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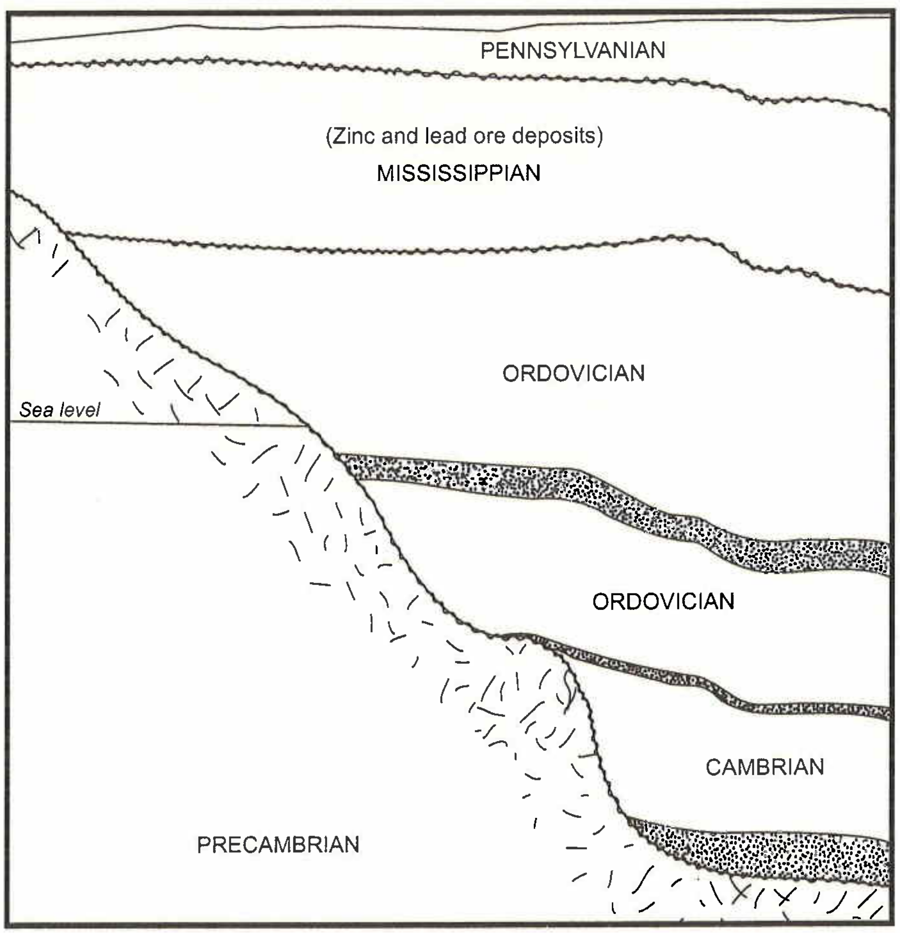
Metallic-Mineral Resources of Oklahoma

Robert O. Fay and Douglas C. Brockie



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Oklahoma Geological Survey
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The University of Oklahoma
Norman, Oklahoma

2002

Front Cover

Cross section through Picher Field showing Precambrian relief and Mississippian ores.

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Metallic-Mineral Resources of Oklahoma

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ABSTRACT. — The main metals produced in Oklahoma have been zinc, lead, and copper. Iron, titanium, manganese, aluminum, gold, silver, uranium, vanadium, and zirconium occur but have not been produced on a large scale. Some germanium, gallium, and cadmium occur in zinc ores. Traces of platinum and palladium have been found in the Wichita Mountains.

Oklahoma can be subdivided into seven mining districts: Tri-State, Ozark, Ouachita, Arbuckle, Wichita, Red Bed, and Black Mesa. Galena, sphalerite, and chalcopyrite occur in veins and lenses in Pennsylvanian and older rocks in the first five districts. Chalcocite, azurite, and malachite copper minerals occur in lenses, pipes, and sheets in stratabound formations in Pennsylvanian, Permian, and Triassic red beds in the last two districts.

The Tri-State area produced 7.2 million short tons of zinc and 1.7 million short tons of lead from 1891 to 1970, and the mines are now abandoned. The Creta strip mine in the Red Bed District of southwestern Oklahoma yielded 1.5 million short tons of copper ore while in operation from 1965 to 1976, when it was shut down because of the low price of copper.

Metallic minerals are not currently being produced in Oklahoma. In most areas, the resources are limited to a few tons of minerals at each prospect and were mostly mined out. Where substantial resources occur, the price of the commodity is too low or the tenor of the commodity is too low for commercial production.

The Indians knew about metallic minerals for more than 1,000 years and guided explorers to these deposits. Many early historical records may need to be checked for opportunities that could have been overlooked as an aid to exploration.

INTRODUCTION

The metallic-mineral resources of Oklahoma consist mainly of zinc, lead, and copper, with minor occurrences of iron, titanium, manganese, aluminum, gold, silver, uranium, vanadium, and zirconium. Some germanium, gallium, and cadmium have been extracted from zinc ores. Silver was extracted as a by-product at one copper mine.

Virtually all the work for this report was completed in 1983. To the authors' knowledge, no subsequent mining or prospecting has taken place since that time. Several relevant studies published since 1983 have been cited in the text and added to the list of references at the back.

Oklahoma can be subdivided into seven mining districts: (1) Tri-State District of Missouri, Kansas, and Oklahoma; (2) Ozark District; (3) Ouachita District; (4) Arbuckle District; (5) Wichita District; (6) Red Bed District; and (7) Black Mesa District of Colorado, New Mexico, and Oklahoma (Fig. 1).

Copper and uranium occur in most of the districts. Lead and zinc occur in the first five districts. Iron occurs in the Arbuckle, Wichita, and Tri-State Districts. Manganese occurs in the Arbuckles and Ouachitas. Aluminum, titanium, and zirconium occur in the Wichitas. Gold and silver occur in trace quantities in copper–lead–zinc minerals in most of the districts.

Metals are not currently being produced in Oklahoma. In the past, from 1891 to 1970, the Tri-State District of Oklahoma produced about 7.2 million tons of zinc and 1.7 million tons of lead (short tons, 2,000 lb, used throughout this report). In the Red Bed District, the Creta Mine yielded about 1.5 million tons of copper ore from 1965 to 1976. Otherwise, the remaining districts yielded a few tons of ore each, consisting mainly of copper, lead, and zinc, with some manganese, iron, uranium, and vana-

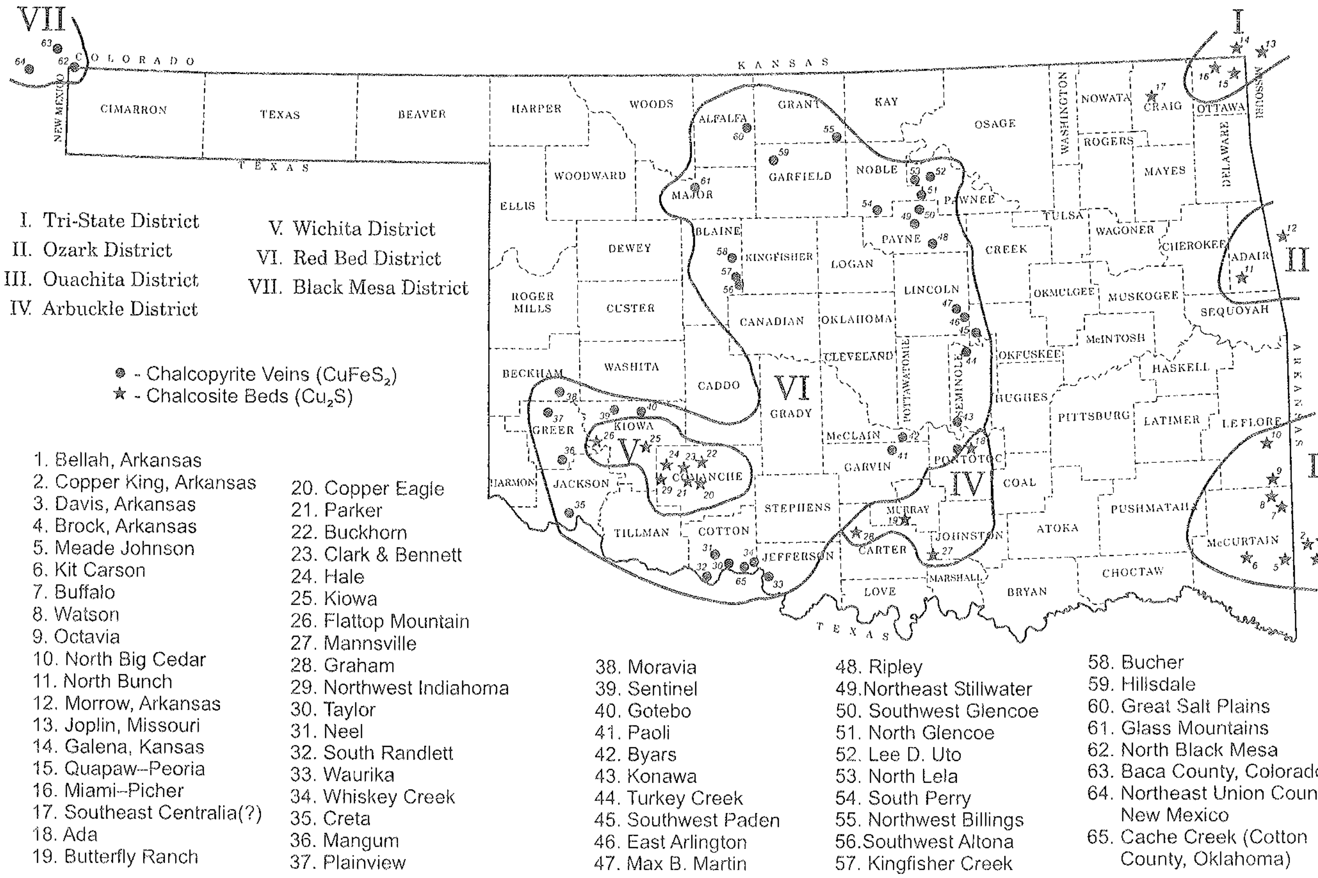

Figure 1. Map showing mining districts in Oklahoma and adjacent areas. Arabic numerals refer to listing of named mines and prospects. Stars indicate vein deposits: galena, chalcopyrite, sphalerite. Solid circles indicate stratabound copper deposits: chalcocite, azurite, malachite.

dium of minor commercial importance. The resources for most areas are unknown to the Oklahoma Geological Survey, principally because most of the prospects have not been drilled by the Survey.

HISTORY OF MINING

The history of mining in Oklahoma begins with the original Caddo Indians and related cultures. These people collected or used copper, lead, iron, quartz, salt, and other minerals for many hundreds of years before Columbus came to the New World. They hammered native copper into plates, ornaments, and utensils, and used copper for a medium of exchange. Galena, malachite, azurite, limonite, and hematite were ground into powder by rubbing them against grindstones, and then the powder was mixed with clay and water to form paint. Many pieces of galena (gray), limonite (yellow), and hematite (red) have been found in burial grounds in the Mississippi River Valley and Arkansas River Valley regions. More than 1,500 lb of rounded galena balls as large as 11 cm (4.5 in.) were found at the Spiro burial mound in northern Le Flore County, Oklahoma, and at the Harlan Site in Cherokee County, Oklahoma (Brown, 1976, p. 464–476; Bell, 1972, p. 234). The sites date from A.D. 700 to 1400.

Quartz crystals of immense size were found in a burial mound on the Knapp farm about 16 mi southeast of Little Rock, Arkansas (Herndon, 1922, p. 42). Salt was gathered in southwestern Arkansas, in Sevier County, as far back as A.D. 1000, at the Salt Slough about 4 mi west of DeQueen, and on the Saline River about 8 mi from Brownstown (Mabry, 1966, p. 11–12). Swanton (1942) gives much background information on the Caddo Indians, who settled in Oklahoma, Texas, Arkansas, and Louisiana. Many modern names in these States come from these tribes—Teijas (Texas, or friend), Nadacoc (Nacogdoches), Natchitoches, Natchez, Caddo Gap, Cannesy (Kansas), etc. These Indians were mostly friendly farm people who settled along rivers and lakes.

The early Spanish and French explorers were guided to the mineral areas in Oklahoma and adjacent states by the Indians. In 1541, the Coronado and DeSoto expeditions penetrated western and eastern Oklahoma. DeSoto's men collected galena, chalcopyrite, and salt from southeastern Missouri, and Coronado described the Big Salt Plain on the Cimarron River in Woods County, Oklahoma. Coronado had seen the Wichita Mountains in the distance but did not visit them. Buel (1904, p. 246–247), Goodspeed (1904, p. 33), and Winship (1893) are excellent references. Thomas (1928, p. 188, 197) documents 10

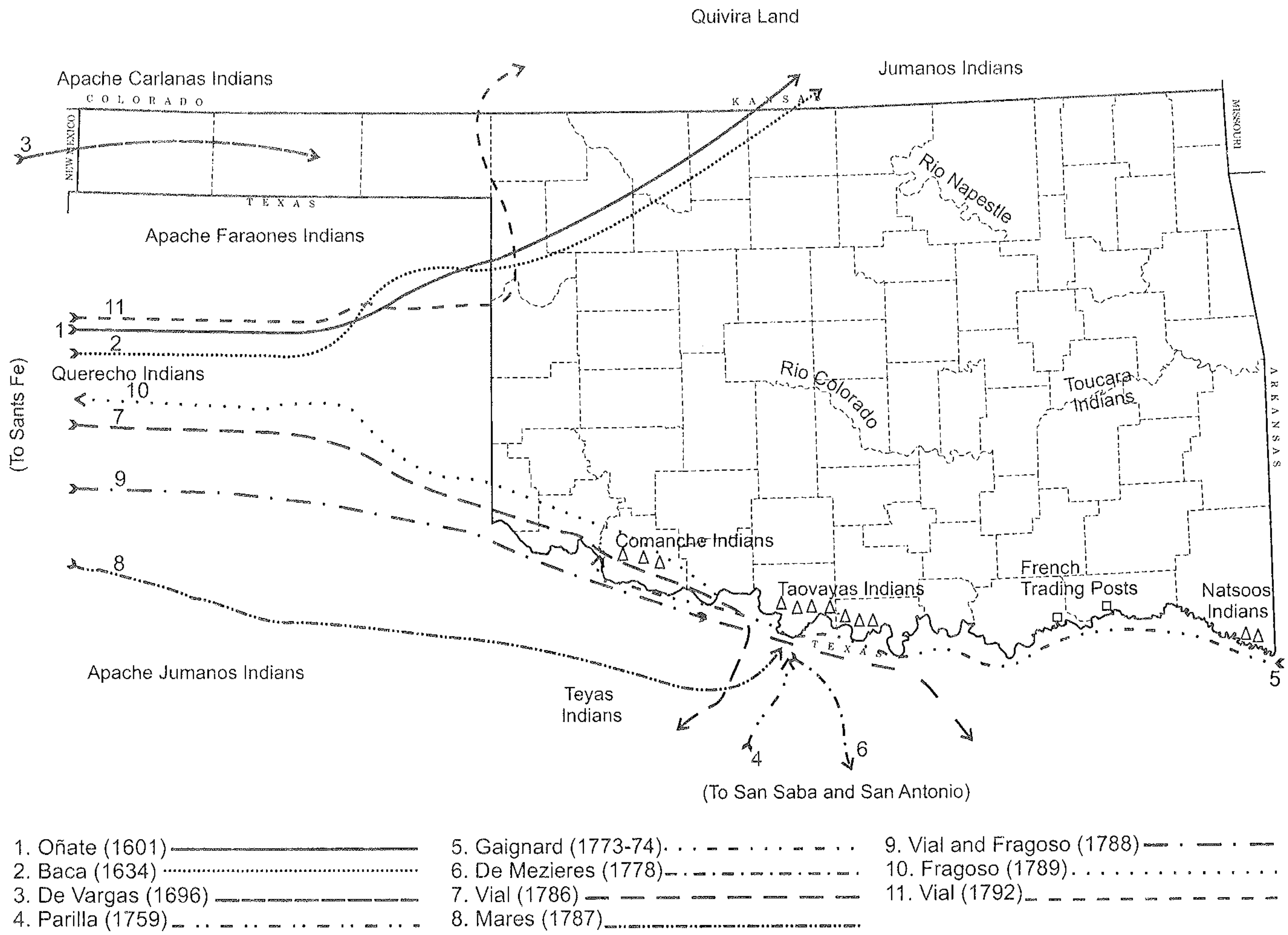

Figure 2. Map showing Spanish exploration in Oklahoma, 1601–1792. (From Thomas, 1928.)

