Feldspar Diagenesis in Cambrian Clastic Rocks of the Southern Ozark Mountains and Reelfoot Rift, Southeastern Missouri and Northeastern Arkansas—Implications for Mississippi Valley–Type Ore Genesis

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Chapter F

Feldspar Diagenesis in Cambrian Clastic Rocks of the Southern Ozark Mountains and Reelfoot Rift, Southeastern Missouri and Northeastern Arkansas— Implications for Mississippi Valley–Type Ore Genesis

By S.F. DIEHL and M.B. GOLDHABER

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By S.F. Diehl *and* M.B. Goldhaber

Abstract

The Upper Cambrian Lamotte Sandstone is considered to have been a major aquifer for warm basinal brines that formed the Mississippi Valley–type (MVT) mineral deposits in Missouri. Petrographic studies of authigenic potassium feldspar in the Lamotte Sandstone constrain the geochemistry of the ore-forming fluids. Authigenic potassium feldspar is important because (1) it has been dated as late Paleozoic, which broadly coincides with the inferred time of ore genesis, (2) previous petrographic studies constrain the relative time authigenic feldspar dissolved with respect to deposition of the lead-zinc ore, and (3) MVT ore fluids are typically anomalously rich in K^+.

Published petrographic studies of Lamotte-hosted lead-zinc mineralization in southeastern Missouri demonstrate that the first episode of authigenic potassium feldspar formation predated mineralization and that dissolution of the overgrowths accompanied ore formation. Our data show that this ore-stage dissolution event was regionally extensive and was most intense along a northwest-trending corridor that includes the lead belts and the St. Francois Mountains. Fluid inclusion data from southeastern Missouri show very high K^+ concentrations during ore deposition. Potassium feldspar would be stable in a high K^+ environment; however, our data suggest that the ore fluid had a low pH (acidic), which dissolved potassium feldspar overgrowths and carried metals and H_2S in solution. The broad zone of dissolved potassium feldspar in southeastern Missouri suggests that this acidic fluid originated in the Reelfoot Rift.

Although dissolution of potassium feldspar is regional throughout southeastern Missouri, alteration products of potassium feldspar are significantly different in shallowly buried Lamotte Sandstone than in time-equivalent deeply buried sedimentary rocks in the Reelfoot Rift. Potassium feldspar grains in the Reelfoot Rift samples show increasingly greater alteration to albite with depth, and albitization is an important process that enriches pore fluids in K^+.

INTRODUCTION

The Upper Cambrian Lamotte Sandstone is of interest as a major aquifer that transported ore-bearing fluids for the Mississippi Valley–type (MVT) deposits of the southern midcontinent of the United States. We undertook a regional study of the Lamotte Sandstone to characterize diagenetic alterations that could possibly be related to the passage of the ore-forming fluids. The study was conducted as part of the U.S. Geological Survey (USGS) Midcontinent Strategic and Critical Minerals Project. Of the diagenetic phases recognized in the Lamotte Sandstone, potassium feldspar offered potentially critical information about the fluids and their age (Rothbard, 1983; Gutierrez, 1987). Authigenic potassium feldspar in the study area (Hearn and others, 1986) yielded late Paleozoic K-Ar radiometric ages, which are similar to paleomagnetic ages yielded by magnetite (Wu and Beales, 1981; Wisniowiecki and others, 1983). These late Paleozoic ages are considered to represent the time of mineralization, and thus they suggest a general link in time between potassium feldspar precipitation and ore formation. Furthermore, brines that formed MVT deposits are known to be anomalously rich in K^+ compared to typical upper crustal (that is oil-field) brines (Hanor, 1979). Even among MVT brines, the fluids of the main-stage mineralization of the deposits in the southeastern Missouri lead belts are anomalously rich in this ion (Viets and Leach, 1990). Therefore, the ore fluids are good candidates for the source of K+ that favored authigenic potassium feldspar precipitation.

We studied the Lamotte Sandstone in a regional sense, paying particular attention to alteration of the framework minerals and diagenetic potassium feldspar. Initial phases of the work indicated that the distribution of potassium feldspar overgrowths and their regional pattern of dissolution were important in recognizing the flow path of ore fluids. In this paper we discuss in detail results determined from cores from two core fences (fig. F1), which illustrate some key characteristics of alteration in the Lamotte Sandstone and basal clastic rocks in the Reelfoot rift, and we summarize data for additional cores in surrounding drill holes in terms of regional trends.

Acknowledgments.—We wish to thank George Breit, Donley Collins, and Paula Hansley of the U.S. Geological Survey for critical reviews. Elwin Mosier collected the Lamotte Sandstone samples from drill holes on the carbonate platform and Ozark uplift.

REGIONAL STRUCTURE

The Reelfoot rift (fig. F1) is a major crustal structure that underlies the central part of the Mississippi Embayment syncline, approximately 150 km southeast of

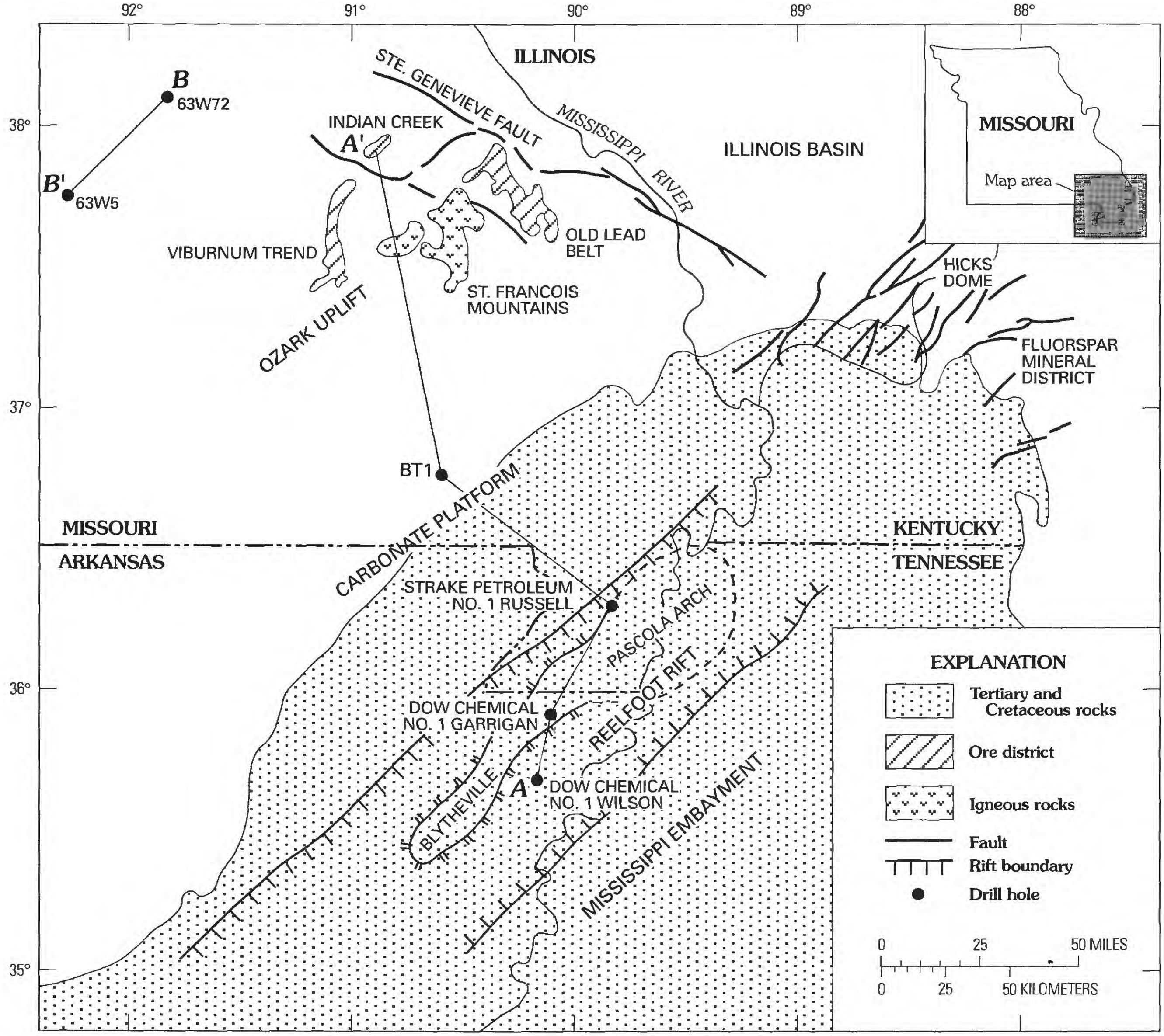

Figure F1. Map showing location of drill holes, major structural terrains, and ore districts in the study area, southeastern Missouri and northeastern Arkansas.

the Missouri lead belts. The rift formed in the Late Proterozoic or Early Cambrian (Ervin and McGinnis, 1975) as a fault-bounded basin that has undergone several subsequent periods of extension (Diehl and others, 1992) and subsidence. Deposition of a thick section of Cambrian rocks (as much as 30,000 ft) along the middle of the rift (Howe and Thompson, 1984) is evidence that the rift was active during the Cambrian. Structurally, the northern part of the rift joins the Rough Creek Graben, the Ste. Genevieve fault system, and the Illinois Basin (fig. F1). Because of the differences in lithologies and lack of drill hole data for the rift, the Cambrian-age carbonate rocks, shale, and siliciclastic rocks that fill the central part of the rift are not readily correlated with the Cambrian units on the adjacent carbonate platform (Collins and others, 1992).

