PRELIMINARY EVALUATION OF THE MINERAL RESOURCE POTENTIAL OF THE SIERRA LADRONES WILDERNESS STUDY AREA, SOCORRO COUNTY, NEW MEXICO

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FOREWORD

In August of 1981 the New Mexico Bureau of Mines and Mineral Resources was contracted to make a "Mineral Resource Inventory" of the Sierra Ladrones Wilderness Study Area for the Socorro District Office of the U.S. Bureau of Land Management. From the start it was recognized that the Ladron Mountains and surrounding lowlands were geologically complex and contained many different types of mineral occurrences representing some mineral potential.

A time-consuming (reiterative) analysis of the available geoscience data ensued. Genetic models for various types of economic mineral deposits were the most penetrating tool used in this analysis. The results of this analysis were presented to the BLM in July 1982, in the form of a report entitled "Preliminary Evaluation of the Mineral Resource Potential of the Sierra Ladrones Wilderness Study Area, Socorro County, New Mexico". A review of this report by the BLM indicated more explanation was needed concerning quantification of mineral potential, expressed as "the probability for discovery of a commercial mineral deposit". A final copy of this report, with appropriate addenda, was delivered to the BLM in September 1982.

This New Mexico Bureau of Mines Open-file Report No. 179 represents a partial revision of the final BLM report. The only significant change incorporated in this open-file report is in the recognition that the apparent potential for commercial resources of uranium and base metals in the Ladron Mountains must actually exist in two different types of mineral deposits (e.g. as stratiform base metal sulfide deposits in metamorphic rocks,

and possibly as metamorphosed sandstone-uranium deposits or uranium mineralization in granites). In the original BLM report these possible resources were assumed to occur in a single type of deposit, which tended to increase their estimated economic potential. Minor changes in organization and syntax have been made in the interest of clarity. Release of this open-file report to the public was approved by the U.S. Bureau of Land Management on February 2, 1983.

ABSTRACT

A detailed analysis of available geoscience data has been made in order to evaluate the mineral resource potential of the Sierra Ladrones Wilderness Study Area (Ladron WSA), located in central New Mexico. Mineral resource potential is expressed here as the probability (high = 10^{-1}, good = 10^{-2}, fair = 10^{-3}, low = 10^{-4}, very low 10^{-5}, and nil = 10^{-6}) for discovery of a commercial mineral deposit, of a particular type, in (and adjacent to) the Ladron WSA. A profitably recoverable mineral deposit worth at least 25 million dollars (gross value in ground) is defined here as commercial. Experience has shown that about one in ten (10^{-1}) economic mineral discoveries (such as a drill-hole intercept of economic grade and thickness) leads to successful mine. In contrast, the chances of discovering a commercial oil reservoir within a granite are about one in a million (10^{-6}).

Different types of mineral deposits and their relative probability for a commercial discovery in the Ladron WSA are:

1) uranium deposit in Precambrian metamorphic or granitic rocks, 10^{-2} ;
2) stratiform polymetallic (copper-zinc-lead-cobalt*-nickel*) sulfide deposit in Precambrian metamorphic rocks, 10^{-2};

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* strategic mineral

3) high-calcium limestone deposit of commercial size (225 million metic tons) suitable for making cement: probability for sufficient future demand to become commercial is good, 10^{-2};

4) Mississippi Valley-type lead-zinc-barite deposit, 10^{-3};

5) oil and/or natural gas reservoir, 10^{-3};

6) supergene uranium-copper deposit (Jeter type), 10^{-4};

7) supergene manganese* deposit (Black Mask type), 10^{-4};

8) siliceous vein deposit (silver-gold-lead-zinc-copper-barite-fluorspar*) in Precambrian rocks , 10^{-5};

9) placer gold deposit of late Paleozoic age, 10^{-5};

10) tungsten*-bismuth-tin* deposit in Precambrian granite, 10^{-5};

11) geothermal energy reservoir, 10^{-5};

12) coal deposit, 10^{-6};

13) gypsum deposit, 10^{-6};

14) manganese-iron deposit, 10^{-6};

15) chromium*-platinum* deposit, 10^{-6}.

A small uranium-copper deposit at the eastern foot of the Ladron Mountains (Jeter Mine) was almost certainly derived from weathering of preexisting uranium mineralization (#1 above) and polymetallic sulfide mineralization (#2 above) in the Precambrian terrane upslope from the mine. The extremely high uranium content (704 ppb) of well waters at the Lazy C Bar J Ranch is a strong indication of ongoing weathering of high-grade uranium

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* strategic mineral

mineralization in Precambrian rocks west of the ranch.

The metal content of the Jeter deposit probably represents less than 1/200th of the total uranium and base metals (Cu-Zn-Pb-Ni-Co) weathered from near-surface mineralization in the Precambrian rocks. As much as 24 million pounds of uranium oxide, worth about 0.4 to 1.1 billion dollars at current to foreseeable prices (17-45 \$/lb U_3O_8), and as much as 18.6 million pounds of base metals, worth about 30 million dollars at current prices, may have been weathered from the Precambrian terrane of the Ladron Mountains over the last few million years. Similar metal values may be preserved below the present zone of weathering.

Future evaluations of mineral resource potential in the Ladron WSA should be based on detailed geologic mapping, multi-media geochemical surveys and systematic geophysical surveys, such as a helicopter-borne electromagnetic survey. A detailed investigation of this nature may reveal specific areas (i.e. drilling targets) that are favorable for discovery of a commercial uranium deposit and/or a commercial polymetallic sulfide deposit. Testing of specific targets, if found, should be left to private industry.

Ideally, all land-use decisions should be based on reasonable estimates of the "price" to be paid for each alternative use. We suggest that in terms of "lost mineral production" the potential price of a "Sierra Ladrones Wilderness Area" could be as much as a billion dollars.

SUMMARY

The Sierra Ladrones Wilderness Study Area (Ladron WSA) is a sixty-one square-mile "island" of undeveloped Federal land centered on the western flank of the rugged and isolated Ladron Mountains in central New Mexico. Geoscience data obtained from a comprehensive literature review and a brief field reconnaissance have been analyzed in detail to make a preliminary estimate of the mineral resource potential of the Ladron WSA. Key data gathered consist of geologic maps, locations and descriptions of surface mineral occurrences (some with chemical analyses and production data), and trace element geochemical analyses of 63 arroyo sediment samples plus 17 ground-water samples collected in the Ladron area as part of the National Uranium Resource Evaluation (NURE).

Geologic concepts are the most penetrating tool used in this hypothetical "look" for concealed mineral resources below the surface of the Ladron WSA. The conclusions presented are not unequivocal, but they are geologically defendable on the basis of available data.

Mineral resource potential is primarily expressed here as the probability (high = 10^{-1}, good = 10^{-2}, fair = 10^{-3}, low = 10^{-4}, very low = 10^{-5}, nil = 10^{-6}) for discovery of a commercial mineral deposit, of a particular type, or for a particular commodity. A commercial mineral deposit is defined here to have an economically recoverable value of at least 20 million dollars, which is approximately equivalent to a gross value (in place) of 25 million dollars. In general, the most positive indication of

an ore depost--a drill hole intercept of economic grade and mineable thickness--has only about one chance in ten (probability = 10^{-1}) of becoming a successful mine. Order-of-magnitude estimates of maximum gross value have been made for commodities (e.g. uranium, base metals) that have a relatively good (10^{-2}) probability for discovery of a commercial deposit in the Ladron WSA.