Spanish expeditions into Oklahoma from 1601 to 1792 (Fig. 2).

In 1650, Don Diego del Castillo, from Santa Fe [New Mexico], prospected for 6 months in the Wichita Mountains (Thoburn, 1916, p. 21). Wilson (1976, p. 111–113) disputes this, but states that in 1657 a Father Gilbert and 100 men dug a shaft 100 ft deep about 9 mi northwest of Mount Scott in the Wichitas.

From 1683 to 1803, the French explored the Louisiana Territory west of the Mississippi River from Canada to Mexico. From 1700 to 1723, many French explorers passed through Oklahoma or lived in Oklahoma searching for metals. Goodspeed (1904, p. 117–183) summarizes much of the information:

> In 1703 about twenty Canadians attempted to make their way from the Illinois to New Mexico by way of the Missouri River . . . to search the country for mines. In 1707 Nicholas D'LaSalle proposed to go up the Missouri with one hundred men . . . it may have been the work of this party in the mines of the Osage Country. From 1716 to 1717, the Mississippi and its tributaries were explored for hundreds of leagues, and the Missouri, all looking for mines. In 1719, M. Dutisnet passed up the Missouri . . . to the country of the Osages, thence about a hundred miles up to the Panis or Pawnees, and thence more than a hundred miles farther to the prairie country of the Padoucas. Dutisnet explored and examined the mineral sections, but found nothing more valuable than lead and rock salt.
>
> He took possession of all the territory visited in the name of the King of France. Much of the country visited was mountainous, particularly in the country of the Osages, where many lead mines were found. In 1723, the Missouri River and its various branches, up probably as far as the mouth of the Platte River in Nebraska, were thoroughly explored by the French miners under Phillip François D'Renault. He came with two hundred Frenchmen and three hundred slaves to Fort Chartres, whence they spread out over the West as far as they could do in safety, and opened many lead and other mines in the present state of Missouri.

Lewis (1932, p. 58) documents the Claude Charles Du Tisné expedition to Oklahoma, mentioning an Osage village, probably on the Neosho River in southeastern Kansas, and translating: "They have a lead mine twelve leagues from them, of which they do not know the use." Du Tisné arrived at a Pawnee village on September 27, 1719, on the Arkansas River northeast of present-day

Newkirk, Kay County, Oklahoma, and erected the first French settlement in Oklahoma—Ferdinandina (McRill, 1963). The site is now a national historical monument and is being restored. Du Tisné knew about the Great Salt Plains of Alfalfa County, Oklahoma: "Two days from their village, in the west a quarter southwest, they have a marsh of hard salt" (Lewis, 1932, p. 58).

The French prepared a map of the Louisiana Territory, showing the mines in Missouri and other areas, probably including the Joplin or Tri-State District. The map was drafted by Guillaume Delisle (1718) and reproduced in many publications. Fite and Freeman (1969, p. 176) reprinted the map and discussed its preparation. A part of the map is here redrafted (Fig. 3).

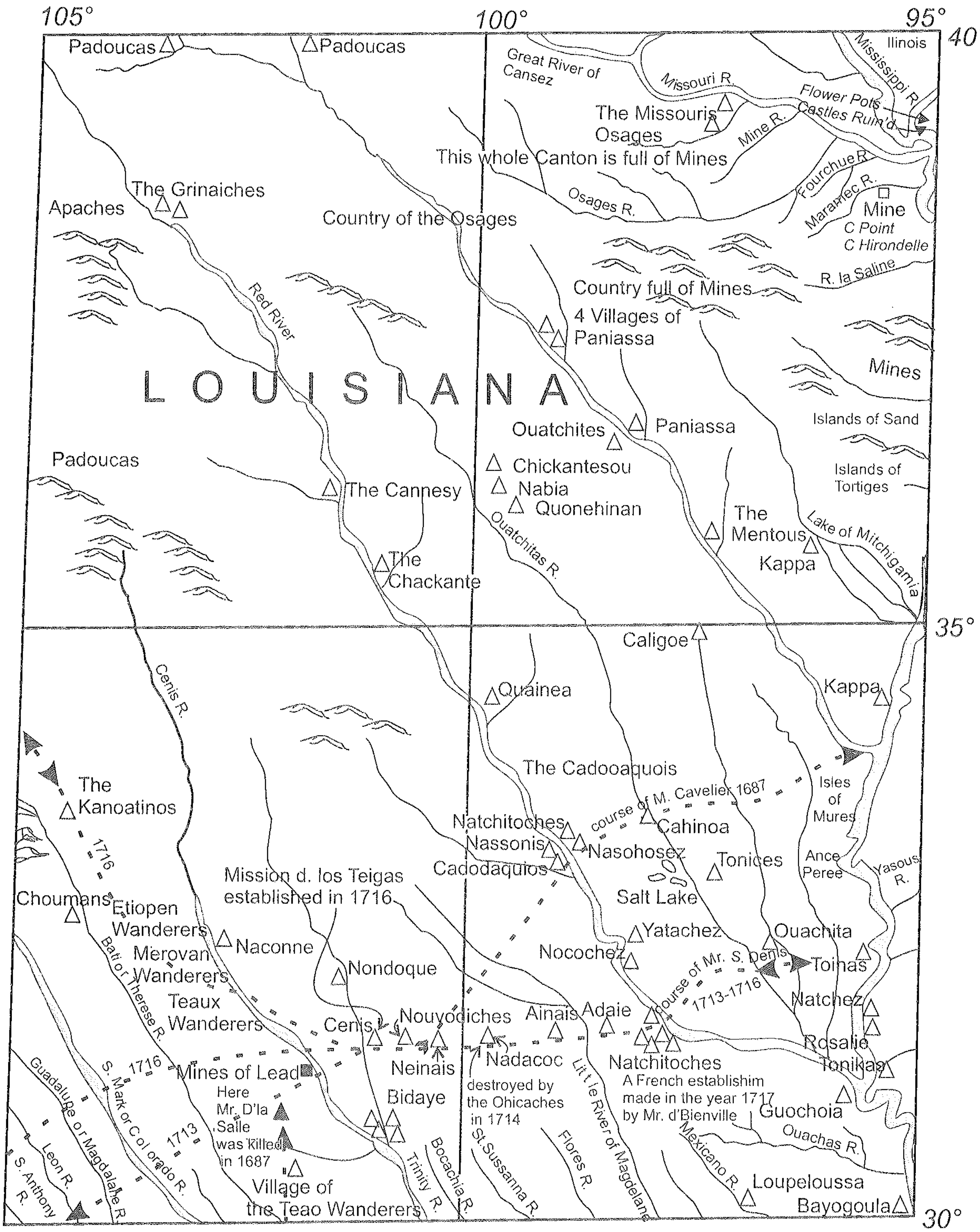

Figure 3. Map of a part of Louisiana Territory. (Modified from Delisle, 1718.)

In 1719, Jean-Baptiste Bénard, Sieur de La Harpe entered Oklahoma from the southeast and met with 6,000 Indians southeast of present-day Tulsa. They traded azurite, malachite, chalcopyrite, salt, and other goods. La Harpe found marcasite, slate, quartz crystals, and coal on his journey, and found out from the Indians that Spanish metallic mines existed in the Ouachitas north of the Red River. An account of La Harpe is given by Margry (1888), Lewis (1924a,b), Smith (1958–59), and Wedel (1971). La Harpe's route is shown by Fay (1980, p. 254), with the first detailed map by Fay (1982, pl. 1), here summarized (Fig. 4).

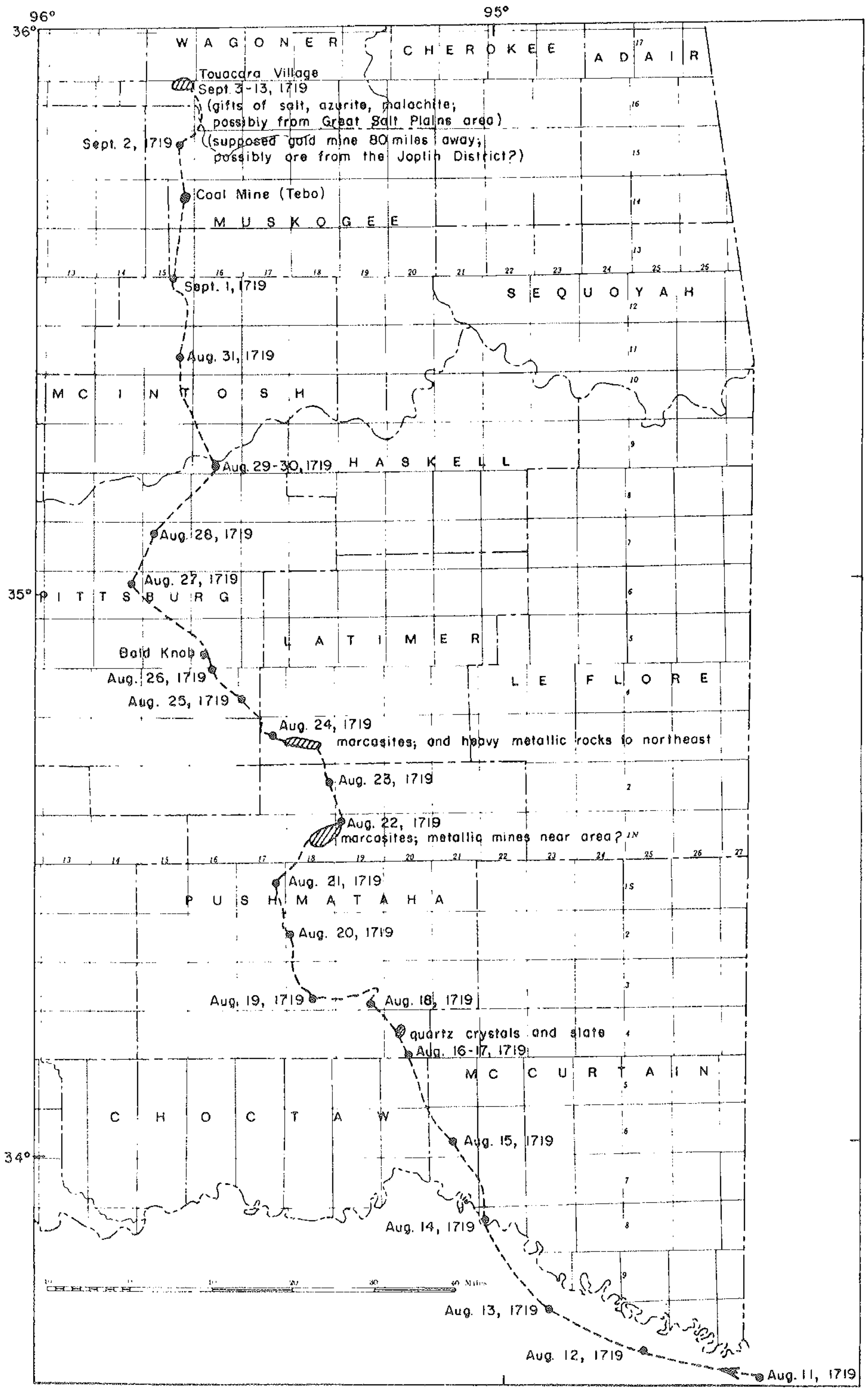

Figure 4. Possible route of La Harpe expedition in Oklahoma, August 14–September 13, 1719. Evening campsites are dated. (From Fay, 1980, p. 254.)

In October 1773, J. Gaignard traveled up the Red River, noting that the Caddo Indians northwest of Texarkana mentioned the existence of a silver mine about 12 leagues northeast of the village, and another on the Kiamichi River about 50 leagues northwest of the village (Bolton, 1914, v. 2, p. 83–84). (A French league was about 2.6 mi at that time.)

After the United States purchased the Louisiana Territory in 1803–04, American expeditions were sent to explore the land. In 1804, Moses Austin, father of the famous Stephen Austin and a mining engineer living in southeastern Missouri since 1797, wrote a history of the mines for President Jefferson. He also commented that valuable lead mines were about 200 mi farther west, which would be close to the Joplin District.

Sibley (1805, p. 729–730) wrote about the Red River area, noting that a silver mine existed on the Kiamichi River about 60 mi up from the mouth by boat, which would be close to Kosoma, Pushmataha County, Oklahoma. He also notes that in 1765 the Spanish were mining in the Wichitas, and that some silver ore was seen along with much rock salt.

Morse (1805, p. 764), writing about the Red River area northwest of Texarkana, mentions a rich silver mine near the Caddo village, and another silver mine farther north. He also mentions that lead ore, iron ore, coal, slate, marble, and plaster of paris occur in the region.

In 1807, Lieutenant James B. Wilkinson, of the Zebulon Pike expedition, visited the Osage Indians on the Arkansas River, mentioning that the country northwest of their village abounded with valuable lead mines (Coues, 1895, v. 2, p. 561; Jackson, 1966, v. 2, p. 19). This was probably a reference to the Tri-State District.

In 1812, John Maley visited the Ouachita, Arbuckle, and Wichita Mountains of Oklahoma, noting asphaltite in the Ouachitas, iron deposits in the Arbuckles, copper minerals south of Wichita Falls, Texas, and gold and old diggings in the Devils Canyon area of the western Wichitas. The Maley Journal is summarized in part by Wilson (1976, p. 79–84) and Fay (1982, p. 7–8).

In 1818, Henry Schoolcraft, an Indian agent, mined and smelted lead in the Joplin area of southwestern Missouri, noting older mines and crude log furnaces about which the Osage Indians knew very little (Gibson, 1972, p. 17). Schoolcraft also notes the occurrence of lead at Bull Shoals, Marion County, Arkansas, and on the Strawberry River, in Lawrence County, Arkansas (Schoolcraft, 1819, p. 60–61; McKnight, 1935, p. 3). Schoolcraft (1821a,b) also published information about the Missouri lead mines.

In 1820, the John Bellah lead mine was opened in Sevier County, Arkansas, about 4 mi from the Oklahoma border from McCurtain County, in the Ouachita Mountains. In 1830, the Davis Mine was opened a few miles farther north. Later discoveries of copper, lead, zinc, antimony, and mercury minerals were made farther east, and other copper, lead, and zinc minerals were found in Oklahoma.

Some of these prospects were probably seen by the Indians and worked by the Spanish much earlier, judging from earlier French accounts. Fay (in press) summarizes many of the details.

In 1838, the Tri-State area around Joplin, Missouri, was opened for commercial mining of lead and zinc ores.

In 1852, Captain Randolph B. Marcy traveled to the Wichita Mountains, noting copper minerals in the red beds around the mountains and along the Red River.

In 1877, John Patrick McNaughton heard of old mines near Peoria, Ottawa County, Oklahoma, from an old Indian friend. The mines were supposedly worked much earlier by the Indians and the Spanish, and could have been the source for the stories told to the early French explorers. Many acres of white flint chips were scattered about the excavations (Wilson, 1976, p. 249). In 1889, McNaughton opened the first mine in the Oklahoma portion of the Tri-State District, naming the company the Peoria Mining Company.

From 1884 to 1925, many small copper mines and prospects were opened in the Oklahoma Panhandle, near Black Mesa, and in adjacent parts of Colorado and New Mexico. Some of these miners were returning from the Klondike in the 1890s and included settlers such as Temple Houston, the son of Sam Houston. Fay (1983) summarizes much of the knowledge of this area.

