PREPARED IN COOPERATION WITH THE
KANSAS GEOLOGICAL SURVEY AND THE MISSOURI DEPARTMENT OF NATURAL RESOURCES,
DIVISION OF GEOLOGY AND LAND SURVEY



## FOLIO NOTE

This map is part of a folio of maps of the Joplin 1° X 2° quadrangle, Kansas and Missouri, prepared under the Conterminous United States Mineral-Resource Assessment Program (CUSMAP). Other publications in this folio to date include U.S. Geological Survey Miscellaneous Field Studies Maps MF-2125-A through D (Erickson and others, 1990; Grisafe and Rueff, 1991; Blair and others, 1992; McCafferty and Cordell, 1992). Additional maps showing bedrock geology and other geologic aspects of the Joplin quadrangle will be published as U.S. Geological Survey maps bearing this same serial number with different letter suffixes (MF-2125-F, -G, and so on).

## INTRODUCTION

This report and the accompanying maps present an assessment of the mineral-resource potential of the Joplin 1° X 2° quadrangle for Mississippi Valley-type (MVT) zinc-lead sulfide deposits and other mineral deposits. The assessment for MVT deposits was done in February 1989 and the assessment for other minerals in October 1991. The Joplin quadrangle is the fourth in a series of quadrangles in the southern Midcontinent whose mineral-resource potential is being evaluated under the CUSMAP program. The first in this series was the Rolla quadrangle, Missouri (Pratt, 1981, 1991; Pratt and others, 1984), the second was the Springfield quadrangle, Missouri (Martin and Pratt, 1985, 1991), and the third was the Harrison quadrangle, Missouri and Arkansas (Pratt and others, 1993) (fig. 1). In each of these projects, various members of the CUSMAP team, composed of geoscientists from the U.S. Geological Survey and the cooperating state geological surveys, compiled a series of maps showing various aspects of the geology, geochemistry, geophysics, and mineral occurrences of the quadrangle; in each case the team then met as a group to review the available data and make an assessment of the resource potential.

The Joplin CUSMAP project began in October 1983 as a cooperative effort between the U.S. Geological Survey, the Kansas Geological Survey, and the Missouri Department of Natural Resources, Division of Geology and Land Survey. After completion of the various map elements, the assessment meeting was held in Nevada, Missouri, February 14-15, 1989. The first section of this report, dealing with MVT deposits, represents a team effort, and it is appropriate to record here the participating members of the entire CUSMAP team:

U.S. Geological Survey--Walden P. Pratt, coordinator; Ralph L. Erickson, Timothy S. Hayes, Anne E. McCafferty, and Helen Whitney.

Kansas Geological Survey--Pieter Berendsen, coordinator; Kevin P. Blair, Lawrence L. Brady, Mary E. Daily, David A. Grisafe, James R. McCauley, and Frank W. Wilson.

Missouri Geological Survey--James A. Martin, coordinator; Michael C. McFarland, Mark A. Middendorf, Bruce W. Netzler, Lawrence M. Nuelle, James R. Palmer, Charles E. Robertson, Ardel W. Rueff, Ira R. Satterfield, Cheryl M. Seeger, David C. Smith, and Thomas L. Thompson.

Also active in the project but not present at the assessment meeting were Lindrith Cordell and Marjorie S. Erickson of the U.S. Geological Survey, and Joy L. Bostic and Eva B. Kisvarsanyi of the Missouri Geological Survey.

The remainder of this report is divided into four parts: a brief summary of the geology of the quadrangle is followed by sections that discuss the potential of the quadrangle for undiscovered MVT zinc-lead deposits, for diamond occurrences and a variety of industrial minerals in Cretaceous lamproites, and for magnetite and hematite deposits in Precambrian basement rocks. Previous reports have addressed the quadrangle's industrial mineral resources (Grisafe and Rueff, 1991), and, briefly, heavy-oil resource potential of sandstones in the Pennsylvanian Cherokee Group (Netzler, 1990). A report on the coal resources of the quadrangle will be published by the U.S. Geological Survey in its Miscellaneous Investigations map series. In the consensus opinion of the Joplin CUSMAP team, this list includes all the economic minerals for which a reasonable potential exists in the Joplin quadrangle, on the basis of geologic information available in February 1989 (for the MVT deposits) and October 1991 (for the other types of deposits).

## SUMMARY OF GEOLOGY OF THE JOPLIN QUADRANGLE
**(Modified from McCauley and others, 1990)**

The Joplin quadrangle is in southeastern Kansas and southwestern Missouri, bounded by long. 94°-96° W. and lat. 37°-38° N. (fig. 1). The quadrangle lies on the Prairie-Plains homocline on the northwest flank of the Ozark dome; consequently the bedrock formations dip gently west to northwest. In the subsurface, and separated from the gently dipping Paleozoic sedimentary bedrocks by a nonconformity, the basement is composed predominantly of Proterozoic granitic rocks and lesser volcanic, metamorphic, and sedimentary rocks (Berendsen and Blair, 1991; McCafferty and Cordell, 1992; Kisvarsanyi, this report). The surface of the nonconformity, which may have as much as 1,000 feet of local relief, is overlain by a relatively thin Upper Cambrian basal sandstone (Lamotte or Reagan Sandstone) that passes upward into a sequence of about 340 to 1,250 feet of Upper Cambrian and Lower Ordovician carbonate rocks (fig. 2); the thickness variation is largely due to the pronounced paleorelief on the top of the Precambrian basement (McKnight and Fischer, 1970, p. 14). In western Missouri these strata are divisible into Cambrian and Ordovician formations. The Cambrian includes (from oldest to youngest) the Bonneterre Formation, the Davis Formation, and the Derby-Doerun, Potosi, and Eminence Dolomites, or alternatively for Davis through Eminence, the post-Bonneterre Cambrian (Palmer, 1991). The Lower Ordovician formations are successively the Gasconade Dolomite, Roubidoux Formation, and Jefferson City and Cotter Dolomites. In Kansas, however, which includes two-thirds of the Joplin quadrangle, the entire succession of predominantly carbonate strata above the basal Reagan Sandstone, from Bonneterre or Davis up through Cotter, is combined and commonly referred to as the Arbuckle Group. Most of this section is present in the Joplin quadrangle only in the subsurface; the Jefferson City and Cotter Dolomites are the only parts of the section exposed in the quadrangle, in the northeast corner. These units are overlain unconformably by limestone and minor shale of Mississippian age, which crop out in the southeast quadrant of the quadrangle over an area extending about 30-35 miles north and west from the southeast corner. A few small patches of Mississippian rocks also crop out along the east edge of the quadrangle. Chattanooga Shale of Late Devonian age, bounded above and below by unconformities, occurs locally in the subsurface between the Ordovician and Mississippian rocks. The exposed bedrock in the rest of the quadrangle consists of Pennsylvanian shale, sandstone, limestone, and coal; these rocks form a series of subparallel northeast-trending outcrop bands that expose progressively younger rocks to the northwest. The stratigraphic succession is broken by two major northwest-trending fault zones and by numerous minor structures. The Rose and Silver City domes in the northwestern part of the quadrangle are Cretaceous laccoliths (Berendsen, this report).

## RESOURCE POTENTIAL FOR MISSISSIPPI VALLEY-TYPE ZINC-LEAD DEPOSITS
**By Walden P. Pratt, Timothy S. Hayes, and Ralph L. Erickson**

### INTRODUCTION

Mississippi Valley-type (MVT) deposits are defined as predominantly sphalerite-galena replacement and vein deposits (including vug and breccia fillings) in carbonate host rocks, generally restricted to certain formations but not restricted to specific beds, and postconformable but clearly crosscutting -- that is, the deposits are epigenetic and stratabound but not *stratiform*.