The Ladron Mountains are a geologically young topographic feature not more than about 5-10 million years (m.y.) old. The core of the Ladron range is comprised of upwarped Precambrian rocks formed in a relatively obscure environment of sedimentation, volcanism, granitic intrusion, and mountain building about 1300 to 1600 m.y. ago (middle Proterozoic time). Major Precambrian rock units consist of: 1) an older heterogeneous granitic complex (Capirote granitoid), 2) a complex sequence of metamorphosed sedimentary and volcanic rocks (mostly nonmarine), and 3) a younger quartz monzonite pluton (Ladron pluton) characterized by the presence of two micas, muscovite and biotite. It appears likely that the sedimentary-volcanic sequence and underlying(?) Capirote granitoid were tightly folded, faulted, and metamorphosed during at least one major compressional event, prior to the intrusion of the Ladron pluton about 1300 m.y. ago.

On a global scale, metamorphosed sedimentary and volcanic rocks of middle Proterozoic age (1800-1000 m.y. old) are known to be particularly favorable hosts for very large deposits of uranium, or base metals, often worth billions of dollars. Numerous uranium and copper occurrences around the Ladron Mountains are

found either within, or closely associated with, the Precambrian rocks.

The western flank of the Ladron Mountains is underlain by 1480-1740 meters of marine and continental sedimentary rocks deposited in late Paleozoic basins about 330-230 m.y. ago. Thin basal conglomerates (0.3 m) of Mississippian age near Cerro Colorado rest unconformably on Precambrian rocks and contain subeconomic concentrations of gold (0.01 oz/ton). A commercial placer-gold deposit along the late Paleozoic unconformity is considered as possible, but unlikely (discovery probability = 10^{-5}).

Mississippian and Pennsylvanian limestones have been productive hosts for replacement and vein-type deposits of lead, zinc, and barite (minor silver and copper) in the relatively nearby Magdalena and Hansonburg mining districts of Socorro County. Ores of the Hansonburg district have chemical fingerprints indicative of a sedimentary-hydrothermal origin (i.e. Mississippi Valley-type deposit). That is, they were presumably formed in late Paleozoic time by progressive loading and compaction of basin-floor strata, which drove metal-rich pore waters (brines) toward basin margins where the metals were preferentially trapped (precipitated) in chemically reactive limestone beds. Lead-zinc-barite-silver-copper-bearing siliceous veins occur in Precambrian rocks within the Ladron WSA, and Pennsylvanian limestones contain similar veins a few miles north of the WSA. Silicified limestones west of Ladron Peak, which occur in a fault zone of probable late Paleozoic age, may reflect

lead-zinc-barite replacement deposits at depth. The potential for a Mississippi Valley-type lead-zinc-barite deposit in the Ladron WSA is speculative (discovery probability = 10^{-3}), but worthy of further research.

Gypsum beds within the Yeso Formation (Permian) are exposed along the western margin of the WSA. The gypsum beds are too thin (1-2 m) and too far from a market to be economic.

A proposed addition (under appeal) to the Ladron WSA, near the settlement of Riley, is underlain by Triassic red beds (195-210 m.y. old), and Cretaceous sandstones and shales (85-105 m.y. old) of an intertonguing marine-nonmarine sequence. Nonmarine Cretaceous strata contain seams of bituminous coal that are too thin (<0.5 m) and lenticular to be an economic resource.

Marine limestones and shales of Pennsylvanian age are regionally known to be favorable source rocks for petroleum and natural gas. In the southwestern corner of the Ladron WSA, near Riley, Pennsylvanian source beds are at a favorable depth (2900-3600 m) for the generation of petroleum or natural gas. A northwest-trending basement structure of Pennsylvanian ancestry in the favorable area may form stratigraphic and structural traps at depth. Although the probability for generation of oil and/or gas is high (10^{-1}), numerous faults and dikes in the Riley area may have allowed hydrocarbons to leak from reservoirs, which reduces the probability for discovery of a commercial oil and/or natural gas reservoir to about 10^{-3}.

In a prior mineral survey of the Riley-Puerticito area, continental sandstones of the Baca Formation (ca. 45-38 m.y. old) were interpreted to have the capacity for commercial uranium

deposits. The Baca uranium potential does not extend into the Ladron WSA.

Thirty million years ago the entire Ladron area was covered by a continuous apron of volcanic rocks erupted from volcanoes and calderas about 30 miles to the south, in Socorro-Magdalena area. Basaltic flows erupted from fissures in the Riley area then capped the volcanic plateau. Volcanic rocks now found as down-faulted blocks along the eastern flank of the Ladron Mountains lack siliceous veins and vent features of rhyolitic volcanoes, both of which are commonly associated with porphyry-type hydrothermal mineral deposits. The potential for porphyry-type mineral deposits of Tertiary age, such as molybdenum, is therefore considered to be nil.

Volcanic-rich conglomerates and playa mud deposits of the Popotosa Formation (ca. 25-7 m.y. old), which filled a closed basin of the early Rio Grande rift, are known to contain lithium-rich ash beds (0.2% Li) and some shows of uranium in sandstones. Where the Popotosa Formation underlies a proposed addition to the Ladron WSA (near "The Box"), it would be too deep for most mineral exploitation.

The Ladron Mountains are now surrounded by a dissected apron of alluvial fan deposits (Sierra Ladrones Formation), which contain abundant clasts of Precambrian and Paleozoic rocks shed from the rising Ladron block in fairly recent geologic time (Pliocene-Pleistocene). Since these alluvial fan deposits locally rest in distinct angular unconformity on the Popotosa Formation, they are almost certainly younger than 10 m.y., and

are most likely 1-5 m.y. old. Limestone-cobble fan deposits on the western flank of the Ladrons are locally interbedded with and capped by a limestone spring deposit (travertine caprock). These stratigraphic relationships indicate an early period of accelerated sediment flux, an intermediate period of accelerated ground-water flux, and a later period of accelerated sediment flux off the western flank of the Ladron Mountains during the last 5 million years. The period of high ground-water flux probably reflects a cool/wet climate associated with the onset of continental glaciation in late Pliocene to early Pleistocene time (ca. 1-3 m.y. ago). Manganese deposits on the west flank of the Ladrons (Black Mask mine) and uranium-copper deposits on the east side of the Ladrons (Jeter mine) are Plio-Pleistocene in age. Thus, they may be reasonably interpreted as having been deposited from low-temperature, metal-rich, ground waters flowing away from the core of the Ladron Mountains.

The commercial-grade Black Mask manganese deposit (production 566 tons Mn, avg. grade 42% Mn) was probably formed by shallow ground waters locally rising along a north-trending fault zone, which is now concealed by the cogenetic travertine cap for a distance of 6 km north of the mine. The probability for discovery of a small (10^5 metric tons, i.e. subcommercial) Black Mask-type manganese deposit in the WSA (concealed below the travertine caprock) is judged to be relatively good (10^{-2}), but the probability for discovery of a commercial manganese deposit (1.4×10^7 metric tons) is judged to be low (10^{-4}).

A travertine caprock, which covers the western half of the Ladron WSA, represents about 225 million tons (150 million tons

in WSA) of strippable high-calcium limestone suitable for cement production. Other materials used in cement production (e.g. coal, shale and gypsum) are available near Riley. This substantial limestone resource is presently too far from a market to be economically exploited, but the probability of sufficient future demand to become commercial is judged to be good (10^{-2}).

Since its discovery in 1954, the Jeter uranium-copper deposit (production 58,582 lbs U_3O_8, avg. grade 0.33% U_3O_8) has been interpreted to be of magmatic hydrothermal origin; that is, presumably deposited from hot waters ascending along the Jeter fault from an intrusion at depth. However, the asymmetry of alteration and mineralization (restricted to footwall), and the lack of silicification argue otherwise. Strong evidence for a supergene origin--presumably deposited from low-temperature ground waters descending along the Jeter fault--is found in trace element analyses (NURE data, 1981) of three vertically oriented samples from the Jeter ore zone.

