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1985, pp. 289-299. https://doi.org/10.56577/FFC-36.289

in:

Santa Rosa, Tucumcari Region, Lucas, S. G.; Zidek, J.; [eds.], New Mexico Geological Society 36th Annual Fall Field Conference Guidebook, 344 p. https://doi.org/10.56577/FFC-36

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COPPER AND URANIUM MINERALIZATION IN EAST-CENTRAL NEW MEXICO

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INTRODUCTION

Copper and uranium mineralization commonly occurs within clastic red-bed sedimentary rocks throughout New Mexico and the western United States without any obvious association of magmatic or volcanic activity (Phillips, 1960; Fischer and Stewart, 1961; Finch, 1967). In east-central New Mexico, copper and uranium mineralization occurs in Pennsylvanian, Permian, Triassic and Jurassic rocks (Fig. 1, Table 1). These deposits have common geologic characteristics, although local variations in composition and lithologic features occur. Some deposits contain only copper or uranium, whereas a few deposits contain both. The geology, geochemistry and mineralogy of these deposits are briefly described in this paper to aid in evaluating the economic potential of copper and uranium in east-central New Mexico.

Production from east-central New Mexico has amounted to over $2.7 million worth of copper, silver, lead, uranium, vanadium and gold

TABLE 1. Sedimentary copper and uranium deposits in east-central New Mexico. [a]Host: PPs – Sangre de Cristo Formation, Pg – Grayburg–Queen Formation, Trsr – Santa Rosa Sandstone, Tr – Redonda Formation, Trc – Chinle Formation, Jm – Morrison Formation. [b]Commodities: U – uranium, V – vanadium, Cu – copper, Pb – lead, Ag – silver, Au – gold, Se – selenium. [c]Properties reported uranium and/or copper production (Tables 2, 3).

Map No. on Fig. 1	Name	Location (section, township, range)	Host rock[a]	Commodities present[b]	Source of data (FN – field notes)
	Colfax County				
1	Black Lake	6 T24N R16E	PPs	U,V	McLemore (1983a), May et al. (1977), FN 6/82
	Mora County				
2	Unknown-Ocate	18 T23N R18E	PPs	U	May et al. (1977)
3	[c]Coyote Creek district (Ledoux)	T21,22,23N R16,17E	PPs	Cu,U,Pb,Ag,Se	Tschanz et al. (1958), Soulé (1956), North and McLemore (1984)
4	Bustos-Mora River Gap	16,17 T20N R16E	PPs	Cu,U	May et al. (1977), Reid et al. (1982)
5	Rociada district	T16,17N R15,16E	PPs	Cu,Pb,Ag,Au	Anderson (1957), Soulé (1956)
6	Sanford Ranch	1 T19N R23E, 5 T20N R24E	Jm	U	U.S. Atomic Energy Commission (1970)
	San Miguel County				
7	El Porvenir district (Los Vigiles prospect)	T17N R16E	PPs	Cu,U,Ag	Harley (1940), Anderson (1957), Reid et al. (1982), FN 6/82
8	Continental Leatherwood Reed well	15 T16N R17E	PPs	U,Au,Ag,Se,Pb	McLemore (1983a), Finch (1972)
9	[c]Tecolote district-north	T14N R15,16E	PPs	Cu,U,Ag,Au	Soulé (1956), Griggs (1954), Harley (1940)
10	Tecolote district-south	T13N R14E	PPs	Cu,Ag,Au	Soulé (1956), Harley (1940)
11	Sowell Ranch area	13,23,24 T12N R17E	Trc	U	Reid et al. (1982), Finch (1972)
12	Park Springs Ranch	27 T13N R19E	Trc	U,V	Reid et al. (1982), Finch (1972)
13	East Point Mesa Montosa	19 T13N R21E	Trc	U,V	Reid et al. (1982), Finch (1972)
14	AEC Anomaly No. 12	34 T14N R20E	Trc	U,V,Cu	Reid et al. (1982), Finch (1972)
15	Eloy Estrada	24 T15N R21E	Jm	U	Reid et al. (1982), Finch (1972)
16	[c]Sabinoso district	T16,17N R23,24,25E	Trc	U,Cu,Ag	McLemore and Menzie (1983), FN 8/82
17	Brookout Ranch-Neafus	20,23 T12N R23E, 31 T12N R24E	Trc	U,V	U.S. Atomic Energy Commission (1970)
18	St. Anne Claims	5 T12N R25E	Trc	U	Reid et al. (1982), Finch (1972)
19	Baca #2 Grant area	T11-14N R30E	Trc	U	U.S. Atomic Energy Commission (1970)
	Harding County				
20	[c]Polita #2	6 T17N R29E	Jm	U,V	Anderson (1980), Finch (1972)
21	Gallagher Brothers	4 T21N R30E	Jm	U	Consulting Professionals, Inc. (1980)
22	Gallegos district	T16N R30,31E	Trc	Cu,Ag,Au	Harley (1940)
23	State Land	14 T14N R32E	Trc	U	Finch (1972)
	Quay County				
24	Logan	25 T13N R31E 12,24,25 T13N R32E	Trc	Cu,U,Ag,Au	Harley (1940), Soulé (1956), McLemore (1983a)
25	[c]San Jon area (Red Peak area; Little Rattler)	T9-12N R32,33E	Trc	U,Cu,Ag	Soulé (1956), McLemore (1983a), Anderson (1980), Finch (1972), FN 2/85
26	Fife Prospects	3 T8N R31E, 27,34 T9N R31E	Tr	U	Finch (1972)
27	[c]Good Luck	6 T7N R32E	Trc	U,V	Anderson (1980), Griggs (1954)
28	Ima	12,13 T8N R27E	Trc	U	U.S. Atomic Energy Commission (1970)
29	Tucumcari area	T10-12N R28-30E	Jm	U	Finch (1972), U.S. Atomic Energy Commission (1970)
30	Beasley Brothers #4	16 T10N R27E	Trc	U	Reid et al. (1982), FN 2/85
	Guadalupe County				
31	Branch Ranch-Neafus Ranch	17,27 T11N R25E	Trc	U,V	Reid et al. (1982), Finch (1972)
32	Santa Rosa tar sand	1 T9N R21E	Trsr	U (tar sand)	Gorman and Robeck (1946), Hail (1955), Budding (1980)
33	Santa Rosa RR cut	2 T8N R21E	Trsr	U	Finch (1972)
34	[c]Pastura district (Stauber, Pintada, American, Porcupine)	T7,8N R18-20E	Trsr, Pg	Cu,Ag,U,Pb	Holmquist (1947), Soulé (1956), Finch (1972), Sandusky and Kaufman (1972), FN 2/85
	Union County				
35	Smithson Ranch	28 T22N R33E	Jm	U	Consulting Professionals, Inc. (1980), Abbott (1979)

(Tables 2, 3). Most of this production has come from one deposit, the Stauber (or Guadalupe) mine in the Pastura district (#34, Fig. 1), where more than 13 million lbs (5.9 million kg) of copper, 42,000 oz (1.2 million g) of silver, 58,000 lbs (26,000 kg) of lead and 2 oz (57 g) of gold were produced intermittently from 1915 to 1957 (Table 4; Soulè, 1956). Only one other stratabound sedimentary (red-bed or sandstone) copper deposit in New Mexico, the Nacimiento in Sandoval County, has produced more copper and silver than the Stauber mine. Additional production was reported from the Pintada mine, also in the Pastura district, in 1916, 1917, 1951 and 1967–1970. However, the total production is withheld by the U.S. Bureau of Mines (Table 4). Sandusky and Kaufman (1972) reported that more than 41,600 lbs (18,900 kg) of copper concentrate were shipped to El Paso during 1967–1970. Copper, silver, lead and gold also were produced from the Coyote Creek and Tecolote districts (#'s 3, 9, 10, Fig. 1), but total production was insignificant (Table 2). Some uranium and vanadium were produced from six mines in east-central New Mexico, but total production was small (Table 3).