The Joplin quadrangle includes a major part of the world-class Tri-State MVT zinc-lead district of Missouri, Kansas, and Oklahoma (fig. 3). Mining in the Tri-State district began in about 1848 and continued until 1970, when increasing environmental regulations and decreasing ore grades combined to force closure of the mines. The most productive area in the district was the Picher field, which extends southward into Oklahoma from the southern boundary of the Joplin quadrangle. Other areas of major importance were the Galena, Joplin, and Oronogo-Webb City-Duenweg fields (fig. 3). There are several other small zinc-lead mines and prospects in the quadrangle but none of them are currently active. Through its life the district produced more than $2 billion in zinc and lead concentrates from more than 500 million tons of ore at average grades of about 4.5 percent zinc and 0.75 percent lead (Brockie and others, 1968). The ores consisted predominantly of sphalerite and galena as vug and fracture fillings in silicified and dolomitized Mississippian limestone. With this history in mind, the potential for undiscovered MVT deposits in the Joplin quadrangle was of prime importance in this CUSMAP assessment.

### ASSESSMENT METHOD

The assessment for MVT deposits consisted of four steps. First, the team agreed on a descriptive model for MVT deposits, based on the known characteristics of MVT deposits in the mining districts within the Joplin quadrangle and elsewhere in the region (Northern Arkansas, Central Missouri, and Southeast Missouri districts). We defined this descriptive model in terms of six geologic "recognition criteria" believed to be required or at least favorable for the presence of an MVT deposit; implicit in the selection of these criteria was that at least some data were available on their presence or absence in the quadrangle. Second, we superimposed maps of the quadrangle showing the areal extent of these recognition criteria. Inspection of these stacked map overlays showed some areas where all or some of the criteria were present (in varying degrees), and other areas where only a few or none of the criteria were present. Third, we drew outlines around areas containing similar combinations of criteria. This process divided the quadrangle into a number of assessment areas or blocks. Fourth, to each assessment block we assigned levels of potential and certainty for the occurrence of MVT deposits, based on a subjective "gut level" consensus, and using the resource classification developed by Taylor and others (1984). This classification assigns resource categories on the basis of two independent factors: (1) the amount and kinds of evidence suggesting a favorable geologic environment for mineralization (the level of mineral potential), and (2) the availability of data (the level of certainty). These factors are combined in a simple matrix (fig. 4) that indicates the classes of mineral-resource potential and certainty. The Joplin CUSMAP team used this matrix as a guide to assign assessment levels to each outlined area; the assignments are *qualitative* and reflect a team consensus.

### ASSESSMENT MODEL

The generalized model for MVT deposits in the Joplin quadrangle differs somewhat from the models used for the preceding Midcontinent CUSMAP assessments, and represents a stage in the evolution of our thinking about the controls on MVT mineralization--in particular, our ideas on the importance of carbonate lithofacies as a controlling factor. In the assessment of the Rolla quadrangle (Pratt, 1981) the favorable lithofacies were considered to be (1) dolomite, close to the limestone-dolomite interface, and (2) finely crystalline, organic-rich dolomite (known to the miners as "brown rock"), close to its interface with coarsely recrystallized pastel-colored dolomite ("white rock"). In the next assessment, the Springfield quadrangle (Martin and Pratt, 1991), the single favorable lithofacies criterion was defined as shallow-water dolomite; we also recognized that deposits "commonly are below an impermeable lithology such as shale and (or) siltstone that acted as a confining cap rock to fluid movement" (Erickson and Chazin, 1991, p. 90). The assessment model for the Harrison quadrangle (Pratt and others, 1993) again included proximity to a limestone-dolomite interface as a favorable criterion, but also introduced a new criterion: any zone of abrupt change in depositional lithofacies at ramp facies margins.

The Joplin study incorporated a major change in the philosophy of the model. Continuing studies of carbonate facies indicated that the critical lithologic factor is not the *favorability* of a particular carbonate facies, but only the *unfavorability* of impermeable, shaly, ramp and basinal facies rocks--all other lithofacies are favorable, particularly where they are adjacent to, and upsection from, a shale (or shaly facies) pinchout. This reaffirms and lends new support to the old concept that 'windows' in underlying shale units control ore deposition (Siebenthal, 1916; Brockie and others, 1968, p. 416). This led to a generalized concept of the MVT mineralization process in the Joplin quadrangle which assumes the following elements: (1) Lateral migration of metalliferous brines into the region from a source probably located to the south or southeast, through (2) a basal-sandstone aquifer (Lamotte or Reagan Sandstone) or a permeable, probably dolomitized, carbonate aquifer, confined (especially in the case of a carbonate aquifer) under an overlying shale or impermeable limestone, and then (3) upward movement into the host rocks along edges or through windows in the shale and (or) along fracture zones.

This concept--in reality a partial genetic model--is incomplete because it does not take into account the source of the brines or metals, or the processes responsible for precipitating the metals as sulfides. However, it forms the basis for the descriptive assessment model that follows.

The MVT assessment model used for both the Cambrian-Ordovician and Mississippian sequences consisted of the six criteria listed below. Inasmuch as the potential host formations underlie the entire quadrangle, presence of the host formations was not considered as a separate criterion, as was done in the assessment of the Harrison quadrangle.

1. Presence or proximity of a pinchout or window in the underlying shale or shales, to allow upward movement of metalliferous brines under regional artesian pressure. Source of data: J.R. Palmer (Missouri Geological Survey) and T.S. Hayes (U.S. Geological Survey), unpublished maps.

2. Presence or proximity of faults or fault zones, also to allow upward movement of metalliferous brines. Faults and fault zones in the Paleozoic sedimentary rocks were mapped at the surface and compiled on unpublished maps by J.R. McCauley (Kansas Geological Survey) and D.C. Smith (Missouri Geological Survey), or were interpreted from drill-hole data (Blair and others, 1992). Faults in the Precambrian basement were inferred from unpublished gravity and aeromagnetic terrace maps provided by L.E. Cordell and A.E. McCafferty (U.S. Geological Survey) and from a basement map by Berendsen and Blair (1991). This criterion was interpreted rather subjectively, without regard to length or orientation of faults; the only factor considered was the presence or absence of faults, with increasing weight given (qualitatively) for a greater number of faults present in the assessment block under consideration.

3. Presence of "favorable geochemistry", that is, geochemical anomalies--anomalously high concentrations of the typical MVT metal suite (Pb-Zn-Ag-Cu-Ni-Co-As-Mo) in insoluble residues of the carbonate rocks, as determined by semiquantitative spectrographic analysis. The use of geochemical analyses of insoluble residues in the Rolla, Springfield, Harrison, and Joplin CUSMAP studies has been fully documented in Erickson and others (1978, 1981, 1985, 1989, 1990, and 1991); the method can be described briefly as follows. Hydrochloric acid-insoluble residues obtained from thousands of drill-hole samples of the carbonate rocks of the region have been analyzed by semiquantitative spectrographic methods. These analyses have revealed--even in rocks that appear to be barren of sulfide ores--a suite of metals (Pb-Zn-Ag-Cu-Ni-Co-As-Mo) characteristic of MVT deposits, whose abundances vary across the region. For the purposes of this study, the results of the analyses were plotted on the maps (Erickson and others, 1990) in anomalous metal feet (AMF), a reporting unit derived by normalizing the ratio of a reported anomalous metal content to the threshold for that metal, multiplied by the length of the sample interval in feet. The thresholds of anomalous metal concentrations of insoluble residues, in parts per million (ppm), were established by inspection of the data and are as follows: As, 200; Zn, 200; Pb, 100; Cu, 100; Ni, 70; Mo, 70; Co, 30; and Ag, 1. Thus, reported values of 500 ppm Pb and 3 ppm Ag for a 10-foot interval normalize to 50 AMF of Pb and 30 AMF of Ag. The AMF can be summed for an entire drill hole, for each formation, or for dolomite (fig. 2); the AMF values have been plotted on the quadrangle map, form lines (not contours) are drawn on the map to call attention to clusters of similar AMF values. The geochemical patterns thus generated permit comparison and integration with lithologic, structural, and geophysical trends. They are integral to the resource assessment because anomalous amounts of the metal suite are believed to record the presence, at some time, of metal-bearing fluids, which are essential to the formation of MVT deposits.