In Wyoming-type sandstone uranium deposits, which are of widely accepted supergene origin, concentrations of molybdenum consistently peak down dip (down flow path) from peak uranium values; both metals accumulate in reduced ground down dip from an oxidation-reduction boundary. Jeter ore metals (copper-uranium, 0.4 to 0.2%; zinc-nickel-cobalt-lead, 0.05 to 0.01%; and molybdenum-tin-vanadium, 0.007 to 0.002%)[1] all show strong vertical zonation. Key peaks of uranium, at top of ore zone, and

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[1]maximum metal values of ore on stock pile.

molybdenum, at middle of ore zone, indicate deposition from waters with a downward component of flow (i.e. descending ground waters). Other constraints (such as late Cenozoic age, presence of copper, and only one reasonable source of descending ground water) indicate that the Jeter deposit was formed by acidic ground waters derived from weathering (wetting and oxidation) of copper-zinc-lead-sulfide mineralization and uranium-oxide mineralization in Precambrian rocks that underlie the crest of the Ladron Mountains. In the vernacular of Canadian exploration geochemists, the Jeter deposit may be classified as a displaced geochemical anomaly, which has been laterally shifted from its source. Discovery of additional Jeter-type deposits is virtually assured at points where the metal-rich ground waters passed through a strongly reducing media, such as fault slivers of carbonaceous shales (Pennsylvanian Sandia Formation). Most of the potential for small Jeter-type uranium deposits ($\sim 10^5$ lbs U_3O_8), which would be subcommercial at either current prices ($\sim$17-20\$/lb U_3O_8) or at foreseeable prices ($\sim$45 \$/lb U_3O_8), lies just east of the WSA boundary. The probability for discovery of a commercial Jeter-type deposit east of the WSA is judged to be fair (10^{-3}).

The original bulk metal content of the Jeter deposit (production plus reserves) is estimated to have been as much as 120,000 lbs of uranium oxide; 60,000 lbs of copper; 15,000 lbs of zinc; 9,000 lbs of nickel; 6,000 lbs of cobalt, and 3,000 lbs of lead. Essentially continuous alteration and low-grade mineralization along the 11.2 km length of the Jeter fault implies that the Jeter deposit (55 m strike length) may represent

as little as 1/200th of the metals weathered from the Precambrian rocks upslope. Therefore, the metals potential of near-surface Precambrian rocks in the Ladron Mountains may be as much as 200 times the metal content of the Jeter deposit. Available data indicate that the Cu-Zn-Pb-Co-Ni content of the Jeter deposit was primarily derived from weathering of high-grade sulfide mineralization and that uranium was weathered from a separate source consisting of uranium-oxide mineralization. At current metal prices the polymetallic source (sulfide mineralization) would have an aggregate value of about 30.6 million dollars. Likewise, at current to foreseeable uranium prices the uranium source (oxide mineralization) would have an aggregate value of about 0.4 to 1.2 billion dollars. Based on these rough estimates of bulk metal content, the Precambian core of the Ladron Mountains is judged to have a relatively good probability (10^{-2}) for discovery of a commercial uranium deposit and a good probability (10^{-2}) for discovery of a commercial polymetallic sulfide deposit. This area of commercial mineral resource potential lies in the scenic heart (~16 square miles = 41 km^2) of the Ladron WSA.

Two detailed studies of the Ladron Mountains (Black, 1964; Condie, 1976) report numerous copper occurrences (oxides after sulfides) scattered throughout the Precambrian metamorphic terrane. Unfortunately, exact locations of these occurrences are not given. However, our reconnaissance has located a small copper prospect (1.2 x 2.4 x 4.5 m shaft, parallel to layering) in quartz-mica schist (Torres Schist of Black) near the head of

Alamito Canyon. Dump material at the Alamito Canyon prospect includes a limonite gossan indicative of high-grade metallic sulfide mineralization; traces of unoxidized copper sulfides are also present. Analysis of the gossan indicates that it was a suitable source for the Cu-Zn-Pb-Ni-Co metal suite of Jeter deposit. An anomalous concentration of uranium in the gossan (0.1%) is surprising since there is no anomalous radioactivity at the prospect. The observations may be reasonably explained if uranium was recently weathered from a nearby source (leaving radioactive daughters behind) and then adsorbed by iron oxides in the gossan. Upslope exposures of metamorphic rocks and the Ladron quartz monzonite pluton are the only reasonable sources of uranium at the Alamito Canyon prospect.

Black (1964, p. 77) interpreted copper sulfide occurrences like that of the Alamito Canyon prospect to be of Precambrian age and described them in terms of a magmatic hydrothermal origin. Black states: "hypogene copper-sulfide fissure veins....are scattered throughout the Torres Schist and are generally controlled by fissures along the schistocity or bedding planes". Clearly, the description is of a copper sulfide mineralization parallel to the dominant schistocity and bedding (structural layering?). An alternative working hypothesis proposed here is that "copper- sulfide fissure veins" of Black and the Alamito Canyon prospect most likely represent stratiform polymetallic sulfide deposits of premetamorphic age and of sedimentary or volcanic origin. This stratiform interpretation reasonably explains the parallelism of mineralization to layering and the apparent spatial limitation of mineralization to a metamorphosed

sedimentary-volcanic unit (Torres Schist).

Weathering of stratiform polymetallic sulfide deposits is the most likely source of base metals (excludes uranium) in the Jeter deposit. A rough estimate of the bulk metal content in near surface polymetallic sulfide deposits (extrapolated from the Jeter deposit, see p. xv) indicates a potential for stratiform deposits of commercial significance. The probability for discovery of a small commercial deposit (~5 million metric tons) of stratiform polymetallic sulfides in Precambrian metamorphic rocks of the Ladron WSA is judged to be relatively good (10^{-2}). Geochemical data suggest that a commercial deposit of polymetallic sulfides could produce significant amounts of the strategic metals, cobalt and nickel, as byproducts.

The extremely high uranium content (704 ppb) of well waters at the Lazy C Bar J Ranch (at eastern foot of Ladron Mountains) is a strong indication of ongoing weathering of high-grade uranium mineralization in Precambrian rocks west of the ranch. Earlier weathering of similar uranium mineralization in Precambrian rocks was the most likely source of uranium now trapped in the Jeter deposit. A rough estimate of the bulk uranium content of near-surface Precambrian rocks (see p. xv) indicates a commercial uranium potential of as much as hundreds of millions to a billion dollars. The probability for discovery of a commercial uranium deposit in the Precambrian core of the Ladron Mountains is judged to be relatively good (10^{-2}).

Possible, but unverified, types of uranium deposits that could be discovered in the Ladron Mountains are: 1) metamorphosed

sandstone-type uranium deposits in a quartzite-schist transition zone, peripheral to sulfide mineralization; 2) contact metasomatic or hydrothermal hematite-uranium oxide veins associated with the two-mica[1] Ladron pluton; 3) high-grade and low-grade uranium oxides disseminated in the two-mica Ladron pluton; and 4) unconformity-type uranium veins associated with a possible unconformity separating the Capirote granitoid and overlying(?) arkosic metasediments.

Precambrian rocks of the Ladron Mountains contain three other areas favorable for mineral resources. Thin (mostly less than 1 meter), siliceous veins on the east flank of the Ladrons (Hanson district of Jones, 1904) have been verified to contain minor lead-zinc-copper sulfides, barite, as much as 10 oz/ton silver, and as much as 0.02 oz/ton gold. Although silver values are economic, veins of mineable width and grade are not known to be present at the surface. Because they are mostly thin and discontinuous, silver veins of the Hanson district are judged to be of low economic potential (probability of commercial deposit = 10^{-5}). However, as previously stated, similar lead-zinc-barite veins may be associated with replacement deposits in limestones west of Ladron Peak, which are more likely to be of commercial size and grade.