Precambrian granite and volcanic rocks of the St. Francois Mountains are exposed in the central part of the Ozark uplift (fig. F1). Unconformities within Paleozoic rocks in and around the St. Francois Mountains demonstrate that the Ozarks have been repeatedly uplifted and eroded throughout the Paleozoic Era. Clendenin (1989) and Palmer (1989) speculated that the St. Francois Mountains are part of the rift-border fault system or an uplifted rift shoulder behind the rift-border fault system.

DESCRIPTION OF THE LAMOTTE SANDSTONE AND TIME-EQUIVALENT ROCKS IN THE REELFOOT RIFT

The Upper Cambrian Lamotte Sandstone is the first sedimentary unit overlying Precambrian basement rock in the study area. It ranges from less than 100 ft in thickness where it pinches out against Precambrian knobby terrain in the Ozark Mountains, to several thousands of feet in midcontinent basins, particularly the Reelfoot Rift. The Lamotte Sandstone has been correlated with the Mount Simon Sandstone (Upper Cambrian) in the Illinois basin and with parts of the Reagan Sandstone (Upper Cambrian) in Kansas, Oklahoma, and Nebraska (Houseknecht and Ethridge, 1978).

The Lamotte Sandstone varies considerably in lithology. The base of the Lamotte Sandstone is commonly conglomeratic where it overlies Precambrian basement in pinchouts. The lower part of the Lamotte Sandstone is a continental red-bed deposit (or its bleached equivalent) in much of Missouri. Upsection, there is a transition from a terrestrial depositional environment, which is recorded by a red feldspathic arenite, to a transgressive marine unit, which is commonly a white quartz arenite. From the quartz arenite, the Lamotte grades conformably upward through a glauconitic transition zone into the overlying Bonneterre Formation (Upper Cambrian). In outcrop, the Lamotte Sandstone is commonly thinly layered, crossbedded, and well sorted. The depositional history and composition of the Lamotte Sandstone was described by Ojakangas (1963), Abraham (1978), Houseknecht and Ethridge (1978), and Yesburger (1982). Three lithologic types were recognized: feldspathic, lithic, and quartzitic (Houseknecht and Ethridge, 1978). Feldspathic units contain abundant potassium feldspar and plutonic rock fragments, lithic units contain a greater percentage of volcanic rock fragments, and quartzitic units are predominantly composed of monocrystalline quartz grains (Houseknecht and Ethridge, 1978). These lithologic types are commonly interbedded and represent parts of braided fluvial deposits in and around the St. Francois Mountains. These various lithologies are thought to represent detritus from different source areas (Houseknecht and Ethridge, 1978), but we conclude from our study that the quartz-arenite composition of some units in the Lamotte Sandstone may be the result of extensive dissolution of potassium feldspar.

The basal Cambrian rocks in the Reelfoot Rift that may be time-equivalents of the Lamotte (Diehl and others, 1992) consist of feldspathic graywacke, feldspathic arenite, and quartz arenite. These rocks are commonly crossbedded at thin-section scale. The shale overlying the graywacke and arenite may be time equivalent to the Bonneterre Formation and Elvins Group (Collins and others, 1992). Rock fragments of graphic-granite texture are common to sedimentary rocks both in the rift and in the Lamotte on the adjacent carbonate platform.

METHODS AND MATERIALS

Drill hole locations are shown in figure F1. Core samples of the Lamotte Sandstone were obtained from cores housed at the Missouri Division of Land Survey. Drill cuttings of the Garrigan and Wilson wells were obtained from the Arkansas Geologic Commission. Seventy thin sections of the Lamotte Sandstone from 25 holes and 1 mine in southeastern Missouri and northeastern Arkansas were examined for feldspar content and dissolution effects. Generally, several depth intervals were sampled in each core. The results of these petrographic studies of selected thin sections from drill holes in the core fences are listed in table F1. Petrographic data were determined with standard-size thin sections and a petrographic microscope. One-half of each thin section was stained with a solution of sodium cobaltinitrate for identification of potassium feldspar grains. The samples were impregnated with blue epoxy to determine porosity. Selected samples were examined with a Cambridge 250 Mark 2 scanning electron microscope (SEM) equipped with an energy-dispersive X-ray (EDX). Sedimentary rocks were classified on the basis of the system of Pettijohn and others (1973). Modal analyses on core samples to determine bulk composition were made by 300

Table F1. Percent of bulk rock constituents in selected thin sections (percentage based on 300 points per thin section) of samples from core fence *A–A'* and *B–B'*.

[---, none observed]

		Feldspar		Rock fragments						
Drill hole (depth, in ft)	Quartz	Potassium feldspar	Plagio-clase	Volcanic	Igneous	Other	Carbonate cement	Clay matrix	Voids	Opaque minerals
Wilson (12,523)	88	1	3	---	---	---	7	---	---	<1
Wilson (12,690)	38	35	5	5	9	1	---	7	---	---
Wilson (13,930-13,940)	49	27	7	---	13	---	---	2	---	2
Garrigan (11.980-12.040)	62	7	1	---	---	---	8[a]	22	---	---
Strake-Russell (4,717)	38	37[b]	---	---	---	2	23	---	---	---
BT1 (2,092-2,114)	78.7	1.3	---	3	---	---	11.3	---	5.3	.3
Goose Creek 2	48.3	---	---	1.3	---	---	39.3[c]	---	4	7[d]
Goose Creek 3	58.8	.3[e]	---	7.7[f]	---	---	21.3	---	5.9	6
63W5 (1,214-1,267)	71	4.7	---	---	---	---	---	11	13[g]	.3
63W72 (1,288-1,344)	70.5	16.6[h]	---	.6	---	---	---	1.9	10.3	---

[a] Siderite and dolomite.

[b] Total of 10 percent overgrowths.

[c] Dolomite.

[d] Galena and marcasite.

[e] Overgrowths on volcanic rock fragments.

[f] Volcanic rock fragments containing sanidine.

[g] Total of 8 percent dissolution voids in potassium feldspar overgrowths.

[h] Total of 4.5 percent overgrowths.

point-counts per thin section (table F1). When only drill cuttings were available for thin sections, 100 point-counts per thin section were made, using several large chips of the same lithology. To estimate the amount of dissolution of potassium feldspar overgrowths, a small-scale grid was superimposed on 3–10 single, randomly selected feldspar grains that had overgrowths. Although dissolution of detrital feldspar grains was apparent, the dissolution effects on the overgrowths was the main topic of interest. Therefore, only the percentages of dissolution of the overgrowths were used to construct a map of dissolution areas. A Cold Cathode Luminescence scope Model 8200 MK 11 was used to examine detrital feldspar grains and their overgrowths in the Strake Russell No. 1 hole.

PETROGRAPHIC DESCRIPTIONS OF SAMPLES FROM CORE FENCE *A–A'*

The line *A–A'* traces the abundance of potassium feldspar overgrowths and the amount of dissolution in drill hole samples of Cambrian siliciclastic rocks from the Reelfoot Rift northwestward onto the adjacent carbonate platform and then into the Ozark uplift (fig. F1).

Reelfoot Rift

Samples of feldspathic arenite from three drill holes in the Reelfoot Rift were examined: the Dow Chemical Co. No. 1 Wilson, Dow Chemical Co. No. 1 Garrigan, and

Strake Petroleum No. 1 Russell (hereafter called the Wilson, Garrigan, and Strake holes) (fig. F1). The upper part of the Cambrian siliciclastic deposits in the Wilson and Garrigan holes in the Reelfoot Rift are considered to be a time-equivalent of the Lamotte Sandstone (Diehl and others, 1992). The Strake hole, in the northwestern part of the rift near the shelf margin, bottomed in a feldspathic arenite that was identified as the Lamotte Sandstone (Grohskopf, 1955).

Dow Chemical No. 1 Wilson Drill Hole

The Wilson hole, the deepest drill hole in the Reelfoot Rift, penetrates the Precambrian basement (total depth 14,868 ft, or 4,531.8 m). The siliciclastic rocks penetrated by this drill hole consist of a basal red feldspathic arenite (12,630–14,300 ft, or 3,850–4,358.6 m) overlain by a gray feldspathic to quartz arenite (12,300–12,630 ft, or 3,749–3,850 m). The latter is considered to be a time-equivalent of the Lamotte Sandstone (Diehl and others, 1992). However, previous studies have considered all of the basal siliciclastic deposits in the rift to be older than the Lamotte and have separated these rocks into distinct formations (Weaverling, 1987; Houseknecht, 1989).

Potassium feldspar in the red feldspathic arenite (12,630–14,300 ft, or 3,850–4,358.6 m) contains hematite inclusions, which impart a red coloration to the rock. The hematitic feldspar grains are commonly partially replaced by siderite and (or) illitic clay. Potassium feldspar is present as discrete framework grains and as part of igneous rock fragments, which commonly have a graphic-granite texture. Perthitic rock fragments are common near the basement contact, but many of these may be partially albitized potassium feldspar grains (for example, see Saigal and others, 1988). Framework grains consisting of illite and chlorite(?) appear to be altered volcanic rock fragments because they have remnant textures suggestive of phenocrysts.