For the purpose of this assessment, significant geochemical anomalies are defined as those having an AMF value that exceeds a certain minimum, and are characterized as "moderate" and "strong." In the Cambrian and Ordovician rocks (map A), moderate anomalies are defined as those having a value of 300-1,000 AMF of total metals in the MVT suite, and strong anomalies, a value greater than 1,000 AMF. Anomalies in the Mississippian rocks (map B) are defined on the basis of zinc only; moderate anomalies are defined as those with a value of 100-300 AMF zinc, and strong anomalies, a value greater than 300 AMF zinc. Additional details on the geochemical data for the Joplin quadrangle, and the significance of the geochemical anomalies, are discussed in Erickson and others (1990).

4. Presence of knobs or highs on the Precambrian surface, as indicated by drilling data. This exploration guide for MVT deposits originated in the Southeast Missouri district because pinchouts of the basal Lamotte Sandstone against basement knobs apparently localized many ore bodies in the overlying carbonates; the same principle applies in similar terranes elsewhere. The most significant basement features in the Joplin quadrangle are a series of individual rhyolitic to andesitic basement highs identified from drilling in a dominantly rhyolitic terrane in the southwestern part of the quadrangle. The knobs are not discernible on geophysical maps. Since the knobs are not discernible on geophysical maps, it is likely that more of them probably exist in undrilled parts of the region. Source of data: Unpublished oilfield drilling data from R.L. Erickson (U.S. Geological Survey) and Mary Daily (Kansas Geological Survey).

5. Presence of visible sulfides at the surface or reported on drill logs. Source of data: Missouri Geological Survey, unpublished log. (This part of the data base is available only for the Missouri part of the quadrangle.)

6. Zones of dense or intersecting linear features on LANDSAT and SLAR (side-looking airborne radar) data, which are believed to indicate faults or zones of structural weakness. Source of data: Kansas Geological Survey.

### MINERAL-RESOURCE ASSESSMENT

As with the Springfield and Harrison quadrangles, the assessment of the Joplin quadrangle was done for individual "packages" of sedimentary rocks--the Arbuckle (Upper Cambrian and Lower Ordovician), the Mississippian, and the Pennsylvanian.

Maps A and B show the distribution of the six assessment criteria through the quadrangle in the Upper Cambrian and Lower Ordovician rocks (Map A) and in the Mississippian rocks (Map B). Figures 5 through 7 show the same information diagrammatically, in a less cluttered form, and at a smaller scale (1:2,000,000); figure 5 shows lithofacies and geochemical criteria for the Cambrian and Ordovician rocks, figure 6 shows lithofacies and geochemical criteria for the Mississippian rocks, and figure 7 shows structural criteria that apply to both sequences.

#### Assessment of Potential in Upper Cambrian and Lower Ordovician Rocks -- Map A

As described above, the Upper Cambrian and Lower Ordovician section is not subdivided into formations in the two-thirds of the Joplin quadrangle that lies in Kansas, but is recorded in subsurface logs as the undivided Arbuckle Group. For this reason, geochemical data used for the mineral-resource assessment could not be assigned to specific formations, and consequently the Upper Cambrian and Lower Ordovician rocks are lumped into a single unit.

The primary lithofacies criterion in the MVT assessment model is a pinchout or window in the underlying Davis-equivalent shales. Shale of the Davis Formation is present in the northeastern part of the quadrangle but pinches out to the west along a line located somewhere within a north-northwest-trending zone that extends across the eastern part of the quadrangle. As there is insufficient subsurface data to locate this pinchout accurately, it is shown on map A as a zone about 15-20 mi wide; note the distribution of individual drill-hole data points that control the delineation of the zone. *There probably is no Davis shale west of this zone.* Davis shale is also present along the south edge of the eastern half of the quadrangle, pinching out along an east-west arc located just slightly inside the south edge of the quadrangle.

After examination of the distribution of all the assessment criteria, the quadrangle was divided into seven assessment blocks, as follows (see map A):

Area 1, the most interesting area, is in the east-central part of the quadrangle above the pinchout of the Davis Formation. It includes part of the Chesapeake tectonic zone (fig. 8) and an intersecting northeast-trending fault zone, the northeastern extremity of moderate geochemical anomaly, several drill-log reports of visible sulfides in Cambrian rocks and numerous reports of sulfides in Mississippian rocks, and an intersection of northeast- and northwest-trending zones of dense or intersecting linear features on LANDSAT and SLAR images. This area is considered to have moderate potential for undiscovered MVT deposits, with a moderate degree of certainty (M/M as defined on fig. 4).

Area 2. The next most favorable area is in the southwestern part of the quadrangle. It includes most of a large, strong geochemical anomaly, northwest- and northeast-trending faults, a west-northwest-trending line of basement knobs (providing a site for possible pinchout of basal Reagan sandstone), and part of a northwest-trending zone of linear features seen in remote-sensing images. The area is considered to have moderate resource potential, with a moderate degree of certainty (M/M) -- slightly less certainty than area 1.

Area 3. The entire eastern part (approximately two-fifths) of the quadrangle is considered to be an area of moderate resource potential with a low level of certainty (M/L), based on a combination of factors including Davis shale pinchout, major fault zones, geochemical anomalies, drill-log reports of visible sulfides, and linear features in remote-sensing images. This area includes the Tri-State district, with production from the overlying Mississippian rocks and significant but noncommercial mineralized rock in Ordovician rocks (Brockie and others, 1968, p. 414). Excluded from this area is the extreme northeast corner of the quadrangle, where Davis shale is present (see area 6).

Area 4. This small area northeast of the center of the quadrangle is west of the Davis pinchout but contains a strong geochemical anomaly and an inferred basement structure, which could be a fault, providing a site for pinchout of the Lamotte Sandstone. On the basis of these two favorable criteria the area is assigned a moderate potential with a low level of certainty (M/L).

Area 5. On the basis of its proximity to area 2, the southwestern part (approximately one-fourth) of the quadrangle is assigned a moderate potential with a low level of certainty (M/L). The northeastern limit of this area is defined in such a way as to include a prominent northeast-trending fault zone and the (generalized) northeast limit of the geochemical anomaly in area 2.

Areas 6A and 6B. The remainder of the quadrangle is assigned a low potential, with a low level of certainty (L/L). These areas contain a few major faults in the sedimentary rocks as well as in the basement, but the pinchout of Davis shale is probably remote. More specifically, Davis shale is present in area 6A, limiting prospective ground to areas where the shale is breached by faults. Davis shale is absent in area 6B, thus nowhere in this area would upward movement of ore solutions be focused by a shale pinchout. In both areas the fairly sparse geochemical data show no significant anomalies.

