_2$, $S_2$
Sec. 11: $E_2$, $E_2$SW
Sec. 12: $N_2$, NWSE, $N_2$SW, SWSW
Sec. 13: $E_2$NE, NESE
Sec. 14: NWNE, $E_2$NW
Sec. 24: SWSE
Sec. 25: $W_2$NE, SESE
Sec. 28: SWNE

T. 10N., R. 33E.
Sec. 3: SWNW, SWSW
Sec. 4: $S_2$SE, SESW
Sec. 5: NESE
Sec. 6: Lots 2 to 7, SWNE, SENW, $E_2$SW, $W_2$SE
Sec. 7: Lots 1 & 2, $E_2$NW, NWNE
Sec. 9: NE, $N_2$SE, SESE
Sec. 14: NWNE
Sec. 15: NWNE, $N_2$NW
Sec. 18: NENW
Sec. 19: SESW, $E_2$SE, SENE
Sec. 20: $W_2$SW
Sec. 29: $W_2W_2$, SENW, NESW
Sec. 30: Lot 3, $E_2W_2$, NE, $S_2$SE
Sec. 31: $E_2$NE, $N_2$SE
Sec. 34: NENE

T. 11N., R. 28E.
Sec. 1: Lots 1, 3, & 4, SENE, $S_2$NW, $N_2$SW, SESE
Sec. 2: SENE, $N_2S_2$, SESW, SWSE
Sec. 5: Lots 5, 6, 7, & 8
Sec. 9: SWNW
Sec. 10: NWNE
Sec. 11: NWNE, NENW
Sec. 12: NENE, $N_2$NW, SWNE

T. 11N., R. 29E.
Sec. 3: SWNE, SENW
Sec. 4: Lot 2, $S_2$NE, SENW, $N_2$SW, $W_2$SE
Sec. 6: Lots 3, 5, & 6
Sec. 18: SWSE

T. 11N., R. 33E.
Sec. 1: SWNW
Sec. 4: SENE
Sec. 7: NE
Sec. 8: $N_2$NW, SENW, NWSE

Table 1. State Lands with Some or all Mineral Rights
Owned by U.S. Government (cont.)

SSUSM*

Sec. 10: N$_2$SW, SESW, NESE
Sec. 15: SENW
Sec. 30: Lot 4
Sec. 33: SESW, SWSE

T. 11N., R. 37E.
Sec. 5: Lot 1

T. 12N., R. 28E.
Sec. 34: Lots 1 to 3, S$_2$SE
Sec. 35: N$_2$SW, Lots 1 to 12

T. 12N., R. 29E.
Sec. 20: Lot 7
Sec. 22: Lots 1 to 4
Sec. 25: Lots 2 to 4
Sec. 26: NWSE, SESW
Sec. 27: Lots 3, 6, & 7, E$_2$SW, SWSE
Sec. 31: N$_2$NE, S$_2$SE
Sec. 33: N$_2$NE, SWNE, NW, N$_2$S$_2$, Lots 1 to 4
Sec. 34: N$_2$NW
Sec. 35: Lots 2 & 3

T. 12N., R. 33E.
Sec. 1: SWNW
Sec. 14: SWSE, S$_2$SW
Sec. 20: E$_2$NW, SW
Sec. 23: W$_2$NE, SENE, NW, S$_2$
Sec. 24: SW, SWSE
Sec. 25: NW
Sec. 26
Sec. 27: E$_2$, SENW, NESW
Sec. 29: N$_2$NE
Sec. 34: E$_2$

T. 12N., R. 34E.
Sec. 12: SESW

T. 12N., R. 35E.
Sec. 1: Lot 1, SENE
Sec. 4: Lots 1 & 2, S$_2$NE, NWSW
Sec. 7: Lot 4
Sec. 9: SESE
Sec. 17: SWSW
Sec. 18: W$_2$NE
Sec. 22: SW
Sec. 27: E$_2$NW

T. 12N., R. 36E.
Sec. 5: Lots 3 & 4

T. 12N., R. 37E.
Sec. 5: Lots 4 & 5

Table 1. State Lands with Some or all Mineral Rights
Owned by U.S. Government (cont.)

SSUSM*

T. 2S., R. 29E.
Sec. 1: Lot 1, SENE, $E_2SE$
Sec. 10: $E_2W_2$, $W_2E_2$
Sec. 11: SE
Sec. 13: $S_2SE$, $W_2NW$, NWSW
Sec. 14: $N_2$
Sec. 15: SENE

PUSOG*

T. 1N., R. 20E.
Sec. 30: Lots 1 to 4

SSUSP*

T. 2N., R. 25E.
Sec. 4: SENE

T. 2N., R. 27E.
Sec. 30: $E_2W_2$

T. 8N., R. 35E.
Sec. 3: Lots 1 & 2

SSUSP*(cont.)

Sec. 4: Lots 1 & 2, $N_2SW$

T. 5S., R. 28E.
Sec. 23: $N_2N_2$
Sec. 24: $N_2N_2$

PCUSOG*

T. 4N., R. 20E.
Sec. 2: $E_2SE$
Sec. 5: NWSW

T. 4N., R. 21E.
Sec. 8: $S_2$

T. 5N., R. 19E.
Sec. 26: $W_2W_2$
Sec. 27: $E_2$

T. 5N., R. 20E.
Sec. 17: $N_2S_2$
Sec. 29: $S_2S_2$
Sec. 30: NENE

T. 7N., R. 20E.

PCUSOG* (cont.)

Sec. 35: $S_2SE$

T. 1S., R. 19E.
Sec. 19: Lot 1, NENW

SSUSP&S*

T. 8N., R. 35E.
Sec. 1: Lots 1 to 4

T. 8N., R. 36E.
Sec. 5: Lots 1 to 4
Sec. 6: Lots 1 to 4 & 11

T. 2S., R. 25E.
Sec. 22: $S_2SE$
Sec. 23: SW
Sec. 26: NW
Sec. 27: NE, $E_2NW$

T. 2S., R. 26E.
Sec. 23: NE, $N_2NW$, SENW, $S_2$

T. 2S., R. 27E.
Sec. 31: $E_2W_2$, $W_2E_2$

Table 1. State Lands with Some or all Mineral Rights
Owned by U.S. Government (cont.)

SSUSP&S*(cont.)

T. 3S., R. 27E.
Sec. 30: Lot 1, NENW

T. 4S., R. 28E.
Sec. 27: SWNE, $W_2$SE
Sec. 28: SWSE
Sec. 34: $S_2$NW, NE

T. 5S., R. 25E.
Sec. 1: $W_2$SE

T. 5S., R. 26E.
Sec. 6: Lots 3, 4, 5, 6&7, SENW, $E_2$SW
Sec. 7: Lots 1 to 4, $E_2W_2$, $E_2$

T. 5S., R. 28E.
Sec. 23: $S_2N_2$
Sec. 24: $S_2N_2$

T. 5S., R. 29E.
Sec. 35: $E_2$NE, SWNE, SE

T. 6S., R. 30E.
Sec. 3: Lots 1, 2, & 3
Sec. 4: Lot 2

SSUSOG*

T. 1S., R. 19E.
Sec. 29: $W_2$NE, $E_2$NW, $W_2$SW

SSUSOG, S, &P*

T. 1S., R. 27E.
Sec. 3: NWSE

T. 5S., R. 25E.
Sec. 1: Lots 1&2, $S_2$NE, $E_2$SE

T. 5S., R. 29E.
Sec. 7: NESW
Sec. 18: $E_2$NW

SSUSS*

T. 2S., R. 22E.
Sec. 14: SWNW, $W_2$SW

Table 1. State Lands with Some or all Mineral Rights
Owned by U.S. Government (cont.)

PCUSP*

T. 3S., R. 27E.
Sec. 6: Lots 6&7

PCUSS&P*

T. 3S., R. 27E.
Sec. 26: NW
Sec. 29: SW
Sec. 33: SWSW, NESW, SE
Sec. 34: $S_2$
Sec. 35: NWSW, SESW, SE

T. 4S., R. 27E.
Sec. 3: Lot 3, SWSW
Sec. 4: Lots 1, 3, &4, $S_2$NE, $S_2$NW, SWSW, SESE
Sec. 9: $E_2$NE, NWNE, SENW, $S_2$SE

PCUSOG&P*

T. 3S., R. 28E.
Sec. 17: $S_2$

SSUSOG&P*

T. 4S., R. 28E.
Sec. 25: $E_2$NE
Sec. 35: NW

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* Explanation of Abbreviations

SSUSM: State surface; U.S. minerals
PUSOG: Patented; U.S. oil and gas
SSUSP: State surface; U.S. potash
PCUSOG: Purchase contract; U.S. oil and gas
SSUSP&S: State surface; U.S. potash and sodium
SSUSOG: State surface; U.S. oil and gas
SSUSOG, S, &P: State surface; U.S. oil, gas, sodium, and potash
SSUSS: State surface; U.S. sodium
PCUSP: Purchase contract; U.S. potash
PCUSS&P: Purchase contract; U.S. sodium and potash
PCUSOG&P: Purchase contract; U.S. oil, gas, and potash

Table 2: Lands with None or Expiring State Ownership

PMC*

T. 4N., R. 24E.
- Sec. 1: Lots 2, 3, &4
- Sec. 2: Lots 1, 2, &3, NWSE, $E_2$SW

T. 8N., R. 33E.
- Sec. 5: Lots 3&4

T. 1S., R. 34E.
- Sec. 36

T. 1S., R. 35E.
- Sec. 2: Lots 10, 11, 12 (part), $N_2$SW, $W_2$SE
- Sec. 3: Lot 9 (part), NESE (part)

T. 5S., R. 30E.
- Sec. 20: NW

PCUSM*

T. 8N., R. 28E.
- Sec. 1: Lots 1 to 12

T. 8N., R. 29E.
- Sec. 6: Lots 3 to 12, SE, $E_2$SW
- Sec. 10: NE, $E_2$NW, $W_2$SE, $E_2$SW, SWSE

PCUSM* (cont.)