An exposure of coarse-grained granite, about one mile southwest of Ladron Peak, is reported to contain minor amounts (0.1-0.6 volume percent) of disseminated "primary" fluorspar in

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[1]Two-mica granitic rocks are commonly associated with uranium deposits.

three of six samples from the area. Trace-element analyses (NURE data) of sediments in arroyos, generally emanating from this area, contain anomalous values of tungsten (15 ppm) and bismuth (6 ppm). The apparent (but not verified) association of high tungsten and bismuth with a fluorite-bearing granite suggests that a tungsten-bismuth (-tin?) greisen deposit may be present in this area of the WSA.

An area of microearthquake activity, which has a signature of magma intrusion, has been identified on the northeast flank of the Ladron Mountains (Sanford and others, 1979; A.R. Sanford, oral comm., 1982). Average depth of earthquake foci (5 km), indicate a potential geothermal reservoir may be present near this depth. No thermal springs and no heat-flow tests are known in the area. Deep geothermal reservoirs of this nature have not yet produced commercial energy, and would certainly test the limits of current technology.

The Ladron WSA contains no discernible potential for the strategically important metals of the platinum group or chromium, as ultramafic rocks are not known in the area. However, as previously stated, the Ladron WSA has varying potential for production of some strategic metals, namely cobalt, nickel, manganese, tin and tungsten.

In conclusion, Precambrian rocks that form the core of the Ladron Mountains (and the scenic heart of the Ladron WSA) are judged to have a relatively good probability (10^{-2}) for discovery of a commercial uranium deposit and a relatively good probability (10^{-2}) for discovery of a commercial polymetallic (Cu-Zn-Pb-Ni-

Co) sulfide deposit of stratiform geometry. This uranium potential could be worth as much as a billion dollars, at foreseeable prices. Discovery and development of a large uranium ore deposit would certainly benefit the local population and economy, consumers in general, and all levels of government.

Delineation of specific exploration targets for uranium deposits and polymetallic sulfide deposits in the Ladron Mountains could be achieved by a combination of detailed geologic mapping (~1:12,000), detailed structural and stratigraphic analysis of metamorphic rocks, detailed multi-media geochemical surveys, and detailed geophysical surveys such as a helicopter-borne electromagnetic survey. Detailed studies of this nature would require a dollar investment in the hundreds of thousands, and several years to complete.

Private industry is considered to be the most appropriate entity to test our interpretation of high mineral resource potential in the Ladron Mountains, with the least expense to the taxpayer. Should the U.S. Bureau of Land Management recommend the Ladron study area for "wilderness" status, then the U.S. Geological Survey and U.S. Bureau of Mines will be required to make a "final"[1] mineral resource evaluation. The conclusions of this preliminary evaluation should allow any future evaluation to take advantage of the first law of serendipity: "In order to discover anything, you must be looking for something" (Ohle and Bates, 1981).

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[1]The state-of-the-art in mineral exploration requires that a comprehensive drilling program be a major part of the final (ultimate) resource evaluation in any area of high potential.

Our preliminary interpretation of the mineral resource potential of the Sierra Ladrones Wilderness Study Area and vicinity is summarized as explicitly as possible in Figure 7 (page 65).

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INTRODUCTION

Problem and Purpose

The Sierra Ladrones Wilderness Study Area (Ladron WSA) is a sixty-one square-mile "island" of undeveloped Federal land centered on the western flank of the rugged Ladron Mountains in central New Mexico. As appropriate for undeveloped land, the Ladron WSA does not contain any well defined mineral deposits of commercial significance. Yet, there are numerous mineral prospects, some small mines with recorded production, anomalously high metal values in arroyo sediments (National Uranium Resource Evaluation, NURE data), and other more subtle signs (e.g. known petroleum source beds at depth), all of which indicate a wide variety of economic mineral deposits may be concealed below the surface of the Ladron WSA. What type of mineral deposits? Where would they be found? How valuable could they be? What is the probability for discovery of a commercial mineral deposit?

The purpose of this report is to present a preliminary evaluation of the mineral resource potential of the Ladron WSA, which provides tentative answers to the above questions. The preliminary evaluation is based on a detailed analysis of geoscience data obtained from a thorough literature review and a brief field reconnaissance. From the start it should be made clear that the available data base is inadequate to make more than "order-of-magnitude" estimates of potential mineral value. The most important use of this report should be to define those areas of the Ladron WSA that warrant further detailed study and data collection, because they have a significant probability for

discovery of commercial mineral deposits.

Luchitta and others (1981) have summarized the newly appreciated reality of life on a finite earth.

> Limitations, tradeoffs and price: these are the attributes of the new reality. In today's closed system nothing is free, everything has a price. If I want this, I must expect to pay for it with that. To add here, I must take away there. There are no acquisitions only exchanges.

The administrator of the Ladron WSA (Socorro District Office of the U.S. Bureau of Land Management) may weigh this preliminary estimate of mineral value against wildlife, grazing, and wilderness values to determine the potential "price" of a Sierra Ladrones Wilderness, which would be closed to utilization of mineral resources. Determining the "price" for different types of land use is a serious and challenging task for all involved. How does one estimate the mineral value, or the wilderness value, of any area in comparable units--presumably dollars? Can, or should, wilderness values be measured in dollars? Natural resources play a key role in determining the economic stature and political power of all nations. The concept of preserving wild areas, primarily for recreational and conservational purposes, is relatively new. So far, wilderness areas play an uncertain role in our national well being. Some newly designated wilderness areas are so popular that a perpetual "visitor" population has become a jeopardy to maintaining wilderness values.

Location and Accessibility

The Ladron WSA is located in central New Mexico, on the west flank of the Rio Grande valley (Fig. 1). The towns of Belen, Socorro and Magdalena are respectively about 48 km to the northeast, 40 km to the southeast, and 32 km to the southwest of the WSA. The crossroads community of Bernardo is about 16 km east of the Ladron area.

The main routes of access to the WSA are graded dirt roads that extend from Interstate 25 at Bernardo and U.S. 60 at Magdalena to the settlement of Riley, which lies on the west margin of the WSA. Numerous ranch roads and jeep trails branch off of these main roads and lead to windmills, cattle tanks and mineral prospects within the boundaries of the WSA. Only a 12 square mile area of rugged terrain around Ladron Peak contains no access roadways. Permission to use roads through the Sevilleta National Wildlife Refuge is required to gain access to the Cerro Colorado area on the southeast flank of the WSA. During the summer thunderstorm season many of the dirt roads and trails are passable only with a four-wheel-drive vehicle. Perennially flowing portions of the Rio Salado (east of "The Box") should be crossed at moderate speed, since even four-wheel-drive vehicles have been known to sink to the frame in the oversaturated channel sands (quicksand).

Physiography

The Ladron WSA lies across a gradational boundary between the southeastern margin of the Colorado Plateau, underlain by Paleozoic and Mesozoic strata, and the western flank of the Rio

Grande rift, which is expressed by fault-block mountain ranges and intervening alluvial basins of late Cenozoic age. A significant change in the physiographic expression of the rift occurs at the Ladron Mountains. To the south, the rift appears as a wide zone of north-trending basins and ranges, and to the north the rift narrows into a singular looking "rift valley".

