CIRC. 1068

U.S. GEOLOGICAL SURVEY CIRCULAR 1068

The Conterminous United States Mineral-Resource Assessment Program—Background Information to Accompany Folio of Geologic and Mineral-Resource Maps of the Rolla 1° × 2° Quadrangle, Missouri

Prepared in cooperation with the Missouri Department of Natural Resources, Division of Geology and Land Survey

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The Conterminous United States Mineral-Resource Assessment Program— Background Information to Accompany Folio of Geologic and Mineral-Resource Maps of the Rolla 1° × 2° Quadrangle, Missouri

By WALDEN P. PRATT

Prepared in cooperation with the Missouri Department
of Natural Resources, Division of Geology
and Land Survey

U.S. GEOLOGICAL SURVEY CIRCULAR 1068

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The Conterminous United States Mineral-Resource Assessment Program—Background Information to Accompany Folio of Geologic and Mineral-Resource Maps of the Rolla 1°×2° Quadrangle, Missouri

By Walden P. Pratt

PURPOSE OF REPORT

As the title implies, this report contains background information; that is, an account of the *operations and products* of the Rolla project of the U.S. Geological Survey's Conterminous United States Mineral Assessment Program (CUSMAP). It is not intended as a review of the scientific conclusions of the project, except for a brief summary of the mineral-resource assessment. The scientific results are in the Rolla CUSMAP folio itself and in related publications listed at the end of this report.

INTRODUCTION

Since 1976 the U.S. Geological Survey's Conterminous United States Mineral Assessment Program (CUSMAP) has been making regional assessments of mineral-resource potential in selected 1°×2° quadrangles by integrating as many data on mineral deposits and occurrences, geology, geochemistry, and geophysics as are available or can be obtained within the 3–5-year time span of each project.

The Rolla quadrangle in southeast Missouri (fig. 1) was selected as one of the first CUSMAP projects for two principal reasons. One reason is the area's known importance in U.S. metal production. In 1980 the State of Missouri produced 91 percent of U.S. mine production of lead, ranked second among the 50 States in production of zinc and barite and fourth in silver, and was among the top 10 States in total value of metals and nonmetals produced. All of the metal production came from southeast Missouri, and most of this was from within the Rolla 1°×2° quadrangle (fig. 2), which still contains the largest known lead reserves in the world and important resources of zinc, barite, silver, copper, iron, cobalt, and nickel. The other reason is that the platform carbonate terranes in the quadrangle are representative of much of the Midcontinent region, and we felt that if we could develop an appraisal strategy that could be successfully tested in the known mineralized areas of southeast Missouri, we should then be able to export that strategy, not only to other areas in the Midcontinent but also to platform carbonate terranes elsewhere.

We believe that the Rolla project was a success—that we did indeed develop a strategy or methodology of mineral-resource assessment that is valid not only for the Rolla quadrangle but also for similar geologic terranes elsewhere. The 1:250,000-scale map products that make up the Rolla CUSMAP folio include 20 maps in the U.S. Geological Survey (USGS) Miscellaneous Field Studies (MF) series and 2 maps in the USGS Miscellaneous Geologic Investigations (I) series; related discussions and interpretations have been published as numerous journal articles and as open-file reports of the USGS and Missouri Geological Survey (MGS).

GEOLOGY OF THE ROLLA QUADRANGLE

The principal geologic formations of the Rolla quadrangle are sedimentary rocks, mostly dolomite, of Late Cambrian and Early Ordovician age, that overlie volcanic and granitic rocks of Middle Proterozoic (Precambrian Y) age (fig. 2). The Precambrian rocks are exposed mainly in the St. Francois Mountains in the eastern part of the quadrangle, where a complex of dominantly rhyolitic ash-flow tuff was intruded by a composite batholith of biotite and amphibole-biotite granite. The buried Precambrian