T. 8N., R. 31E.
- Sec. 1: $S_2$SW, SWSE
- Sec. 2: SESE
- Sec. 3: Lots 1 to 12, $N_2$SE, NESW
- Sec. 4: Lots 1 to 12
- Sec. 5: Lots 8&9, $E_2$SE, SWSE, $S_2$SW
- Sec. 7: NENE, NWSE
- Sec. 8: $W_2$NE, NENW

T. 8N., R. 32E.
- Sec. 3: Lot 3
- Sec. 4: Lot 7

T. 9N., R. 28E.
- Sec. 35: SESW, $S_2$SE

T. 9N., R. 29E.
- Sec. 30: Lot 4, SESW
- Sec. 31: Lots 1 to 4, $E_2$NW, $W_2$NE, $W_2$SE, NESW

T. 9N., R. 32E.
- Sec. 33: SESE

T. 10N., R. 27E.
- Sec. 24: $S_2S_2$, NESE
- Sec. 25: NWSE, SWNW, SW
- Sec. 26: $W_2$NE, $N_2$SE, NESW

* Explanation of Abbreviations at End of Table.

PCUSM* (cont.)

T. 10N., R. 28E.
Sec. 31: E$_2$NE, SWNE

PUSM*

T. 9N., R. 30E.
Sec. 27: NESW

T. 9N., R. 33E.
Sec. 31: NENE

T. 9N., R. 34E.
Sec. 20: SWSE
Sec. 29: NENE

T. 11N., R. 30E.
Sec. 6: Lots 1&2

T. 12N., R. 30E.
Sec. 30: Lots 1, 3, &5, SESW, S$_2$SE
Sec. 31: SENE, SENW, Lot 3, NWSE, SESE

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* Explanation of Abbreviations

PMC: Patented; minerals conveyed
PCUSM: Purchase contract; U.S. minerals
PUSM: Patented; U.S. minerals

# PERSONNEL AND ACKNOWLEDGMENTS

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It would have been impossible to have accumulated the data on the surficial deposits of the area in the time alloted for this project without the use of both published and unpublished geologic maps prepared by the State Highway Department. The cooperation of Arlon Lovelace and the geologists in his group is greatly appreciated. Much unpublished data used in the compilation of the ground-water map was supplied by the State Engineers Office.

With the exception of the sections on clay and shale and dimension stone (prepared by William L. Hawks) and ground water the final report was written by the principal investigator.

# GEOGRAPHY

East-central New Mexico is entirely in the Great Plains Province, but is characterized by a variety of land forms. On the east lies the New Mexico portion of the Llano Estacado or staked-plains, a plateau-like surface. This high plain slopes to the southeast from over 5, 000 feet on the north to below 4, 000 feet at the southern border of the map area (fig. 1). Remnants of this late-Tertiary-early Pleistocene surface now form the high, generally caliche-capped, buttes and mesas between the Canadian escarpment to the north and the Caprock escarpment on the south.

The Pecos River and its tributarties have dissected much of the western one-third of the area, but large remnants of a higher surface still remain west of the river. Projection of this surface indicates a once-continuous southeast-sloping plain connecting across the present Pecos River valley with the Llano Estacado to the east.

## Precipitation, Temperature, Census, Transportation, Energy

The average annual rainfall ranges from approximately 14 inches in the western one-half of the area to between 16 and 20 inches in the eastern one-half. The average yearly temperature is about 57°F.

A comparison of 1970 and 1960 census figures is given in the following table for the eight counties partially or totally included in the present study.

Table 3. Census Data, Area 7A

| County | 1970 | 1960 | Change |
|---|---|---|---|
| Chaves (1) | 43,335 | 57,649 | - 14,314 |
| Curry | 39,517 | 32,691 | + 6,826 |
| DeBaca | 2,547 | 2,991 | - 444 |
| Guadalupe | 4,969 | 5,810 | - 841 |
| Lincoln (1) | 7,560 | 7,744 | - 184 |
| Quay | 10,903 | 12,279 | - 1,376 |
| Roosevelt (1) | 16,479 | 16,198 | + 281 |
| San Miguel (1) | 21,951 | 23,468 | - 1,517 |
| Totals | 147,261 | 158,830 | - 11,569 |

(1) Only a small percentage reside in Area 7A

## Transmission lines

Electrical energy, pipelines, paved roads, railroads, and airport facilities are shown in Figures 2, 3, 4, and 5.

# REGIONAL GEOLOGY

Rocks underlying east-central New Mexico range in age from Precambrian to Recent, but parts of geologic time are either not represented by rock units or are present only locally. There are no sediments of Cambrian age; Ordovician, Silurian, and Devonian rocks are restricted to the extreme southeastern part of the area; only thin remnants of Mississippian strata are present; and Jurassic and Cretaceous sediments are only locally preserved. Rocks older than Permian in age are not exposed in the area occurring only in the subsurface.

Regionally the rocks dip at a low angle to the southeast. There are very few faults exposed at the surface, and these with the exception of Bonita Fault have very small displacement. The numerous anticlines and synclines are generally rather broad structural features with low dips and little closure. Older structural events that occurred during Pennsylvanian and Permian time were much more intense, but have been smoothed over by sedimentation during Permian and Triassic time.

## Stratigraphy

### Quaternary

Only a few of the possible subdivisions of the Quaternary are indicated on the geologic map (fig. 1). Alluvial deposits (Qal) are shown only in the present major drainage areas or in the small lakes. Except in the larger stream beds and bordering the caprock where gravels occur, sediments consist primarily of sands and silts.

Eolian deposits (Qd.) cover large areas of the Llano Estacado, particularly bordering the Portales Valley. Dune sands are generally red or pink in color. The sand grains are mostly quartz and usually are fine to very fine in size. Considerable silt also is present.

Terrace deposits (Qt) of coarse gravel border the Pecos River, particularly south of Alamogordo Reservoir. The gravels are composed of resistant rock types such as quartzite, chert, silicified limestone, and a variety of igneous rocks.

Higher alluvial deposits (Qab) form a thin veneer of unconsolidated sediments overlying bedrock on the divides between the present drainageways. For the most part these sediments are fine-grained, reflecting the nature of the material source. They consist of a mixture of fine sand, silt, and clay usually derived from the easily eroded rocks of Triassic age. Almost everywhere these deposits contain a minor percentage of fine gravel, either of resistant types or of caliche-cemented sandstone fragments. Caliche also is present as small, soft nodules and as thin, crumbly, discontinuous lenses.

Hard, resistant beds of caliche (QTc) cap most of the upland surfaces such as the Llano Estacado and the plains west of the Pecos River. On the Llano Estacado caliche is included in the Ogallala Formation (To). This caliche very likely was deposited at the same time as the caliche mapped as (QTc) west of the Pecos River.

The caliche is white, gray or brown in color and consists of a mixture of calcium carbonate with varying amounts of sand and silt. The older caliche is generally banded, pisolitic, and hard. The percentage of caliche decreases downward into the underlying gravels, sands or older carbonates. Some fairly continuous beds of hard caliche occur at altitudes below that of the late Tertiary plain, indicating a second period of sustained caliche development. Rapidly changing conditions during the period of dissection that followed the older caliche development resulted in these deposits being local in extent.

Tertiary

The Ogallala Formation (To) underlies most of the Llano Estacado. It consists of a mixture of sand, silt and gravel from a few feet to as much as 200 feet thick. The sediments were deposited by braided streams on a broad slightly dissected plain sloping east and south away from the uplifting Rocky Mountains. Although the Ogallala Formation is restricted to the area east of the Pecos River, some of the caliche-cemented gravels west of the river were undoubtedly deposited at the same time.

Igneous Rocks

Small dikes and possibly plugs of igneous rocks were intruded into the older sediments during Tertiary time. Only two areas of igneous intrusions of this age are known. The more extensive is located east of Yeso in the southwestern part of the area. The other occurs northeast of Santa Rosa. The rocks in both areas are basaltic in composition.

Cretaceous

The most extensive exposures of Cretaceous sediments are found west of Tucumcari on Mesa Rica and both sides of U. S. 66. Most of the higher buttes and mesas south of U. S. 66 are either capped by Cretaceous rocks or the Cretaceous is preserved beneath the Ogallala Formation. Cretaceous rocks are present locally along the escarpment of the Llano Estacado particularly in the cliff faces of the semi-detached Louisiana Mesa and in the Bonita Fault area.

Fairly extensive exposures are present along the headwaters of Alamosa Creek near the western edge of the Caprock.

The Cretaceous rocks of the area have been subdivided into the Tucumcari Shale at the base, the Mesa Rica Sandstone, and the Pajarito Shale. The maximum thickness of Cretaceous sediments is on the order of 900 feet but varies considerably in short distances as a result of pre-Ogallala erosion. It is not known how extensive Cretaceous rocks are beneath the Llano Estacado, but well data indicates that beds of this age are of very limited extent. On the map, Cretaceous rocks (K) are locally combined with sediments of Jurassic age (KJ).

## Jurassic

Jurassic sediments (J) include a basal sandstone interval, equivalent to the Entrada Sandstone, and an overlying sequence of sandstones and shales correlated with the Morrison Formation.

The distribution of Jurassic rocks is essentially the same as the Cretaceous strata. Cretaceous rocks overlap the Jurassic to the south and rest directly on the Triassic along Alamosa Creek.

Jurassic beds thin to the south and east, probably as a result of both non-deposition and truncation of the Morrison Formation. East along the caprock escarpment Morrison beds are missing and the Jurassic is represented by the Entrada Sandstone. The maximum thickness of Jurassic rocks is from 300 to 500 feet.