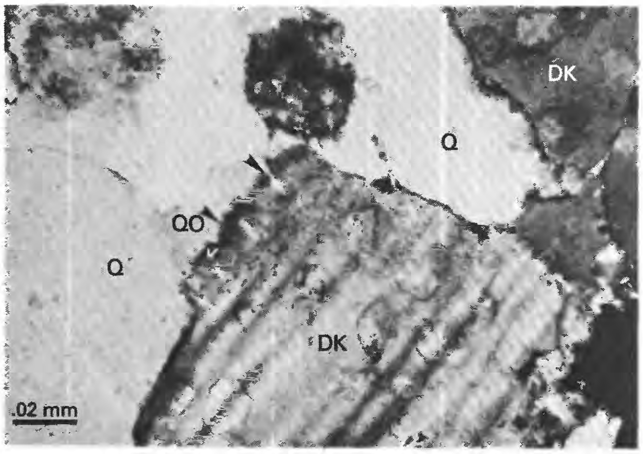

Figure F2. Photomicrograph (crossed polars) of detrital microcline grain (DK) and partially dissolved overgrowth (KO; arrows). Other diagenetic products in photo are quartz overgrowths (QO) on detrital quartz grains (Q). Dow Chemical No. 1 Wilson drill hole, depth 13,426 ft (4,092.3 m) (location shown in fig. F1).

In the gray feldspathic and quartz arenite samples (12,300–12,630 ft, or 3,749–3,850 m), the abundance of detrital potassium feldspar and plagioclase grains indicate an igneous source rock. In layers where detrital outlines are visible owing to iron-oxide dust rims, framework grains are generally well rounded. Potassium feldspar (mostly microcline) grains constitute between 2 and 25 percent of these rocks.

Fossil-rich, feldspar-poor quartz arenite is interbedded with the feldspathic arenite (12,782 ft, or 3,896 m). The lack of feldspar in these units appears to be due to diagenetic alteration: feldspar is largely replaced by carbonate cement and clay minerals. Minor pyrite and galena cement were detected in these units.

Potassium feldspar overgrowths in both the red and gray arenite appear to be an early authigenic cement because the overgrowths are in contact with the edges of rounded detrital quartz grains. This suggests that authigenic potassium feldspar was the first pore-filling cement. However, earlier authigenic phases may have existed prior to the formation of the authigenic feldspar in the late Paleozoic, such as calcite, which is not present because of the long time interval. The potassium feldspar overgrowths constitute only 1 percent or less of the rock, are commonly twinned, and usually show partial dissolution (fig. F2). The black arrows in figure F2 point to potassium feldspar overgrowths that have ragged, partially dissolved edges on a microcline grain.

Importantly, throughout the red and gray arenite samples from the Wilson hole, authigenic albite occurs as overgrowths around plagioclase grains and as a replacement mineral of detrital potassium feldspar. Irregular staining by sodium cobaltinitrate and SEM semi-quantitative analysis show that the potassium feldspar in the Wilson hole has been partially replaced by albite. Table F1 shows a minor increase in bulk plagioclase content downhole, and this increase may reflect the albitization process.

Dow Chemical No. 1 Garrigan Drill Hole

The Garrigan hole (total depth 12,038 ft, or 3,669 m) (fig. F1) bottoms in a quartz and feldspathic arenite that may be a time-equivalent of the Lamotte Sandstone (Diehl and others, 1992). Detrital outlines are not visible on most of the framework grains. Because the pore spaces have been totally filled with authigenic cements, the quartz and feldspar grains have a deceptively angular appearance (fig. F3*A*). Microcline is the predominant detrital potassium feldspar. Feldspar grains and their

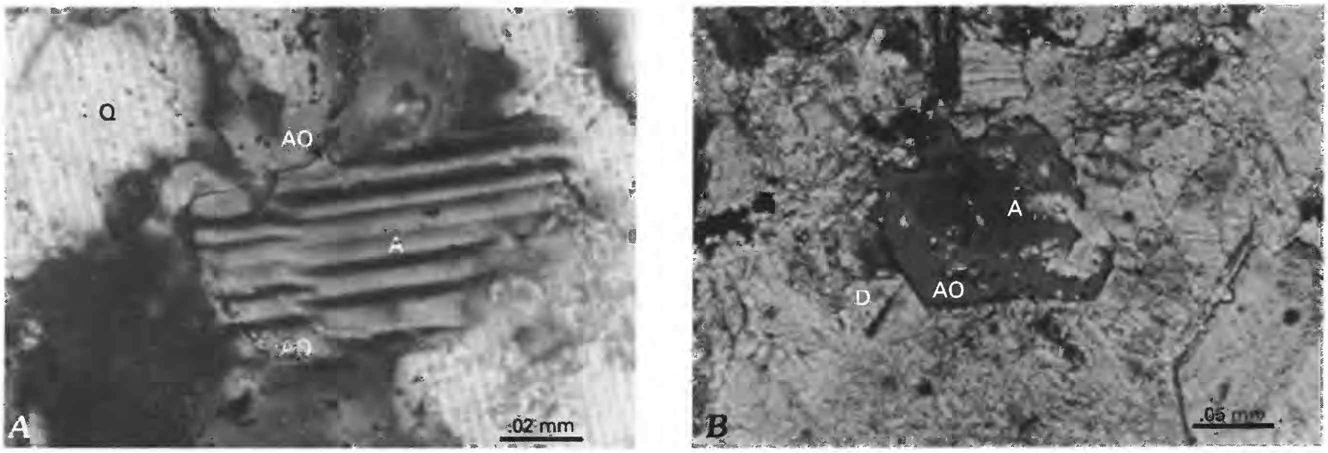

Figure F3. Photomicrographs (crossed polars) of sample from Dow Chemical No. 1 Garrigan drill hole. *A*, Plagioclase grain (A) and albite overgrowths (AO) that fill the surrounding pore space. *B*, Authigenic albite (AO) enclosing remnants of carbonate minerals (D). Q, quartz. Depth 11,980–12,040 (3,651.5–3,669.8 m) (location shown in fig. F1).

overgrowths are commonly partially replaced by illitic clay or carbonate minerals.

As in the Wilson hole, euhedral albite overgrowths are also common in the Garrigan samples as a late diagenetic cement, forming optically continuous overgrowths on plagioclase. The authigenic albite has inclusions of remnant carbonate minerals and therefore appears to have partially replaced earlier diagenetic carbonate cement (fig. F3*B*). The euhedral outlines of the albite affirm its authigenic nature.

Strake Petroleum No. 1 Russell Drill Hole

The Strake hole, which is near the northwestern shoulder of the rift in the area of the Pascola Arch, bottomed in the Lamotte Sandstone (Grohskopf, 1955) at 4,740 ft (1,444.8 m) (fig. F1). Staining revealed only potassium feldspar detrital grains and overgrowths; there are no plagioclase grains or diagenetic albite.

In contrast to the wells discussed above, at least two generations of potassium feldspar overgrowths are present in the Lamotte Sandstone at this location. The first and quantitatively predominant generation of potassium feldspar overgrowth is turbid because of abundant fluid inclusions (fig. F4). This contrasts markedly with observations of authigenic potassium feldspar elsewhere in the region. The second generation is clear, which is typical of potassium feldspar overgrowths in other drill holes. The first-generation potassium feldspar overgrowths constitute approximately 10 percent of the total volume of the rock at 4,717 ft (1,438 m) (table F1). The sodium cobaltinitrate used to stain the feldspars colored both detrital cores and overgrowths the same dark yellow. Authigenic potassium feldspar has been documented to stain a darker yellow than do detrital cores (Duffin and others, 1989), and we also observed this staining phenomenon in samples from other drill holes. Therefore, the potassium feldspar in the Strake samples is anomalous and may indicate potassium metasomatism of the detrital cores. Further study is needed to confirm this hypothesis.

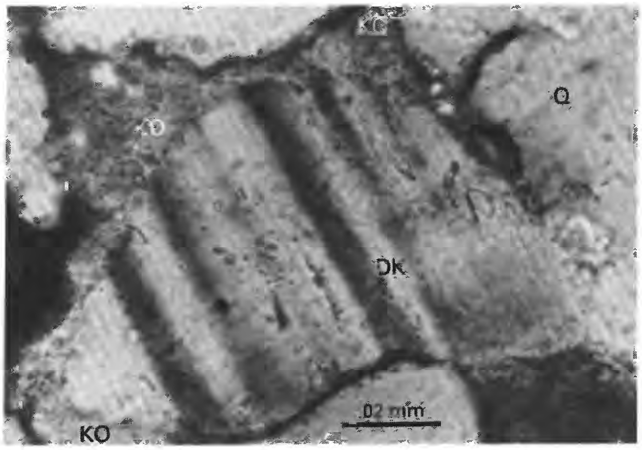

Figure F4. Photomicrograph (crossed polars) of inclusion-rich authigenic potassium feldspar overgrowths (KO) on detrital feldspar grains (DK); Q, quartz. Strake Petroleum No. 1 Russell drill hole, depth 4,717 ft (1,437.7 m) (location shown in fig. F1).

Under cathodoluminescence (CL), detrital potassium feldspar luminesces blue. The potassium feldspar overgrowths show a faint zonation, which may be related to the two generations of feldspar cement observed under transmitted light. There are two phases: a dark, nonluminescent phase and a brown, luminescent phase. It should be noted that Kastner (1971) reported that authigenic feldspar is nonluminescent. However, these feldspar overgrowths do contain trace amounts of iron that may be acting as an activator.