#### Assessment of Potential in Mississippian Rocks -- Map B

The principal areas of interest in the Mississippian rocks are centered on windows through the underlying Chattanooga and Northview Shales: a fairly small window in the southeastern corner of the quadrangle and a larger, irregular window in the southeastern and south-central parts of the quadrangle (fig. 6). The quadrangle was divided into eight assessment blocks:

Area 1. The combination of the shale window, strong geochemical anomalies, major northwest- and northeast-trending fault zones, and numerous occurrences of sulfides at the surface and in drill logs, indicates an apparently high potential for this area in the southeastern part of the quadrangle, with a high level of certainty (H/H). In fact, this area is part of the Tri-State district, and its long history of production indicates that any significant potential for undiscovered deposits has already been realized. But the identification of the area using the objective recognition criteria substantiates the validity of the method, and is analogous to the identification of the Viburnum Trend in the Rolla CUSMAP assessment (Pratt, 1981).

Area 2. Another area of high potential for undiscovered deposits is defined by the coincidence of windows in the Chattanooga and Northview Shales and by a strong geochemical anomaly near the northeastern corner of the quadrangle; this area is also between the Bolivar-Mansfield and Chesapeake tectonic zones, and contains numerous occurrences of galena and sphalerite. With an assigned level of high potential and moderate certainty (H/M), in the majority opinion of the CUSMAP assessment team this is the most favorable target for prospecting in the Joplin quadrangle. (However, a minority opinion held that on the basis of field-inclusion studies then recently completed, MVT ores could have formed only down-section from the Mississippian rocks in this part of the quadrangle.)

Area 3. A banana-shaped area near the east-central part of the quadrangle contains another strong geochemical anomaly and numerous sulfide occurrences, and includes part of intersecting fault zones and intersecting complexes of linear features seen in remote-sensing images. This area is assigned a moderate potential with a moderate level of certainty (M/M).

Area 4. The remainder of the eastern two-fifths of the quadrangle contains numerous sulfide occurrences, a moderate geochemical anomaly, and several fault zones; it is assigned a moderate potential with a low level of certainty (M/L).

Area 5. A small area north of Oswego, in the south-central part of the quadrangle, encloses several hundred exploratory holes that have been drilled into the top of the Mississippian rocks during the last 15 years; one quarter-section alone within this area contains more than 100 holes. No cuttings from these holes have been submitted to the Kansas Geological Survey well-sample library, hence no geochemical data are available for the area. The area is at the edge of a large window in the underlying shales, and straddles the regionally important northwest-trending Fall River tectonic zone (see fig. 9). These factors, combined with the "circumstantial" evidence of the density of drilling, compel us to believe that a significant but probably uneconomic discovery was made in this area, and for this reason area 5 is assigned a high potential with a high level of certainty (H/H).

Area 6. The remainder of this shale window, with the exception of area 7 discussed below, is considered to have a moderate potential because it is a shale window and contains several throughgoing faults. South of a line trending approximately northwest through Parsons, the level of certainty is moderate (M/M); northeast of this line, information is scarcer and the level of certainty is low (M/L).

Area 7. In a small area centered about 10 mi north of Coffeyville, a northeast-trending geochemical anomaly crosses the line of basement knobs in the vicinity of two northeast-trending faults and extends into the shale window. Most of this area is also within one of the areas containing complexes of linear features seen in remote-sensing images. The area is considered to have a high potential, with a moderate level of certainty within the shale window (H/M) and a low level of certainty outside the shale window (H/L).

Area 8. The remainder of the quadrangle, that is, most of the western three-fifths of the quadrangle except for the shale window, contains no striking combination of favorable criteria and is considered to have a low potential with a low level of certainty (L/L).

#### Assessment of Potential in Pennsylvanian Rocks

No large MVT deposits hosted by Pennsylvanian rocks are known in the quadrangle, and the Pennsylvanian section in the subsurface has been reasonably well sampled through drilling tests for oil, gas, and water. Pennsylvanian rocks have been removed by erosion in the southeastern part of the quadrangle. In the remainder of the quadrangle, isolated occurrences of zinc and lead sulfides are common in Pennsylvanian rocks (Hatch and others, 1976; Coveney and others, 1987; Whelan and others, 1988), and there is probably some potential for small deposits that could be mined on a very small scale. An example of these is the relatively small Jumbo mine, located just 11 miles north of the quadrangle, near Pleasanton, Kansas; this mine was operated sporadically from 1899 to 1940 to develop ore in Pennsylvanian collapse breccias related to Mississippian karst topography (Schoewe, 1959). Similar ores have been mined from numerous near-surface deposits on the periphery of the Tri-State district. However, we consider the potential for MVT deposits of major economic importance in the Pennsylvanian rocks to be extremely low.

### SUMMARY

In conclusion, the assessment criteria indicate two areas of high potential for undiscovered MVT deposits in Mississippian rocks, with a moderate level of certainty: north of Nevada, Missouri, and north of Coffeyville, Kansas. The assessment also confirms the validity of the method by indicating a high potential for MVT deposits in Mississippian rocks in the Tri-State district, although that area has been so thoroughly prospected that the actual potential for new discoveries is low. In Cambrian and Ordovician rocks, two areas are considered to have moderate potential for undiscovered deposits, one in the east-central part of the quadrangle and one in the southwest. The potential for significant MVT deposits in the Pennsylvanian rocks is extremely low.

## RESOURCE POTENTIAL FOR DIAMOND OCCURRENCES AND INDUSTRIAL MINERALS IN CRETACEOUS LAMPROITES
**By Pieter Berendsen**

Lamproites, closely related chemically to peridotites, occur at two locations in the Joplin quadrangle, one in the Rose dome and the other in the Silver City dome (fig. 8). The intrusives were identified as peridotites as early as 1932 (Knight and Landes, 1932) and are restricted to two northeast-trending, three-mile-long depressions that may be related to structural collapse after initial doming. The lamproites occur as dikes and sills intruding rocks of the Pennsylvanian System. They are alkalic and ultrapotassic (Cullers and others, 1985). At Silver City dome (Hills and others, 1991), sills as much as 35 m thick intrude Pennsylvanian shales; the rock is porphyritic and consists of phlogopite, diopside, potassic richterite, serpentine pseudomorphs after olivine, and chrome spinel in a groundmass of mostly serpentine (Cullers and others, 1985). Accessory minerals are perovskite, apatite, and magnetite. At the surface the rocks are weathered, soft, and olive-brown. A Late Cretaceous K-Ar age of 90±5 Ma was determined on three samples of phlogopite (Zartman and others, 1967). At Rose dome (Hills and others, 1991), where the lamproite is known only from drill samples, the rock intrudes Pennsylvanian shale. The minerals include 25 percent or more phlogopite and less than 5 percent each of olivine, diopsidic augite, and amphibole, in a dolomitized, serpentinized groundmass; accessory minerals are apatite, magnetite, and iron-rich chromite. The phlogopite K-Ar age is 88±4 Ma (Zartman and others, 1967).

The 35-m-thick lamproite sill that occurs at and near the surface along the northern perimeter of Silver City dome has been considered as a possible source for vermiculite, bauxite, chromite, and road ballast since the 1940's. A mining and processing operation produced insulating material from 1961 to about 1966. Soft weathered lamproite has been mined continually since 1982; 98 percent of the material is used as an animal feed additive and pellet binder, and the remainder in specialty applications.

Lamproite of the same composition as these is the host rock in the Argyle mine, one of the richest diamond mines in Australia (Jaques and others, 1989), and so some potential for diamonds may exist at Rose and Silver City domes.