Landforms in the Ladron area consist of: 1) mountain peaks and canyons cut in granitic and metamorphic rocks of Precambrian age that form the core of the Ladron Mountains; 2) a hogback of west-tilted Pennsylvanian limestones along the western flank of the Ladron Mountains; 3) generally south-facing cuestas of Permian limestones and Cretaceous sandstones in the Riley area; 4) a broad travertine-capped mesa north of the Rio Salado; 5) a band of dendritic drainages and irregular hillslopes developed on beds of the Santa Fe Group along the flanks of the Rio Salado; 6) broad and/or locally dissected gentle slopes of coalescent alluvial fans (bajadas) of Pleistocene age, along the western and northern flanks of the Ladron Mountains; and 7) the narrow floodplain of the Rio Salado. A mile-wide band of rounded foothills along the eastern flank of the Ladron Mountains has been described by Condie (1976) as a zone of sheared and altered Precambrian rocks. This band of low hills may also represent an exhumed pediment surface, once mantled by alluvial fan deposits similar to those that form the hills east of the Lazy C Bar J Ranch (QTs, Fig. 2).

Elevations in the WSA range from 9,176 feet (2,797 m) at Ladron Peak to about 5,200 feet (1,585 m) in the Rio Salado just east of "The Box". Sparse desert vegetation consisting mainly of

creosote bush and varieties of gramma grass reflects the semiarid climate of lowlands in the WSA. An area of piñon/juniper forest is present around Ladron Peak above an elevation of about 6,500 feet (1,981 m). Also, small stands of Ponderosa Pine, Douglas Fir, and Aspen occur locally on the highest of north-facing slopes (Manthey, 1976). The forested area is indicative of a relatively cool climate and greater precipitation in the highlands.

Previous Geologic Investigations

Numerous publications and unpublished theses are available that describe various geologic aspects of the Ladron region. However, most of these references are of a reconnaissance nature and contain relatively little detailed information pertinent to the mineral potential of the Ladron WSA.

For this evaluation, the most informative geologic reports and maps were found to be: Black (1964), Condie (1976), Kelley and Wood (1946), Denny (1940), Bruning (1973), and Chapin and others (1979). Other reports and maps concerning the Ladron area are provided by Noble (1950), Duschatko and Poldervaart (1955), Haederle (1966), and Massingill (1971). Generalized geologic maps that include the Ladron area have been published by Winchester (1921), Darton (1928), Spiegel (1955), Dane and Bachman (1965), Kelley (1977), and Machette (1978). The Riley 15' quadrangle within Machette's 1978 compilation is taken from an unpublished map by G.O. Bachman (ca. 1977). The Riley Quadrangle includes all of the Ladron WSA.

When the above sixteen geologic maps are compared in areas of overlap, numerous discrepancies become apparent, indicating

several problem areas for additional study. The most notable problem areas involve: 1) the structure, "stratigraphy" (tectonic layering?), and age relationships of Precambrian rocks in the Ladron Mountains (cf. Noble, 1950; Black, 1964; Condie, 1976); 2) the correlation and structure of Paleozoic and Cenozoic strata in fault blocks along the east flank of the Ladron Mountains (cf. Denny, 1940; Black, 1964; Bruning, 1973; Kelley, 1977; Machette, 1978); and 3) the structure in Paleozoic rocks west of Ladron Peak (cf. Kelley and Wood, 1946; Machette, 1978).

The most informative description of mineralized areas in the Ladron Mountains is provided by Black (1964, p. 77-80). Cursory descriptions of the same and other mineral prospects are briefly presented by Noble (1950), Haederle (1966), and Condie (1976). Regional mineral surveys by Johnston (1928), Lasky (1932), Farnham (1961), and Hilpert (1969) provide some information on, respectively, fluorspar, copper-fluorspar, manganese and uranium prospects in the Ladron area. Collins and Nye (1957) summarize key observations from drill holes around the Jeter uranium mine.

Results of over a decade of detailed geologic mapping in the Socorro-Magdalena-Riley area are summarized in papers by Chapin and Seager (1975), Chapin and others (1978), and Chapin and others (1979). Combined, these papers provide a regional stratigraphic and structural framework applicable to problems in the Ladron area. Chapin's 1979 paper discusses the coal, uranium, oil and gas potential of the Riley-Puerticito area, which overlaps the southwest side of the Ladron WSA.

Geochemical data for Precambrian rocks from the Ladron Mountains may be found in Condie and Budding (1979), Cookro

(1978), and Farquhar (1976). D.L. White (1977) determined the age of the Ladron pluton as part of a Rb-Sr geochronologic study of Precambrian rocks in central New Mexico. Chemical analyses of trace elements in stream sediments and ground waters in the Ladron area have been tabulated by Planner (1980) and by Pierson and others (1981). Pierson's report also lists definitive trace element data on mineralized rocks from the Jeter uranium mine. Planner's and Pierson's reports are just two of hundreds of similar reports spawned by the Department of Energy's National Uranium Resource Evaluation (NURE) program.

Geophysical studies in central New Mexico have been focused on the Rio Grande rift. Numerous papers describing the geophysics and geology of the Rio Grande rift are found in a symposium volume edited by Riecker (1979) and a symposium field guide compiled by Hawley (1978). Cordell (1978) has summarized the geophysical setting of the Rio Grande rift. A regional gravity map (Cordell and others, 1978) and magnetic intensity map (Geometrics, 1973) of the Ladron area are available.

Many other papers pertinent to the Ladron area are cited in various sections of this report and listed in the References.

Present Investigation

The assignment is to "locate all known and indicated mineral resources" in the Ladron WSA on the basis of geoscience data obtained from a thorough literature review and a brief field reconnaissance. The key data gathered from the literature consist of geologic maps, locations and descriptions of surface mineral occurrences (some with chemical analyses and production

data), and trace-element geochemical analyses of 63 arroyo sediment samples plus 17 ground water samples collected in the Ladron area as part of the National Uranium Resource Evaluation (NURE).

Some additional information was obtained through a six-week field reconnaissance that was done to: 1) verify locations and descriptions of reported mineral occurrences, 2) spot-check geologic maps, and 3) make scintillometer surveys along traverses in areas of reported uranium mineralization. Thirty rock and vein samples collected during the reconnaissance were selected for chemical analysis. Siliceous vein materials and one conglomerate were fire-assayed to determine gold and silver content. Emission spectrography was used to determine trace element contents of four travertines and one limestone. Atomic absorption techniques were used to determine trace metal (Cu, Pb, Zn, Co, Ni, U) contents of a few key samples. Results of these analyses are listed in the Appendix and incorporated within appropriate sections of the report. As much as possible, the key data used in this analysis are presented "as received" in the figures and tables that accompany the report.

Analysis of the available data involved several steps:

1) formulating a rudimentary geologic history (geologic setting in a time framework);
2) grouping (classification) of similar mineral occurrences--presumably tied by genetic threads (e.g. oxide copper-uranium occurrences along the Jeter fault);

3) placing grouped occurrences (types of deposits) in time and space framework of geologic history (requires working interpretation of age of mineralization);

4) deducing a rudimentary working model (concept) for the genesis of each type of deposit--supported by authoritative literature;

5) using predictive capabilities of each model to outline a favorable area for discovery and to place limits on economic potential.

In practice, the first four steps were not completed in any specific order, and in some cases all steps were made implicitly (with no explanation). Depending on the degree of understanding (data base and concepts) for the different types of deposits, the analysis could be done in essentially one quick step (e.g. coal), begin and end with a concept (e.g. geothermal), or require complex chains of thought and reiterations through multiple working hypotheses (e.g. uranium-copper).

Geologic concepts are the most penetrating tool used in this hypothetical "look" for mineral resources below the surface of the Ladron WSA. Many of the conceptual models used here have been gleaned from a "state-of-the-art" volume honoring the 75th Anniversary of the Economic Geology Publishing Company (Economic Geology, 75th Anniv. Vol., 1981). The conclusions presented in this preliminary evaulation are not unequivocal, but they are geologically defendable on the basis of available data.