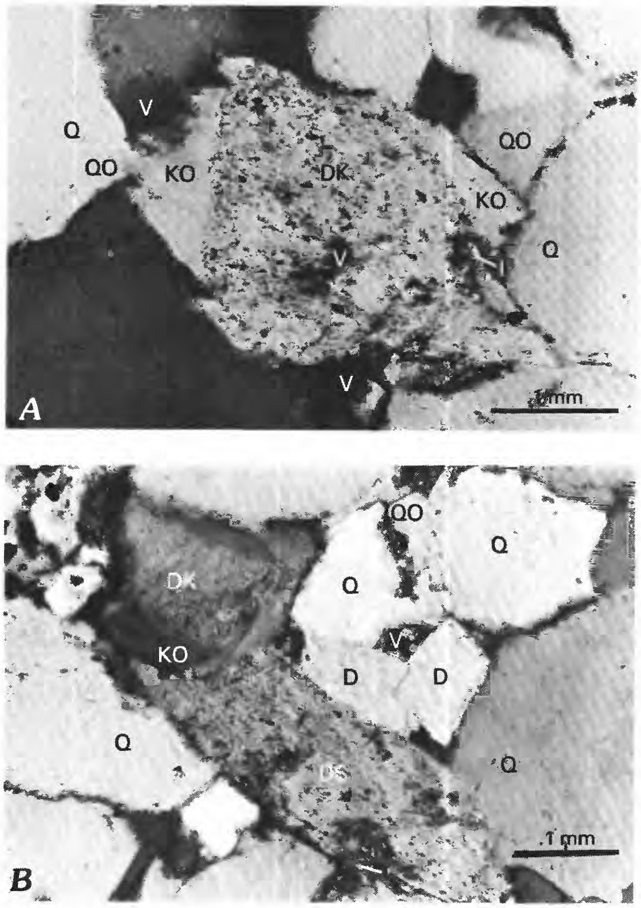

Figure F5. Photomicrographs (crossed polars) of sample from drill hole BT1. *A*, Etched rhombic potassium feldspar overgrowths (KO) on a hematitic feldspar grain (DK). *B*, an orthoclase grain (DK) and its overgrowth (KO, upper left) that have not undergone the dissolution effects shown by the sanidine grain (DS) and its overgrowth. Other diagenetic products are dolomite (D), quartz overgrowths (QO) on detrital quartz grains (Q), and illitic clay (I). Void spaces (V) are due to dissolution. Depth 2,092–2,114 ft (637.6–644.4 m) (location shown in fig. F1).

The Lamotte Sandstone is fractured at this locality, and detrital grains are commonly brecciated and rotated. This structural feature is apparent under CL. The nonluminescent authigenic feldspar partially replaces as well as heals fractures in the detrital grains.

Dissolution effects are difficult to determine in these samples because of extensive replacement of the rock by dolomite cement. However, second-generation overgrowths on feldspar grains do show minor dissolution embayments next to quartz overgrowths.

Drill Hole BT1

This drill hole, located between the Reelfoot Rift and the St. Francois Mountains, bottoms in the Lamotte Sandstone at 2,114 ft (644.4 m). The Lamotte Sandstone is thin at this locality, and the sample was obtained from the transition zone with the overlying Bonneterre Formation (E.L. Mosier, oral commun., 1992).

Potassium feldspar overgrowths are a pore-filling cement that commonly formed before quartz overgrowths, and they are present as a series of rhombs on detrital feldspar grains (fig. F5*A*). Many of the igneous rock fragments contain feldspar that is turbid because of hematite flakes, but their overgrowths are clear. Many of the devitrified volcanic rock fragments, which have a chertlike appearance, also have clear potassium feldspar overgrowths. Dissolution voids in the detrital feldspar grains and authigenic overgrowths are prominent and are filled with blue-epoxy resin, indicating that this void space is part of the effective porosity of the rock (Heald and Larese, 1973). Dissolution has also occurred between detrital quartz grains and their overgrowths.

Orthoclase, which is plutonic in origin, and sanidine, which is volcanic in origin show different dissolution effects (fig. F5*B*). For example, the detrital sodic sanidine, volcanic rock-fragment grains, and overgrowths have partially dissolved. Feldspar from a volcanic, high-temperature, more sodium-rich source is known to dissolve more easily than feldspar from a lower temperature igneous-rock source (Heald and Larese, 1973), and this may be the cause of the uneven dissolution effects at this locality.

Indian Creek Subdistrict—Goose Creek Mine

The Lamotte Sandstone is extensively mineralized in pinchouts against the Precambrian terrain in the Goose Creek Mine, in the Indian Creek subdistrict, which is north of the Viburnum Trend and the St. Francois Mountains (Gutierrez, 1987) (fig. F1). The Goose Creek Mine is in the Lamotte Sandstone and is the northernmost lead-zinc deposit in the southeastern Missouri lead district. Mineralization in this locality has been attributed to the control of fluid flow by the underlying Precambrian topography (Gutierrez, 1987; Kyle and Gutierrez, 1988). The "clotted" or "spotted" ore textures at Goose Creek Mine are similar to ore textures in sandstone in the lead deposits of Laisvall, Sweden (Kyle and Gutierrez, 1988). In the study of clotted ore textures in Laisvall, Sweden, galena was determined to have precipitated preferentially in feldspar-rich layers (Boorder, 1986). In the Goose Creek Mine samples, clotted galena textures do occur with altered feldspar, but it does not appear to be a preferential association. Rather, the galena occurs in conjunction with coarse-grained sandstone layers containing volcanic rock fragments and silicified shell material as well as detrital feldspar. In these layers, galena occurs within dissolution voids in detrital potassium feldspar grains, silicified shell fragments, volcanic rock fragments, and dolomite rhombs. Porosity has been enhanced and intergranular void space has been enlarged by dissolution of framework grains and overgrowths. Galena and marcasite commonly have geopetal textures within these dissolution voids.

The volcanic rock fragments in the Goose Creek Mine contain sanidine phenocrysts. Many of the feldspar framework grains appear to be sanidine phenocrysts that weathered out of the volcanic rock fragments or the original volcanic matrix.

The contact relations between galena and authigenic potassium feldspar cement constrain the relative ages of these minerals. Early galena cement postdates the precipitation of potassium feldspar overgrowths and predates the dissolution of those overgrowths (fig. F6*A*). This early galena surrounds the rhombic outlines of potassium feldspar overgrowths. However, a later stage of galena cement invades the dissolution voids in feldspar along with minute cubes of pyrite (fig. F6*B*).

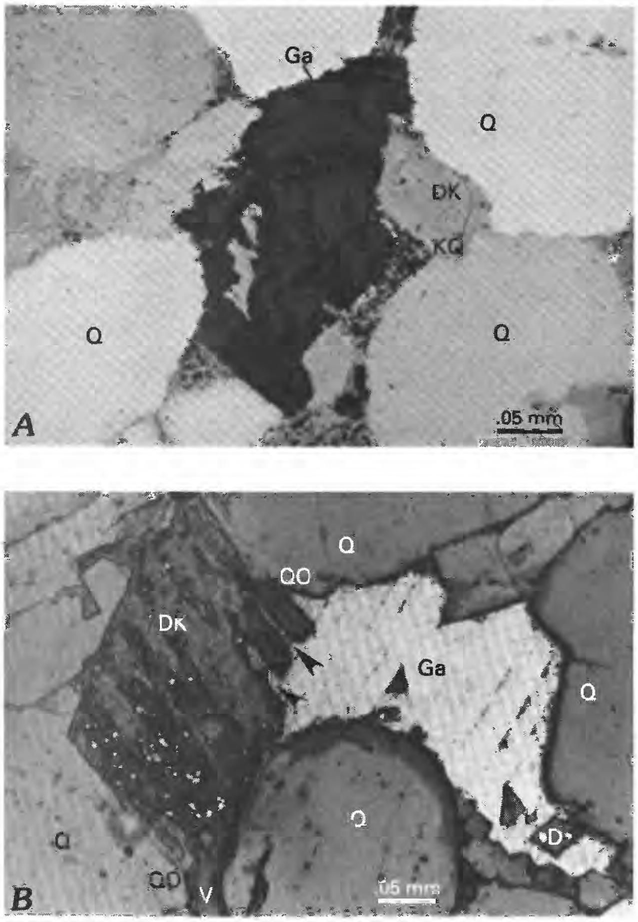

Figure F6. Photomicrographs of sample from Goose Creek Mine, in Indian Creek subdistrict (location shown in fig. F1). *A*, Galena cement (Ga) that partially encloses a detrital potassium feldspar grain (DK) and its overgrowth (KO); plane-polarized light. *B*, Galena cement (Ga) that invaded dissolution voids (arrows) in a partially dissolved potassium feldspar grain (DK) and its overgrowth; reflected light. Other cements are quartz overgrowths (QO) on quartz detrital grains (Q) and dolomite (D). V, void space.