## GEOLOGY AND MINERAL-RESOURCE POTENTIAL OF THE PRECAMBRIAN BASEMENT
**By Eva B. Kisvarsanyi**

The region of Kansas and Missouri that includes the Joplin quadrangle is underlain by the Middle Proterozoic (1.35-1.40 Ga) Spavinaw granite-rhyolite terrane (Sims and others, 1987), similar to the epizonal St. Francois granite-rhyolite terrane, which is well known from outcrops and drill cores in southeastern Missouri (Kisvarsanyi, 1981; fig. 9). Two alternative interpretations of the Precambrian basement geology, both outgrowths of this CUSMAP project, have been published separately (Berendsen and Blair, 1991; McCafferty and Cordell, 1992), but the generalized geologic map of the Precambrian basement shown in figure 8 is adequate for this discussion of resource potential. The Precambrian basement is covered by Phanerozoic sedimentary rocks throughout the quadrangle. The basement in this region has no historic record of mineral production, and its unidentified resources must necessarily be appraised from sparse drill-hole information, geophysical maps, and analogies with similar terranes.

The identification of the Spavinaw terrane in the quadrangle is based on basement-rock samples collected from 15 drill holes, most of which are in Missouri. Fine- to medium-grained, red, granophyric alkali-feldspar granite and rapakivi granite, typical of Middle Proterozoic anorogenic terranes of the region, was found in samples from seven drill holes; volcanic rock, mostly rhyolite and some trachyte and trachyandesite, was present in samples from eight. A Rb-Sr whole-rock age of 1.37 Ga was obtained by Muehlberger and others (1966) from rapakivi granite core samples collected in Vernon County, Missouri. Clastic sedimentary rock, classified as lower greenschist facies meta-arkose derived from a Spavinaw-type source, was identified from three drill holes in the eastern third of the quadrangle. The presence of the 1.65-Ga Central Plains orogenic terrane is inferred in the northeasternmost part of the quadrangle from several drill holes just east of the quadrangle.

Two major Precambrian tectonic zones, the Bolivar-Mansfield (BMTZ) and the Chesapeake (CTZ) (Kisvarsanyi, 1984), strike northwesterward across the quadrangle (fig. 9). They coincide with known structures in overlying Paleozoic rocks and were reactivated in Paleozoic time. The Precambrian rocks are generally downfaulted between the two tectonic zones and form a complex graben in which pre-Upper Cambrian clastic sequences locally accumulated. The broad pre-sediment Spavinaw arch extends northeastward from central Oklahoma into southwestern Missouri and is underlain by granite and associated volcanic rocks of the Spavinaw terrane. By analogy with the St. Francois terrane, it may be assumed that the Spavinaw arch has a rugged surface and somewhat similar geology to that of southeastern Missouri, where several calderas, cauldron subsidence structures, and granite ring complexes have been mapped (Kisvarsanyi, 1981).

Petrographic, geochemical, and tectonic analogies suggest that the Spavinaw and St. Francois terranes may have similar metallogenesis and that the same types of mineral deposits should be expected in both. The most important deposit type that may occur in this area is a class of Proterozoic iron oxide-rich deposits that often contain anomalous concentrations of rare-earth elements and other metals (copper, uranium, gold, and silver) and are referred to as "Olympic Dam-type" deposits (Hauck, 1990). Elsewhere in the world these deposits typically occur in anorogenic granite-rhyolite terranes, are associated with magnetic and gravity anomalies, and can be targets for exploration in buried terranes. In the St. Francois terrane, more than two dozen magnetite and hematite deposits are known, some with associated rare-earth-element and copper-gold concentrations; many of these iron-oxide deposits are associated with a distinctive suite of alkaline-intermediate rocks consisting of syenite, trachyte, magnetite trachyte, and trachyandesite (Kisvarsanyi, 1990). Two areas in the Joplin quadrangle are judged favorable for the occurrence of undiscovered Olympic Dam-type deposits. (1) An area of volcanic rock in Cherokee Co. in the south-central part of the Joplin quadrangle, represented by four core holes, is characterized by altered trachytes and trachyandesites (fig. 8). The alteration is propylitic; hematite, epidote, and chlorite form massive replacements, and calcite and chalcedony form veins and fill lithophysae. This type of alteration is typically associated with magnetite and hematite deposits in the St. Francois terrane. This area (area 1 on fig. 8) is considered the most favorable for the occurrence of Olympic Dam-type deposits because the host rock is a trachyte or trachyandesite, because the alteration mineralogy is diagnostic of that associated with southeast Missouri iron deposits, and because of the presence of known faults. (2) A sequence of red clastic rocks within the graben defined by the Bolivar-Mansfield tectonic zone and the Chesapeake tectonic zone near the Kansas-Missouri state line is as thick as 300 m and is underlain by syenite (fig. 8, area 2). It appears to be a local accumulation of detritus derived from nearby granite and rhyolite terranes. Samples from the clastic sequence consist of very fine drill cuttings, and the fabric of the rock cannot be positively identified. The rock has a low metamorphic grade; granite and rhyolite clasts are unaffected, but the clay-size matrix is partly sericitized. This sequence may represent rapid deposition of clastic sediments in the graben; alternatively, it may be a heterolithic volcanic breccia. Drill holes immediately south of the clastic sequence bottom in rhyolite. Large-scale brecciation could be associated with volcanic eruptions and caldera formation and could provide favorable sites for ore genesis.

## REFERENCES CITED

Berendsen, Pieter, and Blair, K.P., 1991, Interpretive subcrop map of the Precambrian basement in the Joplin 1° x 2° quadrangle: Kansas Geological Survey, Subsurface geology series 14, 10 p.

Blair, K.P., Berendsen, Pieter, and Seeger, C.M., 1992, Structure-contour maps on the top of the Mississippian carbonates and on the top of the Upper Cambrian and Lower Ordovician Arbuckle Group, Joplin 1° X 2° quadrangle, Kansas and Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-2125-C, scale 1:250,000.

Brockie, D.C., Hare, E.H., Jr., and Dingess, P.R., 1968, The geology and ore deposits of the Tri-State District of Missouri, Kansas, and Oklahoma, in Ridge, J.D., ed., Ore Deposits of the United States, 1933-1967, The Graton-Sales Volume: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. 1, p. 400-430.

Coveney, R.M., Jr., Goebel, E.D., and Ragan, V.M., 1987, Pressures and temperatures from aqueous fluid inclusions in sphalerite from Midcontinent country rocks: Economic Geology, v. 82, p. 740-751.

Cullers, R.L., Subramanian, R., Berendsen, Pieter, and Griffin, T., 1985, Geochemistry and petrogenesis of lamproites, Late Cretaceous age, Woodson County, Kansas, U.S.A.: Geochimica et Cosmochimica Acta, v. 49, p. 1383-1402.

Denison, R.E., 1981, Basement rocks in northeastern Oklahoma: Oklahoma Geological Survey Circular 84, 84 p.

Erickson, R.L., and Chazin, Barbara, 1991, Resource assessment for Mississippi Valley-type base-metal deposits, *in* Martin, J.A., and Pratt, W.P., Geology and mineral-resource assessment of the Springfield 1° X 2° quadrangle, Missouri, as appraised in September 1985: U.S. Geological Survey Bulletin 1942, p. 90-94.

Erickson, R.L., Chazin, Barbara, and Erickson, M.S., 1989, Summary geochemical maps of the Harrison 1° X 2° quadrangle, Missouri and Arkansas: U.S. Geological Survey Miscellaneous Field Studies Map MF-1994-A, scales 1:250,000 and 1:500,000.

Erickson, R.L., Erickson, M.S., Mosier, E.L., and Chazin, Barbara, 1985, Summary geochemical and generalized geologic maps of the Springfield 1° X 2° quadrangle, Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-1830-A, scale 1:500,000.

Erickson, R.L., Mosier, E.L., Folger, H.W., Bullock, J.H., Jr., Berendsen, Pieter, and Daly [Daily], Mary, 1990, Summary geochemical maps of the Joplin 1° X 2° quadrangle, Kansas and Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-2125-A, scales 1:250,000 and 1:500,000.