## Triassic

Triassic rocks are subdivided into the Santa Rosa Sandstone (Ꞧs) at the base and the Chinle Formation (Ꞧ) above. Large areas of east-central New Mexico are underlain by rocks of this age.

The Santa Rosa Sandstone forms bluffs along the Pecos River, particularly from Fort Sumner north. The interval consists of conglomerate, sandstone, and shale of varying thickness. As can be seen on the isopach map (fig. 6) the sandstone is best developed in the northern part of the area. It thins to the southeast and is not recognizable from Portales to south of Dora.

The Chinle Formation consists of alternating beds of siltstone, sandstone and shale with minor conglomeratic intervals and a few thin impure beds of limestone. A prominent sandstone sequence in the lower part of this unit forms a stripped cuesta-like surface over large areas from Santa Rosa east to Montoya along U. S. 66. This same sandstone caps many mesas and buttes in the area west of State Road 129.

It is difficult to obtain any accurate outcrop data on the thickness of the Chinle Formation because of the broad area of exposures. Very few oil tests drilled in the area begin in the overlying Jurassic rocks so only a rough estimate can be gained from this source of information. The maximum thickness appears to be on the order of from 1,000 to 1,200 feet; although it may be as much as 1,500 feet thick in the southeastern part of the area.

## Permian

The stratigraphic nomenclature applied to the Permian rocks of east-central New Mexico is in general the standard usage of central New Mexico. In ascending order these units are; Abo Formation, Yeso Formation, Glorieta Sandstone, San Andres Formation, and Artesia Group.

No attempt was made to subdivide the Artesia Group (Pat) into the various formations recognized to the south. In the southeastern quarter of the area equivalents of Permian rocks younger than the Artesia Group have been included in this interval.

The Artesia Group is widely exposed west of the Pecos River. It consists of an alternating sequence of red sandstones and shales and beds of white gypsum. In the subsurface in the eastern part of the area the Artesia Group contains numerous beds of salt. Sediments included in this unit are about 200 feet thick in the northwestern part of the area but thicken to the southeast to over 1,300 feet.

Carbonates and evaporites of the San Andres Formation (Psa) are exposed in the southwestern part of the area and in small patches in the northwest. The Glorieta Sandstone has been combined with the San Andres Formation in this report. Although recognizable as a separate formation to the west it is a facies of the San Andres Formation. To the east the sandstones grade into dolomites, and the Glorieta interval loses its identity. In addition to the rather remarkable Glorieta facies change to the east there are other lateral changes in rock type within the San Andres Formation. Salt beds are widely distributed in the subsurface but locally grade rapidly into either dolomite or anhydrite.

San Andres-Glorieta beds thicken east and south from 400 feet northwest of Fort Sumner to from 1,300 to 1,800 feet (fig. 7).

The Yeso Formation does not crop out in Area 7A. Subsurface studies reveal a complex sedimentary sequence including a variety of sandstones and shales, plus anhydrite, gypsum, salt, and dolomite. Similar to the Artesia Group and the San Andres Formation the clastic-evaporite-carbonate sequence of the north and west changes to the south and east to one dominated by carbonates and evaporites. However, similar to the Artesia Group clastic sediments continue to make up an important part of the interval, particularly in the upper one-half of the formation. The Yeso

Formation thickens from around 1,100 feet along the northern edge of the study area to over 2,000 feet in the south.

Dark red shales and light red to orange arkosic sandstones and conglomerates make up the Abo Formation. To the southeast these rocks in part grade into dolomites generally referred to as the Wolfcamp Formation. For convenience the Wolfcamp dolomites have been combined with the underlying marine sediments of Pennsylvanian age. Without some additional fossil determinations such as spores or fusulinids it is extremely difficult in many areas to select a contact between the Abo Formation and sediments of Pennsylvanian age. It was arbitrarily decided to base the top of the Pennsylvanian on the first appearance of black shale or marine limestone. Below this there may be several hundred feet of beds similar in composition to the Abo Formation, and in many instances the top as selected, occurs in beds of lower Permian age.

The coarse arkosic material of the Abo Formation was derived from the uplift of the Ancestral Rocky Mountains and associated uplifts such as the Pedernal and Sierra Grande arches to the west and north respectively. The amount and size of coarse material in the Abo decreases to the south and east.

Because of the major tectonic events that took place prior to and during deposition of the Abo Formation, the thickness varies considerably. However, even taking into account the exclusion of Wolfcamp carbonates, there is a marked southward thinning in contrast with the rest of the Permian sequence. In the south, Abo sediments are much less than 1,000 feet thick. To the north, the Tucumcari basin (fig. 8) was largely filled by sediments of the Abo type although the age of some of this material may be Pennsylvanian. In this area the coarse clastics and red shales of the Abo Formation approach 2,000 feet in thickness.

Pennsylvanian

Strata of Pennsylvanian age vary considerably in rock type and thickness. The sediments that filled the Cuervo subbasin are largely black shales and white arkosic conglomerates, and sandstones. Only minor limestones and quartz sandstones are present in this basin. To the south the sequence consists of alternating beds of limestone, shale, and sandstone that grade upward into the arkoses and red shales of the overlying Abo Formation. Rocks of Pennsylvanian age are absent on the higher parts of the Sierra Grande uplift that extend into the area from the north (figs. 8, 9). They also are locally absent in the southeast on the Matador uplift. Here the thickness shown on the isopach map refers to carbonates of the Wolfcamp Formation.

The maximum thickness of marine or largely marine Pennsylvanian rocks is in the Cuervo subbasin, where these sediments measure over 3,500 feet. Elsewhere, even when combined with marine sediments of Permian age, these strata are less than 2,000 feet thick. In the western part of the area thinning is the result of non-deposition combined with various erosional cycles on the east slope of the Pedernal uplift.

Pre-Pennsylvanian

Pre-Pennsylvanian sediments are preserved in the central part of Area 7A (fig. 10). The sediments around Santa Rosa are limestones and minor clastics of Mississippian age. The maximum thickness of these rocks is about 150 feet. In the extreme southern part of the area limestones, dolomites, and shales of Mississippian, Devonian-Silurian and Ordovician age are present. These rocks, with a maximum thickness of 800 feet, represent the erosional edge of much thicker deposits to the south. In the central area between Taiban and Melrose, meager well information indicates thin sections of Mississippian limestone. Whether these are local remnants encountered in drilling or are connected with the northern and southern deposits as indicated on the map is not known.

Precambrian

Pre-Pennsylvanian, Pennsylvanian or Permian sediments overlie the Precambrian in various parts of the area. These rocks have been reached by only a relatively few wells. Whereas in many parts of New Mexico large areas of Precambrian rocks consist of granite, a variety of rock types are present beneath the east-central part of the State. Although the datum is sparse it appears that much of the Precambrian terrane consists of basic igneous rocks such as gabbro and diabase, metamorphic rocks, and in the eastern part late Precambrian rhyolites.

## Structure

The contour map on the surface of the Precambrian (fig. 8) shows the major structural features of the area. Except for the general southeast slope of the surface these structural features were developed primarily during late Pennsylvanian to early Permian time.

The western margin of the Palo Duro basin occupies much of the area. It terminates on the west against the gentle east slope of the Pedernal uplift. On the north lies the southern edge of the Sierra Grande uplift; and on the south is the northern margin of the Matador uplift.

Two relatively small but prominent depressions are present in the northwest part of the Palo Duro basin. These have been labeled the Cuervo and Tucumcari subbasins. The time of formation of these basins is questionable but it appears that the Cuervo subbasin developed earlier than the Tucumcari depression. A comparison of the isopach and structural contour maps of the Pennsylvanian-Wolfcampian intervals (figs. 9, 11) tend to support this conclusion. However there is a lack of conclusive data as to the exact ages of the rocks that fill the depressions.

By the end of deposition of Abo sediments, the relief on the Precambrian surface was essentially smoothed over. The structural contour map on top of the San Andres Formation (fig. 12) only vaguely reflects the underlying structural features and no correlation can be seen between the buried Precambrian surface and the structural contour map on the Santa Rosa Sandstone (fig. 13).

Later structural events related to the Larmide orogeny produced the general southeast dip and minor faults and folds. The only feature with appreciable displacement is the Bonita fault. Numerous anticlines are present in the area but most have rather small closure. In addition to the structures of this type that have been mapped, there are numerous others, particularly north of U. S. 66 between Santa Rosa and Tucumcari. Detailed surface mapping would be necessary to delineate these features.

# ECONOMIC GEOLOGY

Topic headings in the following discussion are based on mineral commodity groupings in the lease regulations of the State Land Office. In some respects this was not convenient and in a few cases it was not clear as to where some materials should be placed. However, it seemed best to follow this system because of the use of the report by personnel of the State Land Office.

## General Mining Leases

These leases cover all rocks, minerals, and elements except potassium, sodium, sulfur, phosphorus, and other minerals of similar occurrence, and their salts and compounds; plus salt, oil and gas, carbon dioxide, helium, coal, shale, clay, gravel, building stone, and building materials. It therefore includes all the metallic elements and their compounds such as antimony, aluminum, arsenic, beryllium, bismuth, cadmium, chromium, cobalt, niobium, tantalum, copper, germanium, gold, iron, lead, lithium, manganese, mercury, molybdenum, nickel, platinum, silver, selenium, tellurium, thorium, tin, titanium, tungsten, uranium, vanadium, and zinc. Also included here are such industrial rocks and minerals as asbestos, barite, feldspar, fluorspar, cryolite, gemstones, graphite, magnesite, brucite, mica, optical calcite, sillimanite, kyanite, talc, vermiculite, zirconium, and hafnium. The list at the head of the computer data sheets for general mining leases (table 4) is not complete but the few mineral commodities not listed can be grouped with those considered not present. The hydrocarbons included here refer to solid hydrocarbons such as gilsonite and jet that normally occur in vein-type deposits.