From the above accounts, it is clear that the Indians knew about metals and metallic minerals for hundreds of years before Columbus. The early explorers, hunters, trappers, Indian agents, and miners learned about these deposits from the Indians. More detailed accounts can be found in Wilson (1976), Morris and others (1982), and Fay (in press).

MINING DISTRICTS

Each of the seven mining districts in Oklahoma has distinctive geology and origin of deposits (Fig. 1). Individual mines may not be related in time and areal extent, but each type of mineral deposit of each district is of similar origin. For instance, in the Ouachita District, the manganese deposits are stratigraphically related to the Arkansas Novaculite, whereas the copper, lead, and zinc mineralization occurs in veins in Ordovician and Mississippian rocks of quite different origin.

Tri-State District

The Tri-State District covers about 700 mi^2 in parts of Ottawa County, Oklahoma, Cherokee County, Kansas, and Newton and Jasper Counties, Missouri (Fig. 5). Many hundreds of publications have been written about the area, some of which are by Winslow and Robertson (1894), Bain and others (1901), Siebenthal (1908, 1915), Snider (1912), Wright (1913), Weidman and others (1932), Fowler and Lyden (1932), Brichta and Perkins (1955), Brockie and others (1968), McKnight and Fischer (1970), Gibson (1972), and Cathles and Smith (1983).

The geology of the region consists of a few hundred feet of Mississippian carbonates, which contain the ores and dip gently northwestward beneath Pennsylvanian clastics (with some ore) of the Cherokee Group. About

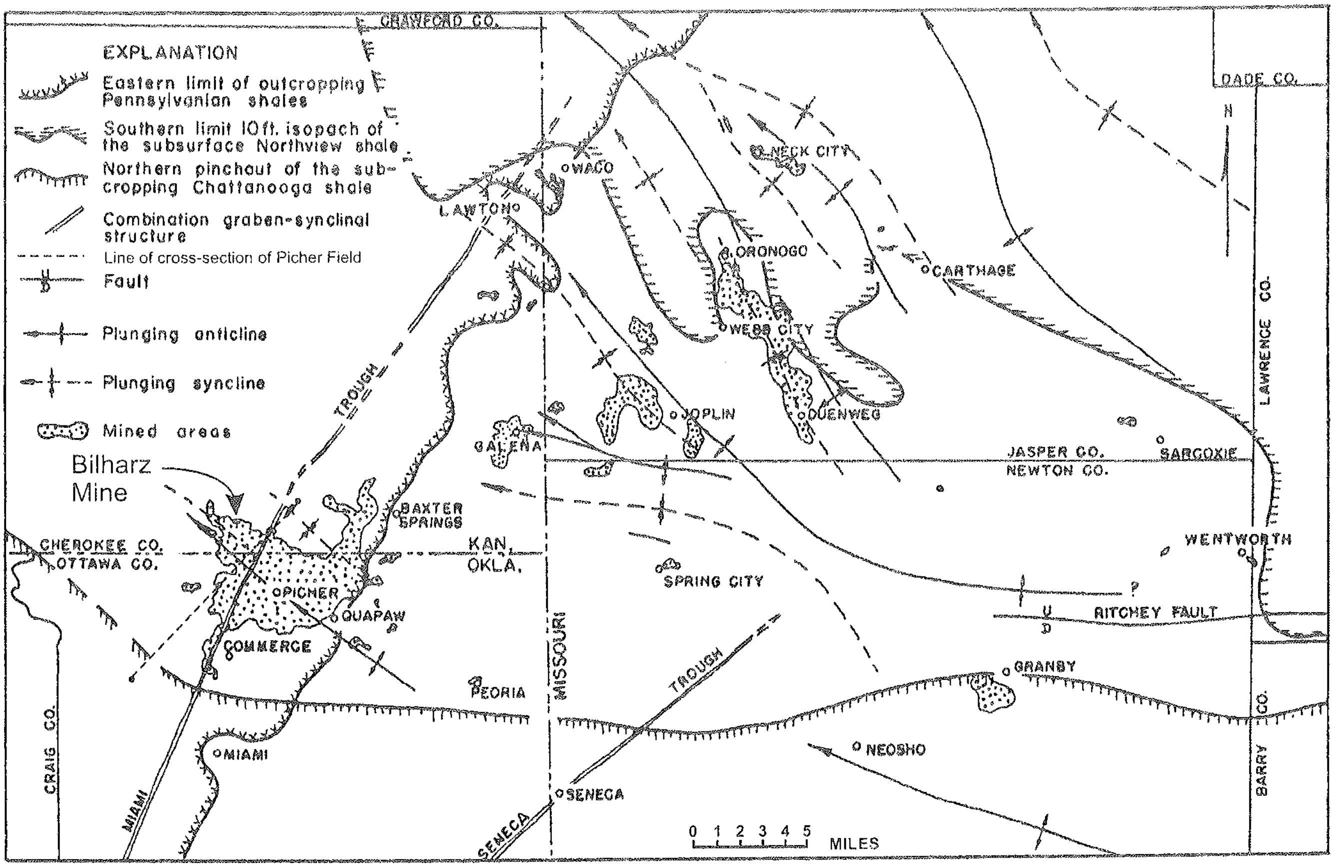

Figure 5. Map of the Tri-State District, showing major structural and other geologic features. (From Brockie and others, 1968, fig. 1, p. 402.)

1,000 ft of Cambrian–Ordovician carbonates underlie the Mississippian carbonates in low structural areas. Major faults, such as the Miami trough, strike northeastward, with minor anticlines and synclines that strike northwestward (Fig. 5). The stratigraphy is shown in Figures 6 and 7.

After the Cherokee Group rocks were deposited, the region was uplifted, eroded, and cracked along major and minor structures. Then, dissolution began forming caves and underground channels along sheared lines of weakness, accompanied by slump-collapsed breccias. The brecciated collapsed areas were later invaded by cool solutions bearing metallic ions. The solutions were warmest along the Miami trough, being about 135°C. The basement igneous rocks are the Spavinaw Granite to the east and the Washington County Volcanic Suite to the west, meeting west of the Miami trough (Denison, 1966, map). The rhyolites, andesites, and granites near the contact areas are sufficiently altered hydrothermally so that the original igneous rocks are almost unrecognizable. The igneous rocks are dated at 1.1 to 1.3 billion years (b.y.) old. There is 1,000 ft or more of Precambrian relief, with Cambrian through Mississippian rocks resting directly against Precambrian rocks (Fig. 8). The lead in the Tri-State District is high in radiogenic lead isotopes 206, 207, 208 and is termed *J-lead* for the Joplin District. The lead is dated at 1.3 ± 0.3 b.y. old, or about the same age as the basement rocks. The metallic-bearing saline solutions either came up directly through the basement and dissolved the J-lead from the igneous rocks (minihydrothermal theory), or the solutions moved laterally a long distance from a basin after picking up the J-lead from basement rocks or from J-lead that was deposited along an unconformable weathered surface at the top of the basement (telethermal theory). McKnight and Fischer (1970, p. 150–151) and Cathles and Smith (1983) discuss these closely related theories.

The main minerals are sphalerite (ZnS), galena (PbS), and chalcopyrite ($CuFeS_2$), along with gangue minerals of dolomite ($CaMgCO_3$) and chert (SiO_2). Marcasite (FeS_2) is a main iron mineral. The ore occurs in brecciated cherts in sheets, pipes, cracks, and pods around dolomite centers adjacent to jasperoid, along sheared or cracked zones along minor uplifts, in Mississippian flat-lying cherty limestones (Fig. 9A,B). From 1850 to 1970, more than 0.5 billion tons of ore was removed, valued at more than $2 billion. The ores averaged 1.5–6.5% zinc and 0.4–2.4% lead (Table 1). The total Oklahoma production from 1891 to 1970 was about 7.2 million tons of zinc and 1.7 million tons of lead. Germanium, gallium, and cadmium have been extracted as by-products. Deeper Cambrian–Ordovician carbonates have been explored, but no new deposits have been found.

	SERIES	FORMATION	REMARKS	
PENNSYLVANIAN	Desmoinesian	Cherokee Group 0–200′+	Cherokee Group is the surface formation in the Picher Field	
MISSISSIPPIAN	Chesterian	Fayetteville Shale 0–70′ Batesville Sandstone 0–70′ Hindsville Limestone 0–85′	The Chesterian Series is referred to as the Mayes Formation in older literature. The Carterville Formation in the Joplin area is faunally related to the Fayetteville and the Batesville Formations.	
MISSISSIPPIAN	Meramecian	Warsaw Ls. 65–162′	B-J bed=Warsaw Formation; J bed is equivalent to Cowley Formation of southeastern Kan.	All Meramec and Osage sediments are referred to in same literature as the Boone Formation or Group
MISSISSIPPIAN	Osagean	Keokuk Ls. 28–255′	K–Q beds (N,O,P,& Q=Grand Falls Chert)	
MISSISSIPPIAN	Osagean	Reeds Spring Ls. 50–100′	R bed	
MISSISSIPPIAN	Osagean	St. Joe Group: Fern Glen Ls. 15–65′	Corresponds to Pierson Formation in recent literature	
MISSISSIPPIAN	Kinderhookian	St. Joe Group: Northview Shale 0–10′	Thin to absent in Picher Field	
MISSISSIPPIAN	Kinderhookian	St. Joe Group: Compton Limestone 0–10′		
MISSISSIPPIAN DEVONIAN		Chattanooga Group 0–50′	Absent except as local patches in Picher Field; subcrop edge is located a few miles south of district	
ORDOVICIAN	Canadian	Cotter Dolomite 0–300′ Jefferson City Dolomite 0–200′ Roubidoux Ss. 0–200′ Gasconade Dolomite 0–300′ Gunter Ss. Member 0–30′		
CAMBRIAN	Croixian	Eminence Dolomite 0–150′		
CAMBRIAN	Croixian	Potosi Dol. 0–30′		
CAMBRIAN	Croixian	Elvins Group: Derby - Doe Run Dol. + Davis Fm. 0–125′		
CAMBRIAN	Croixian	Reagan Ss. 0–200′		
Precambrian Complex (1.1 to 1.3 b.y. old)		Washington County Volcanic Suite to west. Spavinaw Granitic Suite to east.		

Figure 6. Generalized stratigraphic section, Tri-State District. (Modified from Brockie and others, 1968, fig. 3, p. 407.)

Ozark District

The geology of the Ozarks is similar to that of the Tri-State area, consisting of Paleozoic rocks dipping gently southward to southwestward. The host rocks range in age from Ordovician through Early Pennsylvanian (Fig. 10). About 252 small prospects and mines are recorded by McKnight (1935, pl. 5) in Arkansas (Fig. 11). One small lead and zinc prospect is in the Boone Group north of Bunch in sec. 9, T. 14 N., R. 24 E., Adair County, Oklahoma. In this district the minerals occur in collapsed structures or along faults and cracks (Fig. 12). The main minerals are galena, sphalerite, chalcopyrite, smithsonite ($ZnCO_3$), and cerrusite ($PbCO_3$).

About 1,500 tons of lead and 24,000 tons of zinc were produced in Arkansas from 1907 to 1930, valued at approximately $5 million, according to McKnight (1935, p. 6) (Table 2).

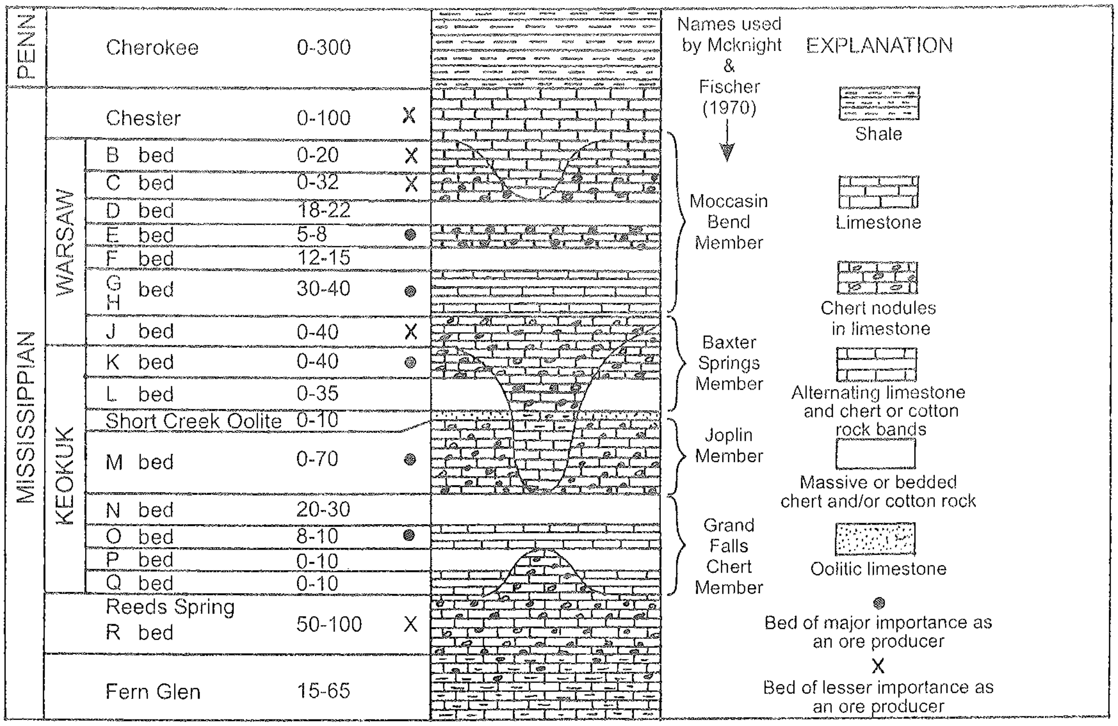

Figure 7. Geologic section of Mississippian formations, Picher Field. (Modified from Brockie and others, 1968, fig. 4, p. 408.)

Ouachita District

The Ouachita Mountains of southeastern Oklahoma and adjacent parts of Arkansas cover more than 20,000 mi^2. The geology consists of folded and thrust-faulted Lower Ordovician through Middle Pennsylvanian clastics and turbidites striking east–west in Arkansas but curving southwestward in Oklahoma. In Oklahoma, the core area consists of intensely folded and slightly metamorphosed slates, cherts, phyllites, quartzites, and dolomitic marbles, covering about 750 mi^2 (Fig. 13). Lower Cretaceous beds onlap unconformably upon Ouachita rocks on the south side, dipping gently southward. The stratigraphy is shown in Figure 14. The main minerals occur in veins, cracks, pods, and lenses in Paleozoic rocks in Oklahoma, which contain copper, lead, zinc, manganese, and vanadium.

Vanadium was extracted from impsonite in the Jackfork Sandstone (Lower Pennsylvanian) east of Page, Le Flore County, in the NE¼SE¼ sec. 23, T. 3 N., R. 26 E. The vein was 0.5–10.5 ft wide and 120 ft long, branching into many veins in the side of the mountain. The impsonite, formed from dried-up oil, was burnt, and the ash (0.17–0.28% V_2O_5) was shipped from Page. About 2,000 lb was shipped in about 1917. Ham (1956, p. 10, 78) summarizes the information.

Manganese was extracted from psilomelane (MnO (Mn,K,Ba)O • $nH_2O + H_4Mn_5$) in the lower Arkansas Novaculite (Silurian), although other parts of the formation contain some manganese minerals. Disseminated manganese in the novaculite was probably oxidized and eroded and redeposited stratigraphically in crusts, veins, and lenses 0–4 ft or more thick, extending several hundred feet along strike at each prospect. The mineral deposits are 6–15 ft deep and appear to die out at depth. Merritt (1941) describes 10 or more occurrences in McCurtain County (Fig. 13). The deposits range from 7% to 49% manganese where hand picked. One carload of ore was shipped to Hatton, Arkansas, in 1916 from Pine Mountain in the SW¼ sec. 15, T. 3 S., R. 26 E. Honess (1923, p. 42–47) discusses the Oklahoma occurrences, and Penrose (1891) and Miser (1917) discuss the Arkansas occurrences.