Erickson, R.L., Mosier, E.L., Odland, S.K., and Erickson, M.S., 1981, A favorable belt for possible mineral discovery in subsurface Cambrian rocks in southern Missouri: Economic Geology, v. 76, p. 921-933.

Erickson, R.L., Mosier, E.L., and Viets, J.G., 1978, Generalized geologic and summary geochemical maps of the Rolla 1° X 2° quadrangle, Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-1004-A, scale 1:250,000.

Grisafe, D.A., and Rueff, A.W., 1991, Industrial minerals of the Joplin 1° X 2° quadrangle, Kansas and Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-2125-B, scale 1:500,000.

Hatch, J.R., Avcin, M.J., Wedge, W.K., and Brady, L.L., 1976, Sphalerite in coals from southeastern Iowa, Missouri, and southeastern Kansas: U.S. Geological Survey Open-File Report 76-796, 26 p.

Hauck, S.A., 1990, Petrogenesis and tectonic setting of Middle Proterozoic iron oxide-rich ore deposits--An ore deposit model for Olympic Dam-type mineralization, *in* Pratt, W.P., and Sims, P.K., eds., The Midcontinent of the United States--Permissive terrane for an Olympic Dam-type deposit?: U.S. Geological Survey Bulletin 1932, p. 4-39.

Hills, F.A., Scott, R.W., Jr., Armbrustmacher, T.J., and Berendsen, Pieter, 1991, Map showing distribution of alkaline igneous rocks and associated carbonatite and peridotites in the northern Midcontinent, U.S.A.: U.S. Geological Survey Miscellaneous Field Studies Map MF-1835-F, scale 1:1,000,000.

Jaques, A.L., Haggerty, S.E., Lucas, H., and Boxer, G.L., 1989, Mineralogy and petrology of the Argyle (AK1) lamproite pipe, Western Australia: Geological Society of Australia, Special Publication 14, p. 153-169.

Kisvarsanyi, E.B., 1981, Geology of the Precambrian St. Francois terrane, southeastern Missouri: Missouri Department of Natural Resources Report of Investigations 64, 58 p.

Kisvarsanyi, E.B., 1984, The Precambrian tectonic framework of Missouri as interpreted from the magnetic anomaly map: Missouri Department of Natural Resources Contribution to Precambrian Geology 14, 19 p.

Kisvarsanyi, E.B., 1990, General features of the St. Francois and Spavinaw granite-rhyolite terranes and the Precambrian metallogenic region of southeast Missouri, *in* Pratt, W.P., and Sims, P.K., eds., The Midcontinent of the United States--Permissive terrane for an Olympic Dam-type deposit?: U.S. Geological Survey Bulletin 1932, p. 48-57.

Knight, G.L., and Landes, K.K., 1932, Kansas laccoliths: Journal of Geology, v. 40, p. 1-15.

Martin, J.A., and Pratt, W.P., eds., 1985, Geology and mineral-resource potential of the Springfield 1° X 2° quadrangle, Missouri, as appraised in September 1985: Missouri Department of Natural Resources, Division of Geology and Land Survey, Open-file Report OFR-85-42-MR, 82 p.

_____1991, Geology and mineral-resource assessment of the Springfield 1° X 2° quadrangle, Missouri, as appraised in September 1985: U.S. Geological Survey Bulletin 1942, 115 p.

McCafferty, A.E., and Cordell, L.E., 1992, Geophysically inferred structural and lithologic map of the Precambrian basement in the Joplin 1° X 2° quadrangle, Kansas and Missouri: U.S. Geological Survey Miscellaneous Field Studies Map MF-2125-D, scale 1:500,000.

McCauley, J.R., Smith, D.C., and Robertson, C.E., 1990, Geology of the Joplin quadrangle, *in* Pratt, W.P., and Goldhaber, M.B., eds., U.S. Geological Survey - Missouri Geological Survey Symposium, Mineral-Resource Potential of the Midcontinent, Program and Abstracts: U.S. Geological Survey Circular 1043, p. 17.

McKnight, E.T., and Fischer, R.P., 1970, Geology and ore deposits of the Picher field, Oklahoma and Kansas: U.S. Geological Survey Professional paper 588, 165 p.

Muehlberger, W.R., Hedge, C.E., Denison, R.E., and Marvin, R.F., 1966, Geochronology of the Midcontinent region, United States, 3. Southern Area: Journal of Geophysical Research, v. 71, p. 5409-5426.

Netzler, B.W., 1990, Heavy-oil resource potential of the Joplin quadrangle, *in* Pratt, W.P., and Goldhaber, M.B., eds., U.S. Geological Survey - Missouri Geological Survey Symposium, Mineral-Resource Potential of the Midcontinent, Program and Abstracts: U.S. Geological Survey Circular 1043, p. 20.

Palmer, J.R., 1991, Distribution of lithofacies and inferred depositional environments in the Cambrian system, *in* Martin, J.A., and Pratt, W.P., eds., Geology and mineral-resource assessment of the Springfield 1° X 2° quadrangle, Missouri, as appraised in September 1985: U.S. Geological Survey Bulletin 1942, p. 9-38.

Pratt, W.P., ed., 1981, Metallic mineral-resource potential of the Rolla 1° X 2° quadrangle, Missouri, as appraised in September 1981: U.S. Geological Survey Open-File Report 81-518, 77 p.

Pratt, W.P., 1991, The Conterminous United States Mineral-Resource Assessment Program: Background information to accompany folio of geologic and mineral-resource maps of the Rolla 1° X 2° quadrangle, Missouri: U.S. Geological Survey Circular 1068, 10 p.

Pratt, W.P., Erickson, R.L., Kisvarsanyi, E.B., and Wharton, H.M., 1984, Maps showing areas of significant metallic mineral-resource potential in the Rolla 1° X 2° quadrangle, Missouri, as appraised in September 1980: U.S. Geological Survey Miscellaneous Field Studies Map MF-1005-A, scale 1:250,000.

Pratt, W.P., Hayes, T.S., Erickson, R.L., Kisvarsanyi, E.B., McFarland, M.C., Rueff, Ardel, Bush, W.V., Colton, G.W., and McFarland, J.D. III, 1993, Mineral-resource potential of the Harrison 1° X 2° quadrangle, Missouri and Arkansas: U.S. Geological Survey Miscellaneous Field Studies Map MF-1994-D, scale 1:250,000.

Schoewe, W.H., 1959, The first Kansas lead mines: Kansas Historical Quarterly, Winter 1959, p. 391-401.

Siebenthal, C.E., 1916, Origin of the zinc and lead deposits of the Joplin region, Missouri, Kansas, and Oklahoma: U.S. Geological Survey Bulletin 606, 283 p.

Sims, P.K., compiler, 1990, Precambrian basement map of the northern Midcontinent, U.S.A.: U.S. Geological Survey Miscellaneous Investigations Map I-1853-A, scale 1:1,000,000.

Sims, P.K., Kisvarsanyi, E.B., and Morey, G.B., 1987, Geology and metallogeny of Archean and Proterozoic basement terranes in the northern midcontinent, U.S.A.--an overview: U.S. Geological Survey Bulletin 1815, 51 p.

Taylor, R.B., Stoneman, R.J., and Marsh, S.P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, 42 p.

Whelan, J.F., Cobb, J.C., and Rye, R.O., 1988, Stable isotope geochemistry of sphalerite and other mineral matter in coal beds of the Illinois and Forest City basins: Economic Geology, v. 83, p. 990-1007.

Zartman, R.E., Brock, M.R., Heyl, A.V., and Thomas, H.H., 1967, K-Ar and Rb-Sr ages of some alkalic intrusive rocks from central and eastern United States: American Journal of Science, v. 265, p. 848-870.