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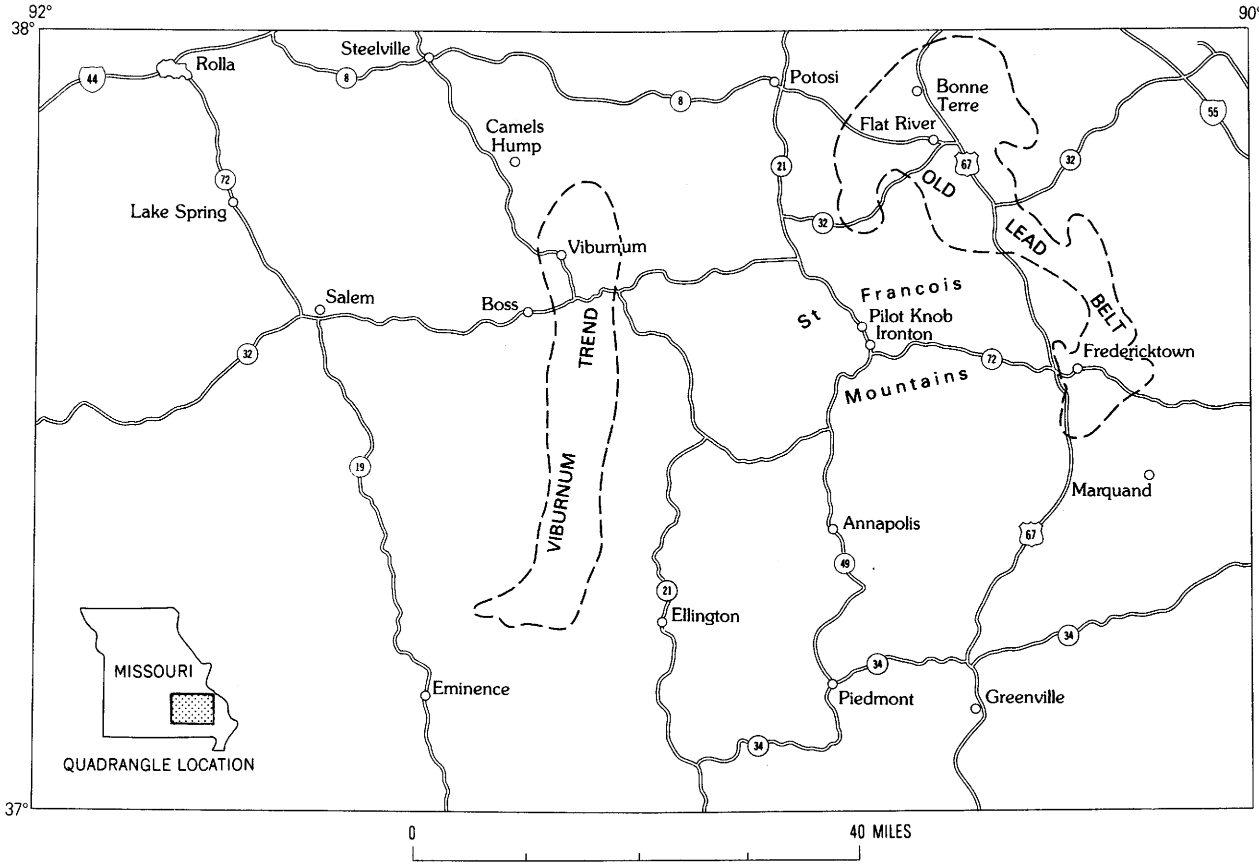


Figure 1. Rolla 1°×2° quadrangle, Missouri, showing principal towns, highways, and base-metal mining districts (enclosed by dashed lines).

basement in the rest of the quadrangle is dominated by subvolcanic massifs of biotite granite, central plutons of two-mica microcline and albite granite ("tin" granite), and ring intrusions of amphibole-biotite granite. Numerous alkalic ultrabasic diatremes of Devonian age intruded the sedimentary rocks in the northeastern part of the quadrangle, in an area east of Farmington and north of Fredericktown. Cambrian and Ordovician rocks in the quadrangle generally are flat lying or dip gently away from the St. Francois Mountains; they are fairly well exposed around the flanks of these mountains but elsewhere in the quadrangle are mantled by thick residual cherty clays. Where the entire section of Upper Cambrian and Lower Ordovician rocks is preserved, mostly in the western part of the quadrangle, its total thickness is about 2,000 ft. It is overlain by Middle Ordovician through Upper Mississippian sedimentary carbonate rocks in the extreme northeastern part of the quadrangle and by Quaternary alluvium in the extreme southeastern corner.

BRIEF HISTORY OF PROJECT OPERATIONS

Work on the Rolla project was begun by the USGS in October 1975; the project was formally funded under the new CUSMAP program, as a cooperative with the Missouri Division of Geology and Land Survey, beginning in October 1976. A meeting to report on interim progress of the project was held in Rolla for the mining industry in May 1978, and the first formal publication to come from the project was a summary geochemical map of the quadrangle published in 1978 (Erickson and others, 1978). An appraisal of the metallic mineral-resource potential of the quadrangle—the principal objective of the project—was submitted on schedule in September 1980, 5 years after the project's informal beginning, and was released as an open-file report in May 1981 (Pratt, 1981). Numerous other products were released either as formal publications or as open-file reports from time to time through 1987; the last formal map publication, a full-color geologic map of the quadrangle, is now in press (Pratt and others, in press).

Although most project activities went on concurrently over a period of 4 years in both the USGS and the MGS, for the sake of organization they are reviewed here by principal geologic discipline.