Copper, lead, and zinc minerals have been mined in the Ouachita Mountains since the early 1800s. Most of the prospects and mines were closed before 1920. Only a few hundred tons of minerals were mined in Oklahoma. Most of the pits were less than 100 ft deep and about 8 ft square. Galena, sphalerite, and chalcopyrite occur with quartz veins in the Lower Ordovician Collier Shale and in the Stanley shale in the Choctaw anticlinorium of McCurtain County (Fig. 13). The quartz veins cut all Paleozoic rocks in the area and are present southeast of a line extending from sec. 16, T. 4 S., R. 20 E., to sec. 28, T. 1 N., R. 26 E. The basal Cretaceous Antlers Formation contains reworked quartz pebbles derived from erosion of the veins, proving that the veins are pre-Cretaceous in age, according to Miser (1943). Honess (1923, p. 35–42) and Fay (in press) summarize information on 15 prospects in Oklahoma. Mabry (1966), Owen (1860), Phipps (1929),

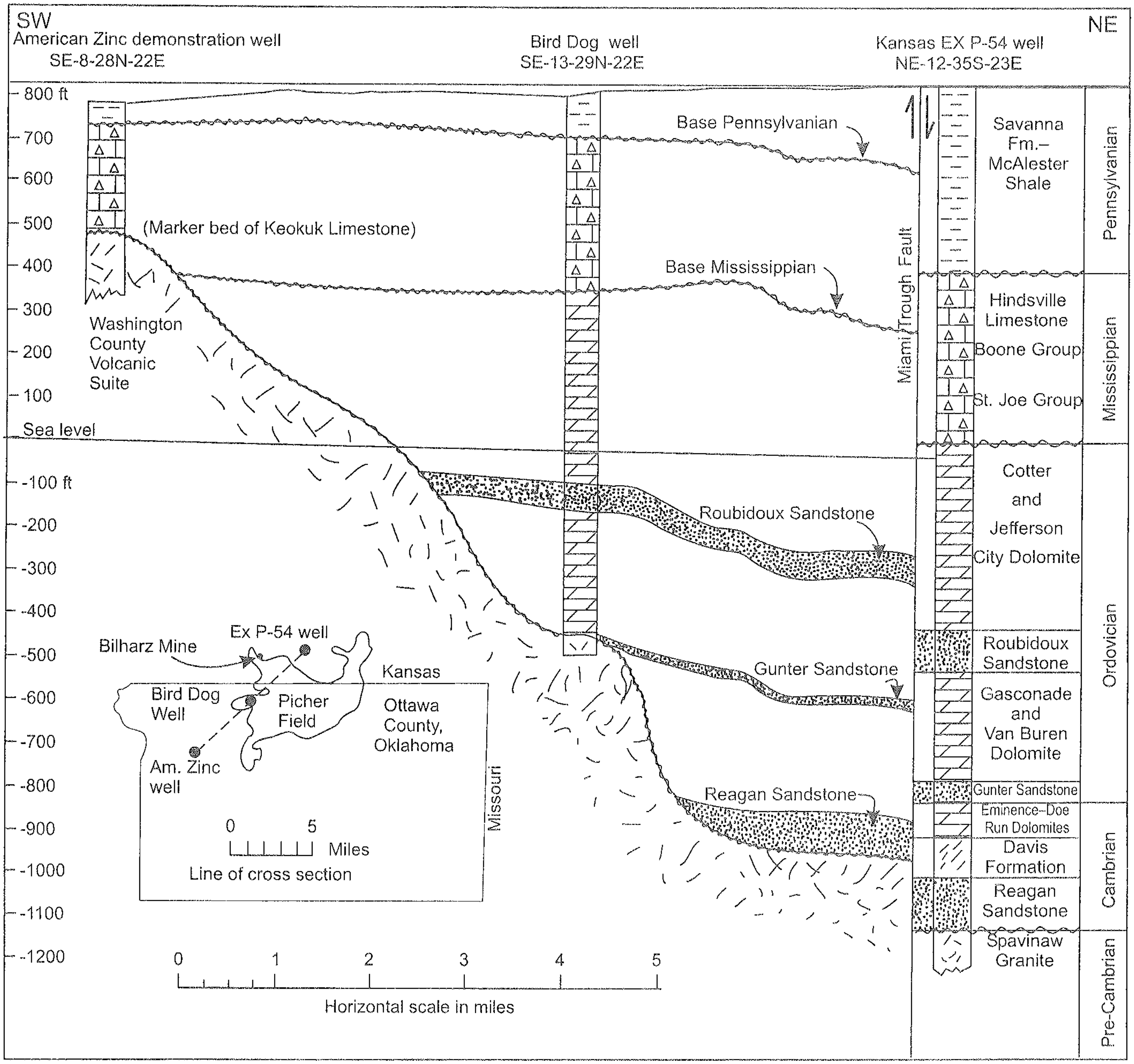

Figure 8. Cross section through Picher Field. (Modified from McKnight and Fischer, 1970, fig. 3.)

and Probert (1977) give additional historical information on the region. Bass and Ferrara (1969) dated adularia associated with the veins as Pennsylvanian in age, but Scull (1959) thought that the mineral deposits were Cretaceous in age, especially the antimony (stibnite) and mercury (cinnabar) deposits in Arkansas. These latter minerals have not been found in Oklahoma but were reported just a few miles east of the Oklahoma border by Williams (1875), Dunnington (1878), Waite (1880), Hess (1908), Schriver (1917), Mitchell (1922), Miser and Purdue (1929), Hall (1940), Thoenen (1944), Scull (1959), Pittenger (1974), and Pittenger and Konig (1979).

Arbuckle District

The Arbuckle Mountains of south-central Oklahoma cover about 1,000 mi^2. The geology consists of northwest-trending faulted anticlines and synclines with Paleozoic shelf rocks, about 12,000 ft thick, with Precambrian granite basement rocks to the east and Cambrian rhyolite basement rocks to the southwest (Figs. 15–17).

The main mineralization probably took place at the end of the Pennsylvanian Period, when connate brines and hydrothermal solutions moved upward and erosion occurred. Iron, manganese, zinc, and lead minerals

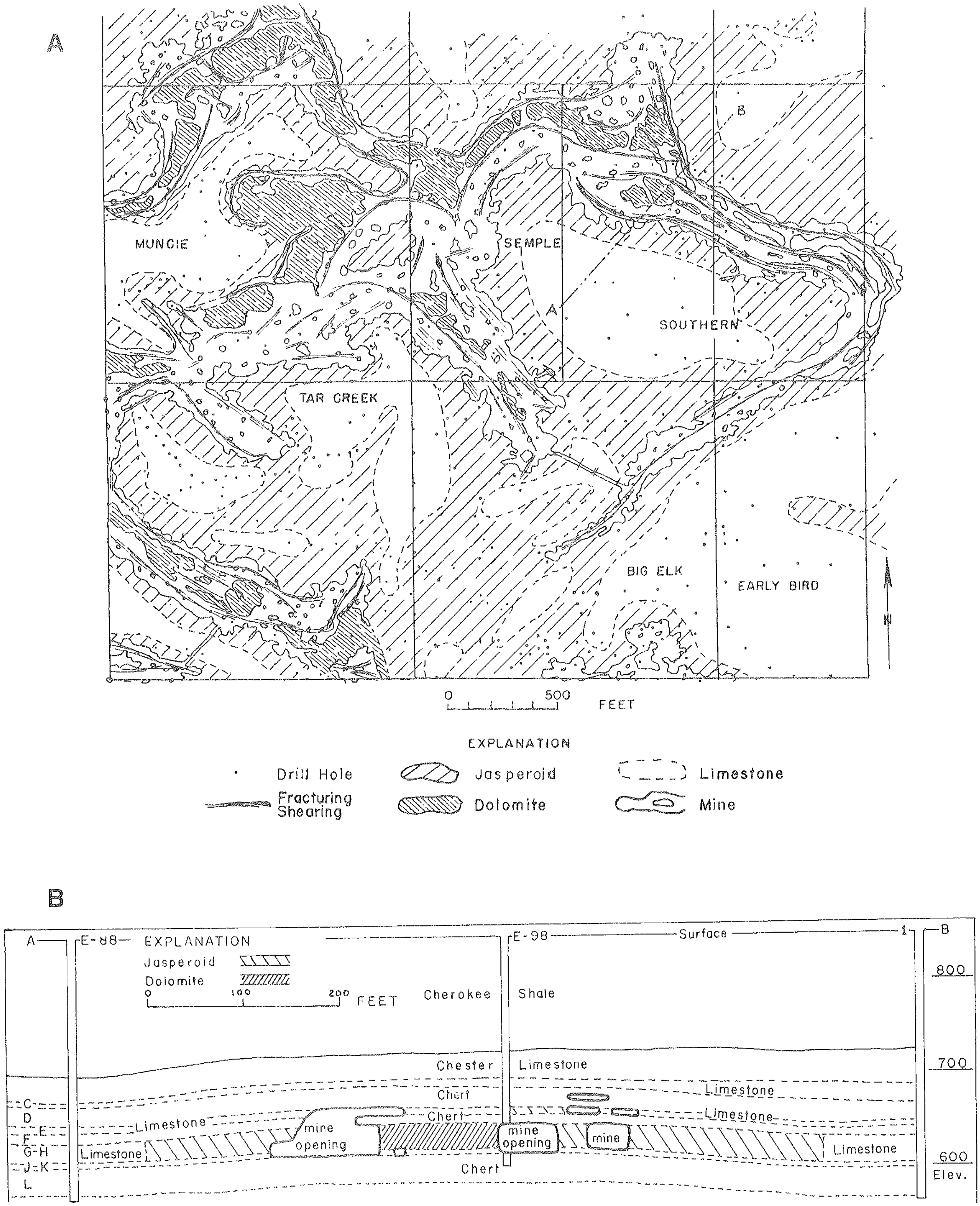

Figure 9. (A) Map of G, H, J, and K beds of the Bilharz Mine, Picher Field, showing mineralization and fracturing or shearing. (From Brockie and others, 1968, fig. 7, p. 418.) (B) Cross section of Bilharz Mine in NE¼SE¼SE¼ sec. 2, T. 35 S., R. 23 E., Kansas, showing relationship of jasperoid and dolomite to mined areas. (From Brockie and others, 1968, fig. 8, p. 419.)

TABLE 1. — Tri-State District Production—Missouri, Kansas, and Oklahoma, 1850–1964
(From Brockie and others, 1968, table 1)

Years (inclusive)	Crude ore treated[a]	Metal recovered from ore heads: Lead (%)	Metal recovered from ore heads: Zinc (%)	Old tailings treated[a]	Mill concentrates: Lead[b]	Mill concentrates: Zinc[b]	Mill concentrates: Total value[c]	Recoverable metal at smelters: Lead[d]	Recoverable metal at smelters: Zinc[d]	Recoverable metal at smelters: Total value[c]
1850–1906	([e])	([e])	([e])	None	831	4,355	$157,241	599	2,042	$255,852
1907–1910	34,192	0.40	1.64	([f])	171	1,130	52,067	132	559	72,254
1911–1920	109,179	0.47	1.81	([f])	652	3,811	249,168	505	1,978	405,001
1921–1930	107,311	0.75	3.00	16,119[g]	1,030	6,137	339,770	799	3,195	524,015
1931–1940	45,772	0.72	3.23	57,853	436	3,389	131,551	332	1,808	210,848
1941–1950	75,656	0.39	1.75	76,678	394	2,832	304,058	298	1,519	390,048
1951–1960	29,935	0.48	1.56	1,985	198	894	133,676	145	476	177,647
1961–1964	1,959	0.73	2.71	None	19	90	9,661	14	53	16,054
1907–1964	399,004			152,635	2,901	18,284	$1,319,951	2,226	9,588	$1,795,867
1850–1964	?	?	?	152,635	3,732	22,639	$1,477,192	2,825	11,631	$2,051,719

[a] Thousands of short tons of ore or tailings.
[b] Thousands of short tons of zinc and lead concentrates.
[c] Thousands of dollars.
[d] Thousands of short tons of zinc and lead metal.
[e] Not available.
[f] Some old tailings were treated in the Tri-State.
[g] Some old tailings were treated in the Tri-State. 1921–1925, inclusive, but are not included here. The tailings figures for 1926 pertain only to Oklahoma.

formed along bedding planes and fault zones in permeable carbonates. Most prospecting and mining was done from 1891 to 1942. Only a few wagonloads of minerals were removed from the manganese and zinc prospects. The mines were less than 100 ft deep, each covering less than 1 acre of ground.

Iron occurs mainly as limonite and goethite ($Fe_2O_3 \cdot nH_2O$) in Arbuckle Group carbonates, in lenses, crusts, and layers along bedding planes and faults, especially in the Hunton anticline. Some mineralization occurs in the Simpson, Viola, and Hunton rocks. Eight main deposits are described by Merritt (1940a), each covering a few acres or less, being less than 20 ft thick. The average iron content is 57%. The total resources are about 250,000 tons. Maley (1812) first reported iron deposits in the Arbuckles. Merritt (1940a) is the main source of information. Almost none of the deposits have been mined.

Manganese occurs as manganite ($Mn_2O_3 \cdot H_2O$) and manganiferous carbonate (Mn-Ca-Fe-Mg)(CO_3) along faults and unconformities in the Chimneyhill Subgroup (Ordovician–Silurian) in the eastern part of the Hunton anticline. The deposits are 5–20 ft wide, up to 1,000 ft long, and 5–100 ft deep in places. The manganese content ranges from 17% to 66% and amounted to about 5,000 tons of reserves. The deposits were worked from 1891 to 1942, when 476 tons of 37–39% ore was shipped out. The main publications on these deposits are those by Weeks (1893), Hewett (1921), Merritt (1941), and Ham and Oakes (1944).

Zinc and lead occur as sphalerite (ZnS) and galena (PbS) in Cambrian and Ordovician carbonates of the Arbuckle Group, especially in the Royer and Butterly Dolomites along the Washita Valley fault zone in the western Arbuckle Mountains. Smithsonite ($ZnCO_3$) is also an important mineral. From 1904 to 1918, about 1,500 tons of zinc ore was removed, averaging 0.17–5.4%, with higher percentages to 25% in hand samples. Most of the mining activity was southwest of Davis in T. 1 S., R. 1 E., with some reports of activity in T. 2 S., R. 2 E., and T. 2 S., R. 4 E. The latter locality has lead and zinc in the top of the Reagan Sandstone. Most of the shafts were less than 100 ft deep, with the minerals occurring in veins, sheets, lenses, and cracks. The principal publications on the area are those by Gould (1910), Snider (1911), Benge (1936), Sargent (1974), Ryan (1976), Kranak (1978), and Fay (1981).