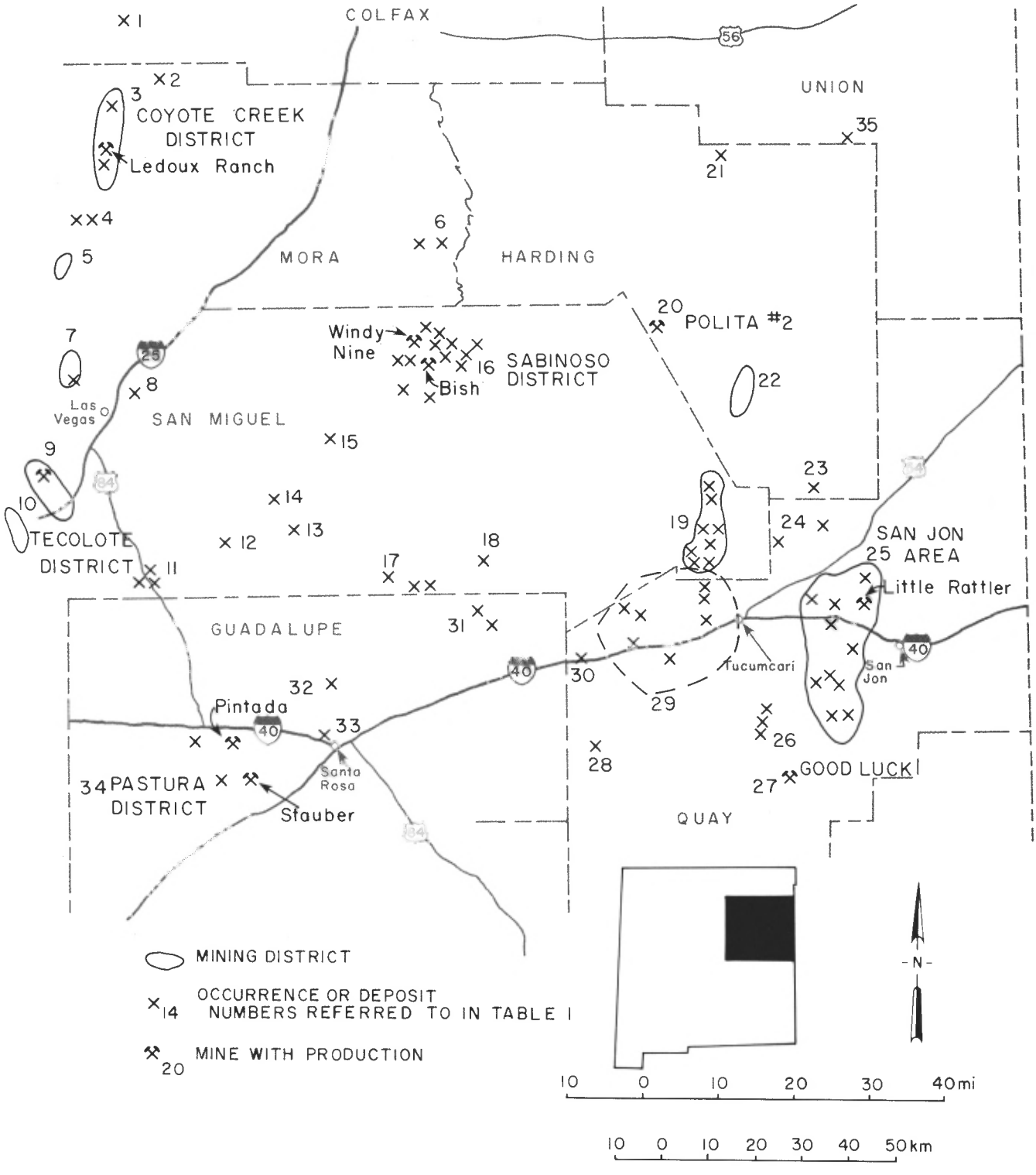


FIGURE 1. Copper and uranium mineralization in sedimentary rocks in east-central New Mexico. Numbers represent localities given in Table 1.

DESCRIPTION OF MINERALIZATION

Copper and uranium mineralization in east-central New Mexico occurs within six formations (Fig. 2). Most ore deposits are within gray, green, white, tan, brown or pink sandstone or conglomerate, although ore-bodies in adjacent shale, siltstone, and limestone are common. However, the majority of the red, reddish-brown or maroon rocks that characterize these formations are not mineralized. Mineralization typically occurs as (1) disseminations or cement within host rocks, (2) along fractures, bedding planes and contact zones and (3) replacements of wood or other organic material and is generally associated with iron oxides or pyrite and/or clay galls or clay interbeds.

Most ore deposits in east-central New Mexico are controlled by sedimentary features such as bedding and crossbedding, paleochannels and intraformational slumping. Ore-bodies typically occur at or near the bottom of thick sandstone lenses or adjacent to impermeable barriers such as shale, siltstone and limestone. The paleochannels were deposited in basins adjacent to local and regional uplifts that are shown in Figure 3. These uplifts influenced sedimentation throughout the Pennsylvanian–Jurassic.

Local structures appear to control mineralization in some areas. Mineralization in the Tecolote district (#9, Fig. 1) is distributed along the crests of anticlinal folds and associated fractures (Harley, 1940). Mineralization at the Stauber mine (#34, Fig. 1) is related to a shallow syncline or structural depression of uncertain origin (Fig. 4). Harley (1940) suggests that this depression is the result of soft-sediment squeezing and redistribution of underlying clay beds. LaPoint (1979) suggests that the depression is related to karst of sinkhole topography caused by the dissolution of underlying Permian evaporite and carbonate rocks. However, the circular geometry typical of sinkholes in the Santa Rosa area (Kelley, 1972c) was not observed at the Stauber mine. Gentle regional folding similar to north-trending folds in north-central Guadalupe County (Gorman and Robeck, 1946) may have formed this

TABLE 2. Reported copper production in east-central New Mexico from U.S. Bureau of Mines Mineral Yearbooks (not including withheld values) and Soulè (1956). [a]Estimated value. [b]Soulè (1956) reported 58,723 lbs Pb and 42,494 oz Au produced through 1954. Figures presented are from U.S. Bureau of Mines Mineral Yearbooks.