Mineral deposits and occurrences.—Known sites of mineralization in the quadrangle at the start of the project ranged from major operating lead-zinc and iron mines, through large and small mines no longer active, to numerous

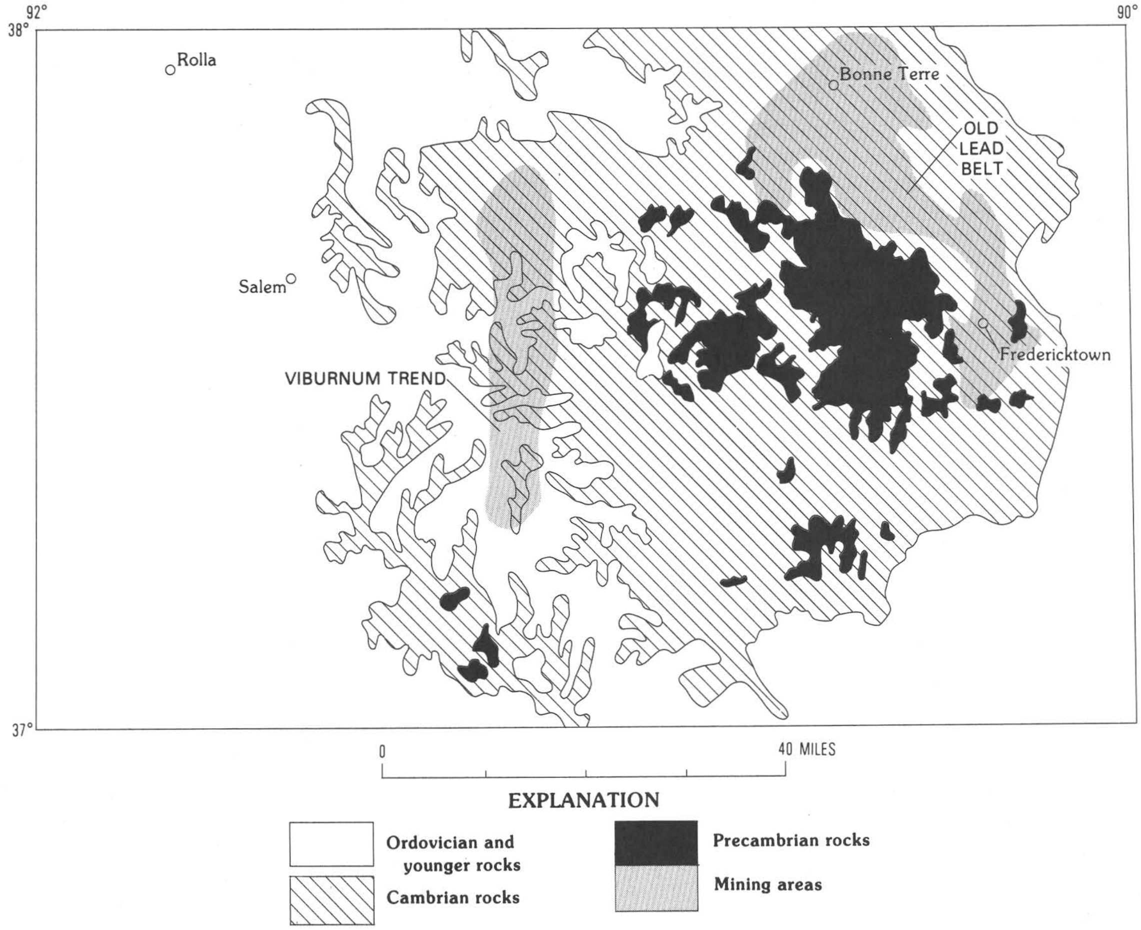


Figure 2. Generalized geology of Rolla 1°×2° quadrangle and areas of base-metal mining districts.

prospects and isolated occurrences of a variety of economic minerals. Mary H. Miller of the USGS made a thorough search of the literature and of commodity mineral map files of the MGS and compiled all available information on mines, prospects, and occurrences (Miller, 1982).

Geology.—The project required new reconnaissance geologic mapping of about 65 percent of the quadrangle to supplement previous mapping, both published and unpublished, that was considered of adequate geologic detail for the purposes of the project (fig. 3). Reconnaissance was directed toward the resolution of four principal problems that were perceived. First, detailed studies in the Precambrian terrane of the St. Francois Mountains, building on R.E. Anderson's (1962, 1970) discovery that most of the volcanic rocks were not flows but ignimbrites, had established a new volcanic stratigraphy for the northern St. Francois Mountains and provided abundant new petrographic and chemical data on the granitic rocks; a new geologic map of the quadrangle was needed to extend the new volcanic stratigraphy into the areas not yet mapped in detail and to provide a rational classification for both volcanic and intrusive rocks to replace the obsolete stratigraphy and nomenclature of earlier years, belatedly published in 1969 (Tolman and Robertson, 1969). Compilation and reconnaissance of the Precambrian areas were undertaken as the first phase of geologic mapping, and a new map of exposed Precambrian rocks, including recent mapping of several 7½′ quadrangles by Anderson and by M.E. Bickford and some of his students at the University of Kansas, was published in 1979 (Pratt and others, 1979).