Perspective bias is an inherent part of any mineral resource evaluation based on an incomplete data base (Zwartendyk, 1981). Where critical information is lacking, we have been cautious not

to extrapolate significantly beyond the scope of the available data. However, to estimate the full mineral potential of any area requires an optimistic perspective bias, which seems appropriate in a preliminary study of this type.

Expression of Mineral Resource Potential

To express the possiblity that something exists, or does not exist, requires that the "something" be clearly defined. The U.S. Geological Survey defines a mineral resource as "a concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction is currently or potentially feasible" (U.S. Geological Survey, 1976). Mineral resources are dynamic quantities that exist only in a constantly changing frame of reference bound by fluctuating commodity prices, new technologies of extraction, and ongoing consumption (for a discussion of resource terminology and resource assessment see Harris and Agterberg, 1981).

As used here, the term "mineral resource" is synonomous with the term "economic mineral deposit", which Snow and MacKenzie (1981, p. 895) define as: "a deposit that satisfies minimum acceptable size (e.g. total revenue) and profitability (e.g. rate of return) criteria". In their evaluation of possible economic mineral deposits in the Canadian Shield region, Snow and MacKenzie (1981, p. 877) suggest a total revenue of at least 20 million dollars and a rate of return of at least 8 percent as minimum criteria for an economic mineral deposit. Obviously, the minimum size and profitability criteria acceptable to a large corporation, to a weekend prospector, and to the U.S. Government

would not be the same. For the purpose of this report we will assume that a profitably mineable deposit worth about $25 million in the ground (gross value in place) at current or foreseeable commodity prices is an economic mineral deposit of commercial significance. Assuming a nominal 20 percent loss of mineral value during the extraction process, such a deposit would yield Snow and MacKenzies' minimum total revenue of $20 million.

Potential mineral resources--that is, undiscovered economic mineral deposits--cannot be inventoried, they can only be guessed at. Most statistical methods that have been used in regional mineral resource assessments (see Singer and Mosier, 1981) are generally not appropriate for use in a small area like the Ladron WSA. Geologic analogy (comparison with known economic deposits) and simple subjective estimates of the capacity (e.g. volume) of a mineralization system are used in this preliminary evaluation of resource potential.

Types of products found in published resource assessments (Singer and Mosier, 1981) include: tons of rock and associated grade; gross value; potential (relative capacity); number of deposits by type; potential supply (tons recoverable), net value; and probability of one or more economic deposits. The primary expressions of mineral potential used for the Ladron WSA are: 1) the probability of discovery of one economic mineral deposit (for each type of mineral deposit indicated), and 2) a subjective estimate (educated guess) of the maximum gross value for some of the better known types of mineral deposits.

In his textbook entitled "Exploration and Mining Geology",

W.C. Peters (1978, p. 530) presents a summary of statistical data and educated opinions concerning the odds for success; that is, discovery of an economic mineral deposit. From this information, Peters makes the generalization which states:

> "... out of several hundred favorable sites for ore mineralization examined by geologists, one is likely to become an orebody. If the indications are strong enough for detailed surface investigation, one in 100; if attractive enough to drill, one in 50; after ore-grade mineralization has been verified, one in 10."

Peters also cites statistics from a regional exploration project in India (Operation Hardrock), which indicates that simply beginning with a large area (80,000 km^2) the odds for success are about one in 1,000. From exploration data in the Canadian Shield area, Snow and MacKenzie (1981) have estimated that 1 in 50 economic mineral occurrences (drill hole intercept of economic grade and thickness) becomes a successful mine. Under the most favorable conditions (e.g. exploration in an established mining district), the odds for success may reach 5 in 10 (Ohle and Bates, 1981).

For the purpose of this report, statements concerning the probability of discovery of an economic mineral deposit are based on the following list of guidelines (indications), which are in general agreement with the observations cited by Peters. Relative probability terminology used here (e.g. high, fair, nil) is given in parentheses.

Probability		Indication
10^{-1} (high)	-	drill hole intercept or exposure of ore-grade mineralization across mineable thickness;
10^{-2} (good)	-	area of known surface mineralization where geology is similar to that of known ore deposits;
10^{-3} (fair)	-	within region of known mineralization in favorable geologic setting;
10^{-5} (very low)[1]	-	within area with favorable geologic setting but no known mineralization;
10^{-6} (nil)	-	within area of unfavorable geologic setting (e.g. don't look for oil in granite or coal in lava beds).

It should be kept in mind that these probabilities are all numerically small (i.e. ore deposits are rare) and should be applied in a relative fashion to keep the proper perspective. For example, it would be bad news if your doctor said that you have a relatively low (1/10) probability of surviving an operation. But a mining company would be elated to have access

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[1] Note, there is a quantum jump in decreasing probability of success here because the absence of mineralization indicates some key break in the chain of geologic processes that form an ore deposit.

to land with a relatively high (1/10) probability for discovery of a multimillion-dollar ore deposit.

The frequency distribution of ore deposits, by any measure of size, is strongly skewed toward smaller deposits. Data presented by Snow and MacKenzie (1981, fig. 4) illustrate that for every ten ore deposits worth 10-20 million dollars (return after taxes) there is about one or two ore deposits in the 100-200 million dollar range. For our purposes we assume that a ten-fold increase in size of a potential ore deposit represents a ten-fold decrease in the probability for its discovery. There are many other factors (especially commodity price) that influence the actual numerical probability for discovery of an ore deposit (see Snow and MacKenzie, 1981; Ohle and Bates, 1981).

Estimates of the maximum gross value of potential mineral resources in the Ladron area are based on conceptual estimates of the capacity (e.g. volume) of the envisioned mineralization system (commonly limited by the volume of potential host rocks). Commodity prices used are from the May 1982 issue of Engineering and Mining Journal or from other relatively recent sources. Calculation sheets for these order-of-magnitude estimates are included in the Appendix. It is recognized that losses of 10 to 30 percent in mineral value, associated with standard mining and milling processes, must be subtracted from gross value to determine potential recoverable value. Subtracting these lost value percentages from our order-of-magnitude estimates of gross value would simply produce estimates of recoverable mineral value in the same order of magnitude.

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MINING AND EXPLORATION HISTORY

by R.W. Eveleth and R.M. North

Early Discoveries

The Sierra Ladrones (Spanish for "Thieves Mountains") are nearly as obscure and isolated today as they must have been to the Spanish, Mexican, and American miners of the nineteenth century. Some evidence exists that these mountains were prospected for minerals before the arrival of the Americans, during and after the Civil War era. For example, The Lone Star, El Paso, Texas, on March 4, 1882 (4:1) states: "An old Spanish mine has been discovered in the Ladron district, northwest of Socorro." A close examination of other newspapers from this period would doubtless reveal additional citations.

According to Jones (1904, p. 114), the first mineral discovery in the Ladron Mountains (Hanson district) was made in 1868 by an American prospector named Hanson. While American prospectors were doubtless present in the area at that time (Felipe Chaves papers, ca 1870), Hanson does not appear on the scene until ca. 1879-1880 (Socorro County claim records). Prior to 1879, claims were recorded only in the "Ladrones" district.

Although a "Ladrones mine" was located in 1866 by Francisco Armijo in the Sabinal district (location uncertain), the first claim in the Ladron Mountains appears to have been the Santa Iduvigen Lode, Domingo Jaramillo claimant, 1868 (Socorro County claim records). Curiously, no follow-up activity is recorded as a result of Jaramillo's discovery. Doubtless, renegade Indians represented a serious threat, which caused the prospecting

incentive to take a back seat to survival instincts.