Map No. on Fig. 1	Name	Host	Tons of ore	Cu (lbs)	Pb (lbs)	Ag (oz)	Au (oz)	Total Value ($)	Years of Production
	Mora County								
3	Coyote Creek district	PPs	123	10,100	---	48	---	3,251	1917,1955,1956
	San Miguel County								
9	Tecolote district	PPS	596	19,112	2,816	128	19	4,263[a]	through 1954
	Guadalupe County								
34	Pastura district	Pg, T sr	265,954	13,578,214	46,000[b]	8,466[b]	2	2,749,400	1916-1969
	TOTAL		266,673	13,607,426	48,816	8,642	21	2,756,914[a]	----------

TABLE 3. Uranium production from east-central New Mexico from U.S. Atomic Energy Commission ore-production reports, government contracts only. This includes total ore that was received at the buying stations and mills, including "no-pay" ore (ore assaying less than 0.10% U_3O_8). [a]Estimate value of U_3O_8 production from yearly dollar averages (McLemore, 1983b). Ores assaying less than 0.10% U_3O_8 are not included.

Map No. on Fig. 1	Name	Location	Host Rock	Tons Ore	Pounds U_3O_8	% U_3O_8	Pounds V_2O_5	% V_2O_5	Estimated value of U_3O_8[a]	Periods of Production/Shipper
	Mora County (Coyote Creek district)									
3	Ledoux Ranch	13 T22N R16E	PPs	11	9	0.04	81	0.37	---	1954-Galisteo Mining Co.
	San Miguel County (Sabinoso district)									
16	Bish #2	31 T17N R24E	Tr c	30	62	0.10	27	0.04	688	1956-Swain, Brooks, and Holcomb
16	Windy Nine	14 T17N R23E	Tr c	19	19	0.05	147	0.38		1956-San Carlos Uranium Co.
	Harding County									
20	Polita #2	6 T17N R29E	Jm	1	2	0.15	5	0.31	24	1955-Ramon Pachero
	Quay County									
25	Little Rattler-San Jon Area (Sec. 11, Sec. 12)	11 T11N R33E	Tr c	59	41	0.03	44	--	---	1955-1956-Rattler Uranium Co., 1958-Highland Dev. Co., Inc.
27	Good Luck	6 T7N R32E	Tr c	24	50	0.10	38	0.12	346	1955-Standard Uranium Co., 1957-Dennis and Fife
	TOTAL EAST-CENTRAL NEW MEXICO			144	183	0.06	342	--	1,058	1954-1957
	TOTAL NEW MEXICO			38,305,159	171,130,506	0.22	---	--	---	1948-1970

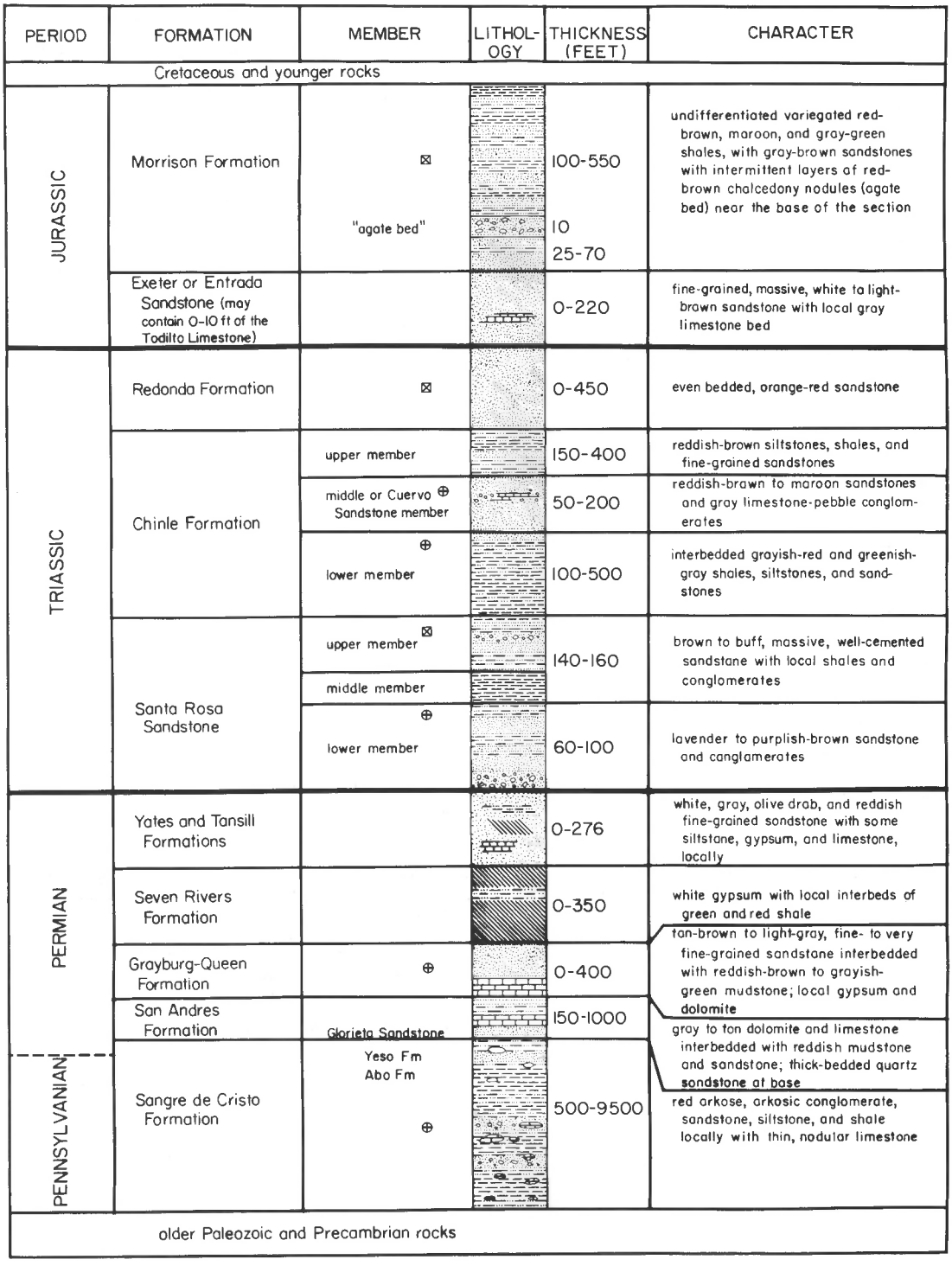


FIGURE 2. Stratigraphic section of mineralized rocks in east-central New Mexico. Modified from Mankin (1958), Kelley (1972a, c), Lochman-Balk (1972) and McGowen et al. (1979).