The three remaining problems all pertained to the sedimentary rocks. First, review of new reconnaissance mapping done by MGS staff for the 1978 revision of the 1:500,000-scale geologic map of Missouri indicated some differences in interpretation of contacts between the Eminence and Potosi Dolomites that would have to be resolved. Second, studies of other parts of the Upper Cambrian section by Kurtz (1960) and Howe (1968) had showed that the primary stratigraphy of the Cambrian carbonate formations was not uniform across the St. Francois Mountains and that this nonuniformity had led to regional and local differences in recrystallization. This

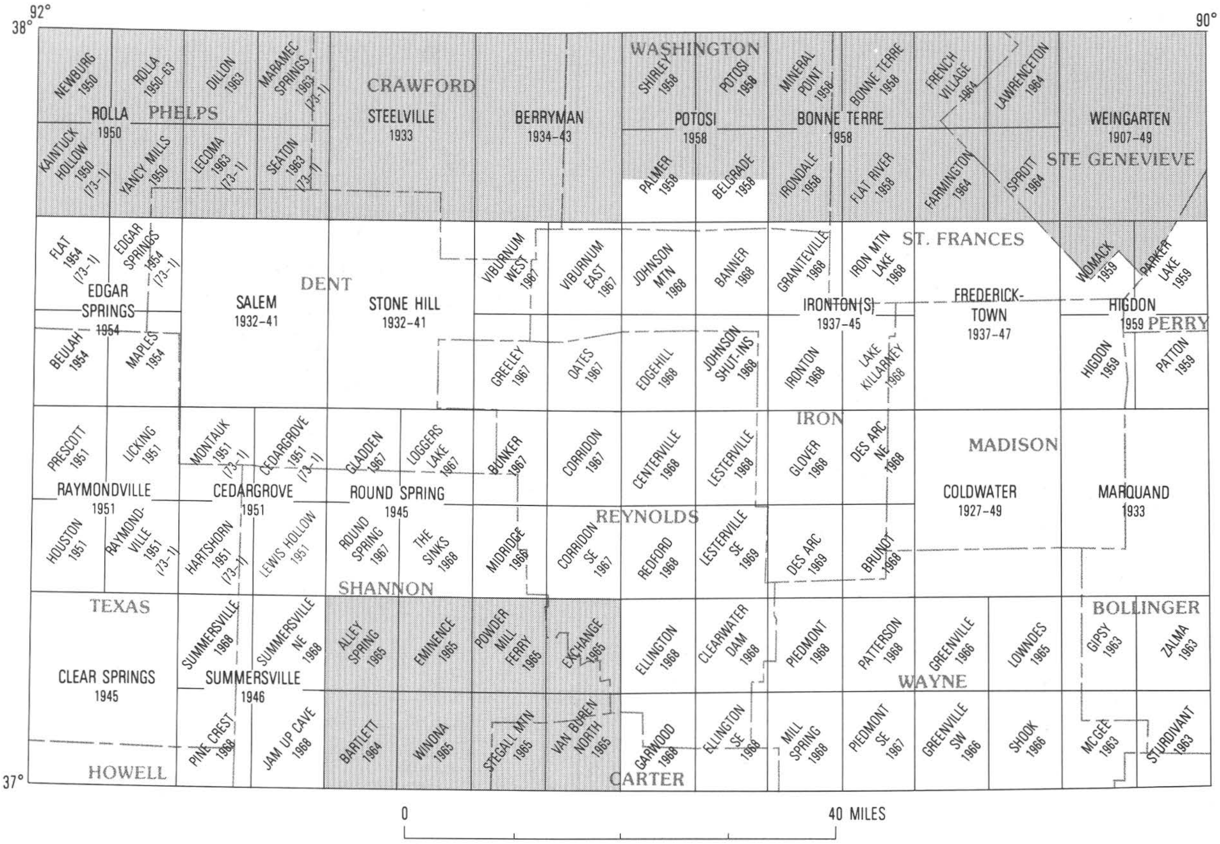
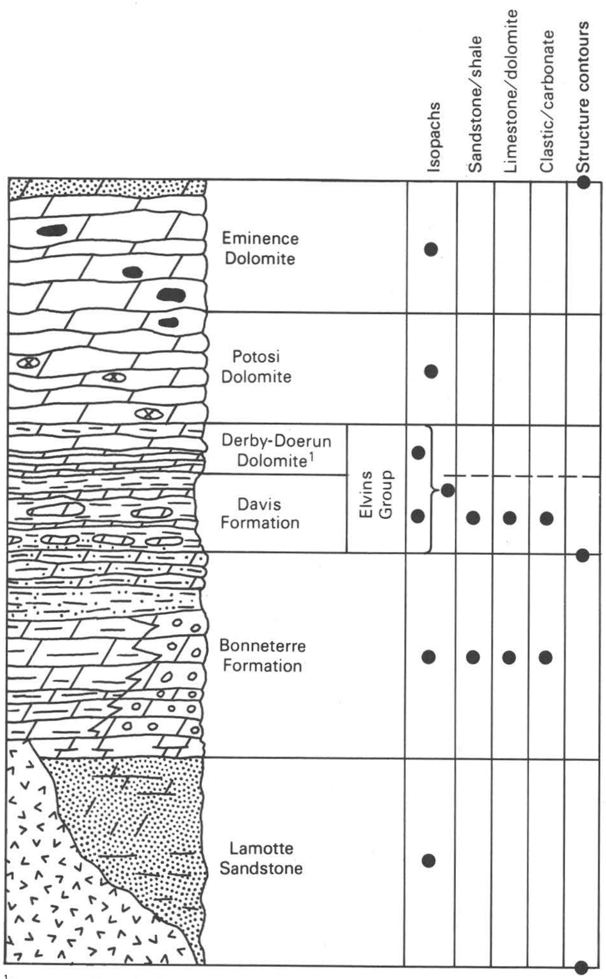