Prospecting, prior to 1900, experienced its greatest activity during two periods: 1879-84 and 1895-97. Much time and effort were directed toward the district during the earlier period, with some 175 claims located. In 1880, a group notably headed by then Territorial Governor, Lew Wallace, was the single largest claim holder with nine claims. "Silver ores, Ladrone Mts" was prominently displayed on an 1882 map of the mineral regions around Socorro (Anonymous, 1882). The only two mineral surveys in the Ladron district were located during this period (Emma, M.S. 622 1/27/1882, and Lawrence, M.S. 631, 1/1/1883). The Lawrence Lode was eventually patented during 1890. Other prospects which attained some degree of prominence at this time were the Picotite lode, adjacent to the Lawrence (field notes, M.S. 631, and Bullion, 1885), and the "Blue mine" (Burchard, 1883, p. 607).

The second flurry of prospecting activity in the Ladron area apparently resulted from a late 1895 or early 1896 discovery which purportedly "uncovered a vein of lead ore that was eight feet wide ...containing... 40 percent lead and $12 in gold per ton" (equivalent to over 1/2 ounce gold per ton) (N.M. Bur. Immigration, 1896, Southwest Illustrated Magazine, 3/1896). While these discoveries resulted in predictions of great production from the district (Southwest Illustrated Magazine, v. II, no. 4, p. 187), little, if any, success seemed to result from them.

Based on the mineral survey locations (Lawrence and Emma lodes), most of this activity was concentrated in an area east

and northeast of Ladron Peak, in sections 22, 27, and 34, T. 3 N., R. 2 W., where numerous pits and shallow shafts may still be observed (Fig. 5). This long established silver mining district on the northeast flank of the Ladron Mountains lies within the proposed Ladron WSA. Historically, this silver district has become obscure, since it was overlooked in Lasky's (1932) report on ore deposits of Socorro County.

Prospecting efforts in the Ladron district were directed toward locating gold and silver minerals, namely the native forms plus argentite and chlorargyrite, usually associated with the lead and copper minerals galena, azurite, and malachite. Gangue minerals include quartz, calcite, and various oxidized compounds of iron and manganese (N.M. Bur., Immigration, 1881, p. 6). Jones (1904, p. 114) reported that "the district has never produced". However, it seems likely that small, hand-sorted shipments of silver-gold ore were probably made to local smelters during the earlier mining period. At that time no less than two smelters were competing for ore in nearby Socorro (unfortunately, no records are extant).

One other prospect, located about one mile west of Ladron Peak, may date from the earlier period. According to Herrick (1912) "a small amount of prospecting has been done [on the western slope of the Ladron Mountain] with rather interesting results." No other information regarding early prospecting on the western slope has been found to date.

Later Activity

In 1926, Juan D. Torres of Magdalena located the Marcia #1

claim in the southern Ladron Mountains near Cerro Colorado (SE1/4, SE1/4 Sec. 18, T. 2 N., R. 2 W.) and produced one car of metallurgical grade fluorspar. This prospect has since become known as the Juan Torres (Johnston, 1928, p. 125). Although the fluorspar is associated with copper carbonates and sulphides, "no attempt seems to have been made to recover the copper" (Lasky, 1932, p. 89). Some work may have been done after Lasky's visit, but no additional production is recorded (NMBMMR file data). Lasky (op. cit.) also mentioned an unsuccessful attempt to produce cement-copper by precipitation on scrap iron at the Rule Prospect, which is located in the Sevilleta Wildlife Refuge on the southeast flank of the WSA (Fig. 5).

Chapin and others (1979, p. 12-15) have summarized coal mining activity in the Riley-Puertecito area that apparently ceased by 1940. Two adits and several small pits are reported to be present in Cretaceous coal-bearing strata about one mile southwest of Riley (Sections 26 and 27, T. 2 N., R. 4 W.). The mine in Section 26 is described as being driven on a coal bed 4 feet 8 inches (1.4 m) thick. Most of the production, estimated to be a few hundred tons, was probably consumed in furnaces of Riley and Magdalena residents.

During the 1940's, when the need for manganese became crucial, several groups of claims were located in the vicinity of the Rio Salado on the southwest side of the Ladron Mountains (Farnham, 1961). These include the Romero Black Cat group in Sec. 5, T. 2 N., R. 4 W.; the Brown Mask group in Sec. 11, T. 2 N., R. 4 W.; the Black Mask group, Sec. 20, T. 2 N., R. 3 W.; the

McPhaul/Hackberry/Santa Rita group in Sec. 1 and 12, T. 1 N., R. 3 W.; and the Sarracino group in Sec. 12, T. 1 N., R. 3 W. In 1954, the Rio Salado group was located in Sec. 6, T. 1 N., R. 2 W. The latter four properties are within the Ladron WSA. Manganese production from these properties is listed in Table 1.

The most productive mining venture in the Ladron area was the Jeter uranium mine (also known as the Charley 2 mine), which is located just east of the WSA boundary (SW1/4, NE1/4, Sec. 35, T. 3 N., R. 2 W.). The workings consist of an open pit and an inclined shaft descending at approximately 25 degrees in an easterly direction from the bottom of the pit. Government records provided by W.L. Chenoweth (DOE, Grand Junction) show that the Jeter mine produced 8,826 tons of ore with an average grade of 0.33 percent U_3O_8 during its lifetime from 1954 to 1958. The Jeter mine is credited with production of 58,562 pounds of U_3O_8 and 3,202 pounds of V_2O_5 (op. cit.); this is equivalent to well over a million dollars worth of uranium at current prices ($20.75/lb U_3O_8, 5/82). The Jeter mine is the largest uranium producer in New Mexico outside of the San Juan Basin, which includes the Grants uranium region and the Shiprock district. However, in comparison, the deposits in the Grants region commonly contain reserves ranging from tens of million to a hundred million pounds of U_3O_8.

During the mid-1970's uranium boom, several mining companies conducted drilling programs east of the Jeter mine to intersect the gently dipping Jeter fault, which hosts the uranium mineralization. The fault was penetrated at appropriately shallow depths (M.N. Machette, oral commun., 1981). However, the

lack of further development suggests that the lenticular character of ore-grade mineralization at the Jeter mine (Collins and Nye, 1957) may be characteristic for much of the fault zone.

TABLE 1. Manganese production in the Ladron WSA (from Farnham, 1961). See text for location of claims.

	Year	Long Tons	Producing Claim	Average grade (percent Mn)
	1941-46	*	Black Mask	--
	1952-55	566	Black Mask	42
	1953-54	33	Santa Rita	22.8
	1955	9.9	Rio Salado	22.8
TOTAL	1941-55	608.9		

* production of two carloads reported

Active Mining Claims

Mining claims reported as currently active in the Ladron area (BLM files) include the early patent, M.S. 631 Lawrence Lode (Patent no. 16977 12/26/1890) and nine additional claims or claim groups. These claims and claim blocks are listed in Table 2 and their location is shown in Figure 5. The "J.C. group" and "Jeanne group" are believed to be for uranium, since they cover what would seem to be the apparent continuation of the Jeter fault along the north flank of the Ladron Mountains. Occurrences of barite (Duster #1-4 claims), silver-copper-lead-zinc (Silver King #1 claim), and gypsum (Z placer #1-4) have recently been staked. A fresh stockpile of barite found next to a shaft in the Duster claim block (SE1/4, NE1/4, sec. 34, T. 3 N., R. 2 W.) suggests some development work was done by Ranger Industries. At the present time, only minor prospecting and assessment work is being done in the district. Since the uranium market is now in a period of depression, it is likely that many uranium claims will lapse for lack of assessment work.