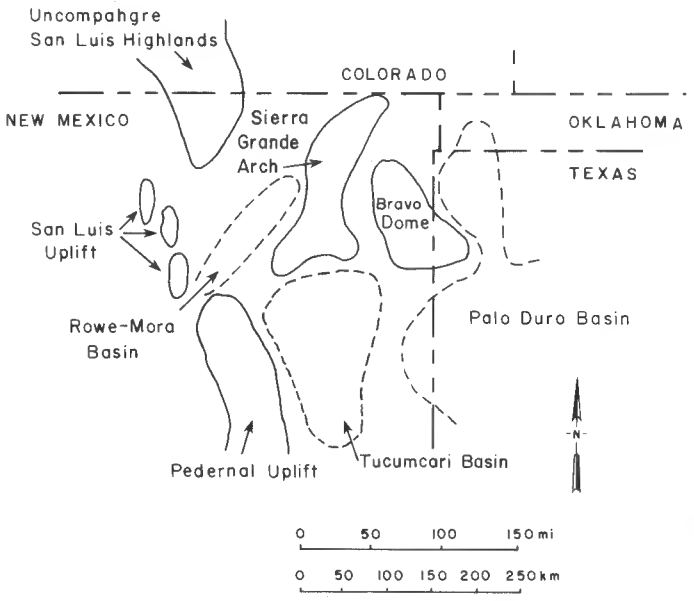


FIGURE 3. Tectonic uplifts and basins of northeastern New Mexico during Late Pennsylvanian and Early Permian time (Dixon, 1967; McKee, 1967). These same features affected deposition during Jurassic time (Abbott, 1979; McGowen et al., 1983).

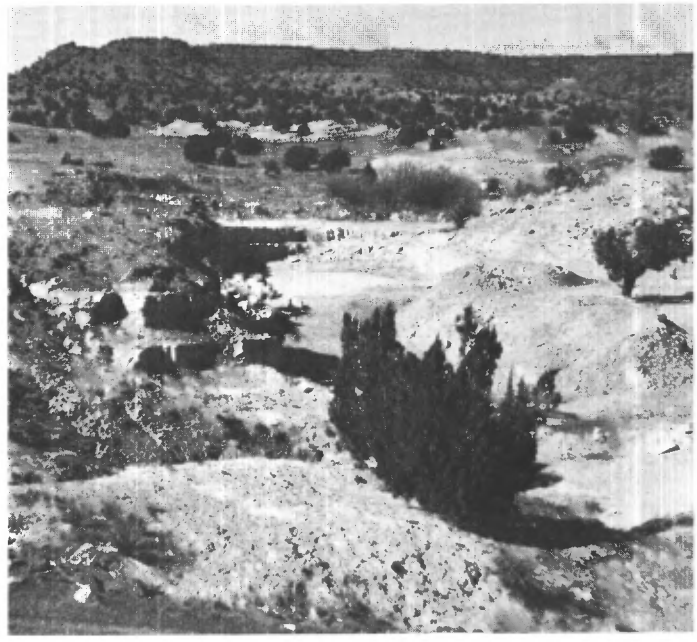


FIGURE 4. West wall of the Stauber open pit mine showing the syncline or structural depression of the beds.

syncline. Detailed regional mapping is required to test this hypothesis. Mineralization at the Pintada mine also may be due to similar features.

Ore-bodies range in size from small occurrences containing less than one ton of ore, such as the Black Lake occurrence (#1, Fig. 1), to large deposits containing several hundred thousand tons of ore, such as the Stauber mine (#34, Fig. 1). In east-central New Mexico, the best copper deposits generally contain little or no uranium mineralization, whereas the best uranium deposits contain only trace amounts of copper. Copper and uranium occur together locally in Pennsylvanian, Permian and Triassic rocks in east-central New Mexico. In general, these deposits are low-grade (less than 1% copper and less than 0.10% U_3O_8), although some small (less than one ton) high-grade (greater than 1% copper and 0.10% U_3O_8) deposits occur locally.

COMPOSITION

The major hypogene copper mineral is chalcocite, although bornite and chalcopyrite occur in some deposits. Malachite and chrysocolla are common supergene minerals with minor azurite and covellite. Cuprite is the major copper mineral in nodules from the Red Peak area. Uranium and vanadium occur with organic material. Although recognizable minerals of these elements are rare, uraninite, tyuyamunite, metatyuyamunite and carnotite have been identified from some deposits (U.S. Atomic Energy Commission files, 1954–1957; Tschanz et al., 1958; Finch, 1972).

The chemical composition of these deposits is highly variable. The Stauber deposit contains relatively high amounts of silver and lead (for stratabound sedimentary copper deposits in New Mexico), whereas the Pintada deposit contains relatively low amounts of silver and lead (Table 4; LaPoint, 1979). Most uranium deposits contain high vanadium concentrations; some copper deposits lacking in uranium also contain high vanadium concentrations (Table 5; Tschanz et al., 1958).

STRATIGRAPHIC DISTRIBUTION

Most of the mineralized host rocks (Fig. 2) are continental deposits derived from adjacent highlands (Fig. 3) and were typically deposited in alluvial-plain, fluvial, deltaic and lacustrine environments near the edge of deeper basins (Fig. 3; Dixon, 1967; McGowen et al., 1979; Abbott, 1979). The depositional environment of the Grayburg–Queen Formation (Permian), host to the Pintada deposit, is uncertain, although stratigraphic and lithologic evidence suggests a marginal-marine environment such as an influx of continental sediment into seas or a local regression of seas (Kelley, 1972a; LaPoint, 1979).

Sangre de Cristo Formation (Pennsylvanian–Permian)

Copper, uranium and copper–uranium mineralization occurs within alluvial-plain deposits in the lower half of the Sangre de Cristo Formation (Pennsylvanian–Permian) in western Mora, Colfax and San Miguel Counties (Fig. 1; Tschanz et al., 1958; May et al., 1977). The copper deposits are small and contain less than 1000 tons of ore that averages 1–3% copper, some silver, some lead, but only trace amounts of uranium (Tschanz et al., 1958). One small deposit at Mineral Hill in the El Porvenir district (#7, Fig. 1) consists of a 1-m-thick sandstone which assayed 2 oz/ton (68 ppm) silver and 16% lead (Harley, 1940). Chalcocite nodules in the Coyote Creek district (#3, Fig. 1) contain up to 57% copper (Tschanz et al., 1958). However, most deposits in the Sangre de Cristo Formation are small and low-grade. Some production was reported from the Coyote Creek and Tecolote districts, where more than 29,000 lbs (13,000 kg) of copper, 2816 lbs (1277 kg) of lead, 176 oz (4990 g) of silver and 19 oz (534 g) of gold were produced (Table 2).