Although almost all metalliferous ores owe their origin to igneous activity, and particularly to hydrothermal solutions associated with this activity, some deposits may be concentrated in sedimentary rocks by ground-water movement, chemical weathering or direct precipitation during the time the rocks were deposited. These include copper, uranium, vanadium, thorium, aluminum, iron and manganese. In addition, important deposits of gold, platinum, titanium, and tin are found concentrated in placers. Most placer deposits, however, usually occur in the immediate area of the igneous host rocks. Of the elements listed above only copper and uranium are commonly found associated with the type of sedimentary rocks deposited in east-central New Mexico. Iron is very widespread throughout the area, imparting the red color that characterizes much of the rock sequence. The amount of iron present, however, is very low, in most cases amounting to less than 1 percent of the rock.

Igneous rocks and associated hydrothermal replacements and veins that might contain important deposits of most of the metals listed under general mining leases are not found at the surface in east-central New Mexico. Rocks of this type underlie the entire area but at depths of from 4, 000 to more than 8, 000 feet. In the few wells that have penetrated to these Precambrian rocks no mineralization has been seen.

Titanium minerals occur in many of the sandstone deposits in the area but nowhere were they observed to be concentrated as in some of the Cretaceous sandstones of the San Juan Basin[1].

Other rocks and minerals listed under general mining leases include barite, asbestos, gemstones, fluorspar, graphite, magnesite, optical calcite, rare earths, sillimanite, kyanite, vermiculite, and talc. Again these materials owe their origins to either hydrothermal or metamorphic processes that have not occurred in this area since

Precambrian time. Therefore it can be safely stated that they are not present in the post-Precambrian sediments of this part of the State. Clastic grains of feldspar are very common in sandstones of Triassic, lower Permian, and Pennsylvanian age but have no commercial value as a source of feldspar.

From the preceding statements it can be determined that the only minerals of possible economic value in this section are copper, uranium, and possibly some associated silver, vanadium, and thorium.

## Copper

Copper deposits of the type occurring in east-central New Mexico are commonly referred to as "sedimentary", or "red-bed" copper. Three deposits in Area 7A have been worked on and off for many years. The one from which the greatest amount of copper has been produced is the Stauber mine. The mine is in the Pastura Mining district and is located in sec. 6, T. 7 N., R. 20 E. The host rock at the Stauber mine is the Santa Rosa Sandstone. The most important copper minerals are chalcocite, covellite, malachite, azurite, and chrysocolla. According to Anderson (1957) production from 1925 to 1954 amounted to 11,333,300 pounds of copper; 7,363 ounces of silver, and a small amount of lead. The association of silver with copper appears to be fairly common in these types of deposits, but very little analytical work has been done on New Mexico occurrences.

Recently in Oklahoma and Texas it has been discovered that the shales adjacent to the mineralized sandstones also contain copper and silver in commercial quantities. Spectrographic analyses of 12 channel samples of shales collected at the Stauber pit, however, failed to reveal any copper or silver mineralization.

Several parcels of State lands are favorably located near the

Stauber mine. These are secs. 1, 2, 3, 10, 11, 12, and 13, T. 7 N., R. 19 E.; secs. 25, 26, 35, and 36, T. 8 N., R. 19 E.; and sec. 32, T. 8 N., R. 20 E. All of these tracts are underlain by the Santa Rosa Sandstone. On-site examinations disclosed no mineralization on the surface, but the potential for additional copper deposits in the general area is good. Drilling and geophysical investigations would be necessary to fully determine the value of these lands.

During field investigations from June to September, intermittent exploratory work, particularly coring, was being conducted at the Stauber deposit.

A second deposit of this type occurs in the lower part of the Artesia Group and in the San Andres Formation in the southwestern corner of sec. 13, T. 8 N., R. 19 E. This small prospect, known as the Pintada mine, also was being worked on a small scale during the summer of 1970. Several State sections are located within two miles of this property.

From 1910 to 1919 copper prospecting took place on claims located in secs. 22, 23, 24, 28, 29, and 33, T. 9 N., R. 33 E., and in sec. 18, T. 9 N., R. 34 E. (Soulé, 1956). An analysis of a dump sample from this area by the U. S. Bureau of Mines showed 0.03 percent copper. The prospects are along the Bonita fault where post-Santa Rosa, Triassic sandstones have been locally silicified.

In Figure 14 favorable exploration areas for copper have been blocked out. Although all of the eastern two-thirds of the area are underlain by Triassic and Permian rocks that might contain copper, these sedimentary units are too deeply buried in much of the area to be considered favorable. The best areas for exploration are based on outcrops of those units known to host copper deposits, or where these units occur at shallow depths. The ratings given in Table 4 are based on these possible exploration areas.

Silver, although associated with the copper deposits at both the Stauber and Pintada mines is rated as not present because it is unlikely that it occurs in economic deposits anywhere in Area 7A.

Uranium

The major uranium deposits of the western United States occur in sedimentary rocks. In general, it is thought that uraniferous low temperature hydrothermal solutions are responsible for the original introduction of uranium. Subsequent to this the uranium was redistributed by ground water and concentrated in areas chemically favorable for deposition.

Two small uranium deposits in east-central New Mexico were mined on a small scale prior to 1956 (Griggs 1955). The Lucky Group prospect is located in sec. 6, T. 7 N., R. 32 E., Quay County. The mineralization occurs at the base of a gray conglomeratic sandstone that occurs in the lower part of the Chinle Formation. The estimated U content ranged from 0.10 to 0.15 percent. The second prospect was the Bel Aro, located in sec. 24, T. 11 N., R. 28 E., Quay County. Here uranium mineralization occurs in a channel sandstone in the Morrison Formation.

During 1970 drilling was being done south of Taiban on property of the Triangle Cattle Co. Outcrops in the area are in the lower part of the Chinle Formation and probably occur in approximately the same sandstone unit as at the Lucky Group. This sandstone appears to underlie most if not all of Area 7A except where Triassic rocks have been removed by erosion. It was recognized in cuttings from several oil tests and is considered to be the lateral equivalent of the cuesta-forming sandstone discussed in the geologic section of this report. Numerous small shows of uranium have been reported from this interval in eastern New Mexico and a similar stratigraphic unit in West Texas.

The Lucky Group prospect is located on State land and there are numerous other favorable sections in the immediate vicinity. Several tracts of State lands are present in the vicinity of the Bel Aro prospect and are underlain by the Morrison Formation, the host rock in this area.

No vanadium or thorium have been reported from the uranium deposits of east-central New Mexico.

Favorable exploration areas for uranium are shown in Figure 15. These areas were used as a basis for evaluating uranium possibilities on State lands.

## Gypsum, Clay, Sand, Gravel, Caliche, Stone, Shale, Pumice, and Perlite.

Materials included in this section, many of which have several or overlapping uses, are primarily important in various phases of the construction industry. Because of this, an explanation is given for each commodity based on the use considered in this report and the resultant evaluations given in Table 5. The materials as grouped in the table include gypsum and anhydrite, limestone and dolomite, clay and shale, sand, gravel, caliche, dimension stone, crushed stone, pumice, perlite, scoria and cinders, diatomite, oil shale, and bedded asphalts. The inclusion of oil shale and diatomite in this section was arbitrary.

### Gypsum and Anhydrite

Time did not allow for separate treatment of gypsum and anhydrite. Where calcium sulfate is present at the surface the beds are invariably gypsum. Where buried at any appreciable depth anhydrite is the rock type normally found. Beds of anhydrite at any depth may be partly hydrated to gypsum if the anhydrite is in contact with water-bearing strata.

Gypsum beds of minable thickness are found in the Artesia Group, San Andres Formation and Yeso Formation. Gypsum present in the Yeso Formation is at considerable depth and such huge reserves are available from shallower beds that these deposits were not considered in the evaluation of this commodity.

Structural contour maps on top of the highest bed of gypsum or anhydrite were prepared for the Artesia Group (fig. 16), San Andres Formation (fig. 17), and Yeso Formation (fig. 18), by subtracting the altitudes shown by the contours from the surface altitudes the depth to gypsum-anhydrite can be calculated.

Surface exposures of gypsum are present in the western part of the area. Where occurring on State lands, evaluation is based on thickness and possibility of using open-pit mining methods. The field evaluations assigned to the deposits were up-graded if additional suitable beds were present at shallow depths in the same general area.

Elsewhere, where gypsum beds are buried by Triassic and younger sediments, evaluation was based on a combination of factors such as thickness, depth, and overlapping of favorable deposits in the Artesia Group and San Andres Formation.

As can be seen on the contour maps, the depth to gypsum increases at a gradual rate to the east and south. South of T. 4 N. thick gypsum beds, at depths of less than 500 feet, are present as far east as T. 27 E. in the Artesia Group. Suitable beds in the San Andres Formation at less than 500-foot depths occur in the south to R. 25 E. and vary in the north from R. 20 E. to R. 24 E.

Gypsum, like salt, depends to a large extent on the local market and particularly the construction industry which consumes nearly all of the U. S. production. At present east-central New Mexico is too sparsely settled to expect mining of the deposits in this area. Markets in California and Texas can be supplied from deposits much closer than those of Area 7A. For local use more than adequate reserves are present for any projected population growth.

Limestone and Dolomite

Limestone or dolomite is used as crushed stone, fluxing agents, soil conditioners, source for lime, chemical raw materials, and dimension stone (Bates, 1960). Dolomite is not used as raw material for the manufacture of Portland cement, but dolomite or dolomitic limestone is used for refractory material.