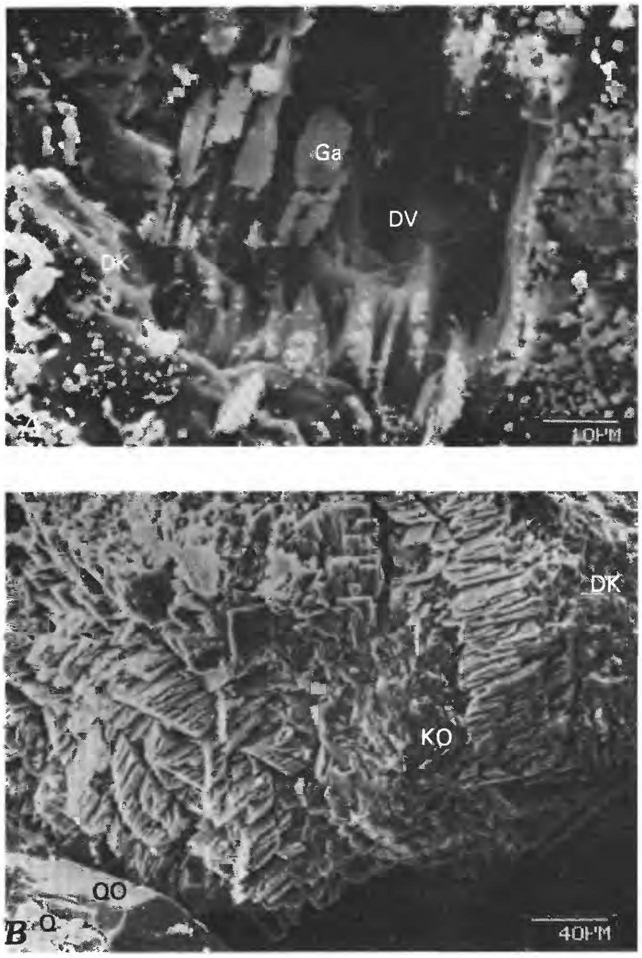

Figure F7. Scanning-electron photomicrographs of samples from Goose Creek Mine, in Indian Creek subdistrict (location shown in fig. F1). *A*, Backscatter image of dissolution pitting in a detrital feldspar grain (DK) with galena (Ga) cement in the dissolution void (DV). *B*, Etched authigenic feldspar rhombs (KO). QO, quartz overgrowth; Q, quartz.

Under the SEM, galena is observed both as an intergranular cement between framework grains and as an intragranular cement in dissolution voids in detrital potassium feldspar grains (fig. F7*A*). This represents at least two different generations of galena precipitation. The potassium feldspar grains are highly altered; cores of the grains are commonly pitted and dissolved and replaced by tiny feldspar rhombs (probably adularia) that also show dissolution etching (fig. F7*B*).

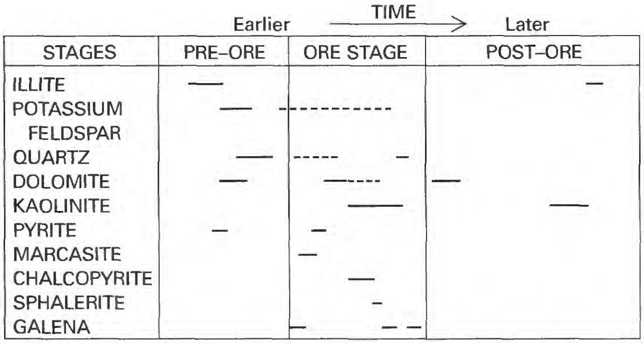

Figure F8. Mineral paragenetic sequence in Indian Creek subdistrict compiled from work of Rothbard (1983), Gutierrez (1987), Horrall and others (1983), and this study. Dashed lines indicate dissolution.

According to these observations and to data from the literature (Gutierrez, 1987), the general diagenetic sequence appears to be (1) precipitation of potassium feldspar overgrowths, (2) precipitation of quartz overgrowths, (3) precipitation of galena cement, (4) dissolution of potassium feldspar and quartz overgrowths and precipitation of a second generation of galena, and (5) precipitation of pyrite and quartz overgrowths. A more extensive paragenetic sequence of ore minerals is given in Horrall and others (1983) and Kyle and Gutierrez (1988) (fig. F8).

PETROGRAPHIC DESCRIPTIONS OF SAMPLES FROM CORE FENCE *B–B′*

Cores along *B–B′* (fig. F1) show a pronounced change in the dissolution of feldspar overgrowths between nearby drill holes. Drill hole 63W72 (fig. F1) has abundant feldspar cement that has largely been unaffected by dissolution. In contrast, feldspar overgrowths from drill hole 63W5 have been almost completely dissolved, creating significant secondary porosity.

Drill Hole 63W72

In drill hole 63W72, two generations of potassium feldspar overgrowths are present, neither of which has been affected by subsequent dissolution (fig. F9). The feldspar overgrowths are generally rhombic, rarely twinned, and completely enclose detrital feldspar cores. This encircling of the potassium feldspar core suggests that the overgrowth precipitated in a loosely packed, porous rock. Overgrowths are evident because they are not in optical continuity with the detrital feldspar grains. The two generations of authigenic feldspar cement are in turn evident because they are not in optical continuity with each other. Authigenic potassium feldspar showing little or no dissolution effects is characteristic of samples from several of the drill holes in the northern extent of the Lamotte Sandstone (figs. F1 and F9).

Potassium feldspar overgrowths are an important volumetric pore-occluding cement in the upper part of the Lamotte Sandstone in porous feldspathic arenite: in feldspar-rich layers, overgrowths make up as much as 18 percent of the authigenic cement (1,394–1,441 ft, or 424.9–439.2 m) (fig. F9). A later authigenic illitic clay coats the authigenic feldspar and detrital framework grains and appears to have inhibited the development of quartz overgrowths.

The sample from the interval 1,441–1,472 ft (439.2–448.7 m) in this drill hole is a quartz arenite; no feldspar is present. Because the rock overlying the crystalline basement (1,527 ft, or 465.4 m) has abundant microcline grains, one must speculate whether the absence of feldspar in this zone is due to dissolution, or to the absence of feldspar in the original sediment. There is no evidence in thin sections of remnant feldspar. However, grain-size pore spaces (a result of dissolution of framework grains), clay drapes, and pendant quartz cements indicate diagenesis in a vadose environment, which is subject to influxes of acidic meteoric waters.

Drill Hole 63W5

There is a marked vertical distribution to the dissolution textures seen in core from drill hole 63W5. Microcline grains and their overgrowths in samples from 1,130 to 1,164 ft (344.4 to 354.8 m) have minor dissolution pitting. In samples from 1,164 to 1,214 ft (354.8 to 370.0 m), potassium feldspar grains are more abundant,

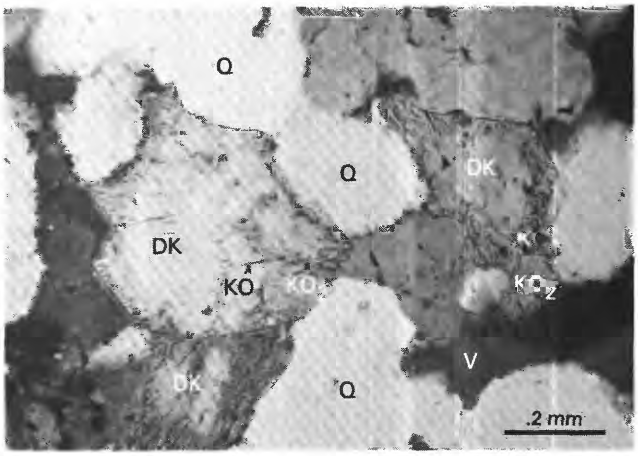

Figure F9. Photomicrograph (plane-polarized light) showing two generations of potassium feldspar overgrowths (KO_1, KO_2) on a microcline grain (DK). Q, quartz grain; V, void. Drill hole 63W72, depth 1,394–1,441 ft (424.9–439.2 m) (location shown in fig. F1).

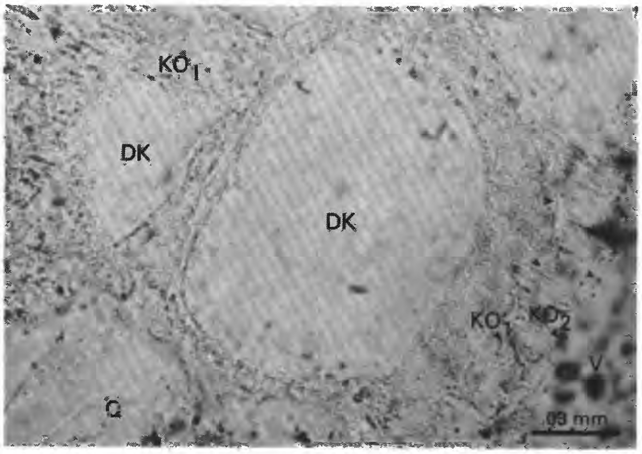

Figure F10. Photomicrograph (plane-polarized light; therefore, twinning is not apparent) of detrital feldspar grain (DK) and two generations of potassium feldspar overgrowths (KO_1, KO_2) that have undergone dissolution. Skeletal outlines of overgrowths remain. Q, quartz; V, void. Drill hole 63W5, depth 1,214–1,267 ft (370–386.2 m) (location shown in fig. F1).

kaolinite and illitic clay appear as common alteration products, and dissolution of feldspar overgrowths is apparent. From 1,214 to 1,267 ft (370.0 to 386.2 m), the illitic clay forms layers several millimeters thick, above and below fine-grained feldspar-rich layers where intense dissolution of potassium feldspar overgrowths has taken place. Two generations of potassium feldspar overgrowths are recognized in this interval (1,214–1,267 ft), and both have undergone partial to total dissolution. Skeletal outlines of the feldspar overgrowths are visible because of clay and (or) iron-oxide coatings (fig. F10).

RESULTS OF PETROGRAPHIC STUDIES OF CORE FROM OTHER DRILL HOLES

The abundance and degree of dissolution of potassium feldspar overgrowths seen in the entire suite of Lamotte thin sections are summarized semiquantitatively in figure F11. Because of the vertical variability in both abundance and dissolution data, this plot focuses on data from the Lower Lamotte, where dissolution effects were most apparent. This plot shows no systematic trends in the abundance of potassium feldspar cement, but it does indicate strongly that dissolution of the potassium feldspar cement was regionally extensive and was most intense along a northwest-trending corridor that includes the Reelfoot Rift, the lead belts, and the St. Francois Mountains. The major exception to this trend is in samples from the Strake well, which do not show extensive dissolution. We discuss the significance of these dissolution trends below.