The best uranium deposits also are small and range in grade up to 0.82% U_3O_8 and almost 3% V_2O_5, with only trace amounts of copper (Tschanz et al., 1958). Most uranium deposits in the Sangre de Cristo Formation average 0.01 to 0.1% U_3O_8, with varying amounts of vanadium (Finch, 1972; May et al., 1977). Assays up to 0.1% U_3O_8 were found in sandstones at depths of 870 and 879 m in the Continental Leatherwood–Reed well (#8, Fig. 1). Uranium mineralization was associated with organic material and contained clausthalite (PbSe). The clausthalite contained 700 ppm gold and 70 ppm silver (Finch, 1972). The Black Lake occurrence is typical of many occurrences in the Sangre de Cristo Formation, where tyuyamunite is distributed along bedding planes and fractures within a 3-m-thick coarse-grained sandstone. A selected sample assayed 0.002% U_3O_8 with no detectable gold or silver (Table 5; McLemore, 1983a). Up to 1% V_2O_5 has been reported (May et al., 1977). However, this occurrence is small and has less than one ton of ore.

Only one mine produced any uranium and vanadium from this formation. Production from the Ledoux Ranch mine in the Coyote Creek district amounted to only 9 lbs (4 kg) of U_3O_8 at 0.04% and 81 lbs (37 kg) of V_2O_5 at 0.37% (Table 3).

Grayburg–Queen Formation (Permian)

Only one known deposit, the Pintada in the Pastura district, occurs in the Grayburg–Queen Formation (terminology from Kelley, 1972 and LaPoint, 1979) in east-central New Mexico. Copper mineralization at the Pintada occurs in a white sandstone that overlies a basal gypsum unit (Fig. 2). Up to five horizons are mineralized, with ore grades averaging 2% copper and some silver. Chemical analyses of selected samples range from 1 to 18% Cu, up to 0.52 oz/ton (17 ppm) silver and 0.002% U_3O_8 (Table 5). The ore was mined by open pit; the largest pit is approximately 15 m wide, 26 m long, and 9 m deep (Fig. 5). Mineralization is associated with organic material and occurs in a zone of distinct color change from gray (or white) to red (LaPoint, 1979). Malachite is the major copper mineral present. Although thin gypsum veins, several centimeters wide, cut across the mineralized sandstone and interbedded shales (Fig. 6), brochantite (hydrous copper sulfate) is absent. Additional mineralization was intersected in drill holes northwest of the open pit (LaPoint, 1979). Total production is not known, but over 47,000 lbs (21,000 kg) of copper and at least 71 oz (2000 g) of silver have been produced (Table 4; Sandusky and Kaufman, 1972).



FIGURE 5. Pintada pit, looking north.

TABLE 4. Reported production from the Stauber and Pintada mines in the Pastura district, Guadalupe County, 1917–1970. From U.S. Bureau of Mines Mineral Yearbooks. [a]Includes minor production from the Pintada mine. [b]Sandusky and Kaufman (1972) reported total production from the Pintada mine from 1967 to 1970 as over 41,600 lbs of copper concentrate. Soulè (1956) reported 58,723 lbs of lead and 42,494 oz of silver produced from the Pastura district through 1954.

Year	Tons of Ore	Cu (lbs)	Ag (oz)	Additional Production	Total Value ($)
STAUBER MINE					
1915	withheld				---
1925	3,278	330,000			46,860
1926	6,642	664,236			92,993
1927	6,953	611,893			80,158
1928	13,700	1,200,000	2,359		174,180
1929	16,344	1,500,000	1,653		264,881
1930	10,123	951,000	1,013		124,020
1940	2,604	230,800	111		26,159
1941	2,411	204,000	232		24,237
1942	7,498	611,000	789		74,492
1943	17,327	1,258,000	1,889	2 oz Au	164,953
1944	8,864	595,000	308		80,544
1945	1,850	93,000			12,555
1949	5,526	152,000			33,556
1950	18,469	640,000	41	16,000 lbs Pb	135,317
1951[a]	25,498	640,000		30,000 lbs Pb	160,070
1952	50,751	1,062,000			257,004
1953	28,985	1,074,000			308,238
1954	7,673	260,000			76,700
1955	114	4,000			1,492
1956	24,621	1,274,300			541,577
1957	5,126	201,500		2 oz Au	60,652
SUBTOTAL[a] STAUBER MINE (not including withheld values)	264,357	13,556,729	8,395[b]	46,000 lbs Pb[b]	2,740,638
PINTADA MINE					
1916	23	1,463	8		365
1917	74	4,022	40		1,131
1967, 1968	withheld				---
1969	1,500	16,000	23		7,266
1970	withheld				---
SUBTOTAL PINTADA MINE (not including withheld values)	1,597	21,485[b]	71		8,762
TOTAL DISTRICT 1916-1970 (not including withheld values)	265,954	13,578,214[b]	8,466	2 oz Au 46,000 lbs Pb[b]	2,749,400

Santa Rosa Sandstone (Triassic)

Most of the copper production in east-central New Mexico has come from the Stauber mine in the Santa Rosa Sandstone (Triassic). Copper mineralization and relatively high amounts of silver and lead occur in the lower member of the Santa Rosa Sandstone (Fig. 2). Ore grades averaged 3–5% copper, 0.1 oz/ton (3 ppm) silver, some lead, but no uranium or vanadium (Holmquist, 1947). The ore is high in silica and proved to be excellent fluxing material for the El Paso smelter. Close proximity to the railroad lowered production costs.

Uranium mineralization with only trace amounts of copper occurs in the upper member of the Santa Rosa Sandstone in the Pastura district and near Santa Rosa (#'s 32, 33, 34, Fig. 1). A selected sample from the American Uranium property contained 0.002% U_3O_8 (Table 5). Uranium also is associated with the Santa Rosa tar sands near Santa Rosa. The tar-sand occurrences are small and low-grade.

Chinle Formation (Triassic)

Uranium mineralization is widespread in the lower and middle members of the Chinle Formation in east-central New Mexico (Fig. 1; Table 1). Uranium deposits with only trace amounts of copper are typical of the Chinle, although only copper mineralization occurs in the Gallegos district (#22, Fig. 1). Several copper–uranium deposits also were found in this area (Table 1).

The greatest concentration of uranium mineralization in the Chinle Formation is in the Sabinoso district (#16, Fig. 1), where production from two mines amounted to 81 lbs (37 kg) of U_3O_8 and 174 lbs (79 kg) of V_2O_5 (Table 3). Uranium mineralization occurs in gray limestone–pebble conglomerate and arenite (McLemore and Menzie, 1983). Uranium analyses range up to 0.89% U_3O_8 with up to 8.8% V_2O_5 and trace amounts of copper and molybdenum (Table 5). An additional sample assayed 0.015% U_3O_8, 0.64% Cu, 0.4% V, <0.15% Mo and 0.74 oz/ton (24 ppm) silver. X-ray-diffraction analysis of the high uranium- and vanadium-bearing sample (no. 2804, Table 5) showed quartz, goethite, plagioclase, orthoclase, barite, montmorillonite, muscovite, kaolinite, metatyuyamunite ($Ca(UO_2)_2(VO_4)_2 \cdot 3\text{–}5H_2O$) and an alunite-group mineral, probably plumbojarosite. The mineral composition does not account for the 8.8% vanadium analysis. This suggests that vanadium is present in an amorphous phase, or is contained in one or more of

TABLE 5. Chemical analyses of selected samples from east-central New Mexico. Analyses by Lynn Brandvold and associates, NMBMMR chemical laboratory. Analyses of Sabinoso samples reported by McLemore and Menzie (1983), and Black Lake sample reported by McLemore (1983a). Trace Au is <0.02 oz/ton (0.7 ppm). U_3O_8 analyzed by wet-chemical methods, Au and Ag by fire assay and remaining elements by atomic-absorption spectrometry.