Beds of limestone or dolomite occur in several stratigraphic intervals. The surficial caliche deposits of the caprock and elsewhere are impure mixtures of calcium carbonate and sand. A few thin beds of impure limestone are found in rocks of Triassic and Jurassic age, and thin beds of dolomite occur locally in the Artesia Group. The thickest and most extensive beds of carbonate rock are in the San Andres Formation. These sediments crop out along the western margin of Area 7A and constitute the only potentially economic deposits of limestone-dolomite in the area.

On the surface the carbonates of the San Andres Formation consist of dolomitic limestone that grade in the subsurface into dolomites. They commonly contain a rather high percentage of acid insoluble material particularly organic matter. In addition some beds contain considerable quartz sand and others a high percentage of gypsum-anhydrite.

These deposits are suitable as crushed stone for road construction or concrete aggregate although the organic content of some of the beds may be detrimental for the latter use. High-purity stone is preferred for calcining in the preparation of lime, making this use questionable. Finely pulverized it would be suitable for agricultural "lime" and beds with little silica might be useful as a fluxing agent in the smelting of ores. Dolomites in the subsurface are probably not of high enough purity for use as a refractory.

Distance to markets and impurities in most of the San Andres dolomites preclude many of the uses discussed above. The exception to this is as a crushed stone for highway aggregate and as dimension stone. These uses are rated separately on the evaluation sheet. Thus the rating under the limestone-dolomite column refers only to possible use as agricultural "lime", fluxing agents, or as refractory material.

## Clay and Shale

Clays may be classified in many ways --- the clay minerals present, the products made from the clay, the fired color of clay, etc. The clays discussed in this report are evaluated primarily by their possible use. Many geologic terms, such as clay, shale, mudstone, siltstone, bentonite, and claystone, are used to identify rocks containing clay minerals. In this report all rocks containing sufficient clay minerals to produce a plastic, workable mixture when finely ground are considered clays.

Clay materials have been used to produce structural clay products in this section of New Mexico for many centuries. The early inhabitants used the sandy alluvial clays from almost any section of the area for making sun-dried adobe brick. The nearest plant for the production of fired common and face brick was located in Las Vegas, N. M. This plant is no longer in operation. Preliminary tests indicate the shales from the lower Chinle Formation would be suitable for use in the manufacture of building brick and sewer pipe. The lower Chinle is exposed in three general areas.

(1) From the northwest corner of the area east to Mesa Rica
(2) North of U. S. 66 from Tucumcari east to the Texas border
(3) Just east of the Pecos River from Colonias, through Santa Rosa, to about 20 miles south of Fort Sumner.

Refractory clays, or fire clays, are used in the manufacture of fire brick and premium grade, buff-colored face brick. Kaolinite is the predominant clay mineral present in typical fire clays. Preliminary testing of the Pajarito Shale of Cretaceous age prove it to be a plastic clay burning to a light buff color. This clay would be suitable for use in premium-grade, light-colored face brick, and possibly as a fire brick. The softening temperature has not yet been determined, therefore the grade of fire brick which could be manufactured is unknown. Another possible source of fire clay is the shale found just below the Mesa Rica Sandstone. Exposures of this shale are poor and in all cases the massive Mesa Rica Sandstone would have to be removed before mining the shale. The shale consists of clean, rounded quartz, sand grains in a matrix of kaolin. Further investigation would be required to determine the purity of the components and a method of separating the two. Both the Pajarito Shale and the shale below the Mesa Rica Sandstone might be found wherever the Mesa Rica Sandstone is exposed. This would include the following areas:

- Mesa Rica, which is west of Tucumcari and north of U. S. 66
- Palomas Hills south of U. S. 66 at Palomas
- Louisiana Mesa south of Montoya
- Just below the caprock north of Grady

In the evaluation tables, clays were rated (6) where the above stratigraphic intervals crop out. This implies a possible use potential but indicates a lack of sufficient data for more precise grading.

Sand

Sand as considered here, and as evaluated in the tables, refers for the most part to high quality sand deposits. These are the high-silica sands used as a source for molding and glass sands and other special purposes. These types of sands are normally obtained from beds of sandstone. Although sandstone is one of the most extensive rock types found in east-central New Mexico very few appear to be of high enough quality for the uses outlined above. A possible exception to this are the sandy clays and sandstones in the upper part of the Morrison Formation on Mesa Rica. Here kaolinitic clays contain grains of quartz that constitute from less than 10 to over 50 percent of the rock. Analysis of this unit has not been completed, and as pointed out in the preceding section on clays, appears everywhere to underlie the massive Mesa Rica Sandstone making open-pit mining impractical. This part of the Morrison Formation does, however, deserve additional critical investigation.

Dune sands not of a quality suitable for the above purposes, are widespread in Area 7A. Because they are useful for highway purposes they have been given a fair (3) rating on the evaluation sheets.. Use of some of these sands in cement mortar would be questionable because of iron oxide coatings and in most areas examined fair amounts of silt-size material. Sand suitable for concrete aggregate is generally available in the various gravel deposits discussed in the following section.

## Gravel

Gravel deposits suitable for road or concrete aggregate occur in many parts of the stratigraphic section and at numerous places in Area 7A. Conglomeratic sandstones and conglomerates containing resistant rock types are generally present in the Santa Rosa and Mesa Rica Sandstones. Extensive gravel deposits make up the terraces bordering the Pecos River and are found in many of the smaller dry creek beds, particularly those that cut the Ogallala Formation. This unit contains thick beds of gravel all along the caprock but, where in place, the clasts normally are coated with caliche making the material unsuitable for aggregate. Natural removal of the caliche coating requires only short transport from the outcrop by the intermittent streams, and suitable deposits can readily be found in most areas below the caprock.

On the Llano Estacado usable deposits of gravel seem to be restricted to the Portales Valley. A privately owned deposit is being worked just north of Portales, and it is probably much more extensive than exposures and mining operations have disclosed.

The evaluation of this commodity on State lands is based on quality and apparent quantity. Examination of the evaluation table readily shows the best areas to obtain this material on State lands.

There appears to be a more than adequate supply, except on much of the Llano Estacado north of U. S. 66 from just east of Santa Rosa to the State line, and in outcrop areas of the Artesia Group and San Andres Formation.

## Caliche

Caliche is so wide spread in the area that it was considered separately in this report. The only commercial use of the caliche deposits has been for crushed stone in highway construction, and ratings given in the evaluation table for this commodity are restricted to that use.

Deposits of caliche vary from coatings on gravel, through soft silty nodules, to thin beds of soft material, to thick beds of laminated and pisolitic, hard, calcium carbonate. Invariably beds of caliche contain some gravel, sand, silt, or clay. Only the hard, relatively pure beds of caliche are used as a source for crushed stone. Beds of this type are widely exposed along the margins of the Llano Estacado and at many places on the surface of this broad plain. Rating of caliche on the Llano Estacado surface was difficult in some areas because of soil or other alluvial cover. The assumption that caliche was present at shallow depth over much of the area is supported by graded exposures along roads north of U. S. 60, and along streams such as Running Water Draw and Alamosa Creek. Part of the Portales Valley and the area as far south as Elida lie below the caliche surface.

Caliche covers large areas west of the Pecos River, and as mentioned previously, this is thought to have developed on the same surface as the Llano Estacado. Many isolated mesas and buttes south of U. S. 66 are erosional remnants of this surface and are capped by similar caliche deposits.

North of U. S. 66 from the west edge of the area to the State line there are only isolated areas of this surface preserved. These include Mesa Rica and West Mesa. Elsewhere north of U. S. 66, caliche though present almost everywhere, is not of commercial quality.

Locally in the Pecos River and Portales Valleys younger caliche deposits are consolidated and thick enough to be of value for local use as a crushed stone.

## Dimension Stone

Dimension stone is broken or cut stone used for constructing buildings, walls and ornamental structures. Because of its weight stone cannot be shipped long distances unless it has high architectural value. There are no high quality stones such as granite or marble in this area.

Many of the early inhabitants, and later the homesteaders, built their homes of sandstones of the Santa Rosa and Chinle Formations or limestones of the San Andres Formation found on or near their property. Another limited use for sandstones of the Chinle was as headstones in the many family and village cemeteries scattered throughout the area. Extensive use of adobe brick and the limited market precluded the need for a commercial rock quarry to service the area. Other factors affecting the development of a stone industry are the poor weathering characteristics and unattractive colors of most of these rocks.

Cretaceous sandstones have been used for construction in other parts of the State, however, the Mesa Rica Sandstone found in this area is too friable to be of value as a building stone. Jurassic sandstones also are loosely cemented and would be of no value as dimension stone.

## Crushed Stone

Considered under this general heading are all rocks other than caliche and gravel that might be useful for aggregate. This includes various sandstones, carbonate rocks of the San Andres Formation, and the igneous rocks.

Sandstones are present in the Permian, Triassic, Jurassic, and Cretaceous sequences, and to a lesser extent, those of Tertiary age. With the possible exception of the limited exposures of Glorieta

Sandstone in the northwestern corner of the area (fig. 1) these sandstones are too weakly cemented for use as crushed stone. Locally, on mesa tops, the Mesa Rica Sandstone is case-hardened and appears fairly tough. This however, is only a surface characteristic and enough well-cemented material for quarrying operations would not be available.

As noted under the section on limestone and dolomite, many of the carbonate intervals of the San Andres Formation would be suitable for use as aggregate, at least for highway construction.

Outcrops of igneous rocks are limited to a few small exposures of basaltic dikes and possibly plugs. Several exposures of these rocks are present north of Cuervo and south of Dunlap (fig. 1). Although limited in amount of material exposed at the surface, these basalts would make excellent aggregate.