Detrital feldspar grains and the two generations of authigenic feldspar commonly show varying degrees of dissolution effects, which are probably due to the chemistry of the overgrowths versus the chemistry of the detrital grain (Kastner and Siever, 1979) because overgrowths tend to be pure end members of the alkali feldspar series and are thus more stable in low-temperature diagenetic environments. Any single feldspar-rich layer may show partial dissolution of both detrital grains and their overgrowths, dissolution of only the detrital grains, or dissolution of only the overgrowths. Where there are two generations of feldspar overgrowths, only one generation may be affected by dissolution (fig. F12).

Additional observations of diagenetic minerals in the Lamotte Sandstone and Reelfoot Rift samples may be pertinent. Several differing trends in alteration minerals exist between the Reelfoot Rift and the Ozark uplift. Within the rift-filling sedimentary rocks, diagenetic clay minerals are predominantly illite and chlorite, whereas on the carbonate platform and in the Ozark mineral districts, the predominant diagenetic clay product is kaolinite accompanied by minor illite. Iron-rich carbonate minerals, such as siderite and ferroan dolomite, are common cements in the Reelfoot Rift samples, whereas dolomite and calcite are more common carbonate cements in samples from west and northwest of the rift (see table F1). As previously discussed, albite is a common cement in the rift but was not detected elsewhere in the study area.

DISCUSSION

A major focus of this study was to evaluate the regional implications of feldspar diagenesis in the Lamotte Sandstone and to determine if feldspar diagenesis and dissolution events are related to the genesis of the MVT districts in the region. As stated in the introduction, there is reason for suspecting such a relationship because of the very potassic nature of the ore-forming brines for MVT deposits. Furthermore, a strong geochemical correlation exists between lead and potassium in that potassium feldspar is a significant residence for lead in igneous and feldspathic sedimentary rocks (Doe and Delevaux, 1972). Thus, the fact that the lead belts surrounding the St. Francois Mountains of southeastern Missouri, which constitute the largest known concentration of lead in the crust of the earth (Kisvarsanyi and others, 1983), overlie the authigenic potassium feldspar-bearing Lamotte Sandstone at least suggest a link between the ores and potassium-bearing fluids in the Lamotte. In addition, the available evidence indicates that the mineralization in southeastern Missouri was profoundly affected by the proximity of the Reelfoot Rift. This influence of this structure led to major differences between ores in southeastern Missouri

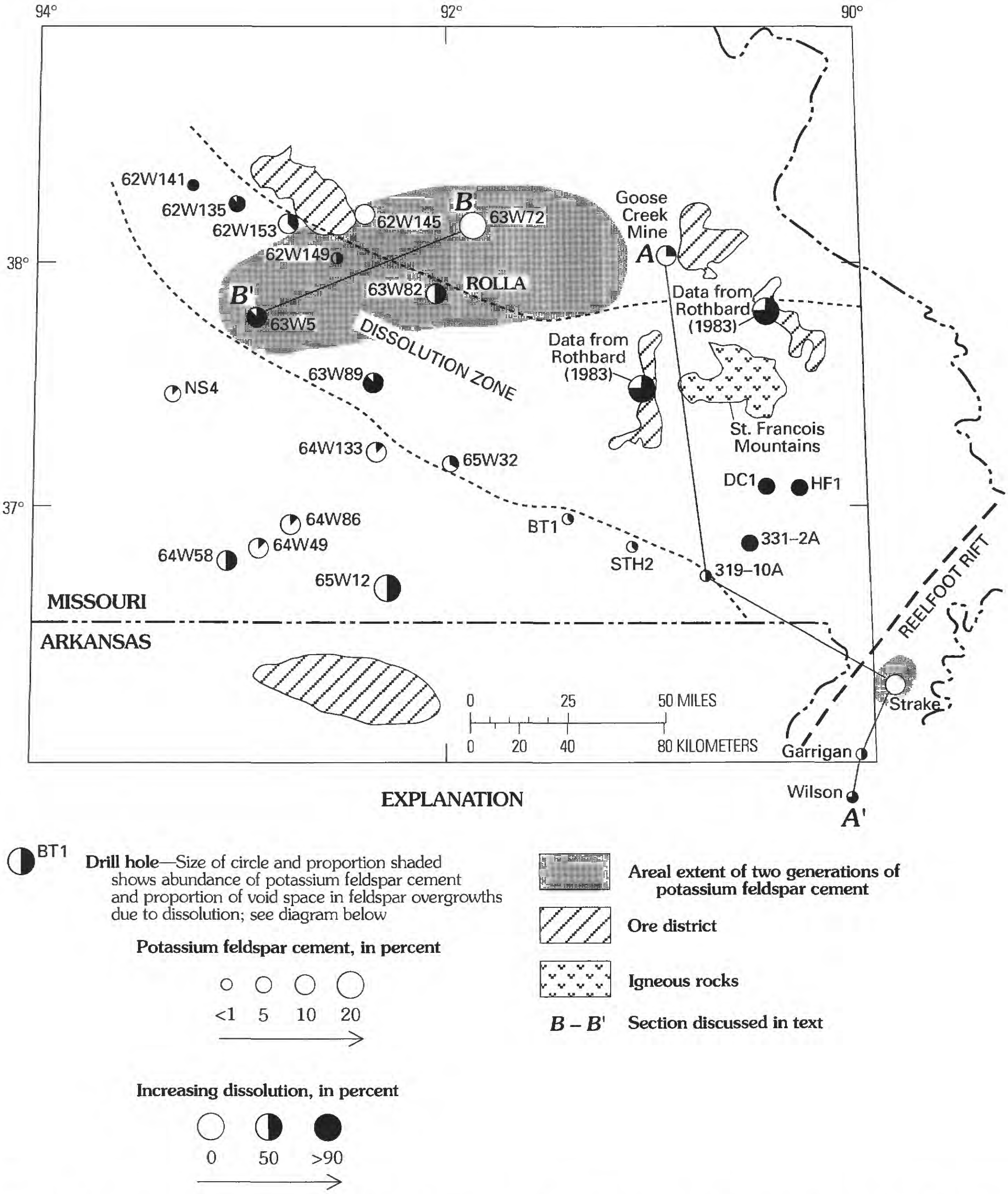

Figure F11. Map showing abundance of potassium feldspar cement (as percentage of rock) and the amount of dissolution of the cement plotted at the drill hole locations.

compared to other MVT ores of the region. Below we discuss these influences in more detail.

Timing of Feldspar Precipitation Relative to Mississippi Valley–Type Ore Genesis

The most direct evidence linking the formation of potassium feldspar and dissolution trends (documented above) with MVT ores comes from both absolute and relative age data. Hearn and others (1986) obtained a late Paleozoic age of 300±60 Ma for authigenic potassium feldspar samples from the transition zone between the Lamotte and the overlying Upper Cambrian Bonneterre Formation in the study area. For comparison, independent evidence based largely on paleomagnetic data has likewise placed the age of MVT mineralization in the Ozark region as late Paleozoic (Wu and Beales, 1981; Wisniowiecki and others, 1983; Pan and others, 1990). Rothbard (1983) reported that illite from the Lamotte Sandstone, which postdated galena, has an age of 255±15 Ma (Permian). Collectively, these dates place the formation of

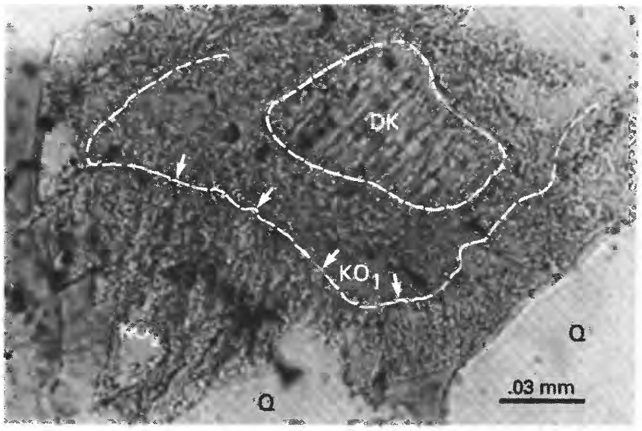

Figure F12. Photomicrograph (plane-polarized light) (drill hole 63W5; location shown in fig. F1) showing that different generations of potassium feldspar overgrowths may be differentially affected by dissolution. Here, the first generation (KO_1) has undergone total dissolution, but the second generation (KO_2) has undergone partial dissolution. The detrital core (DK) also remains. Q, quartz.

authigenic potassium feldspar in the same general late Paleozoic time frame as ore deposition.

Additional evidence of timing that is pertinent to the relations between potassium feldspar and ore mineralization comes from petrographic studies on potassium feldspar and the ore phases. These relations between minerals in the Indian Creek subdistrict are summarized in the paragenetic diagram in figure F8. The figure shows that authigenic potassium feldspar **predated** the main episode of ore genesis, and that ore deposition was associated with the dissolution of authigenic potassium feldspar (Rothbard, 1983; this study).