Map No.	Sample No.	Name	% Cu	% U_3O_8	% V	Ag oz/ton (ppm)	Au oz/ton	Other analyses
16	SABINOSO DISTRICT							
	2809	Windy No. 9	--	0.037	0.35	--	--	--
	2810	Windy No. 9	<0.01	0.031	<0.04	--	--	--
	2811	Windy No. 9	<0.01	0.406	0.88	--	--	--
	2806	Sabinoso Uranium Co.	<0.01	0.021	0.07	--	--	--
	2817	Cip Lujan	<0.01	0.020	<0.04	--	--	--
	2805	Hunt Oil	0.64	0.015	0.40	0.74 (25)	--	<0.15% Mo
	2804	Hunt Oil	<0.01	0.89	8.80	--	--	0.19% Mo
	2807	Bish No. 2	--	0.005	0.06	--	--	--
	2808	Bish No. 2-dump	--	0.071	<0.04	--	--	--
	2812	Locality No. 43	0.18	0.006	<0.04	--	--	--
	2813	Locality No. 43	--	0.033	<0.04	--	--	--
	2814	Lujan Ranch	0.51	0.023	0.41	--	--	--
	2815	Lujan Ranch	0.08	0.001	<0.04	--	--	--
	2816	El Villa	0.22	0.054	0.21	--	--	--
	COLFAX COUNTY							
1	2390	Black Lake	--	0.002	--	0.00	0.00	--
34	PASTURA DISTRICT							
	7654	Pintada mine	3.51	--	--	0.52 (17)	0.00	--
	7660	Pintada mine	5.26	--	--	0.36 (12)	trace	--
	7663	Pintada mine	18.4	0.002	--	0.00	0.00	<50 ppm Co, <100 ppm Pb
	7664	Pintada mine	1.17	--	--	0.00	trace	--
	7667	American Uranium	--	0.002	--	0.00	0.00	--
25	SAN JON AREA							
	7662	Red Peak Nodules	22.6	0.172	--	0.72	0.00	13.1% $BaSO_4$
	7666	Red Peak Nodules	16.9	0.192	--	0.67 (23)	0.00	12.0% $BaSO_4$
	7665	Bedford Springs	--	0.005	--	0.00	0.00	<50 ppm Co
	7668	15 T10N R33E	--	0.031	--	0.00	0.00	--



FIGURE 6. Thin gypsum veins cut across mineralized sandstone at the Pintada mine.

the identified phases in substitution (e.g., in muscovite = roscolite) or as an impurity.

Uranium mineralization also occurs in the Chinle Formation near San Jon (#'s 25, 27, Fig. 1), where two mines produced 91 lbs (41 kg) of U_3O_8 and 82 lbs (37 kg) of V_2O_5 (Table 3). Near Red Peak (#25, Fig. 1), uranium mineralization occurs in the subsurface in the middle (Cuervo Sandstone) member or lower portion of the upper member of the Chinle Formation (Bill Wallace, pers. comm. 26 February 1985). A shale bed in the upper member of the Chinle Formation contains numerous nodules or concretions approximately 5–20 cm in diameter that consist of cuprite, barite, malachite, fluorapatite, quartz and a small amount of chalcocite. Selected samples of these nodules contained up to 22.6% copper, 0.72 oz/ton (25 ppm) silver and 0.19% U_3O_8 (Table 5). Finch (1972) reports that a sample of nodules contained 0.12% U_3O_8, over 10% copper, 0.70% vanadium, 0.003% silver, 1.5% arsenic and 0.003% selenium. An additional sample from sec. 15, T10N, R33E contained 0.031% U_3O_8 (Table 5).

Redonda Formation (Triassic)

Uranium mineralization with only trace amounts of copper occur in the Redonda Formation near San Jon (#26, Fig. 1). Uranium occurrences are small and low-grade, rarely exceeding 0.03% U_3O_8 (Finch, 1972).

Morrison Formation (Jurassic)

Most of the uranium produced from New Mexico has come from the Morrison Formation in the Grants uranium district in northwestern New Mexico (McLemore, 1983b). The Morrison Formation of northeastern New Mexico differs from that of the Colorado Plateau area in northwestern New Mexico. The Morrison Formation of northeast New Mexico appears to have been deposited in a drier climate with less discharge within streams and less organic material than in the Colorado Plateau (Abbott, 1979; Reid et al., 1980, 1982).

Uranium mineralization occurs in the upper two-thirds of the Morrison Formation in northern San Miguel and southern Harding and Union Counties (Fig. 1). All known uranium occurrences are found above the distinctive "agate bed." The agate bed consists of one or more layers of red–brown chalcedony nodules (Mankin, 1958; Abbott, 1979) and may be correlative with the lower Morrison disconformity in the Colorado Plateau described by Green (1980). All known Morrison uranium deposits in the Grants district occur above this disconformity.

One mine, the Polita #2 (#20, Fig. 1), has produced one shipment of ore. In 1955, ore containing 2 lbs (0.9 kg) of U_3O_8 at 0.15% and 5 lbs (2 kg) of V_2O_5 at 0.31% was shipped (Table 3). Uranium and vanadium at the Polita #2 occur in fossil logs and fossil bones. Other occurrences in the Morrison Formation in east-central New Mexico are in sandstone and marls, and are low-grade and small (Abbott, 1979; Consulting Professionals, Inc., 1982). Very little exploratory drilling has been done in the area. Most of the deposits in the Grants district are in the subsurface, indicating that more extensive drilling is needed to adequately assess the uranium-resource potential in east-central New Mexico.

INTERPRETATION OF NURE–HSSR GEOCHEMICAL DATA

The HSSR (Hydrogeochemical and Stream Sediment Reconnaissance) survey of the NURE (National Uranium Resource Evaluation) program of the U.S. Department of Energy consists of geochemical surveys and analyses for each of the 1-by-2-degree quadrangles in New Mexico. The HSSR data were unavailable for interpretation during the assessment of uranium resources in east-central New Mexico by Reed et al. (1980, 1982), U.S. Department of Energy (1980), and Consulting Professionals, Inc. (1982). Therefore, a preliminary examination of geochemical element-distribution maps (Chamberlin and McLemore, 1983) compiled from data tabulated in six quadrangle reports (Morgan and Broxton, 1978; Bolivar, 1980; Morgan, 1980; Langfeldt, 1981; Union Carbide Corporation, 1981; Zinkl et al., 1982) was made by the senior author to aid in evaluating the economic-resource potential for east-central New Mexico. Additional interpretation of the HSSR data could provide more insight into the uranium- and copper-resource potential of this area.