Crushed stone for use as concrete or highway aggregate is abundant in east-central New Mexico. When all suitable rock types such as caliche, gravel, basalt, limestone, and dolomite are considered, there are few areas where extreme haulage distances would be required.

## Pumice, Perlite, Scoria, Cinders

Rocks of this type are not present in east-central New Mexico.

## Diatomite

Diatomite is composed of the siliceous tests of aquatic plants called diatoms. They may occur in both fresh and salt water. Obviously to form in sufficient numbers to supply enough tests to develop an economic deposit the waters must be fairly high in silica. In addition the influx of other material such as sand, silt, and clay must be at a minimum. The possibility for these environmental conditions to have existed in east-central New Mexico are limited to the area of the Llano Estacado. Thin impure deposits of diatomite are known to occur in the Blackwater Draw area in sec. 25, T. 1 N., R. 35 E. and sec. 10, T. 1 S., R. 35 E. (Lohman, 1935). Some State land is located in the vicinity of the southern location but because of the poor quality and limited extent of the deposits a rating of (1) was given for this area. Other possible areas where data was lacking are rated (6).

### Oil Shale

There are no known deposits of oil shale in the area and geologic conditions that existed during deposition of the exposed stratigraphic units were not favorable for development of this type of material. Some of the dark shales in the Pennsylvanian sequence may contain sufficient quantities of insoluble bituminous material to be classified as oil shale, but the depth to these deposits is too great to consider any commercial use.

### Bedded Asphalts

Outcrops of asphaltic sandstone occur just north of Santa Rosa. These deposits are in the Santa Rosa Sandstone on the Preston Beck Grant in sec. 1, T. 9 N., R. 21 E. Asphalt is present over an area of approximately 14 square miles as determined for the most part by drilling. There is no State land in the immediate area and no additional occurrences of asphalt were found on the surface in the Santa Rosa Sandstone on State land in other parts of east-central New Mexico.

In the subsurface asphaltic limestone was observed in drill cuttings in the San Andres Formation at numerous places and asphaltic sandstones are present in the Glorieta Sandstone, Artesia Group, and Santa Rosa Sandstone. The economic potential of these buried deposits is considered to be poor.

Asphalt deposits were rated both on the basis of surface examinations and possible areas for exploration where favorable formations were at a shallow depth.

Potassium, Sulfur, Sodium, Phosphorus, and Other Minerals of Similar Occurrence and their Salts and Compounds (excepting, however, sodium chloride or common salt ).

Under this general heading are included the potash minerals (sylvite, langbeinite, carnallite, kainite, and polyhalite), native sulfur, the sodium minerals (trona, mirabilite, and thenardite); the borates (borax, kernite, colemanite, and ulexite); phosphorus minerals (collophane and apatite) and the rock form phosphorite; and the nitrates and bromines.

Potash

Potash deposits are associated with other evaporates such as salt and anhydrite. The important deposits of New Mexico are located south of Area 7A. Within the area of this study there have been numerous reports of the presence of polyhalite associated with halite beds. These reports for the most part are by drillers on oil tests. In many instances these reports are based on the driller assuming that if the mineral is red in color it is polyhalite. The red coloration is the result of minute amounts of iron oxide and common salt or polyhalite may be clear or red depending on the presence or absence of this compound. The gamma-ray curve on radioactive logs often will show the presence of potash minerals, and next to coring is the best method of determining the presence of this material in a drill hole.

In general the area is not considered favorable for potash. However, because of the presence of thick salt beds in the east, and the high solubility of potash minerals, making their preservation in drill cuttings remote, there exists some possibility for potash beds to be present.

On the data evaluation sheets potash has been rated with a (6) in some areas indicating "unknown, but that there is a potential for discovery" of these minerals. The map (fig. 19) used for evaluating potash is based on thickness and presence of salt in the Artesia Group and San Andres Formation.

## Sulfur

Native sulfur occurs elsewhere in geological environments somewhat similar to that of the Permian of east-central New Mexico. However, no occurrences have been reported in this area and none were seen during the present investigations. The east side would have the best potential for deposits, but in general, native sulfur is not considered to be present.

During the recent sulfur shortage anhydrite (calcium sulfate) was used as a source for elemental sulfur. All of Area 7A is underlain by beds of anhydrite and suitable areas are present where these beds would be at depth shallow enough for economic mining. The use of anhydrite from this area depends on several factors. Among these are: depletion of native sulfur deposits; demand increasing to the point where sulfur produced as a refinery by-product is insufficient to meet requirements; and more economical processes for isolating sulfur from anhydrite.

## Sodium, Borates, Nitrates, and Bromines

Sodium minerals of importance include the sodium carbonate, trona, and two sulfates, mirabolite and thenardite. The important occurrences in the United States are the sodium carbonate deposits of Wyoming in the Tertiary Green River Formation, and both carbonates and sulfates in the brines of Searles Lake, California. Geologic conditions favorable for these sodium minerals do not occur in east-central New Mexico. Brines present in the subsurface in the Permian rocks of the area constitute a potential source for sodium, but only because we have no knowledge of the chemical composition of these waters. Tests analyses of brines encountered in drilling probably should be conducted on a routine basis if for no other reason than the possible economic potential of these waters.

Borates form by concentration from saturated brines similar to the formation of the sodium minerals. The source of the boron is volcanic emanations. Based on geologic conditions there appears to be little likelihood of borate deposits in this part of New Mexico.

Nitrate deposits are not known and it appears extremely unlikely that they would occur in any appreciable quantities. There apparently are no large deposits of bat guano anywhere in the area. Nitrates are present in most shallow groundwater but in amounts of noneconomic importance.

Similar to sodium, bromines may be present in brine waters in the subsurface.

## Phosphorus

There are no known sedimentary phosphate rocks in this part of New Mexico. Some phosphatic fossil fragments may be present in pre-Mississippian rocks in the southeastern part of Area 7A but these occurrences have no economic potential.

## Salt

Bedded salts, salt brines, and salt domes are numerous throughout the world. Michigan, Texas, New York, Louisiana and Ohio lead in the production of this mineral commodity in the United States. There is no shortage and all the states adjacent to New Mexico have adequate, minable deposits, as do other parts of New Mexico south of Area 7A. In fact, salt deposits of the southeastern part of the State have greater possibilities for development because of the potential growth of a chemical industry centered around oil and natural gas. Bedded salt deposits underlie all of east-central New Mexico. They occur in the Artesia Group, San Andres Formation and Yeso Formation. Figures 20,21, and 22 show contours on top of the highest salt bed in each of these formations. The depth to the top of salt beds can readily be determined for each formation by subtracting the altitude of the salt as shown by the contours from the surface altitude at any given point.

The control points used to establish the structural contours were obtained from well cuttings, sample logs, and geophysical logs. Because of the high solubility of salt in water it is difficult to establish the highest salt bed based on drill cuttings obtained by normal oil well drilling methods. The uppermost bed of salt may be at a shallower depth than indicated by the contours.

Salt beds in the Artesia Group and the San Andres Formation appear to be present only in the eastern one-half to two-thirds of the area. It is assumed that salt was originally present throughout this area in the San Andres, and possibly in the Artesia Group, but subsequent to uplift was removed by ground water solution west of the line shown on each map.

Salt beds in the Artesia Group are interbedded with gypsum, anhydrite, red shales, and sandstones. In the San Andres Formation they occur with dolomites and anhydrites.

Salt is present underlying almost the entire area in the Yeso Formation. The salt is interbedded with sandstone, shale, anhydrite, gypsum, and dolomite. Because of the generally thin salt beds and depth of these beds in the Yeso Formation, evaluation of the area for salt was restricted for the most part to occurrences in the Artesia Group and San Andres Formation. An exception is the area from Ts. 1-4 S., Rs. 21-23 E., where thick beds of salt are present in the Yeso Formation at a depth of approximately 1,500 feet.

Several other factors were taken into consideration in determining favorable areas for salt exploration (fig. 23). Areas where thick beds of salt occur in both the Artesia Group and San Andres Formation, and where uppermost beds were at depths of less than 500 feet were considered to be excellent. Where salt was restricted to one unit but at a shallow depth or to both stratigraphic units but at depths in excess of 500 feet the area was considered good. Fair exploration areas were restricted to one stratigraphic unit; beds with good salt deposits but at depths greater than 500 feet; or two dual units with excellent salt deposits, but lying at depths considered not practical for underground mining by conventional means.

Salt mining in the United States by in-place solution requires large quantities of fresh water that are not available for such use in New Mexico. Depth of the salt beds in the southeastern part of the area also make conventional underground mining in such a low-use area impractical.

The best areas for exploration are located near Fort Sumner and Taiban in the center of Area 7A and just west of Kenna in Ts. 5 and 6 S., Rs. 28-29 E.

Oil, Gas, Helium, Carbon Dioxide, and Nitrogen

Petroleum represents the most important potential mineral resource in the area. The best method for evaluation of State lands for their petroleum potential is by regional studies of the structure and stratigraphy of the area. Because adequate large-scale structural maps and geophysical data were not available, individual tracts could not be evaluated from the standpoint of favorable structural conditions underlying a particular parcel of land. Additional reasons for not pursuing a more detailed investigation of local areas were the time involved and the feeling that a State organization should not place itself in the position of locating specific sites for drilling. This determination should be left to private initiative.

The present investigation, however, was detailed enough to establish that much of Area 7A has considerable petroleum potential. Also the investigations were at a level adequate to establish those general areas with the greatest potential as shown in Figure 24. This map was used for evaluating each tract of State land.

The basis for evaluation was the presence of favorable reservoir and source rocks occurring where regional structural features indicated possible traps. Also taken into consideration were the presence of multiple potential pay intervals. Each potential reservoir interval was rated separately. The final evaluation, however, was rated on the total potential for any given tract of State land.