The paragenetic sequence for the Indian Creek subdistrict (fig. F8) is probably valid for a large part of southeastern Missouri. This conclusion is based on the work of Horrall and others (1983), who showed that the Goose Creek Mine was part of a district-wide paragenetically correlated sequence of ore deposition. In particular, galena was deposited as "spots" in the Lamotte Sandstone and has a crude cuboctahedral habit, which correlates texturally with the main phase of cuboctahedral and disseminated mineralization in the Viburnum Trend and contrasts with the morphology of later (minor) cubic galena. Other correlations between Goose Creek and the Viburnum Trend exist. Horrall and others (1983) observed that specific generations of quartz, dolomite, bravoite, pyrite/marcasite, chalcopyrite, siegenite, sphalerite, galena, dickite, and calcite could be correlated between the Goose Creek Mine and at least two mines in the Viburnum Trend. On a more regional scale, Hayes and others (1989) and Rowan (1986) used detailed regional correlations of dolomite microstratigraphy to show that the ores of the entire southern Ozark region formed from a single huge regional hydrothermal system. In view of this regional correlation of paragenetic events, the relative timing of deposition and dissolution of potassium feldspar for the Indian Creek subdistrict (fig. F8) may also apply to the formation of ores in other parts of the region.

Lead-isotope studies reveal an additional geochemical link between authigenic potassium feldspar in the Lamotte Sandstone and main-stage ores of the Viburnum Trend. These studies, which were conducted on authigenic potassium feldspars in the Lamotte Sandstone of southeastern Missouri (Aleinikoff and others, 1993), show that the fluids that formed the authigenic feldspars carried lead whose isotopic composition rather closely matches the $^{208/204}Pb/^{206/204}Pb$ ratio of one end member of the lead that formed main-stage (cuboctahedral) mineralization of the Viburnum Trend ores. This similarity in isotopic compositions is important because the $^{208/204}Pb/^{206/204}Pb$ ratios of main-stage Viburnum Trend ores are unique compared to all other MVT ores of the southern midcontinent (J.N. Aleinikoff, written commun., 1992), and trace lead in other aquifers higher in the stratigraphic section does not match the isotopic signature of the Viburnum Trend ores (Goldhaber and others, 1989). This indicates that the same isotopic lead, which was carried in solution through the Lamotte aquifer, was trapped in potassium feldspar overgrowths as well as in the main-stage ores.

On the basis of the absolute and relative timing evidence and geochemical data enumerated above, several conclusions are possible. Even though potassium feldspar formed before Pb-Zn mineralization, it nevertheless formed in the same late Paleozoic (Carboniferous-Permian) periods as the ores. Thus, authigenic potassium feldspar formation, like MVT ore genesis, may have been associated with the regional flow of brines in the late Paleozoic (Leach and Rowan, 1986) that resulted from the Appalachian-Ouachita orogeny. The lead-isotope data imply that the earlier episode of potassium feldspar precipitation, although predating main-stage ore deposition, nonetheless involved fluids with lead that is isotopically the same as the source of lead for the main-stage ores.

Importantly, fluid-inclusion studies of early to main-stage mineralization in the Viburnum Trend (Crocetti and Holland, 1989; Viets and Leach, 1990) revealed exceptionally high K/Cl ratios compared to other MVT ore-forming brines of the region (table F2) and even compared to paragenetically later parts of the Viburnum Trend mineralization. These high K/Cl values were attributed by Viets and Leach (1990) to a fluid migrating through the Lamotte Sandstone, a conclusion that is consistent with the isotopic data of Aleinikoff and others (1993).

Overall, the evidence suggests that fluids elevated in potassium (compared to brines that formed other ores of the region) and containing isotopically distinctive lead, formed the Pb-Zn deposits in the lead belts of southeastern Missouri. Some key characteristics, such as elevated

K+ concentration and specific lead-isotope ratios, of the main-stage ore fluids may have spanned the time interval during which authigenic feldspar formed and dissolved. In the next section, we examine the hypothesis that the source of this potassium (and by inference a significant part of the lead in the same fluid) came from the Reelfoot Rift, and, subsequently, we examine the shift from conditions favoring precipitation as compared to dissolution of potassium feldspar.

Contrasts Between Reelfoot Rift and Platform Settings in Feldspar Diagenesis

The data from this study show a major change in both the type and distribution of feldspar and the nature of feldspar diagenesis in the Cambrian rocks in southeastern Missouri. A significant difference was detected between the Lamotte Sandstone and basal clastic equivalents in the Reelfoot Rift, in contrast to the same units in the carbonate platform northwest of the rift and in the adjacent Ozark uplift. Feldspar in siliciclastic rocks in the rift is predominantly microcline, plagioclase, or intergrown microcline and plagioclase that were derived from plutonic rock fragments. In the platform area, sanidine is the common feldspar and volcanic rock fragments take precedence over plutonic rock fragments. Another difference is that the potassium feldspar overgrowths in the Reelfoot Rift are not as well developed or abundant as those in the Lamotte section northwest of the rift (although the Strake well is an exception; see below). Furthermore, and perhaps most importantly, extensive replacement of potassium feldspar by albite may have severely changed the original potassium feldspar content of feldspathic arenite and graywacke in the Wilson and Garrigan holes in the rift. No evidence of similar albitization was detected in time (Cambrian) and lithologic-equivalent rocks in the platform area outside the rift.

Figure F13 shows representative point-count data for feldspar in drill hole samples (table F1) of shallowly buried Lamotte Sandstone and deeply buried siliciclastic rocks in the Reelfoot Rift, plotted against depth. We interpret these differences in feldspar alteration between the rift and platform areas to be a function of depth of burial in sedimentary rocks within the rift. Dissolution of feldspar with or without albitization is a well-recognized process that occurs during deep burial diagenesis in a range of settings (Walker, 1984; Milliken, 1988; Saigal and others, 1988). Potassium feldspar is particularly susceptible to destruction by both dissolution and albite replacement, resulting in marked decreases in the ratio of potassium feldspar to total feldspar and increases in the percentage of albitized feldspar with deep burial diagenesis (Walker, 1984; Saigal and others, 1988; Milliken and others, 1989) (fig. F13). (The correlation coefficient (r) of the linear regression line is 0.882917; the trend relating depth to Ab/(Ab + Kspar) is statistically significant. However, the data may also represent two distinct populations.)

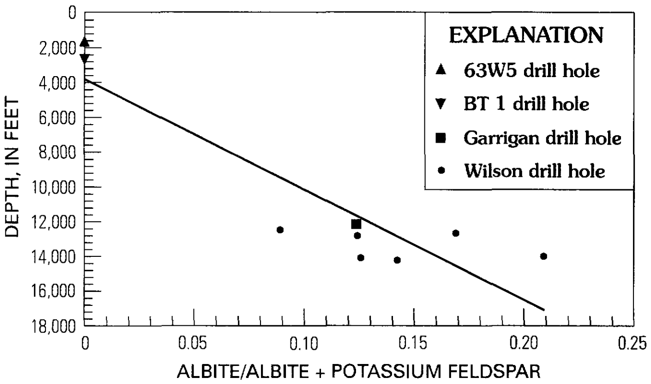

Figure F13. Plot of point-count data for albite and potassium feldspar from shallowly buried Lamotte Sandstone and deeply buried siliciclastic rocks versus depth.

The contrast in the major detrital feldspar type between sanidine in the platform area and microcline in the rift may simply reflect a greater solubility of sanidine in the deeply buried rift section rather than a different provenance. Heald and Larese (1973) showed that in the Mount Simon Sandstone (a Lamotte equivalent) in Ohio, sanidine was partially dissolved whereas microcline was stable. Thus, partial destruction of feldspar can lead to an apparent change in provenance, whereas the actual difference may be due to diagenetic processes (Milliken, 1988).

The destruction of large amounts of feldspar, particularly potassium feldspar, in the deeply buried Reelfoot Rift sedimentary rocks would have resulted in the addition of large amounts of K+ to the pore fluids. We suspect that it is this potassium that led to elevated K/Cl values in main-stage mineralization of the Viburnum Trend. Clearly, other deep sedimentary basins, particularly the Arkoma basin south of the Ozark region, could have contributed K+ by similar processes of burial diagenesis, but the lower K/Cl values of fluids from ores closer to the Arkoma basin (Viets and Leach, 1990) argue against such a source. The proximity of the Viburnum Trend and the other lead ores surrounding the St. Francois Mountains to the Reelfoot Rift thus suggests a fluid-flow path linking the Reelfoot Rift to the lead belt area; this fluid-flow path uniquely contributed extra K+ as well as other ore constituents to the lead belt area.

The inference that ore-forming fluids originated or passed through the rift section is strengthened by the trace amounts of lead and zinc minerals in the siliciclastic rocks of the Garrigan and Wilson drill holes (Diehl and others, 1992). Epigenetic galena occurs within pyrite in a matrix of siderite cement in samples from 12,782 ft (3,896 m) in the Wilson hole. In the Garrigan hole, epigenetic "mineral fronts," which are areas of sulfide alteration in siliciclastic rocks from 7,993 to 8,002 ft (2,436.3 to 2,439 m), are enriched in lead and cobalt. Epigenetic pyrite having the same style of occurrence is present in siliciclastic rocks at 11,998–12,040 ft (3,657–3,670 m) in the same drill hole.

Formation and Dissolution of Potassium in the Lamotte Sandstone Outside the Reelfoot Rift

The precipitation and dissolution of potassium feldspar are related to sample locality and depth (fig. F11; table F1). Authigenic potassium feldspar overgrowths from lower in the Lamotte Sandstone northwest and southwest of the St. Francois Mountains are partially to totally dissolved. However, higher in the Lamotte Sandstone and near the transition zone with the overlying Bonneterre Formation, potassium feldspar overgrowths are less affected by dissolution. Two episodes of potassium feldspar precipitation are commonly indicated because early overgrowths are partly dissolved and are surrounded by later, well-formed rhombic overgrowths. However, only one generation of authigenic potassium feldspar is evident southeast of the St. Francois Mountains toward the Reelfoot Rift (fig. F9).