Figure 3. Geologic map coverage of Rolla 1°×2° quadrangle at beginning of Rolla CUSMAP project.

recrystallization locally masked primary depositional fabrics of several formations overlying the ore-bearing Bonneterre Formation, and these formations had been mapped erroneously as Bonneterre; this too needed to be resolved. Finally, as mapping progressed, the fallacy or pitfalls of attempting to map "ghost" structures through varying thicknesses of residuum became apparent, and the decision was made to distinguish residuum from bedrock on the map where the residuum was thought to be thick enough to obscure true bedrock relationships. Mapping of the sedimentary rocks was carried on by staff members of both the USGS and MGS, intermittently from October 1977 through April 1980. Included as new mapping for this project was reconnaissance of four 15′ quadrangles in the west-central part of the Rolla 1°×2° quadrangle, done in 1955–57 by Paul E. Gerdemann of St. Joe Minerals Company and released to the USGS for the purpose of this project. Mapping responsibility and resolutions of the various problems are shown in the text accompanying the maps as they were finally released (Satterfield and others, 1982; Pratt, Middendorf, and Satterfield, 1984; Pratt and others, 1985). For the resource appraisal, a composite map of geologic structures of the quadrangle (Pratt, 1982) was used in lieu of a final geologic map.

At the outset of the project, Kenneth H. Anderson of the MGS suggested that the State survey provide a much-needed third dimension to the geology by compiling a series of isopach and lithic-ratio maps of the Cambrian units, using data from their extensive library of drill logs. The suggestion was adopted, and a series of maps was prepared showing thicknesses of each of the Cambrian units, structure on two horizons, and ratios of limestone to dolomite, sandstone to shale, and (silicic) clastic rocks to carbonate rocks for selected formations (fig. 4) (Anderson, 1979, 1983; Thacker and Anderson, 1979a–g). These characterizations of the carbonate section were supplemented by an interpretive map of depositional facies of the Bonneterre Formation, purchased by the USGS from a geologic consultant (Kisvarsanyi, 1982). Also part of the subsurface information was a map showing structure on the buried Precambrian surface (Kisvarsanyi, 1979 a, b). All but one of these subsurface maps were arbitrarily extended a few miles north and south beyond the quadrangle boundaries to increase their usefulness because of the availability of data and the known geologic and economic interest in these areas peripheral to the Southeast Missouri district.

Geochemistry.—Traditional stream-sediment surface geochemical studies were not expected to be useful for



[1] Name used by Missouri Geological Survey

Figure 4. Stratigraphy of Cambrian sedimentary rocks in Rolla 1°×2° quadrangle showing intervals selected for isopach and lithofacies maps.

detection of metal anomalies from deeply buried mineral deposits because of the extreme dilution of potential geochemical haloes in the intense surface- and ground-water regime of southern Missouri. (This assumption was later borne out by studies of stream sediments and stream waters done for the project, as reported by Proctor and others, 1982.) Therefore, geochemical studies in the quadrangle were directed first toward determining trace-element signatures of the regional stratigraphic units (including the Precambrian) by using spectrographic and chemical analyses of rock and insoluble-residue samples from 60 regionally spaced drill holes. Determination of regional trace-element background values for each unit provided a frame of reference for evaluation of local metal anomalies and their significance in terms of potential mineralization. Samples used for these analytical studies were taken from the MGS sample library. Virtually all of the analyses, involving about 11,000 individual samples, were made in a USGS mobile spectrographic laboratory that was moved to MGS headquarters at Rolla for this purpose. Results of the subsurface geochemical studies were published as three maps (Erickson and others, 1978, 1979; Odland and others, 1982). The analytical data were released in a series of open-file reports; these reports are listed at the end of this circular.

Geophysics.—Aeromagnetic maps covering most of the eastern half of the Rolla quadrangle at 1:62,500 scale had been published in the 1960's. These were combined graphically into an aeromagnetic form-line map at 1:250,000 scale (U.S. Geological Survey, 1978), and a contract was let for an aeromagnetic survey of the western half of the quadrangle (U.S. Geological Survey, 1979). Meanwhile, a preliminary simple Bouguer gravity map of the quadrangle was compiled from existing data (Cordell and Williams, 1978), and an interpretation was published of gravity and aeromagnetic anomalies over basement structure in the eastern part of the quadrangle (Cordell, 1979). A Bouguer gravity map (Hildenbrand and others, 1979) incorporated additional data but did not substantially change the major gravimetric patterns of the quadrangle. Eventually, the newly acquired aeromagnetic data for the western half of the quadrangle were merged with digitized data from the eastern half to produce a single aeromagnetic map of the entire quadrangle at 1:250,000 scale (L. Cordell, unpublished data).