Wichita District

The Wichita Mountains cover about 1,200 mi^2 in southwestern Oklahoma, with about 1,200 ft of maximum relief. The geology consists of Middle Cambrian or older igneous rocks overlain by Cambrian and Ordovician carbonates on the north flank dipping northward (Fig. 18). The oldest rocks are gabbros and anorthosites, covered

System	Series	Formation	Thicknes (feet)	Character
CARBONIFEROUS	PENNSYLVANIAN	"Winslow" Formation	130+	Shale and sandstone
		Unconformity		
		Hale Formation	190	Black shale, brown ironstones and sandstone, gray to brown limestones
		Unconformity		
	MISSISSIPPIAN	Pitkin Limestone	55–115	Gray bituminous and oolitic limestone
		Unconformity		
		Wedington Sandstone Member	10+	Buff thin-bedded sandstone
		Fayetteville Shale	150–200	Black shale with limy septarian nodules
		Batesville Sandstone	25	Gray sandstone with some sandy limestone and shale
		Hindsville Limestone Member	0–10	Dark-gray bituminous oolitic limestone with chert at base
		Boone Group	350+	Gray massive crinoidal limestone and chert
		St. Joe Group	20–45	Red and gray crystalline limestone, thin-bedded
			0–18	White to brown sandstone with phosphatic pebbles
		Unconformity		
SILURIAN		St. Clair Limestone	0–60	Gray to pink vuggy limestone
		Unconformity		
		Brassfield Limestone	0–30	Glauconitic to pink limestone
		Unconformity		
ORDOVICIAN		Cason Shale	0–23	Green, black, and blue-gray shale
		Unconformity		
		Fernvale Limestone	0–50	Gray to pink coarsely crystalline limestone
		Unconformity	Thin	Unnamed gray sandstone
		Kimmswick Limestone Plattin Limestone	0–100	Blue-gray dense limestone, undifferentiated
		Unconformity		
		Joachim Dolomite	0–13	Dark-gray sandy dolomite
		St. Peter Sandstone	0–136	White to buff saccharoidal sandstone
		Unconformity		
		Jasper Limestone	0–50	Bluish-gray limestone
		Everton Formation	0–400	Bluish-gray limestone, white sandstone, gray dolomite
		Unconformity		
		Powell Dolomite	85–170	Gray medium-bedded dolomite
		Unconformity		
		Cotter and Jefferson City Dolomites	400+	Gray dolomite, with some chert, sandstone, and shale

Figure 10. Stratigraphic column for Ozark District, northern Arkansas, and adjacent parts of Oklahoma. (From McKnight, 1935, pl. 2.)

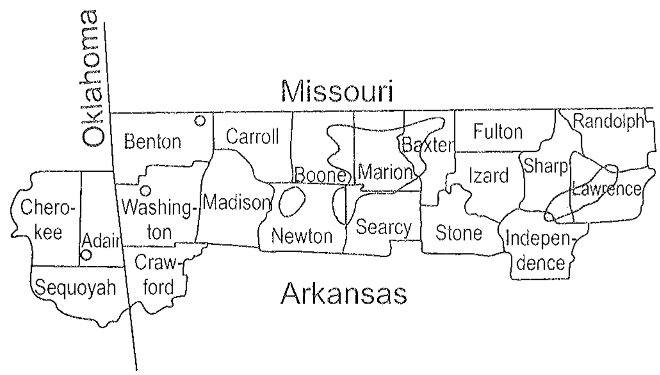

Figure 11. Map of northern Arkansas zinc–lead region, showing 252 prospects and small mines. (Modified from McKnight, 1935, pl. 5.)

by extrusive rhyolites and intruded by later granites (Fig. 19). The rocks strike northwestward, being faulted between the Anadarko basin on the north side and the Marietta-Tillman basin on the south side. They plunge northwestward into the buried Amarillo Mountains in Texas. The rocks also plunge southeastward into the Harrisburg trough and are continuous with the Criner Hills structures of south-central Oklahoma. The Paleozoic rocks were uplifted and eroded in Late Mississippian through Late Pennsylvanian time. Permian red beds onlap unconformably upon all older units and are flat lying around the Wichitas, surrounding many isolated peaks.

A modern account of the geology of the Wichitas is given by Merritt (1958), Ham and others (1964), Gilbert and Donovan (1982), Gilbert (1986), and Donovan (1986). Historical information on mining is given by Sibley (1804), Maley (1810–13), Margry (1888), Winship (1893), DeBarr (1904), Goodspeed (1904), Bain (1904), Woodruff (1904), Bolton (1914), Thoburn (1916), Lewis (1924b, 1925), Thomas (1928), McWilliams (1953), Smith (1958–59), Johnson (1969), Wedel (1971, 1978), Probert (1977), Wilson (1976), Hale (1980, 1981, 1983), and Morris (1982).

Mining and exploration began in the 1650s, culminating in 1901 to 1904, and dying out about 1912.

Copper, lead, and zinc minerals are found in veins in the igneous rocks. Iron, titanium, and aluminum minerals are found associated with weathered igneous rocks or with alluvial deposits along low areas or streams. Some sedimentary iron is in the Reagan Sandstone. Zirconium occurs in zircons in pegmatites in granite. Uranium occurs in trace quantities in pegmatites and granites. Some placer gold was reported in trace amounts in some Pleistocene alluvial deposits. Some gold and silver has been reported in trace amounts in veins in the igneous rocks.

The copper, lead, and zinc minerals were first noted by Bain (1904), DeBarr (1904), and Woodruff (1904), with later comments by Snider (1912). More than 15,000 registered claims were filed from 1884 to 1912, mostly by miners looking for gold, although a dozen or more of the discoveries were copper, lead, and zinc prospects. All of the prospects were less than 200 ft deep, mostly consisting of a single shaft. The minerals are galena, sphalerite, and chalcopyrite, occurring in veins and cracks in the granites and in contact zones of granites with the gabbros and anorthosites. Hale (1981) actually located about 94 known prospects, but he did not publish his map. About

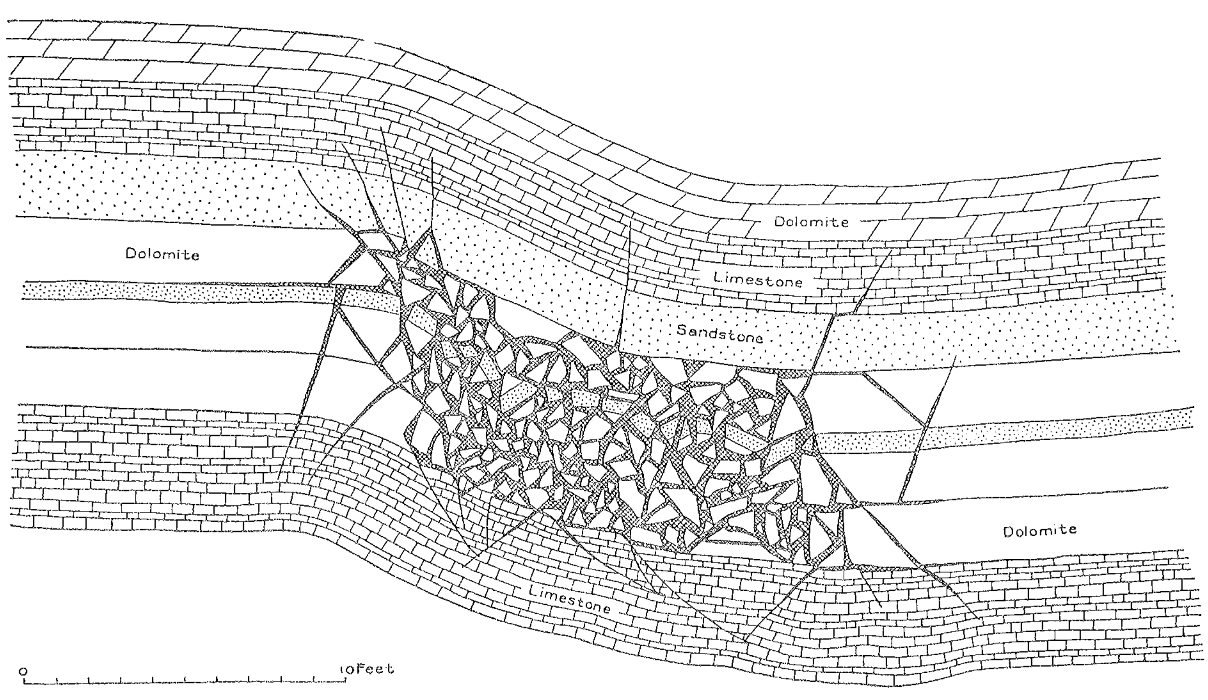

Figure 12. Diagrammatic cross section of mineralization in the Everton Formation along a flexure. (From McKnight, 1935, fig. 8.)

TABLE 2. — Zinc and Lead Produced in Arkansas, 1907–1930
(From McKnight, 1935, p. 6)

	Ores						Metal content			
	Lead concentrates (galena)		Zinc concentrates							
			Sphalerite		Silicate and carbonate		Lead		Zinc	
Year	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1907	15	$800	538	$15,233	663	$16,210	12	$1,272	474	$55,932
1908	18	985	516	18,270	939	21,469	15	1,260	605	56,870
1909	30	1,800	896	33,948	98	2,736	24	2,064	510	55,080
1910	80	3,714	1,857	74,136	128	2,641	63	5,544	994	107,352
1911	80	4,321	1,407	40,425	183	4,239	64	5,760	664	75,696
1912	39	2,180	1,419	56,235	462	11,231	31	2,790	748	103,224
1913	23	1,179	594	16,916	680	15,050	18	1,584	478	53,536
1914	52	2,408	743	19,406	1,143	25,187	41	3,198	608	62,016
1915	79	4,961	606	41,341	7,925	408,079	63	5,922	3,209	795,832
1916	339	28,097	1,670	112,726	16,609	940,224	272	37,536	6,815	1,826,420
1917	474	47,593	916	57,824	17,053	650,585	382	65,704	6,691	1,364,964
1918	155	13,594	310	16,450	2,156	68,333	120	17,040	951	173,082
1919	35	2,400	—	—	510	18,170	28	2,968	189	27,594
1920	10	755	—	—	917	28,925	8	1,280	329	53,298
1921	27	1,510	—	—	42	580	21	1,890	15	1,500
1922	55	4,000	—	—	425	6,870	42	4,620	134	15,276
1923	32	2,559	—	—	444	9,919	25	3,500	148	20,128
1924	25	2,730	—	—	13	330	20	3,200	4	520
1925	93	8,546	58	2,380	44	1,296	58	10,092	43	6,536
1926	28	2,544	8	346	246	7,012	18	2,880	87	13,050
1927	30	2,590	—	—	386	9,453	23	2,898	128	16,384
1928	50	4,010	—	—	224	5,600	38	4,408	86	10,492
1929	66	5,500	—	—	25	605	51	6,426	9	1,188
1930	68	4,033	—	—	—	—	53	5,300	—	—
Total	1,903	$152,809	11,538	$505,636	51,315	$2,254,744	1,490	$199,136	23,919	$4,895,970

10 documented discoveries are shown on the geologic map, depicted as copper (Fig. 18). It is possible that the Spanish first observed these minerals, encouraging further exploration. Snider (1912, p. 94) sampled galena veins in granite in the Starley Mine northwest of Lawton, in Comanche County, finding downward enrichment from 3% to 12% at a depth of 70 ft, with a trace of zinc, silver, and gold. The vein occurs along a faulted zone, which is typical of many other prospects. The Hale Copper Mine in the NE¼NW¼ sec. 9, T. 3 N., R. 15 W., Comanche County, was worked in a granitic dike near the contact of granite and gabbro, where rocks with native copper and chalcopyrite were assayed at 0.35–26% copper by Bain (1904, p. 88, 92) and Woodruff (1904, p. 28). Considerable amounts of sphalerite were found in the American Girl Mine dump, west of the Starley Mine. Snider (1912, p. 96) mentions that the mine was about 170 ft deep and that the minerals may be found in paying quantities. These reports indicate a need for further study of metallic minerals in the Wichitas.

Iron occurs in magnetite (Fe_3O_4) in residual deposits and terrace sands, and in hematite (Fe_2O_3) in the Reagan Sandstone. Chase (1951) and Merritt (1939) studied the magnetite occurrences, describing seven deposits associated with weathered anorthosite. Most of the deposits are associated with hydrothermally altered zones less than 5 acres each in area, 40 ft wide and 100 ft deep. Quartz, malachite, sphalerite, galena, limonite, hematite, ilmen-

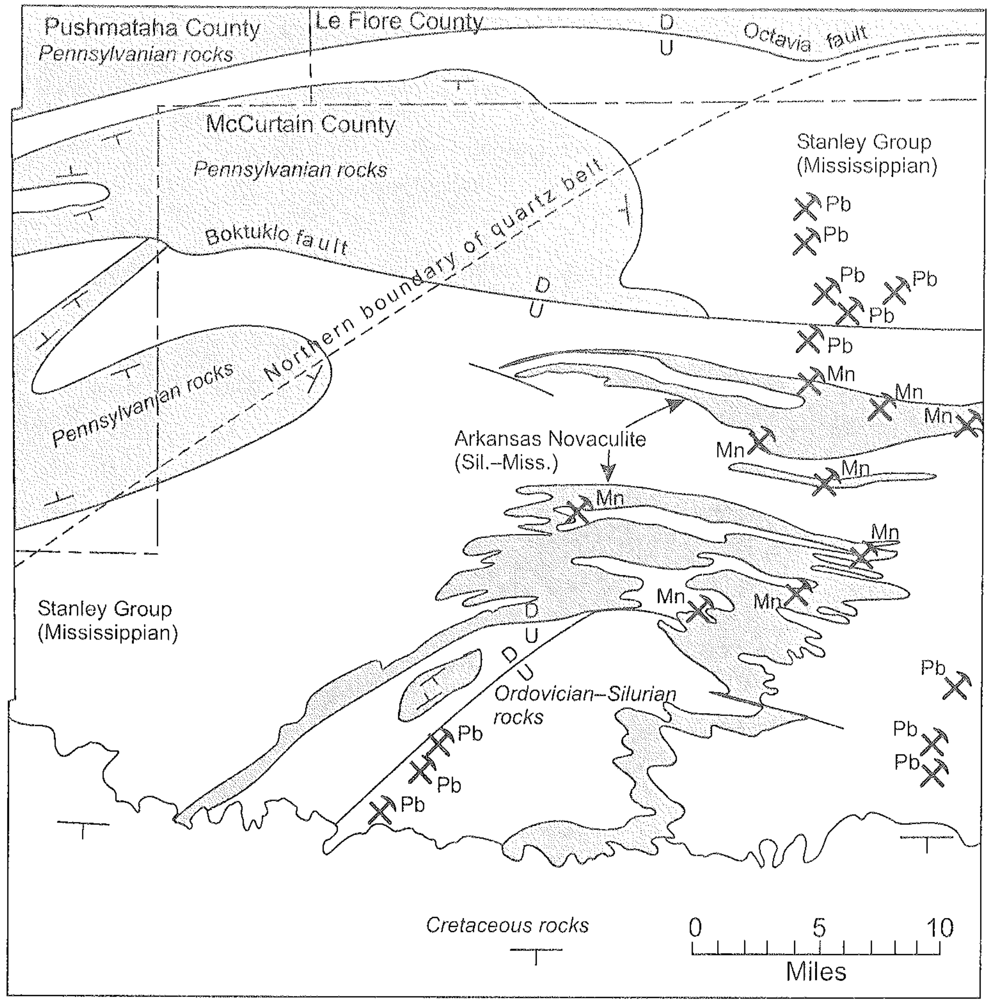

Figure 13. Geologic map of Broken Bow uplift of Ouachita Mountains, McCurtain County, Oklahoma, with manganese (*Mn*) prospects in Lower Arkansas Novaculite (Silurian) and lead–zinc–copper prospects (*Pb*) in Stanley shale and sandstone (Mississippian) and Collier Shale (Ordovician). Selected strike and dip symbols are shown.

ite, leucoxene, and chalcopyrite are associated. The total iron ranges from 43% to 54%, and the TiO_2 ranges from 0% to 16%, averaging 8%. Iron ore with more than 1% TiO_2 is unsuitable for extraction of iron. Thus, these deposits are too small and unsuitable to be worked for iron.

Hematite occurs about 40 ft above the base of the Reagan Sandstone in T. 4 N., Rs. 12–13 W. The hematite zone is 9–23 ft thick and extends several miles along strike and dips 30° northeast (Fig. 18). The hematite occurs as cement around sand grains and as oolites. A few tons was mined and used in shingle paint in Oklahoma City. The iron content ranges from 7% to 35% and is too low for iron ore but is excellent for paint pigment. Merritt (1939, p. 282–286) summarizes previous information, and Cloyd and others (1986, p. 17–20) give additional information.