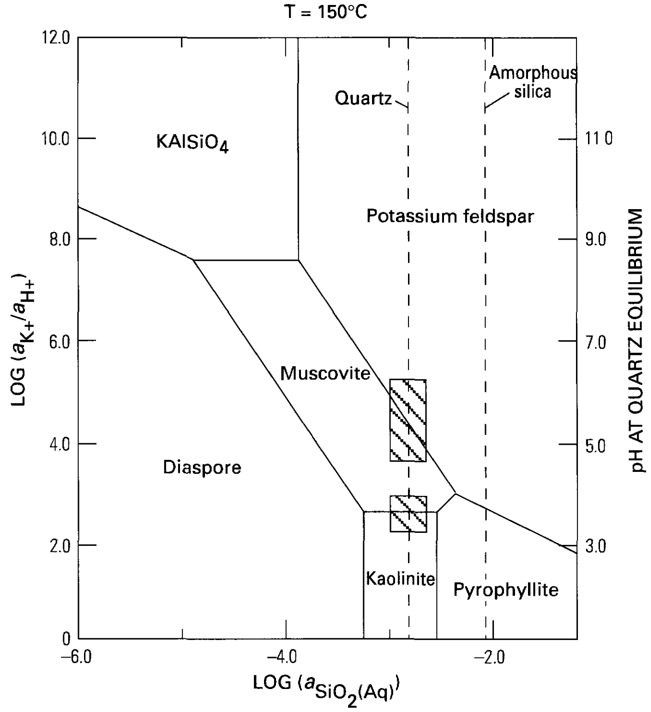

Figure F14. Potassium feldspar stability diagram at 150°C (modified from Garrels and Christ, 1965, p. 359-370). Upper shaded rectangle shows calculated pH range over which potassium feldspar and muscovite would coexist. Lower shaded rectangle shows pH range over which dissolution of potassium feldspar would lead to formation of kaolinite. *a*, activity.

Table F2. Estimation of composition of ore-forming fluid in the study area, southwestern Missouri and northeastern Arkansas.

Weight ratio	Octahedral galena[1]	Cubic galena[1]	Calculated ore fluid[2]
Na/Cl	0.463	0.490	0.504
K/Na	.129	.040	.091
Ca/Mg	2.531	10.2	5.72
Ca/Na	.229	.188	.206

[1] Values from Crocetti (1985).

[2] Molalities for ions in calculated ore-forming fluid: Cl^-, 3.60; HCO_3^-, 0.50; HS^-, 0.01; CA^{++}, 0.35; Mg^{++}, 0.10; K^+, 0.15; Na^+, 2.80.

The dissolution of potassium feldspar is of particular interest because if the results from ore samples can be extrapolated to areas away from the mineralization, then this dissolution event coincided in time with main-stage ore deposition in the lead belts (figs. F1 and F8). Figure F11 shows that feldspar dissolution is most intense in the area south of the St. Francois Mountains between the Reelfoot Rift and the lead belts and continues to the west and northwest of the Ozark Mountains. The proximity of this "dissolution corridor" to the Reelfoot Rift suggests that the source of fluids capable of dissolving feldspar was the rift area. This dissolution coupled with the anomalously high K/Cl values of main-stage ore fluids that formed deposits adjacent to the rift indicate that both the source of ore constituents and destruction of potassium feldspar was influenced by Reelfoot Rift fluids.

Geochemical modeling provides insight into the question of what caused the switch from feldspar precipitation to later dissolution. The most likely causal factor is a change in pH. The pH changes implied by the potassium feldspar precipitation-dissolution events were calculated by first modeling an MVT "ore fluid," and then comparing the activity of K^+ in this fluid with the feldspar-stability diagram of Bowers and others (1984) (fig. F14; table F2). The chemistry of the ore fluid was constrained by the fluid-inclusion data of Crocetti (1985), who measured the chemistry of fluid-inclusion leachates from Viburnum Trend galena. As shown in figure F14, the fluid modeled here conforms to the weight ratios of Crocetti (1985) and, in addition, was constrained to be at equilibrium with dolomite and quartz. Ionic activities were calculated using the computer code Solveq (Reed, 1982). The resulting value of a_{K+} was then used to calculate the pH shown along the right vertical axis of figure F14. The upper shaded rectangle in figure F14 shows that potassium feldspar dissolution requires a pH of about 5.0. If kaolinite formed as potassium feldspar dissolved, as indicated by the paragenetic diagram of ore formation in the Lamotte Sandstone (fig. F8), then the pH would have had to be at least 4.0 (lower shaded rectangle). This calculated pH for feldspar dissolution (and therefore ore formation) corresponds with the value calculated by an independent technique using fluid-inclusion gas compositions by Leach and others (1991).

We do not have direct evidence for what caused the pH of the fluid to change from a brine of relatively higher pH that was capable of depositing potassium feldspar to a brine of lower pH, which caused the dissolution trend of figure F11. It is likely that this shift was related to an increase in P_{CO_2} of the fluid, which caused the low pH values of the MVT ore-forming fluids (Leach and others, 1991). It thus appears that the fluid evolved from lower to higher values of this parameter. We can speculate that this pH change involved the thermal catabolic destruction of organic matter deep in the sedimentary rocks of the Reelfoot Rift. Early stages of sedimentation in the rift included deposition of large amounts of sedimentary organic matter. The release of CO_2 is known to accompany deep burial and heating of organic matter (Capuano, 1990). We can further speculate that this increase in P_{CO_2} was due to a process that was slower than the one that released excess K^+.

Additional Evidence for a Link Between the Reelfoot Rift and Lead-Belt Mineralization

In addition to the zone of dissolution of potassium feldspar that is adjacent to the Reelfoot Rift, other researchers have presented evidence for fluid migration from the rift towards the St. Francois Mountains. Erickson and others (1988) and M.B. Goldhaber (unpub. data, 1990) documented a zone of lead enrichment in Cambrian carbonate rocks adjacent to the Reelfoot Rift, which suggests that ore-forming fluids originated in, or passed through, the Reelfoot Rift. This area of anomalous lead enrichment overlaps the zone of dissolution of the potassium feldspar adjacent to the rift.

Farr (1986) reported an increase in the ratios of strontium isotopes in epigenetic dolomite from less radiogenic ($^{87}Sr/^{86}Sr$=.7090) to more radiogenic ($^{87}Sr/^{86}Sr$=.7140) with increasing proximity to the rift. Radiogenic strontium is largely derived from feldspar dissolution in much the same way as we proposed above for K^+, and thus Farr's work complements ours.

The Anomalous Nature of the Strake Well Samples

Samples from the Strake well have exceedingly high concentrations of authigenic potassium feldspar (as much as 10 percent of the whole rock), and this feldspar is visually different from feldspar overgrowths elsewhere in the area. Furthermore, two generations of overgrowths are present in these samples in contrast to those from the rest of the southern part of the area in figure F11. The anomalous abundance and appearance of the feldspar in this well may be related to the uplift of the Pascola arch, with which it is geographically associated. We attribute the elevated potassium feldspar content in the Strake well to fluids associated with alkaline igneous activity near the Pascola arch. This explanation is based on data from the USGS New Madrid test well (Crone, 1981), which is only 12 mi northeast of the Strake drill hole. Samples from the test well contain exceedingly elevated levels of the rare-earth elements Nb, Be, La, and Th (Erickson and Goldhaber, unpub. data, 1990). This suite of elements is diagnostic for carbonatite magmatism (Mariano, 1989). The upper levels of carbonatite complexes are invariably strongly potassium metasomatized (for example, potassium fenitized, La Bas, 1984), and such a process probably has operated in the area of the Pascola arch. If this igneous activity and associated alteration was associated with the uplift of the Pascola arch, then it postdated the time of MVT ore formation in the Ozark area (Kolata and Nelson, 1990). Therefore, the anomalous potassium feldspar overgrowths in samples from the Strake well may be unrelated to fluids that moved from the Reelfoot Rift.

SUMMARY

We list four principal conclusions:

1. The variety of types of feldspar and the amount of dissolution in the potassium feldspar and its overgrowths in the Lamotte Sandstone vary regionally over southeastern Missouri. Microcline and plutonic igneous rock fragments that contain potassium feldspar were common in basal clastic rocks that were originally deposited in the Reelfoot Rift. Towards the St. Francois Mountains and to the west, volcanic rock fragments are more abundant than plutonic rock fragments, and sanidine was a common detrital feldspar in addition to microcline.

2. Although dissolution of feldspar occurred on a regional basis, dissolution is locally controlled by the type and abundance of feldspar and burial depth. Detrital microcline and orthoclase are less affected by dissolution than are sanidine grains. For example, at the Goose Creek Mine, where sanidine was the predominant feldspar in the Lamotte Sandstone, secondary porosity produced by feldspar dissolution is high. In the Reelfoot Rift, where the sedimentary rocks have undergone a long period of deep burial, albitization as well as dissolution have been important diagenetic processes that altered feldspar and added K^+ to pore fluids.

3. Multiple episodes of precipitation and dissolution of potassium feldspar cement have occurred in the northern limits of the Lamotte Sandstone. These potassium

feldspar cements are the result of the migration of potassium-rich brines through the Lamotte Sandstone in late Paleozoic time.

4. The potassium feldspar grains and their overgrowths dissolved by reaction with an acidic solution of pH 4. This acidic solution may have originated in, or at least passed through, the Reelfoot Rift. The diagenetic changes in the sedimentary rocks in the rift probably provided a large source of K^+ for ore-forming solutions. The Reelfoot Rift had a major influence both on diagenesis of the Lamotte Sandstone and genesis of MVT ores.

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