Resource appraisal.—By August 1980, the essential elements of the geologic data base were in hand, and most of the Rolla CUSMAP team convened in Denver to formally appraise the mineral-resource potential. Previous USGS mineral-resource assessments of quadrangle-size areas had focused on geologic terranes in mountain areas, principally in Alaska, for which geology and ore-deposit models are significantly different from those of southeast Missouri; there were no clear guidelines for mineral-resource appraisal in platform areas where the principal targets are deeply buried in the subsurface. Fortunately for this project, the USGS, in December 1979, had hosted a workshop on regional resource appraisals (Shawe, 1981). As a part of that workshop, two groups of geoscientists from government, industry, and academia worked independently to design a methodology for appraising the resource potential of a 1°×2° quadrangle representative of the Midcontinent geologic province. The area selected was the Poplar Bluff quadrangle, Missouri-Arkansas, which adjoins the Rolla quadrangle on the south. For the purposes of the Rolla project, the timing could hardly have been better, nor could the cast of characters, which included three members of the Rolla team as active participants. Not surprisingly, the method used for the Rolla appraisal was similar to the workshop method in many respects, and we acknowledge here the indirect contributions of the other members of those two working groups to the Rolla appraisal.

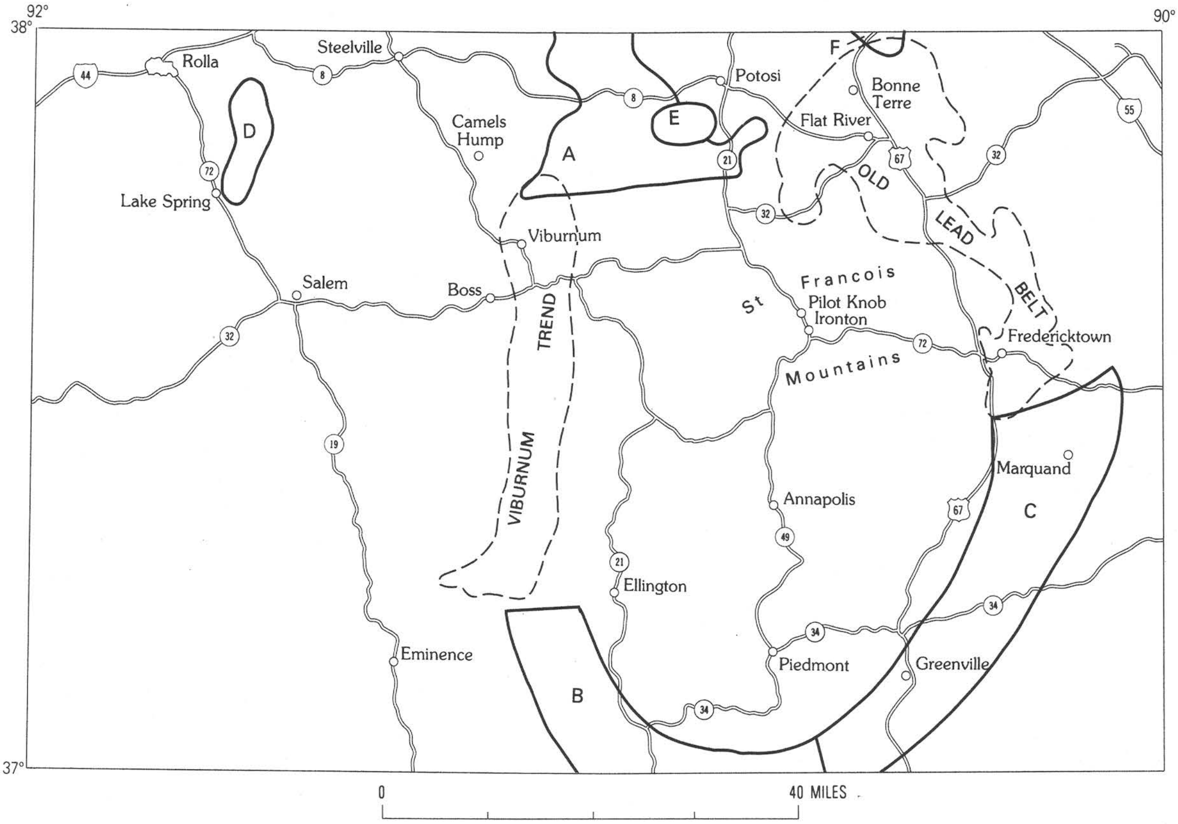


Figure 5. Areas of very high potential for Mississippi Valley–type deposits (A, B, C) and for high-grade iron ore (D, E, F) in the Rolla 1°×2° quadrangle. Dashed lines enclose areas of base-metal mining districts.

At the outset, the Rolla team agreed on the following six-step methodology for the resource assessment.

1. Compilation of mineral-occurrence, geologic, geophysical, subsurface lithofacies and structure, and subsurface trace-element geochemical maps of the quadrangle to define the known and inferred geologic terranes.