Sedimentary intervals having physical properties adequate for potential reservoir rocks are present in pre-Pennsylvanian, Pennsylvanian, Wolfcampian, Yeso, Glorieta, San Andres, and to a lesser extent in the Artesia Group and the lower part of the Triassic. Suitable intervals are also present in the Jurassic and Cretaceous, but exposure and limited area underlain by these sediments make them unfavorable.

Potential source rocks are present in the pre-Pennsylvanian, Pennsylvanian, Wolfcampian, Yeso, and San Andres sediments. Oil generated in the San Andres could supply adjacent reservoir rocks in the Triassic Santa Rosa Sandstone (this is considered to be the source of the hydrocarbons in the Santa Rosa asphalt deposits), and the Permian Glorieta Sandstone and Artesia Group. Asphalt locally occurs in the subsurface in these last two units immediately adjacent to the San Andres Formation.

The isopach map of pre-Pennsylvanian sediments (fig. 10) shows the distribution of these rocks in Area 7A. Sediments in the northern part of the area are of Mississippian age and represent thin erosional remnants of once more widespread deposits. Petroleum possibilities in these rocks are not favorable. In the southeastern part of the area Mississippian, Devonian-Silurian, and Ordovician sediments attain a maximum thickness of 800 feet. These intervals represent a wedge edge of the much thicker and more deeply buried deposits of the Permian basin to the south. Both Devonian and Ordovician rocks are prolific producers of petroleum in the Permian basin. The wedging out and overlap of these sediments in the southern part of east-central New Mexico represents an attractive area for exploration.

As noted previously, the isopach and structural contour maps of Pennsylvanian rocks (figs. 9, 11) include marine Wolfcampian sediments in the southeastern part of the map area. In addition the Pennsylvanian interval is restricted to that part of the section containing marine sediments. In much of the area the marine sediments in the upper part of the Pennsylvanian grade vertically and laterally into a sequence of continental red shales, arkosic sandstones, and conglomerates generally included in the Abo or Sangre de Cristo Formations. Marine Pennsylvanian rocks are absent in the extreme northeastern and northwestern parts of the area. Rocks probably deposited in these areas were removed by erosion during the period of major uplift of the Sierra Grande arch in Late Pennsylvanian-early Permian time.

Some gas has been discovered in Pennsylvanian rocks in Area 7A. This includes the Newmill gas field located in sec. 20, T. 4 S., R. 27 E. (fig. 11). The discovery well gauged 1,850 MCF with top of pay at 6,314 feet in the lower part of the Pennsylvanian. The well was completed in 1956 but there has been no reported production. An earlier test drilled in sec. 18 in 1950 tested approximately the same interval but commercial quantities of gas or adequate pressures were not encountered. A third well, drilled in sec. 9 in 1958 was plugged without any reported show of gas. A recent gas discovery was completed in 1970 in sec. 21, T. 6 S., R. 27 E. This well gauged 5,800 MCF of gas through perforations beginning at a depth of 5,846 feet in the Pennsylvanian. During December a successful offset was drilled but additional data were not available at the time this report was written.

A large area in this part of east-central New Mexico is favorable for gas production from the Pennsylvanian as shown in Figure 24. Other favorable areas for oil and/or gas from these rocks include from Melrose to Ragland; a narrow strip east of a line between Yeso and Pastura; and the general area of the Cuervo subbasin.

Wolfcampian dolomites in the southeastern part of the area have good possibilities for petroleum accumulations. In this area the redbed clastics of the Abo-Sangre de Cristo Formation grade laterally into dolomites of the Wolfcamp Formation. The so-called interface between these facies is a prolific producer in adjacent areas of Texas.

Recently a test drilled in sec. 22, T. 7 S., R. 35 E. was potentialed at 221 barrels of oil per day from Wolfcampian dolomites. This is the northernmost production from the Wolfcamp in New Mexico and should have a considerable impact on future exploration in parts of Area 7A.

In most of east-central New Mexico there seems to be only limited potential for oil and gas in the Yeso Formation. The exception is in the southeast where, similar to Wolfcampian rocks, red clastics and evaporites grade southward into dolomites.

The San Andres Formation contains asphalt or low-gravity oil beneath much of Area 7A. Production so far has been limited to the Linda-San Andres field in the southern part of the area (fig. 12). Although many tests have been drilled into the San Andres, large areas with favorable conditions have yet to be drilled. Particularly favorable areas appear to be those where rapid updip thinning takes place. These areas can be determined by examination of the isopach and structural contour maps of the combined San Andres-Glorieta interval (figs. 7 and 12). The best areas for San Andres exploration seem to be east of Mesa, south of Santa Rosa, and in the vicinity of Tucumcari. Some of these areas are rated fair because potential from other intervals is limited. Even the area of the Linda field is rated fair because much of the established production is to the south, and yields are low.

Production from the Linda-San Andres field is at a depth of about 1,000 feet. Reported gravity of the oil varies from $24^{\circ}$ to $32^{\circ}$ A.P.I. Total production from 1964 to the end of 1969 amounted to 46,541 barrels of oil and 45,510 barrels of water. The producing interval is a dolomite.

Production of carbon dioxide near Bueryos north of Area 7A is from Triassic conglomeratic sandstones and arkosic conglomerates of the Abo-Sangre de Cristo Formation. The best producing zones are in the latter formation. Inasmuch as similar rocks underlie all of east-central New Mexico, and there are numerous possible traps, the entire area is considered to have a fair (3) potential for discovery of this gas.

The possibility for the discovery of helium is considered poor (2). Some helium has been reported from carbon dioxide wells to the northwest, but in general adequate traps needed to contain this gas appear to be lacking.

Nitrogen is commonly associated with carbon dioxide and natural gas. It is not of economic importance from this source.

## Coal

On the surface, minor intervals of coaly material occur in Triassic rocks and carbonaceous shales and are present locally in Cretaceous strata. Thin beds of coal, probably less than one foot thick, were observed in cuttings from several wells in the Pennsylvanian section. This occurrence is similar to the coal beds found in these rocks in the southern part of the Sangre de Cristo Mountains. None of these deposits are of commercial value.

## Geothermal

Thermal gradients were calculated from bottom-hole temperatures of oil tests in Area 7A. These confirm the few published points for New Mexico in the Roswell, Artesia, and Lovington areas (Gutenberg, 1951).

These data indicate a temperature increase of approximately $1^{\circ}F/100$ feet of depth. This is an exceptionally low thermal gradient.

Although measurements taken in bore holes normally filled with mud are not completely reliable, they do give a close enough value to conclude that the geothermal resource potential of this area is very limited.

The temperature of Rock Lake in sec. 14, T. 8 N., R. 29 E. is reported by Summers (1965) to be 65°F. This is a higher than normal temperature for springs in the area but cannot be considered a source for geothermal energy. A spring in sec. 1 of the same township also has a temperature of 65°F. The average annual surface air temperature at Santa Rosa is about 58°F.

## Ground Water

Although not a leaseable mineral, no economic study can be considered complete without including an evaluation of water availability. The quantity and quality of water required by mining operations is almost as varied as the variety of mineral commodities present in any given area.

The numerical evaluation of ground water resources within the report area is defined by the following arbitrary limits:

1. Not present.
2. Very limited distribution and/or quantity, or poor quality.
3. Domestic and livestock availability - limited.
4. Domestic and livestock availability - extensive.
5. Irrigation potential.
6. Unknown.

Evaluation was made on the basis of available ground-water level data compiled from the public record, literature, and other sources. Saturated thickness data were obtained primarily from the State Engineer Office. Basic outcrop maps were the principle source of geologic formation data. Where ground-water level data were available a potentiometric surface map was contoured. In addition, where the base of the saturated sands were known, a thickness of saturated sand could be ascertained and presented (fig. 25). From the evaluation of State tracts, it was possible to construct a map showing the regional availability of ground water (fig. 26).

Where little or no ground-water data were available, the following general criteria were considered before assigning a value to a tract:

1) surface and shallow subsurface geologic formations present, and their topography.
2) known distribution of surface and ground water in the area surrounding the tract (lakes, streams, rivers, irrigation wells, windmill wells, etc.).
3) potential aquifer development.
4) population density.

In areas where outcropping rocks do not contain appreciable quantities of water (i.e. Triassic Chinle Formation), or generally poor quality water (Permian Artesia Group), the population density is very low, there is no irrigation, and even windmill wells are scarce. These tracts were evaluated (2). Dry holes (or bad quality water wells) could be drilled on these tracts.

On the High Plains the Ogallala Formation generally carries sufficient quantities of good quality water to insure very limited (3) to extensive (4) domestic and stock development. In some areas, where the saturated thickness of Ogallala sands exceeds 20 feet, irrigation supplies are present or potentially present (5). Dry holes in the Ogallala are not unknown and can be drilled in well developed areas.

Many areas lack adequate detail, but in no case was a (6; unknown) used. No area was evaluated (1, not present), even though a tract might contain one or more dry holes. Again, the frequent presence of deeper salt waters or mineralized waters does not justify a "not present".

Evaulation of ground-water resources is necessarily restricted to consideration of "fresh" or potable waters usually developed at relatively shallow depths in water wells. Insufficient data prohibits delineation of quality. Local needs for water will permit or require use of water which in another locality would be considered unfit for human consumption.

The quantity and quality of ground water depends upon the amount of water available to the area and the nature of the rocks which are to capture, transmit, or store the water. Thus an understanding of the chemical and physical properties of the rocks is a primary requisite in regional ground-water evaluation.