The HSSR program was initially designed for regional uranium exploration and assessment of uranium potential. Ideally, one sample (stream sediment and/or water) was taken approximately every 10 km^2, and this sample density was found adequate by pilot studies for this type of reconnaissance work. Actually, the sample density ranged from 1 km^2 to 100 km^2 for one sample. Analytical procedures employed were optimized to maximize speed and precision of uranium analyses. Initially, the samples were analyzed only for uranium. Later the HSSR program was expanded to include multielement analyses.

Preliminary examination of these geochemical element-distribution maps indicated that only a few scattered and isolated copper, silver and uranium anomalies occur in stream-sediment samples. Most of these anomalies were near known districts or mineralized areas.

Numerous anomalous values of uranium in ground-water samples occur throughout east-central New Mexico (Fig. 7). For this preliminary study, anomalous values were arbitrarily chosen as values greater than or equal to 10 ppb, representing about the upper third of the sample population. This threshold value compares well with a similar threshold in the Grants uranium district where about 91.5% of the uranium values in ground water were less than 10 ppb (Purson, 1981). However, additional data such as conductivity, pH, drainage patterns, aquifers and mineralogy of deposits must be incorporated with these preliminary results to evaluate adequately the ground-water anomalies in Figure 7.

Clusters of uranium anomalies in ground water occur in areas of known mineralization, such as the Sabinoso district and the San Jon and Santa Rosa areas (Fig. 7). Many of the anomalies north of the extent of Morrison outcrop (Fig. 7) are most likely due to mineralization in the Morrison Formation. Most of the anomalies south of the Morrison outcrop are probably due to mineralization in the Chinle Formation and Santa Rosa Sandstone. These anomalies represent indications of mineralization which are displaced from their source, but do not necessarily indicate that ore-bodies exist up hydrologic gradient.

A few anomalous copper values (greater than 100 ppb copper) in ground waters exist in the Ft. Sumner and Raton quadrangles near areas of known copper mineralization. Uranium concentrations in copper-rich waters were average or below average (typically in the range of 1–6 ppb). Not all of the ground-water samples were analyzed for copper.

ORIGIN OF MINERALIZATION

Copper, uranium and associated metals probably were transported in low-temperature solutions through permeable sediments and along fractures, bedding planes and contact zones. Although the geochemistry of the mineralizing fluids is not precisely known, soluble chloride (Rose, 1976), carbonate (LaPoint, 1976), bicarbonate (Finch, 1967) and organic (LaPoint, 1979; Leventhal, 1980) complexes could transport these metals in low-temperature solutions. Modern ground waters, locally enriched in copper or uranium, may be similar in composition to past mineralizing solutions. The pH of the modern enriched ground waters averages 6.5 to 8.0 (Morgan and Broxton, 1978; Bolivar, 1980; Morgan,

1980; Langfeldt, 1981; Union Carbide Corporation, 1981; Zinkl et al., 1982). Evidence from LaPoint (1979) suggests that copper is best transported as carbonate and hydroxyl complexes. Uranium is most likely transported as organic complexes, such as humic acids (Leventhal, 1980). Precipitation occurred at favorable oxidation–reduction interfaces, typically in the presence of organic material or H_2S-brines, although precipitation could occur with any change in Eh or pH conditions.

The ore metals were derived from ordinary trace amounts present in rock-forming minerals in Precambrian rocks from the uplifts (Fig. 3; LaPoint, 1974, 1979) or in clay minerals and other detrital minerals that occur in the host rocks and adjacent strata (Finch, 1967). Granitic rocks typically contain more uranium than basaltic rocks, whereas basaltic rocks contain more copper than granitic rocks (LaPoint, 1979). Both lithologies are common in Precambrian terrains of the Pedernal Hills and Sangre de Cristo Mountains (Robertson and Moench, 1979; Armstrong and Holcombe, 1982). Precambrian mineral deposits also