2. Determination of the types of mineral deposits that could reasonably be expected to be present in these terranes on the basis of worldwide associations of mineral deposits and favorable geologic environments.

3. Development of descriptive models of these types of deposits.

4. From each model, selection of distinctive "recognition criteria" for the occurrence or nonoccurrence of that type of deposit.

5. Systematic examination of all data from step 1 for the existence or absence of the recognition criteria.

6. Evaluation of the areal distribution and relative importance of the recognition criteria to assess the favorability for the occurrence of each mineral-deposit type.

Two days of spirited discussion resulted in rough drafts of the appraisals for the two most important deposit types—Mississippi Valley–type lead-zinc-silver-copper-nickel-cobalt deposits in the Bonneterre Formation and Kiruna-type iron-ore deposits in the Precambrian rocks—and laid the groundwork for appraisals of other deposit types, which were completed in the succeeding weeks by individual members of the team. A comprehensive report on the mineral-resource appraisal was released to coincide with a public "show and tell" meeting held in Rolla on May 20, 1981 (Pratt, 1981). Summaries of various lengths and depths were presented at the annual meeting of the Geological Society of America (Pratt and others, 1981) and as two USGS publications, one nontechnical (Pratt, 1983) and the other technical but much condensed (Pratt, Erickson, Kisvarsanyi, and Wharton, 1984). We summarize here the principal conclusions of the appraisal; note that the appraisal bears the date of **September 1980**; thus it is based only on information available at that time and does not include any subsequent "second thoughts."

Mississippi Valley–type lead-zinc-silver-copper deposits.—Three specific areas in the quadrangle contain such favorable combinations of the recognition criteria for this type of deposit that we believe the probability is very high that each area contains at least one major deposit, at unknown depths of from 600 to 2,000 ft; these areas are in Washington County north of county highway C (fig. 5, area A), southeast from about 8 mi west of Ellington to the southern boundary of the quadrangle (area B), and southwest from Marquand to beyond Greenville (area C).

Kiruna-type iron ore deposits.—Three areas in the quadrangle are believed to have a very high potential for large- to moderate-sized underground deposits of high-grade iron ores of this type in Precambrian rocks; these areas are northeast of Lake Spring (fig. 5, area D), between Potosi and Belgrade (area E), and northeast of Bonne Terre (area F).

Barite deposits.—A large area in the north-central part of the quadrangle has a high potential for small barite deposits in the clayey subsoil near the surface, which though individually small could be cumulatively large (fig. 6, area A).

Tin-tungsten vein deposits.—An irregular area extending north and west from Fredericktown has a high potential for small vein deposits of tin and tungsten near the surface (fig. 6, area B).

Uranium deposits.—Much of the quadrangle may have a high potential for uranium deposits in granitic rocks at depths of 1,000 ft or more beneath the surface.

Rare-earth-element mineral deposits and thorium.—Three areas in the quadrangle contain occurrences of kimberlitic rocks (fig. 6, areas C, D, and E) and may have a potential for deeply buried veins of rare-earth-element minerals and thorium, as well as diamonds, but the information on these areas is too scanty for us to infer the significance of this potential.

After completion of the Rolla study, staff members of the Earth Resources Observation Systems (EROS) Data Center at Sioux Falls, South Dakota, suggested a collaborative effort to use the Rolla data base and resource appraisal as a pilot test for a computerized digital synthesis. The resulting study "fine tuned" the original appraisal of resource potential for Mississippi Valley–type deposits and demonstrated the utility of the digital synthesis, at least for models dependent on pattern recognition involving several different types of data (Pratt and others, 1983; Walker and others, 1983).

An appraisal of industrial mineral resources of the quadrangle by the MGS, delayed for several years pending completion of the final Rolla 1:250,000-scale geologic map by the USGS, was published in 1987 (Rueff, 1987).

Manpower and cost.—Project-level operations of the Rolla CUSMAP project involved approximately 14.5 professional man-years of USGS time and approximately