Restriction of this evaluation to "fresh" water excludes large quantities of ground water which are most often at greater depths and/or excessively salty or mineralized. Many of these other waters contain as much as 200,000 parts per million total dissolved solids, and frequently are nearly salt saturated. It should be pointed out, however, that these waters are also a valuable resource. In a water-deficient area such as New Mexico, any waters must be considered as precious as any present-day deposit of copper, oil or gas, or other minerals deposit. Bad water can be treated, de-salted, and purified. The cost of water importation can be justified only for very large quantities such as used in irrigation. Water-treatment costs will soon be reduced to a level where industry and municipalities will be able to process presently unuseable water. Cost itself is a relative matter, and non-potable water resources in the State probably exceed fresh water supplies many times.

# STATE LAND EVALUATION

The data sheets included in Part II of this report consist of two sections. The first covers General Mining Leases and the second all other leases plus ground water. Tables are set with State Trust Lands in the left hand column. The major headings give the township and range beginning with T. 1 N., R. 19 E. and continuing to T. 12 N., R. 37 E. This is followed by townships 1 to 6 south. Beneath these major headings the State lands are subdivided by the section in numerical order. After each section the portion owned by the State is listed, if less than the entire section is involved. A further subdivision is given, based on mineral and surface rights controlled by the State. The letters in parenthesis following the section subdivisions indicate the degree of ownership. The following explains the meaning of the letter code used.

S - State surface and minerals.

PC - Purchase contract (surface, private). State minerals.

P - Surface patented (private ownership); State minerals.

PUSOG - Patented, State minerals, except U.S. oil and gas.

SSUSM - State surface; U.S. minerals

SSUSP - State surface and minerals, except U.S. potash.

PCUSOG - Purchase contract; State minerals, except U.S. oil and gas.

PMC - Patented; minerals conveyed.

PCUSM - Purchase contract; U.S. minerals.

SSUSP&S - State surface and minerals, except U.S. potash and sodium.

PUSM - Patented; U.S. minerals.

SSUSOG - State surface and minerals except U.S. oil and gas.

SSUSOG, S, &P - State surface and minerals except U.S. oil, gas, sodium, and potash.

SSUSS - State surface and minerals except U.S. sodium.

PCUSP - Purchase contract; State minerals except U.S. potash.

PCUSS&P - Purchase contract; State minerals except U. S. sodium and potash.

PCUSOG&P - Purchase contract; State minerals except U. S. oil, gas, and potash.

SSUSOG&P - State surface and minerals except U. S. oil, gas, and potash.

Under the commodity heading are listed the elements, minerals, and rocks that would be involved under the different State leases. In the section on general mining leases elements are listed by chemical symbol as follows:

| | | |
|---|---|---|
| Sb - Antimony | Au - Gold | Sn - Tin |
| Al - Aluminum | Pt - Platinum | Ti - Titanium |
| As - Arsenic | Ag - Silver | W - Tungsten |
| Be - Beryllium | Fe - Iron | Ni - Nickel |
| Bi - Bismuth | Pb - Lead | U - Uranium |
| Cd - Cadmium | Zn - Zinc | Th - Thorium |
| Cr - Chromium | Mo - Molybdenum | V - Vanadium |
| Co - Cobalt | Mn - Manganese | Zr - Zirconium |
| Nb - Niobium | Se - Selenium | Hf - Hafnium |
| Ta - Tantalum | Te - Tellurium | Ge - Germanium |
| Cu - Copper | Li - Lithium | Hg - Mercury |

The miscellaneous metals and nonmetals columns refer to mineral commodities not listed elsewhere. Some of these are cesium, indium, radium, gallium, greensand, iodine, quartz crystal, and wollastonite.

Evaluation of the commodities for each tract of State land is given numerically. The classification used is:

1. Not present or not of commercial value.
2. Present but considered to be of poor economic potential, or in the case of uranium, copper, potash, salt, oil and gas, anhydrite and gypsum, and helium, a poor area for exploration.

3. Present and considered of fair economic potential for certain uses, or in the case of uranium, copper, salt, anhydrite, gypsum, carbon dioxide, and oil and gas, a fair area for exploration.

4. Present and considered to have good economic potential, or in the case of salt, anhydrite-gypsum, and oil and gas, to be a good area for exploration.

5. Present and considered to have excellent economic potential, or in the case of salt, to be an excellent area for exploration.

6. Possibly present, or of possible economic potential, but definite rating not feasible because of lack of data. In the case of potash this rating indicates potential areas for exploration.

Although the tables were proofed several times there still may be some errors in the locations of the State Trust lands.

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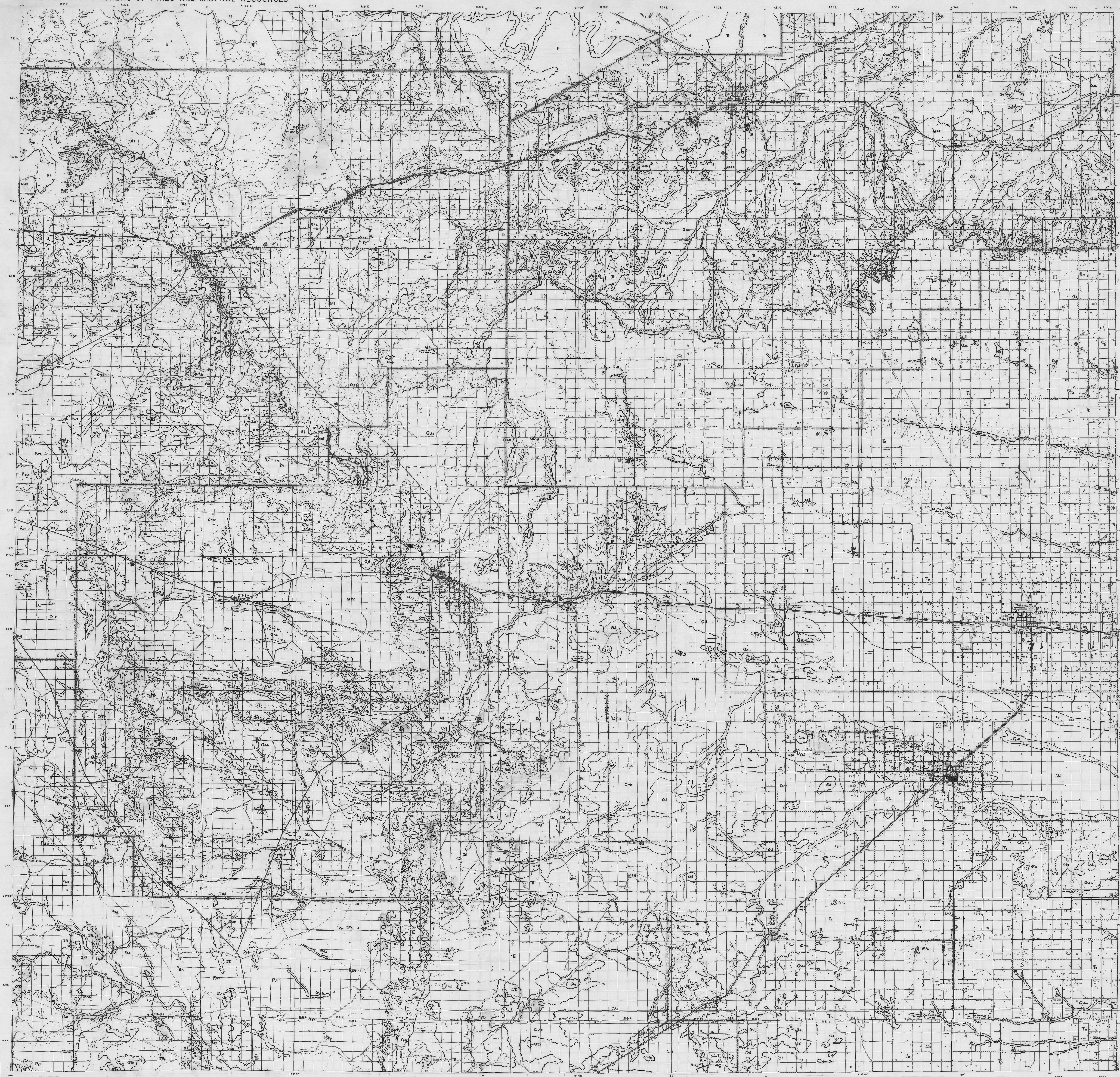

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Scale 1:190080 or 1 inch = 3 Miles

0 1 2 3 4 5 6 7 8 9 10 11 12 miles

Base from New Mexico State Highway Department
Geology from U.S. Geological Survey, New Mexico Bureau of Mines and Mineral Resources, and the New Mexico State Highway Department

| | | |
| --- | --- | --- |
| QAL | Alluvium | QUATERNARY |
| Qd | Eolian deposits | QUATERNARY |
| Qt | Terrace deposits | QUATERNARY |
| QAB | Upland alluvial deposits | QUATERNARY |
| Qtc | Caliche | QUATERNARY–TERTIARY |
| To | Ogallala Formation | TERTIARY |
| Ti | Tertiary intrusives | TERTIARY |
| K | Pajarito Shale, Mesa Rica Sandstone, Tucumcari Shale | CRETACEOUS |
| KJ | Cretaceous and Jurassic rocks undivided | CRETACEOUS–JURASSIC |
| J | Morrison Formation, Entrada Sandstone | JURASSIC |
| TR | Chinle Formation (Locally includes Santa Rosa Sandstone) | TRIASSIC |
| TRs | Santa Rosa Sandstone | TRIASSIC |
| PAT | Artesia Group | PERMIAN |
| PSA | San Andres Formation | PERMIAN |
| Pg | Glorieta Sandstone | PERMIAN |

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Figure 1

Geologic Map of East-Central New Mexico (Area 7A)

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Kay C. Havenor

Water level contour interval 50 & 100 feet

Post-Mesozoic rocks saturated thickness contour interval 20 & 40 feet

Figure 25

Contour Map Showing Water Levels and Saturated Thickness in Area 7A