Titanium occurs in ilmenite ($FeTiO_3$) sand in alluvium in two places in the Wichitas. In the S½ sec. 36, T. 4 N., R. 13 W., north of Lake Lawtonka, about 370,000 tons of ilmenite concentrate of 44% TiO_2 could be extracted from the sands (Chase, 1952). The deposit is about 1 mi long, 0.75 mi wide, and 9–25 ft thick, beneath 4–16 ft of overburden. In Ts. 2–3 N., R. 17 W., along Otter Creek west of Snyder, about 7 million tons of ilmenite concentrate of 45% TiO_2 could be extracted from the alluvial sands (Hahn and Fine, 1960). The deposit is about 8 mi long, 1 mi wide, and 24 ft thick, beneath about 20 ft of overburden. The main source for the ilmenite is the anorthosite and gabbro. Scofield and Roggenthen (1986) studied titanomagnetite and ilmenite, associated with rutile, titanohematite, and pentlandite, in the Glen Mountains Layered Complex.

Aluminum occurs as alumina (Al_2O_3) in anorthosite and weathered anorthosite or kaolin-like clay in T. 4 N., Rs. 16–17 W., in the Glen Mountains. About 3 billion tons of anorthosite of 28% Al_2O_3 was estimated to be available by the U.S. Bureau of Mines (1967, p. 8, 27, 30, 109). About 300 million tons of weathered anorthosite of 20–25% Al_2O_3 was estimated to be available by the U.S. Bureau of Mines (1967, p. 18–19, 27, 30, 110) on the basis of work by Knox (1948). The deposit is generally less than 100 ft thick and is present mostly on the south flank of the mountains. The area has not been mined to date.

PENNSYLVANIAN	*Thickness (meters)*
Lynn Mountain Formation	2,200
Johns Valley Shale	100–615
Jackfork Group	3,000
MISSISSIPPIAN	
Stanley Group	3,660
Moyers Formation	
Tenmile Creek Formation	
SILURIAN–MISSISSIPPIAN	
Arkansas Novaculite	200–275
LOWER SILURIAN	
Missouri Mountain Shale	30–75
Blaylock Sandstone	9–450
UPPER ORDOVICIAN	
Polk Creek Shale	22–62
MIDDLE ORDOVICIAN	
Bigfork Chert	195–255
Womble Shale	300–1,200
Blakely Sandstone	3–180
LOWER ORDOVICIAN	
Mazarn Shale	300–1,050
Crystal Mountain Sandstone	150–270
Collier Shale	300
(pre-Collier, drilled)	3,000

Figure 14. Stratigraphic column for Ouachita Mountains, Oklahoma.

Gold occurs as native gold in Pleistocene alluvial and terrace sands, probably derived from the Rocky Mountains. Gold has not been found in the Wichita igneous rocks except in trace quantities (Snider, 1912, p. 94). The Spanish first looked for gold in the Wichitas in 1650, when Don Diego del Castillo mined there for 6 months (Thoburn, 1916, p. 21). Earlier, a Father DeSalas was a missionary to the Wichita Indians from 1628 to 1648. In 1657, a Father Gilbert opened a prospect about 9 mi northwest of Mount Scott (Wilson, 1976, p. 111–113). Numerous Spanish expeditions passed south of the Wichitas after 1759 (Thomas, 1928, p. 188, 197). Hale (1981, p. 304) cites Spanish documents on mining in the Wichitas from 1774 to 1802. In 1812, Maley found some placer gold in the Pleistocene terrace sands near Devils Canyon along the North Fork close to sec. 12, T. 4 N., R. 20 W. (Wilson, 1976, p. 83–84). In 1904, DeBarr found some Pleistocene placer gold in the terrace sands along creeks and tributaries to Deep Red Run Creek southeast of Snyder in T. 2 N., R. 16 W. (Fay, 1976). Hale (1981) cites many gold stories and assays, which need to be verified, but to date no commercial gold has been found in the igneous rocks of the Wichita Mountains.

Platinum and associated palladium have been found in the Glen Mountains Layered Complex. Since 1982, several mining companies, including Anaconda Minerals Company, have drilled into the complex of anorthosite, gabbro, and troctolite, and have taken stream samples. Platinum anomalies were 55–3,325 parts per billion (ppb), and palladium anomalies were 5–1,400 ppb. Cooper (1986, p. 65–72) summarized much of the information.

Zirconium occurs in zircons in pegmatites, especially in the Quanah Granite on the west side of Charons Garden Mountain in the SE¼SW¼NE¼ sec. 21, T. 3 N., R. 15 W. The zircons are more than 1 in. in diameter. Anderson (1946), Johnson (1955), and Al-Shaieb (1978, 1980) studied these deposits.

Uranium is disseminated in pegmatites and in the Quanah Granite and in other igneous rocks, but no commercial uranium deposits have been found. Al-Shaieb (1978), Al-Shaieb and others (1977), and Al-Shaieb and others (1980) published on uranium in the area.

Red Bed District

In the Red Bed region of central and southwestern Oklahoma, chalcocite ($CuFeS_2$), malachite, and azurite ($Cu(OH)_2 \cdot 2CuCO_3$) occur in Pennsylvanian and Permian rocks (Figs. 20–23). Copper minerals and native copper have been known for many years in this region. In 1719, La Harpe first mentioned trading for ultramarine blue (azurite) and verdigris (malachite) with Indians near present-day Tulsa. The minerals came from upstream, probably near the Great Salt Plains in Alfalfa County, Oklahoma (Fay, 1980, p. 259). Later accounts of Red Bed copper are by Maley (1812), Marcy and McClellan (1854), Haworth and Bennett (1901), Tarr (1910), Fath (1915), Reiter (1920), Merritt (1940b), Ham and Johnson (1964), Johnson (1976), Johnson and Croy (1976), Krason (1976), Schoenike and Zeballos (1976), Waugh and Brady (1976), and Shockey and others (1974).

The copper minerals occur in two different environments: (1) channel-sandstone deposits, with associated carbonaceous trash of plants and fossil bones, with silver and uranium minerals; and (2) sheet deposits in shale or dolomite, associated with evaporite deposits. The copper probably came from the surrounding uplands, from which the ions would have been carried in fresh water under oxidizing conditions and deposited along the delta margins under reducing conditions (Fay, 1975). The evaporite or sabkha-type deposits are discussed by Al-Shaieb and Heine (1976, p. 69), Dingess (1976, p. 18), Hagni and Gann (1976, p. 50), Johnson (1976b, p. 4–6), Kidwell and Bower (1976, p. 60), Lockwood (1976, p. 66–

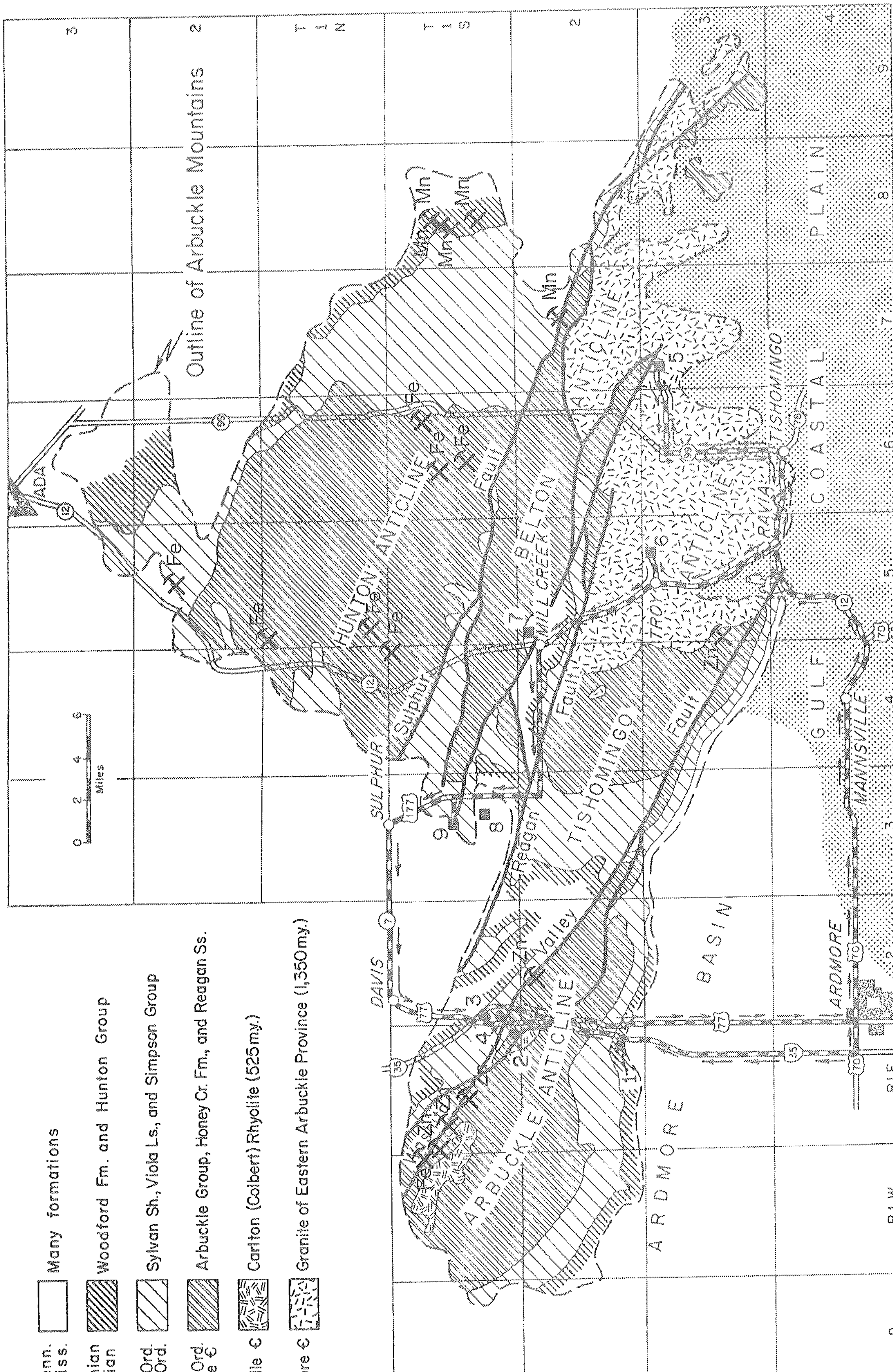

Figure 15. Geologic map of Arbuckle Mountains showing mineral prospects and small mines. (*Fe*—iron, *Mn*—manganese, *Zn*—zinc and lead.) (Modified from Ham, 1969, fig. 13.)

	Thickness (feet)
PENNSYLVANIAN (Virgilian)	
Collings Ranch Conglomerate	3,000
MISSISSIPPIAN	
Goddard Shale	2,500
Delaware Creek Shale	250–425
Sycamore Limestone	5–370
DEVONIAN (Upper), MISSISSIPPIAN (Lower)	
Woodford Shale	250–625
DEVONIAN (Lower)	
Hunton Group (upper)	
Bois d'Arc Limestone	0–900
Haragan Marlstone	0–166
SILURIAN	
Henryhouse Marlstone	0–280
Chimneyhill Subgroup	
Clarita Member	0–13
Cochrane Member	0–13
ORDOVICIAN	
Keel Member	0–7
Sylvan Shale	60–305
Viola Group	425–925
Simpson Group	
Bromide Formation	
Pooleville Member	50–120
Mountain Lake Member	150–300
Tulip Creek Formation	50–400
McLish Formation	400–475
Oil Creek Formation	450–750
Joins Formation	0–300
Arbuckle Group	
West Spring Creek Formation	800–1,500
Kindblade Formation	600–1,400
Cool Creek Formation	700–1,300
McKenzie Hill Formation	500–900
CAMBRIAN	
Butterly Dolomite	200–300
Signal Mountain Formation	300–400
Royer Dolomite	400–700
Fort Sill Limestone	50–150
Timbered Hills Group	
Honey Creek Limestone	0–100
Reagan Sandstone	0–450
Colbert Rhyolite	4,500+
PRECAMBRIAN	
Tishomingo Granite (1.35 b.y.)	12,000+

Figure 16. Stratigraphic column of rocks in the Arbuckle Mountains, Oklahoma.

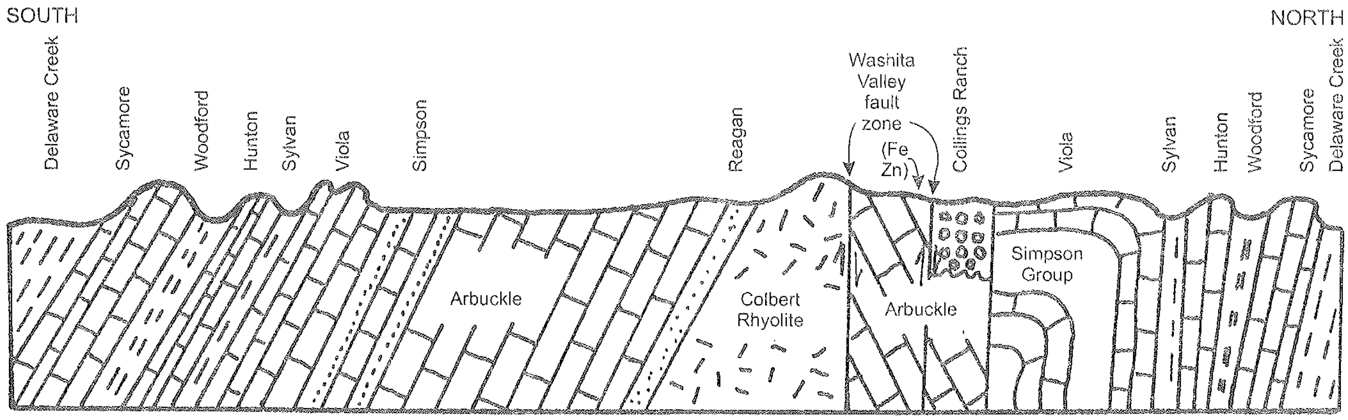

Figure 17. Generalized cross section of Arbuckle Mountains along Interstate Highway 35.

68), Smith (1976), and Vine and Tourtelot (1976, p. 97) (Figs. 24–26).

More than 50 copper prospects were noted by Fay (1975, p. 153), most of which are of the channel-sandstone type. Almost all of these are less than 50 ft deep and a few feet in diameter, covering less than 1 acre of ground. They are not predictable over an extensive area, and most of the areas have been mined out locally. A few prospects are associated with the Blaine dolomites (Permian) of Blaine County, being sheet deposits a few inches thick. A major sheet deposit is that near Creta, in southwestern Oklahoma. From 1965 to 1976, Eagle-Picher Industries strip mined a 6- to 12-in. chalcocite shale bed in the Flowerpot Shale (Permian). The layer averaged 1.9–2.2% copper, with some silver. Approximately 1.5 million tons of ore was processed before the operation was shut down owing to the low price of copper. Dingess (1976) is one of the latest authors on this deposit. This was the only extensive copper mine in Oklahoma. The total resource base of Red Bed copper is unknown. A bibliography is given by Fay (2002).

Black Mesa District

North of Black Mesa, in northwestern Cimarron County, Oklahoma, approximately 14 copper prospects were worked in the early 1900s. The geology of the area comprises Triassic rocks dipping gently southeastward, overlain unconformably by Jurassic and higher units (Fig. 27). Chalcocite, malachite, and azurite occur in cracks, lenses, and clastic dikes in the Sheep Pen Sandstone (Triassic), just below or at the unconformity below the Exeter Sandstone (Jurassic). The Sheep Pen ranges from 0 to 108 ft thick. Copper minerals are not found in the overlying Jurassic and Cretaceous beds and are not found in the underlying Triassic shales and sandstones. The copper content ranges up to 41%, but an average channel sample is less than 1% copper.

From 1884 to 1925, almost 200 small prospects and mines were worked in New Mexico, Colorado, and Oklahoma. Most of the prospects were less than 50 ft deep and 8 ft in diameter. Probably less than 10,000 tons of minerals was mined from Oklahoma (Fay, 1983, p. 1). The main producing mines were the San Miguel and Fort Pitt Mines in New Mexico and the Independence Mine in Colorado. The Fort Pitt was about 280 ft deep, in a vertical clastic dike filled with sandstone, hematite, and chalcocite. The San Miguel was an open strip pit covering several acres, about 30 ft thick, with uranium associated with the copper minerals. The Independence is a 524-ft adit in the side of a hill (Fig. 28), and the mineralization is truly stratabound.