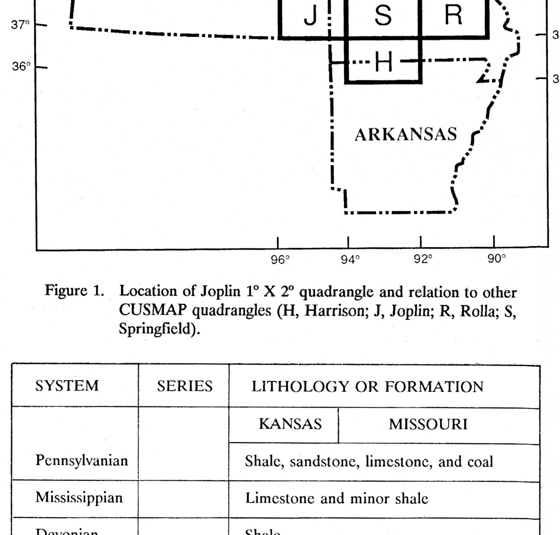



Figure 1. Location of Joplin 1° X 2° quadrangle and relation to other CUSMAP quadrangles (H, Harrison; J, Joplin; R, Rolla; S, Springfield).

| SYSTEM | SERIES | LITHOLOGY OR FORMATION | |
|---|---|---|---|
| | | KANSAS | MISSOURI |
| Pennsylvanian | | Shale, sandstone, limestone, and coal | |
| Mississippian | | Limestone and minor shale | |
| Devonian | | Shale | |
| Ordovician | Lower | Arbuckle | Cotter Dolomite<br>Jefferson City Dolomite<br>Roubidoux Formation<br>Gasconade Dolomite |
| Cambrian | Upper | Group | Eminence Dolomite<br>Potosi Dolomite<br>Derby-Doerun Dolomite<br>Davis Formation<br>Bonneterre Formation |
| | | Lamotte or Reagan Sandstone | |
| Proterozoic | | Granite, rhyolite, metamorphic and sedimentary rocks | |

Figure 2. Stratigraphic nomenclature of Cambrian and Ordovician rocks in the Joplin 1° X 2° quadrangle.

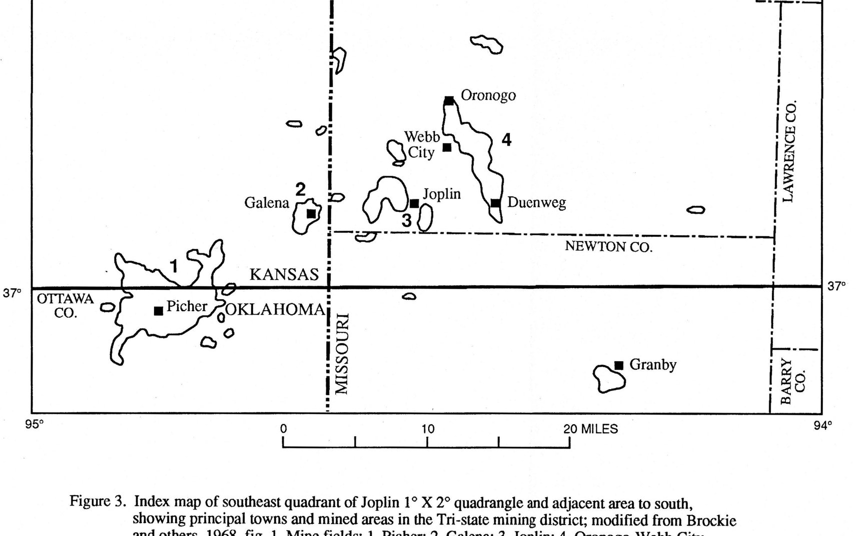



Figure 3. Index map of southeast quadrant of Joplin 1° X 2° quadrangle and adjacent area to south, showing principal towns and mined areas in the Tri-state mining district; modified from Brockie and others, 1968, fig. 1. Mine fields: 1, Picher; 2, Galena; 3, Joplin; 4, Oronogo-Webb City-Duenweg. Line at lat. 37° N. marks the southern boundary of the Joplin quadrangle; west of Missouri it is also the Kansas-Oklahoma state line.

| LEVEL OF RESOURCE POTENTIAL | | | | |
|---|---|---|---|---|
| HIGH | U | H/L HIGH POTENTIAL | H/M HIGH POTENTIAL | H/H HIGH POTENTIAL |
| MODERATE | UNKNOWN | M/L MODERATE POTENTIAL | M/M MODERATE POTENTIAL | M/H MODERATE POTENTIAL |
| LOW | POTENTIAL | L/L LOW POTENTIAL | L/M LOW POTENTIAL | L/H LOW POTENTIAL |
| | | | | N NO POTENTIAL |
| LEVEL OF CERTAINTY → | LOWEST | LOW | MODERATE | HIGH |

Definitions of levels of mineral resource potential

Low potential: Assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment where the existence of resources is unlikely.

Moderate potential: Characteristics indicate a geologic environment favorable for resource occurrence, interpretation of data indicate a reasonable chance for resource accumulation, and an application of models indicates favorable ground.

High potential: Characteristics indicate a geologic environment favorable for resource occurrence, interpretations of data indicate a high likelihood for resource accumulation, data support models indicating presence of resources, and evidence indicates that mineral concentration has taken place. Assignment of high resource potential requires positive knowledge that resource-forming processes have been active in at least part of the area; it does not require that occurrences or deposits be identified.

Unknown potential: The level of knowledge is so inadequate that classification of the area as high, moderate, or low would be misleading.

Definitions of levels of certainty

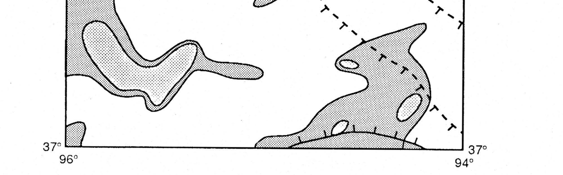
Lowest certainty: The available data are not adequate to determine the level of mineral resource potential.

Low certainty: Available data are adequate to suggest the geologic environment and the level of mineral resource potential, but either evidence is insufficient to establish precisely the likelihood of resource occurrence.

Moderate certainty: Available data give a good indication of the geologic environment and the level of mineral resource potential, but additional evidence is needed to establish precisely the likelihood of resource occurrence or the activity of resource-forming processes.

High certainty: Available data clearly define the geologic environment and the level of mineral resource potential, and indicate the activity of resource-forming processes.

Figure 4. Classification of mineral resource potential and certainty; after Taylor and others, 1984.



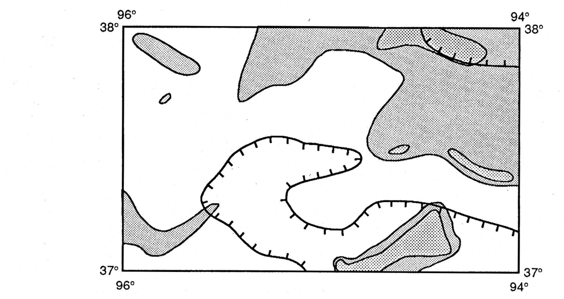
EXPLANATION

Pinchout of underlying shales--Hachures on side where Davis shales are absent; dashed lines indicate inner and outer limits of zone within which pinchout is located (see text)

Area of strong geochemical anomalies

Area of moderate geochemical anomalies

Figure 5. Distribution of lithofacies and geochemical criteria for Upper Cambrian and Lower Ordovician rocks in the Joplin 1° X 2° quadrangle.