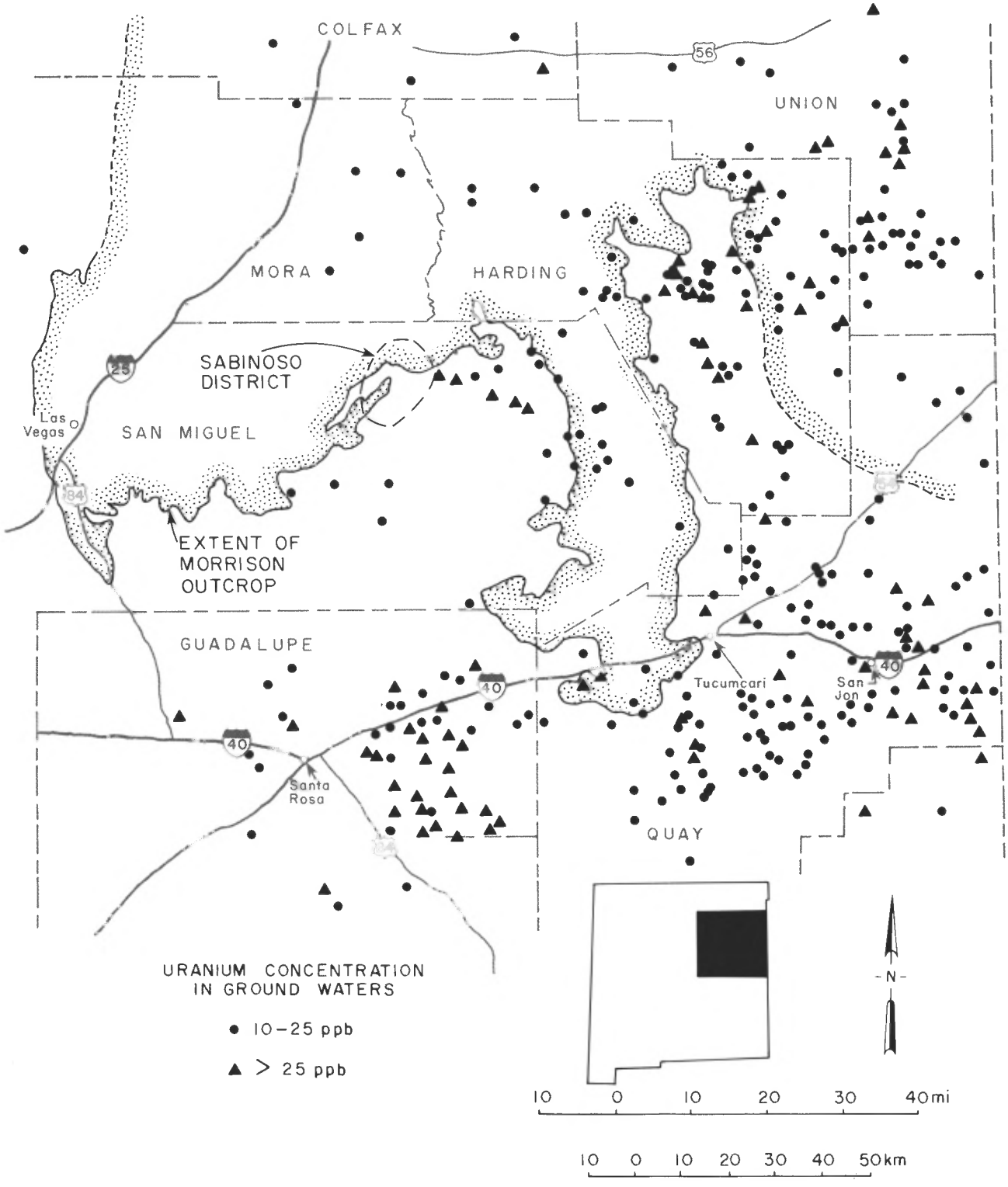


FIGURE 7. Anomalous concentrations of uranium (greater than 10 ppb) in ground waters from the NURE–HSSR data (Bolivar, 1980; Morgan, 1980; Morgan and Broxton, 1978; Langfeldt, 1981; Union Carbide Corporation, 1981; Zinkl et al., 1982).

could have yielded metals to the ground waters (LaPoint, 1974). Paleozoic evaporite and carbonate sequences or basin brines could have been sources of chloride, carbonate and bicarbonate ions. Sulfide could have been obtained from organic material by reduction of sulfate or pyrite (LaPoint, 1979).

ECONOMIC POTENTIAL

Copper mineralization

The Stauber mine in the Pastura district is probably mined out, but additional stratabound sedimentary copper deposits may occur in the area. Detailed geologic mapping and geophysical studies (such as magnetics, gravity or resistivity) are needed to locate additional ore-controlling synclines or structural depressions similar to that at the Stauber mine.

Frontier Resources, Inc. blocked out ore reserves at the Pintada mine in the early 1970's (Sandusky and Kaufman, 1972; LaPoint, 1979), but did not develop them because of low grade and an unfavorable market. The Pintada deposits appear to be controlled by a discontinuous oxidation–reduction front (LaPoint, 1979), although additional mapping and drilling are required to determine the ore-controlling processes of this deposit.

Elsewhere in east-central New Mexico the potential for copper mineralization is not very promising. Most of the known deposits, except for the Pintada and Stauber, are small, discontinuous and low-grade. Unfortunately, the market for copper is unfavorable at the present time for development of most copper deposits, and it is unlikely that development of the deposits in east-central New Mexico will occur in the near future.

Uranium mineralization

East-central New Mexico has some potential for sandstone uranium deposits when the uranium market becomes more favorable, especially if in-situ leaching methods can be used. Integration and evaluation of data on the known uranium occurrences (Fig. 1), favorable host rocks, and the NURE data have delineated several favorable areas.

The Sabinoso district (#16, Fig. 1) is considered favorable for low- to medium-grade, small- to medium-tonnage deposits by McLemore and Menzie (1983). Uranium analyses up to 0.89% U_3O_8 are reported. A cluster of uranium anomalies in ground water greater than 25 ppb uranium occurs east of the Sabinoso district (Fig. 7), further supporting the conclusions of McLemore and Menzie (1983).

A large cluster of uranium anomalies in ground waters occurs east of Santa Rosa (Fig. 7). These anomalies could be indicative of additional mineralization associated with subsurface tar-sand deposits similar to the Santa Rosa tar sands (#32, Fig. 1). However, all known uranium deposits in the Santa Rosa Sandstone are small and low-grade, and probably would not constitute economic ore-bodies.

The Chinle Formation in the San Jon area also may be favorable for sandstone uranium deposits. Uranium anomalies occur in the vicinity of Red Peak, and mineralization occurs in the subsurface. The U.S. Department of Energy (1980; McLemore, 1981) considered the San Jon and Tucumcari areas to have potential for uranium mineralization. Most of the geochemical anomalies in these areas (Fig. 7) are probably from the Chinle Formation. Additional deposits may occur in the Chinle Formation elsewhere in the Tucumcari basin, south of the Sierra Grande arch (Fig. 3).

Alluvial-plain deposits in the lower half of the Sangre de Cristo Formation were considered favorable for speculative uranium deposits by the U.S. Department of Energy (1980; McLemore, 1981) and Reid et al. (1980, 1982). However, known deposits are small and low-grade, and only a few isolated stream-sediment and ground-water anomalies occur. One mine, Ledoux Ranch in the Coyote Creek district, shipped material that was below economic grade in 1954 (Table 3). Favorable alluvial-plain deposits are found in the northern Rowe-Mora basin, where additional uranium deposits may occur (Fig. 3; May et al., 1977).

The Morrison Formation may have potential for uranium mineralization based on (1) one producing mine (Table 3), (2) numerous groundwater anomalies (Fig. 7) and (3) similarity in lithology and depositional environment to ore-bearing units in the Grants uranium district (Abbott, 1979; Consulting Professionals, Inc., 1982). However, known occurrences in the Morrison Formation in east-central New Mexico are low-grade and low tonnage. Drilling is required to properly assess the potential of this formation.

SUMMARY

Copper and uranium mineralization in east-central New Mexico occurs in six formations ranging in age from Pennsylvanian–Permian through Jurassic. These deposits have common source areas, occur in similar sedimentary environments and have similar geologic characteristics; however, differences in composition are apparent. The best copper deposits contain little or no uranium, whereas the best uranium deposits contain only trace amounts of copper. Local concentrations of silver, lead, vanadium and rarely gold, selenium, molybdenum, zinc and cobalt may occur in some deposits.

Copper, uranium and associated metals probably were transported in low-temperature solutions along fractures, bedding planes and contact zones. Precipitation occurred at favorable oxidation–reduction interfaces. Differences in composition between copper deposits (with little or no uranium), uranium deposits (with only trace amounts of copper) and mixed copper–uranium deposits can be explained by (1) different transport/precipitation mechanisms, (2) different periods of mineralization and/or (3) different source terrains.

Although additional copper deposits similar to the Stauber and Pintada mines may occur in east-central New Mexico, it is unlikely that development of these deposits will occur in the near future. Low demand for copper, high production costs, low copper prices and low grade and small size of the stratabound sedimentary copper deposits hamper development and production.

East-central New Mexico has potential for low- to medium-grade (about 0.10%), small- to medium-tonnage deposits in the Chinle Formation at Sabinoso, San Jon and Tucumcari; the Sangre de Cristo Formation in the northern Rowe–Mora basin; and in the Morrison Formation. Development of these deposits will depend upon an increase in demand for, and price of, uranium. These deposits should be evaluated for in-situ leaching methods since these methods are lower in development costs.

ACKNOWLEDGMENTS

We appreciate technical assistance by Kent Anderson, Brian Christiansen and Constance Cooper. This manuscript was improved by reviews from Ronald Broadhead, Robert Weber, Richard Chamberlin and Frank Kottlowski. Mark Tuff assisted in x-ray-diffraction analysis.

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Ute Dam (photo: S. G. Lucas).