The copper ions were probably derived from weathering of adjacent land during Triassic time and were carried by fresh water under oxidizing conditions and deposited in low areas and cracks under reducing conditions. The geology of the region is given by Stovall (1943), McLaughlin (1954), Baldwin and Muehlberger (1959), and Fay (1983). Triassic copper deposits are discussed by Henderson (1926), Parker (1930, 1933), Harley (1940), Soulé (1956), LaPoint (1976), and Fay (1983).

Miscellaneous Uranium Occurrences

Uranium (carnotite) was mined from a vertical vein at Cement, Caddo County, south-central Oklahoma, in 1956. Approximately 13 tons of carnotite was mined from the vein in the Rush Springs Sandstone (Permian), averaging about 2.2% U_3O_8. The vein was about 300 ft long, 5 ft wide, and 14 ft deep, and was mined out. The Rush Springs is flat lying, overlain by the Cloud Chief gypsum locally, and underlain by several thousand feet of Permian red beds and Pennsylvanian conglomerates, sandstones, and shales, unconformably above the Cement oil field. A carbonate halo above the field is due to reduction by leakage of hydrocarbons and H_2S. The uranium would have been carried in ground water and deposited under reducing conditions above the field.

Generally, uranium is found in beds ranging from basement rocks to recent alluvium and occurs in water, oil, and rock in all parts of the State, but no large commercial deposits have been found (Totten and Fay, 1982). Several important works on uranium in Oklahoma are those by Al-Shaieb (1978), Al-Shaieb and others (1977, 1980), and Miller (1981).

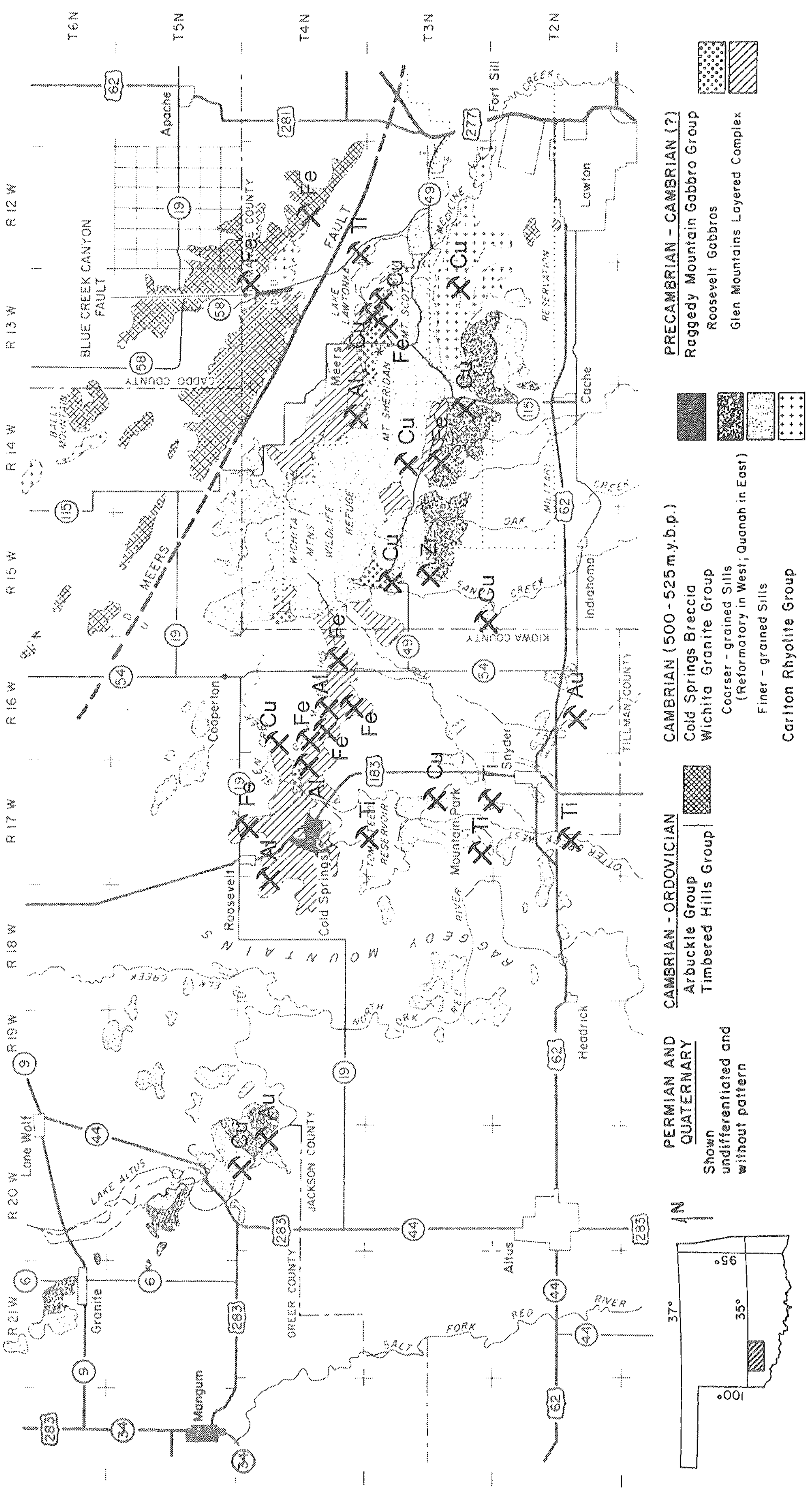

Figure 18. Geologic map of Wichita Mountains showing some mineral prospects and small mines. (*Al*—aluminum, *Au*—gold, *Cu*—copper-lead-zinc, *Fe*—iron, *Ti*—titanium, *Zr*—zirconium.) (Modified from Gilbert and Donovan, 1982, fig. 2.)

Age (m.y.)	Group	Formation	Member	General Lithology
?		Diabase		Fine-grained diabase cutting all older units but not Reagan sandstone
514 ± 10?		Cold Springs Breccia		Dark-gray microdiorite blocks in matrix of pink leucogranite; locally medium-gray quartz monzodiorite blocks in light-gray granodiorite matrix
525 ± 25	Wichita Granite Group	*East*: Quanah, Cache, Medicine Park, Saddle Mountain; *West*: Lugert, Cooperton, Long Mountain, Reformatory, Headquarters; Mount Scott		Group typified by medium- to fine-grained alkali feldspar granites; granophyric texture sporadically distributed within the group
525 ± 25	Carlton Rhyolite Group	Bally Mountain, Blue Creek Canyon, Fort Sill		Rhyolitic lavas interbedded with minor tuffs and agglomerates
?		Otter Creek Microdiorite		Fine-grained diorite and quartz diorite
?	Navajoe Mountain Basalt-Spilite Group			Extrusive basalts variably altered
552 ± 7	Raggedy Mountain Gabbro Group	Roosevelt Gabbros	Mt. Baker hornblende Gabbro	Medium- to fine-grained hornblende-biotite, 2-pyroxene, no olivine, gabbro
			Glen Creek Gabbro	Medium-grained biotite-amphibole-bearing olivine gabbro
			Sandy Creek Gabbro	Medium-grained biotite amphibole-bearing gabbro ± olivine
			Mount Sheridan Gabbro	Medium-grained biotite gabbro locally fractionated to ferrogranodiorite
509-730 1,300-1,500		Glen Mountains Layered Complex	N Zone	Anorthositic gabbro with cumulus plagioclase
			M Zone	Anorthosite, anorthositic gabbro, and troctolite with cumulus plagioclase augite, olivine
			L Zone	Anorthositic gabbro with minor troctolite; coarse-ophitic augite; cumulus plagioclase and olivine
			K Zone	Alternating bands of anorthosite and troctolite; cumulus plagioclase, olivine
			G Zone	Troctolite and olivine gabbro; medium grained; cumulus plagioclase olivine
?	Tillman Metasedimentary Group	Meers Quartzite		Metaquartzite and metagraywacke with andalusite and sillimanite; inclusions in rocks of Raggedy Mountain Gabbro Group and Wichita Granite Group

Figure 19. Basement rocks of Wichita Mountains, Oklahoma. (From Gilbert and Donovan, 1982, table 2.)

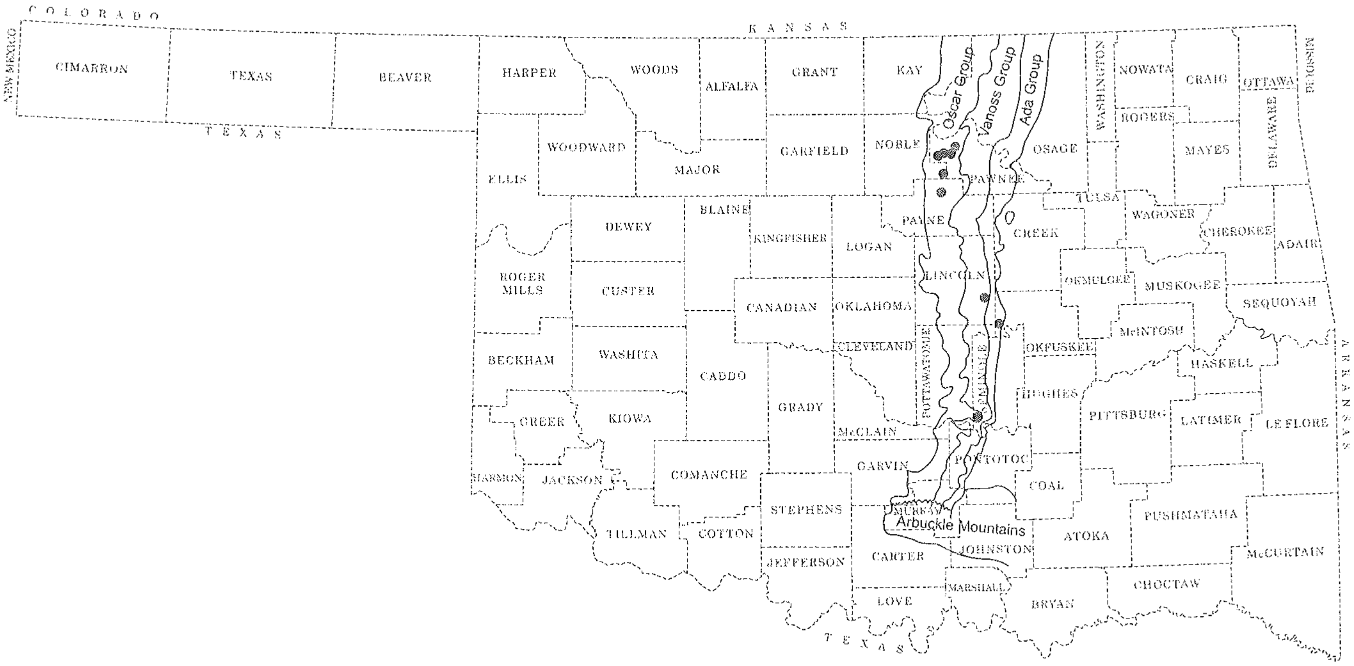

Figure 20. Index map of Oklahoma showing locations of Pennsylvanian copper deposits.

System	Series	Group	Units
PENNSYLVANIAN SYSTEM (upper part)	GEARYAN SERIES	OSCAR GROUP	Herington Limestone Enterprise Shale Winfield Limestone *Doyle Shale *Fort Riley Bed Matfield Shale *Wreford Bed Speiser–Florena sequence Cottonwood Limestone Eskridge Shale *Hart Limestone = Neva Limestone
		VANOSS GROUP	Salem Point–Roca sequence Red Eagle Limestone Johnson Shale Long Creek Limestone Hughes Creek Shale Americus Limestone Unnamed shale and sandstone Brownville Limestone Pony Creek Shale Grayhorse Limestone Unnamed shale and sandstone Elmont Bed Harveyville Shale *Reading Bed
	VIRGILIAN SERIES	ADA GROUP	Auburn Shale Wakarusa Bed Unnamed shale *Unnamed sandstone Unnamed shale Lecompton Limestone

Figure 21. Stratigraphic column showing Pennsylvanian copper occurrences (*) in Oklahoma. (The Pennsylvanian–Permian boundary is controversial; different workers place it at different points in the stratigraphic column. The boundary shown here, based on worldwide correlation of redbeds fauna, is from Romer, 1935.)

SUMMARY

Since 1976, no metallic minerals have been produced in Oklahoma. Many companies have been interested in metals in Oklahoma, but only one new mine was opened during the last 30 years. Copper, lead, and zinc minerals have been the main attraction to most companies, with some interest shown in uranium. Many companies continue to be interested in the metallic-mineral deposits of Oklahoma.

In each of the mining districts, the resources of each mineral are small or are not economically feasible to mine at present. (1) In the Tri-State area, almost all of the zinc and lead was mined out. Water would be a problem for any new mines. (2) In the Ozarks, the small prospects are almost all worked out, and there have been few new prospects. (3) In the Ouachitas, most of the prospects were worked out, but some could still be examined at depth. Water may be a problem. (4) In the Arbuckles, the zinc mineralization has never been extensive enough for major mining. Only a few wagonloads of minerals were removed. About 5,000 tons of manganese minerals is scattered over several prospects, being too small to justify extensive mining. The same is true for iron, with about 250,000 tons of scattered resources. (5) In the Wichitas, the copper, lead, and zinc prospects were never extensive. The aluminum and titanium resources are moderately large but are not competitive with other areas. The iron resources are too low in iron percentage to be mined. Pleistocene gold washings were small. (6) In the Red Bed District, most of the prospects were in channel sandstones and have been mined out. In the Creta-Mangum area of southwestern Oklahoma, minable resources exist, but the price of copper is too low for com-

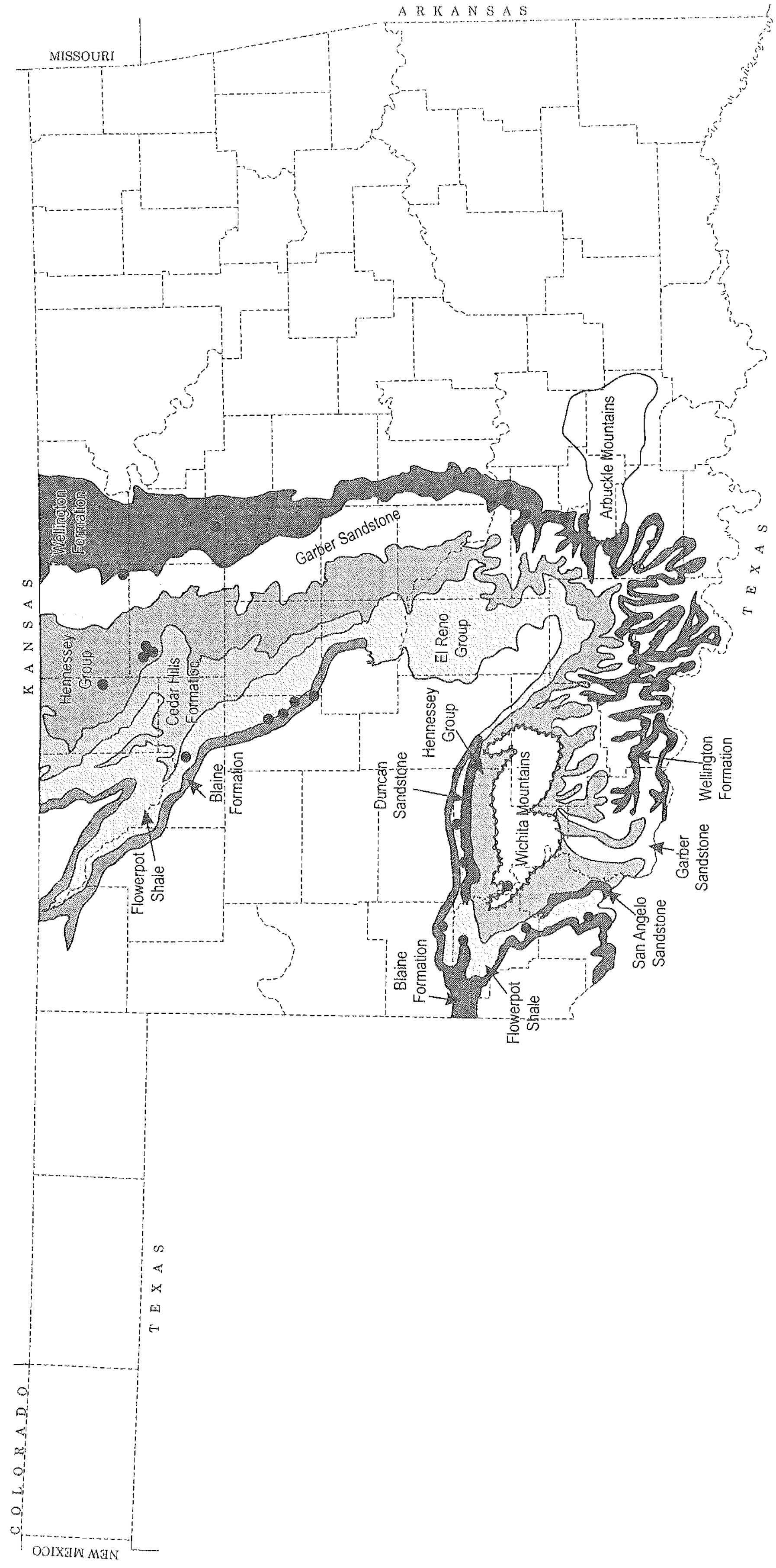

Figure 22. Index map of Oklahoma showing locations of Permian copper deposits.

mercial production. (7) In the Black Mesa area, most of the prospects were in small clastic dikes and were mined out, but possibly some hidden deposits remain. (8) Extensive uranium mineralization has not yet been reported in Oklahoma.