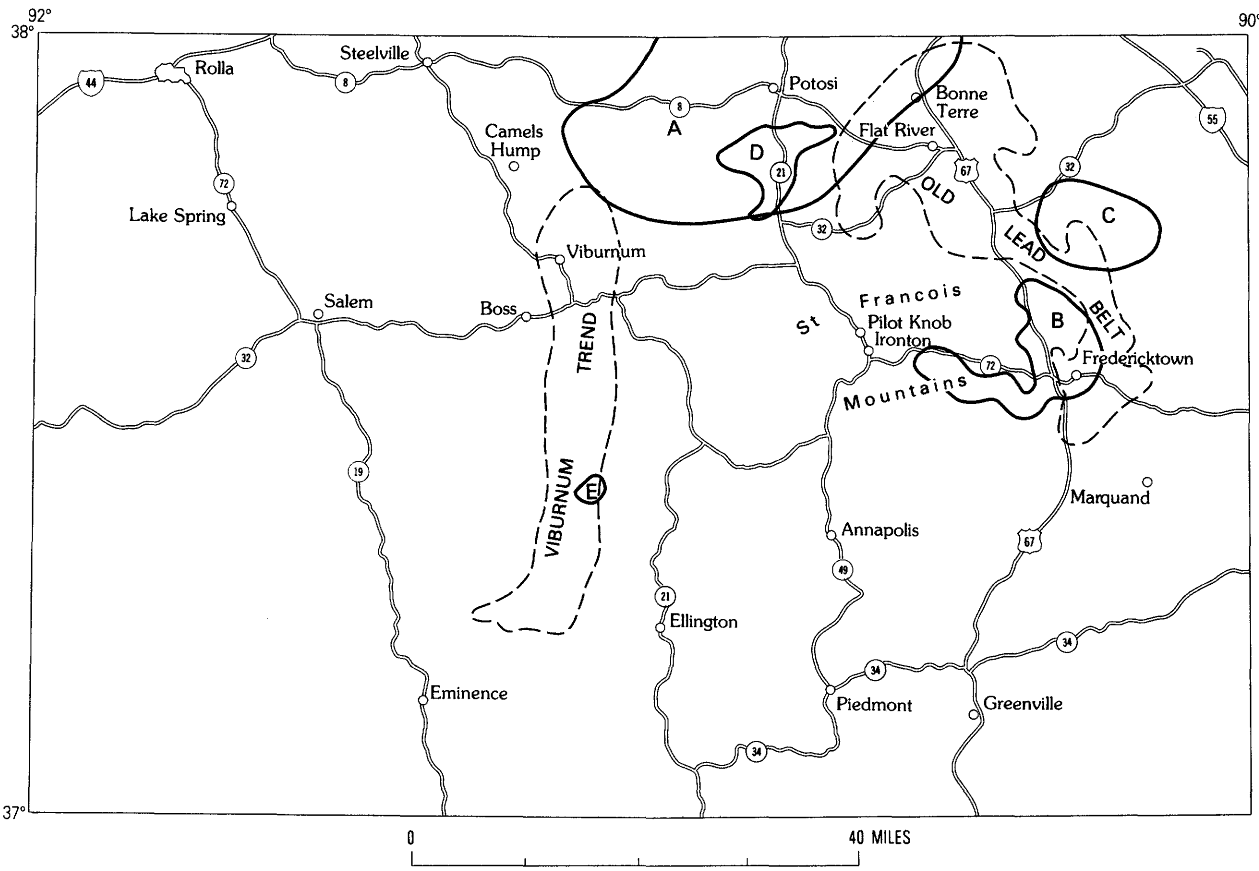


Figure 6. Areas of high potential for small barite deposits (A) and tin-tungsten veins (B) and areas that may have potential for veins of rare-earth-element minerals and thorium (C, D, E) in the Rolla 1°×2° quadrangle. Dashed lines enclose areas of base-metal mining districts.

3.6 man-years of MGS time during the period of formal funding, 1975–1980, and about 2 man-years after 1980 for preparation of reports. Directly involved in this work for various periods of time were 14 geoscientists of the USGS and 8 of the MGS. Direct costs to the USGS, not including administrative, overhead and publication expenses, totaled about $675,000.

PUBLICATIONS

Direct results of the project were published principally through the Rolla CUSMAP folio and as several open-file reports and journal articles. The folio is not a single physical entity but rather a set of maps published individually, all covering the Rolla quadrangle and almost all bearing sequential numbers in the USGS Miscellaneous Field Studies Map (MF) series.

MF–1000–A, B. Bedrock geology. Pratt (1982), Pratt and others (1985).

MF–1001–A, B. Structure on top of Precambrian. Kisvarsanyi (1979a, b).

MF–1002–A–J. Subsurface isopachs and lithofacies. Anderson (1979, 1983), Thacker and Anderson (1979a–g), Kisvarsanyi (1982).

MF–1004–A–C. Geochemical maps. Erickson and others (1978, 1979), Odland and others (1982).

MF–1005–A–C. Mineral resources. Miller (1982), Pratt and others (1984), Rueff (1987).

Six additional reports were released in other series but should be considered integral parts of the Rolla folio: a geologic map of exposed Precambrian rocks (Pratt and others, 1979); a full-color version of the geologic map of the quadrangle (Pratt and others, in press); an aeromagnetic map of part of the area (U.S. Geological Survey, 1979); a Bouguer gravity map (Hildenbrand and others, 1979); a report on the metallic mineral-resource potential (Pratt, 1981); and a nontechnical summary of the mineral-resource appraisal (Pratt, 1983).

Finally, a comprehensive "case history" of the Rolla project, including discussions of the geology, geochemistry, geophysics, and mineral resources, is currently in preparation for proposed publication as a USGS Professional Paper.

Other open-file reports, abstracts, journal articles, and MGS publications include interim reports, topical reports, and spectrographic and chemical analytical data from the thousands of drill-hole and outcrop samples that were analyzed. The following list contains most of the formal and open-file reports that resulted directly or indirectly from the Rolla project.

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