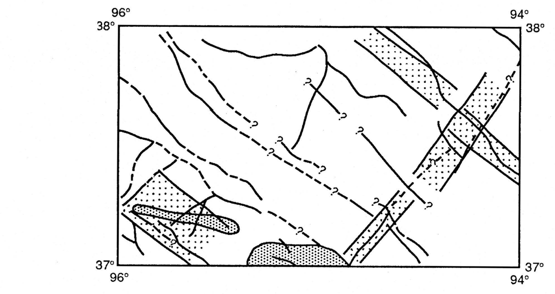
EXPLANATION

Pinchout of underlying Chattanooga and Northview Shales--Hachures on side where both shales are 10 ft thick or less

Area of strong geochemical anomalies

Area of moderate geochemical anomalies

Figure 6. Distribution of lithofacies and geochemical criteria for Mississippian rocks in the Joplin 1° X 2° quadrangle.



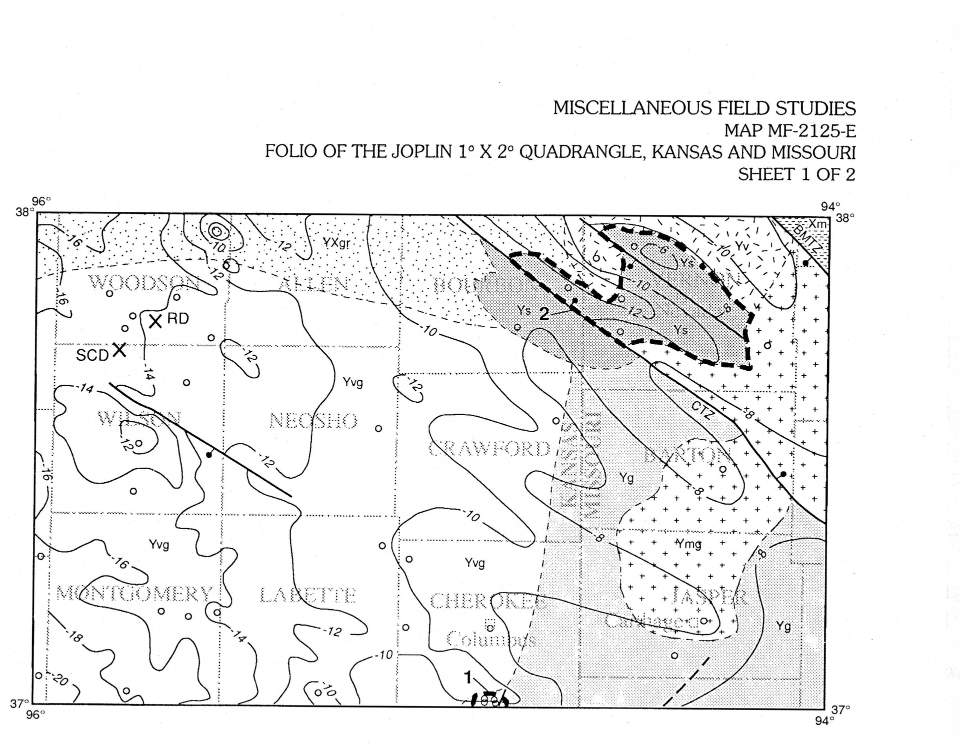
EXPLANATION

Fault--dashed where approximately located, queried where inferred

Area of buried Precambrian basement highs

Zone of faults and dense linear features seen on remote-sensing images

Figure 7. Distribution of structural criteria in the Joplin 1° X 2° quadrangle.




EXPLANATION
(figure 8)

Contact, inferred

Contact, based on geophysical data

Fault or shear zone, based on geophysical data--Bar and ball on downthrown side; BMTZ, Bolivar-Mansfield tectonic zone; CTZ, Chesapeake tectonic zone

Fault or shear zone, inferred

Drill hole penetrating Precambrian basement

Structure contours on Precambrian bedrock surface--In hundreds of feet. Datum is mean sea level. Contour interval 200 feet

Area of resource potential in Precambrian rocks--Numbers refer to text

Locations of Cretaceous lamproites--RD, Rose dome; SCD, Silver City dome

DESCRIPTION OF MAP UNITS
(figure 8)

MIDDLE PROTEROZOIC (0.9-1.6 Ga)

Ys — Red clastic rocks of Midcontinent Rift System (Age 1.0-1.2 Ga)

Rocks of Spavinaw terrane (Age 1.35-1.40 Ga)

Yv — Rhyolite, dacite, and andesite flows and tuffs

Yg — Epizonal micrographic granite porphyry and granite--Includes Spavinaw granite of Denison (1981)

Ymg — Mesozonal granite

Yvg — Rhyolite, dacite, and epizonal granite, undivided

MIDDLE AND EARLY PROTEROZOIC

YXgr — Mesozonal granitoid rocks

EARLY PROTEROZOIC (1.6-2.5 Ga)

Xm — Metamorphic rocks, undivided

Figure 8. Precambrian basement map of the Joplin quadrangle; modified from Sims (1990).

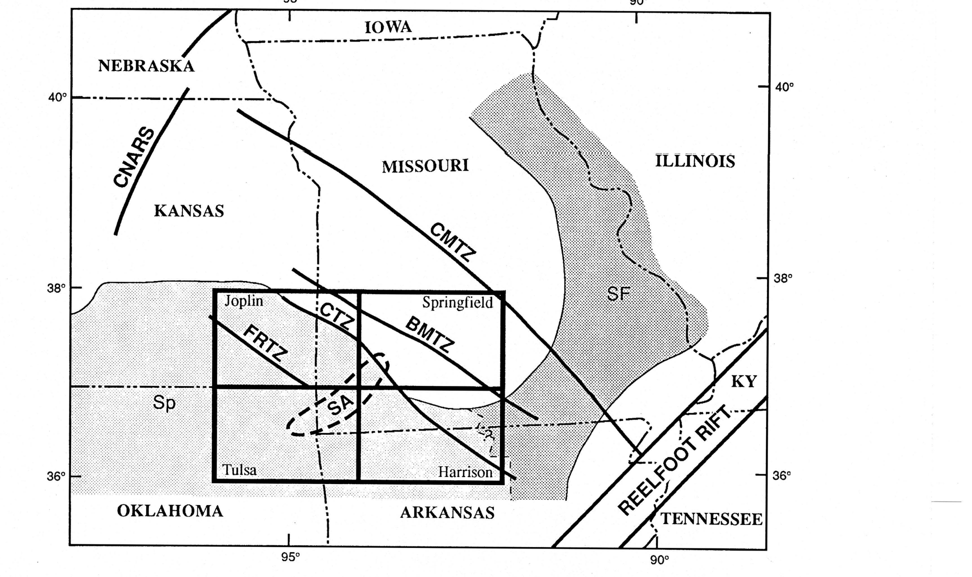



Figure 9. Index map of northern midcontinent area showing location of Joplin, Tulsa, Springfield, and Harrison quadrangles, Central North American rift system (CNARS), Reelfoot rift, and major tectonic zones and structures that cross the area: CMTZ, Central Missouri tectonic zone; BMTZ, Bolivar-Mansfield tectonic zone; CTZ, Chesapeake tectonic zone; FRTZ, Fall River tectonic zone; SA, Spavinaw arch; SF, St. Francois terrane; Sp, Spavinaw terrane. Light solid lines, approximate boundaries of St. Francois and Spavinaw terranes; dashed line, with queries, inferred contact between St. Francois and Spavinaw terranes.

# ASSESSMENT OF THE JOPLIN 1° X 2° QUADRANGLE, KANSAS AND MISSOURI, FOR MISSISSIPPI VALLEY-TYPE DEPOSITS AND OTHER MINERALS

By

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