In summary, the resource base of each mineral is small, and where resources are moderately large the price of the commodity is too low to justify mining. Thus, at present, no metallic minerals are being mined in Oklahoma. The Oklahoma Geological Survey has not conducted a drilling program in any of the districts, and we have had to rely on surface information, along with historical records and company data, for reports. Thus, the extent of metallic-metal resources in Oklahoma is not fully known.

System	Series	Series	Group	Units	(SW Oklahoma terms)
PERMIAN SYSTEM	GUADALUPEAN SERIES	CIMARRONIAN SERIES	EL RENO GROUP	Dog Creek Shale Unnamed Shale Southard Dolomite Bed Unnamed shale Watonga Dolomite Bed Unnamed shale Haskew Gypsum Bed Unnamed shale	
				Blaine Formation Shimer Gypsum Member Altona Dolomite Bed Unnamed shale Nescatunga Gypsum Member *Magpie Dolomite Bed Unnamed shale Kingfisher Creek Gypsum Member Unnamed shale Medicine Lodge Gypsum Member *Cedar Springs Dolomite Bed	(SW Oklahoma terms) Haystack Gypsum Member *Unnamed dolomite bed
				Flowerpot Shale *Unnamed shale *Unnamed dolomite Unnamed shale, siltstones, and gypsiferous beds *Unnamed shale	Unnamed shale, gypsums, and dolomites Marty Dolomite Bed Unnamed shale Kiser Gypsum Bed Unnamed shale *Meadows Shale Bed Unnamed shale *Prewitt Shale Bed Unnamed shale Chaney Gypsum Bed Unnamed shale
				Cedar Hills Sandstone	*Duncan Sandstone
	?		HENNESSEY GROUP	Bison Formation	
	LEONARDIAN SERIES			Salt Plains Formation Unnamed shale and siltstone *Crisfield Sandstone Bed Unnamed shale and siltstone	
				Kingman Siltstone	
				Fairmont Shale	
			SUMNER GROUP	*Garber Sandstone	
				*Wellington Formation	

Figure 23. Stratigraphic column (Romer, 1935) showing Permian copper occurrences (*) in Oklahoma.

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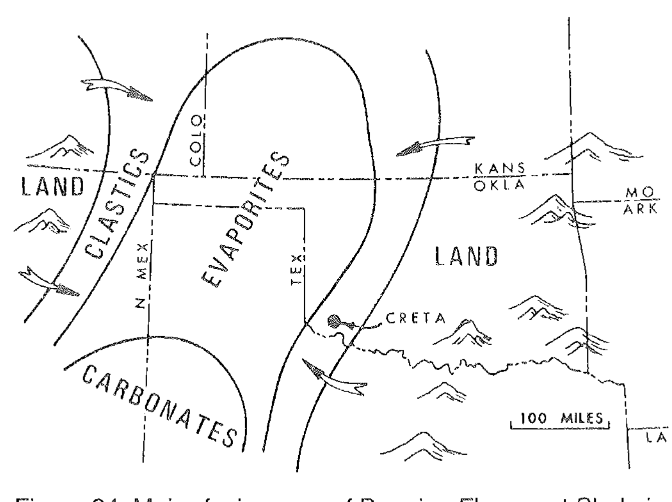

Figure 24. Major-facies map of Permian Flowerpot Shale in southwestern United States. (From Dingess, 1976, p. 18.)

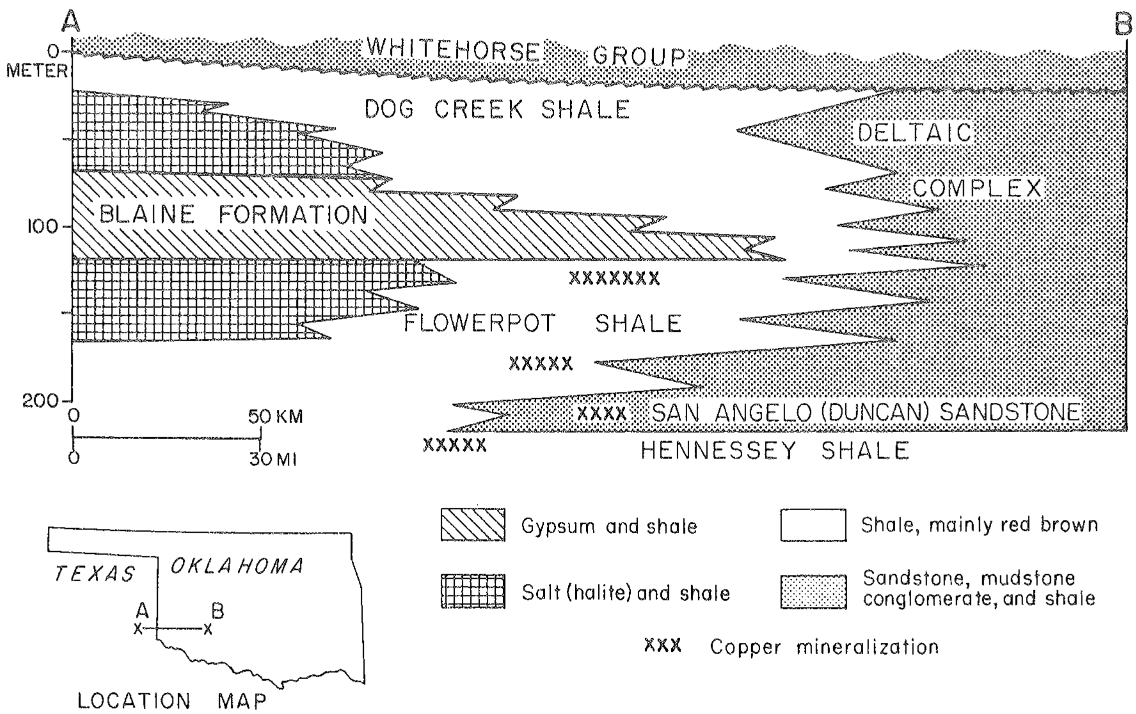

Figure 25. Stratigraphic cross section showing copper mineralization in Permian strata of southwestern Oklahoma and northern Texas. (From Johnson, 1976b, p. 6.)

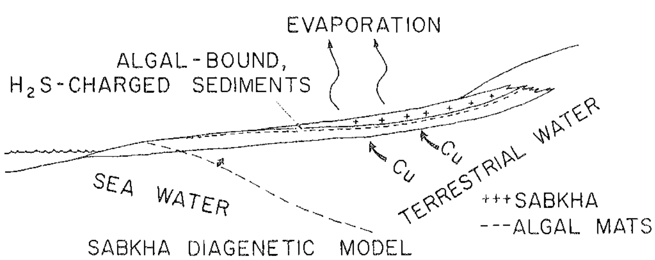

Figure 26. Sabkha diagenetic model for copper mineralization. (From Smith, 1976, p. 35.)

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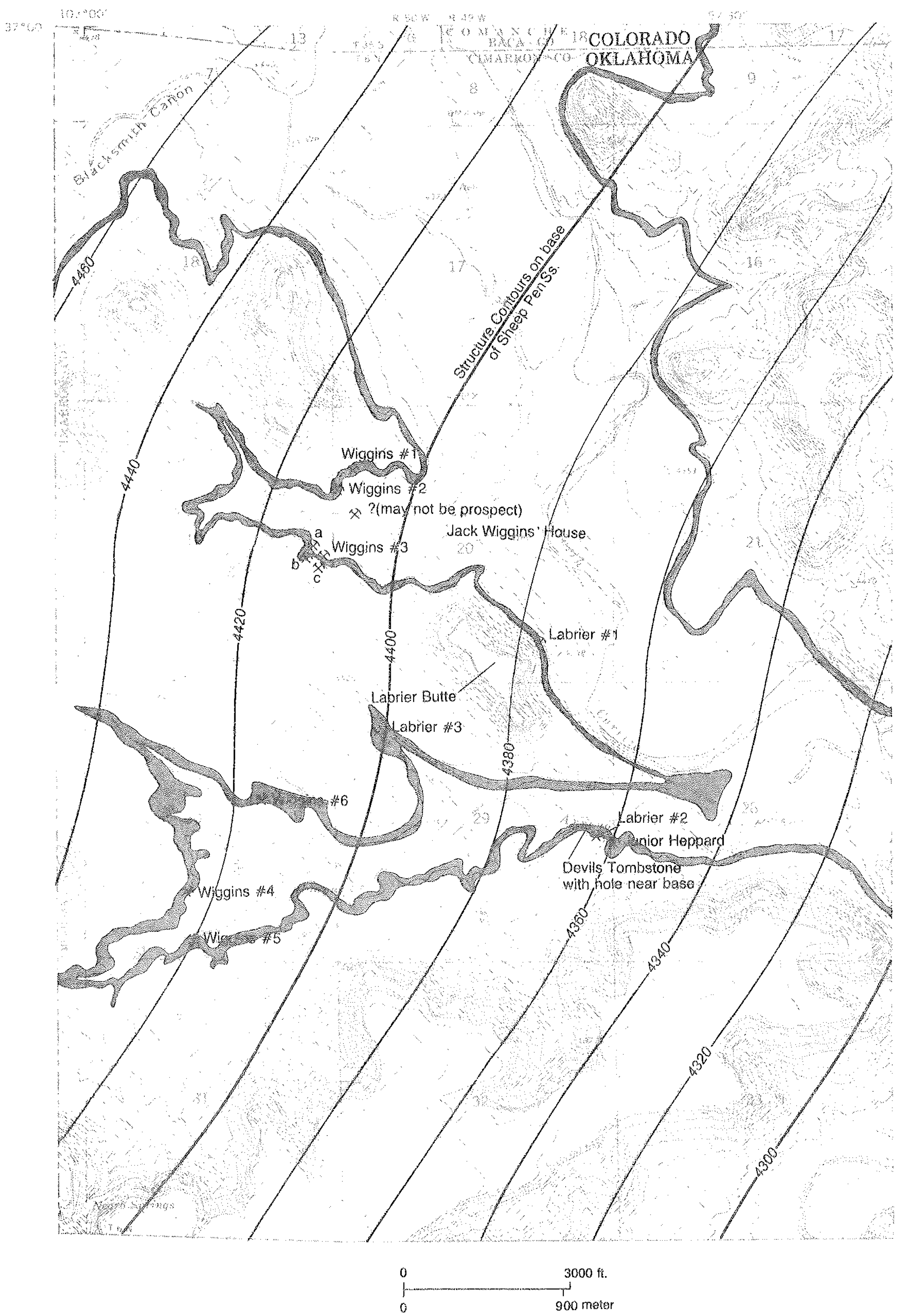

Figure 27. Map of Sheep Pen Sandstone north of Black Mesa, showing locations of copper prospects and small mines. Structure contours in feet. (From Fay, 1983, fig. 5.)

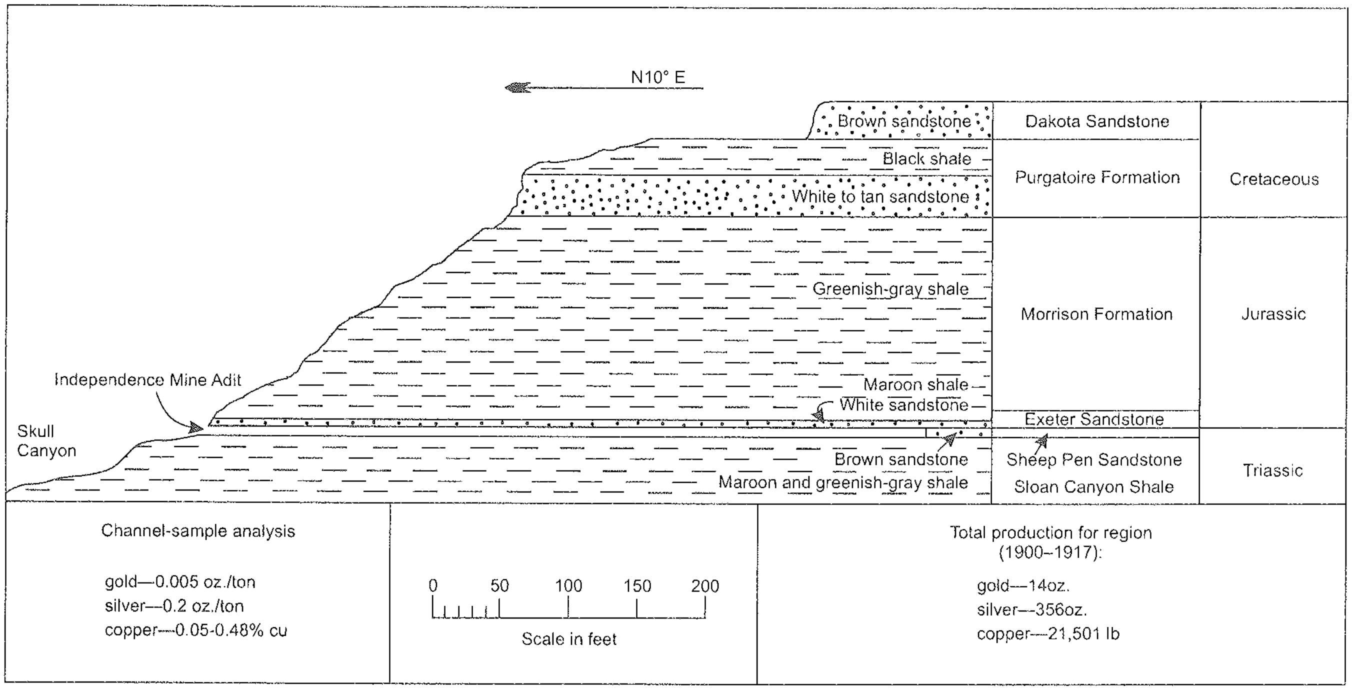

Figure 28. Vertical section of Independence Mine, showing local stratigraphy in NE¼NW¼NW¼ sec. 21, T. 34 S., R. 50 W., Baca County, southeastern Colorado. (Modified from Soulé, 1956, fig. 4.)

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