TABLE 2. Active Mining Claims in the Ladron WSA. See Figure 5 for approximate locations.

Claim Name		Date filed	BLM Lead File No.
Lawrence Lode (patented)	--	12/26/1890	--
Lubek #1	John A. Garcia	8/15/63	82023
JC #316-351,388-423,498	Roy E. Johnson	12/30/78	44814
Jeanne #64-126,137	Roy E. Johnson	1/02/79	44814
Duster #1-4	Ranger Industries	2/08/79	48346
The Three P's #1-27	Edward R. Pittman	6/15/79	67791
Z Placer #1-4	Donald Drake	12/10/81	99687
Silver King #1	George W. Green	2/19/81	105448
Ladronie	Glen R. Patrick	7/25/81	108311

GEOLOGIC SETTING

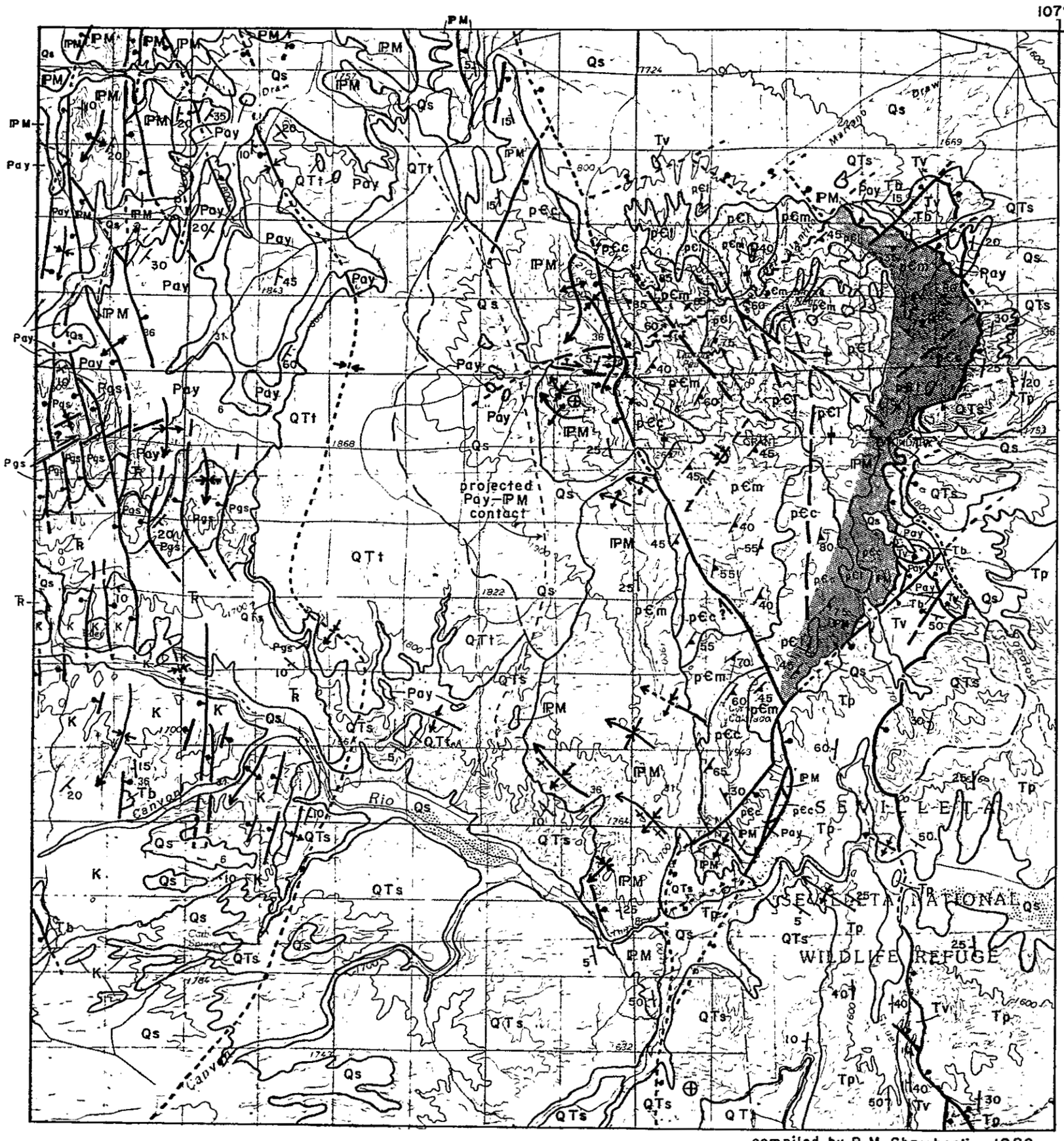
Late Cenozoic Rifting

The Ladron WSA lies across a zone of transition between the northwestern flank of the Rio Grande rift, an active zone of crustal extension, and the southwestern margin of the Colorado Plateau, a relatively rigid crustal block. Since the onset of rifting about 30 million years ago (Chapin, 1979), the Colorado Plateau has largely resisted crustal extension, although minor yielding is evident along its margins.

The Ladron area is also located on the northeastern periphery of the Datil-Mogollon volcanic field of Oligocene to early Miocene age (38-24 m.y.) Down-faulted and strongly tilted volcanic rocks along the eastern foot of the Ladron Mountains (Tv, Fig. 2, Table 3) represent a fragment of an apron of volcanic sediments and sheets of ash-flow tuff that once covered the entire Ladron area. The ash-flow sheets were erupted about 33 to 32 million years ago from a caldera complex that trends southwest from Socorro into the heart of the Datil-Mogollon volcanic field (Chapin and others, 1978).

Swarms of north-trending basaltic dikes in the Riley area (Ti, Table 3, Fig. 3) reflect an early stage of crustal extension contemporaneous with the waning of the Datil-Mogollon volcanism (Chapin and others, 1979). Radiometric ages (K/Ar) of the dikes (op. cit.) indicate that they are in part equivalent to numerous basaltic andesite flows (La Jara Peak Basaltic Andesite, Table 3) that cap the Datil volcanic pile in the Ladron area. Although not shown on geologic maps, similar north-trending basaltic dikes

Figure 2. GENERALIZED GEOLOGIC MAP OF THE LADRON AREA



compiled by R.M. Chamberlin, 1982

Approximate age (m.y.)		MAP UNITS*
<.5	Qs	Quaternary surficial deposits
1-3	QTt	Travertine
1-5	QTs	Sierra Ladrones Formation
7-25	Tp	Popotosa Formation
24-30	Ti	Basaltic dikes and sills (see Fig. 3)
24-38	Tv	Rocks of the Datil-Mogollon volcanic field
38-45	Tb	Baca Formation
85-105	K	Cretaceous rocks
195-210	TR	Triassic rocks
250-270	Pgs	Glorieta Sandstone and San Andres Limestone
270-280	Pay	Abo Formation and Yeso Formation
280-335	IPM	Pennsylvanian-Mississippian rocks
1300	p€l	Precambrian Ladron pluton
1600	p€m	Precambrian metamorphic rocks
?	p€c	Precambrian Capirote granitoid

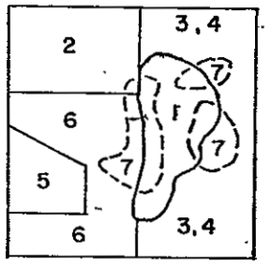
altered Precambrian rocks (Condie, 1976)

* See Table 3 for descriptions of map units

EXPLANATION

- contact
- fault, ball on downthrown side
- low-angle normal fault
- possible shear zone
- fold axes: anticlinal, synclinal, monoclinal
- strike & dip: bedding, foliation, joint plane

SOURCE INDEX



SOURCES:

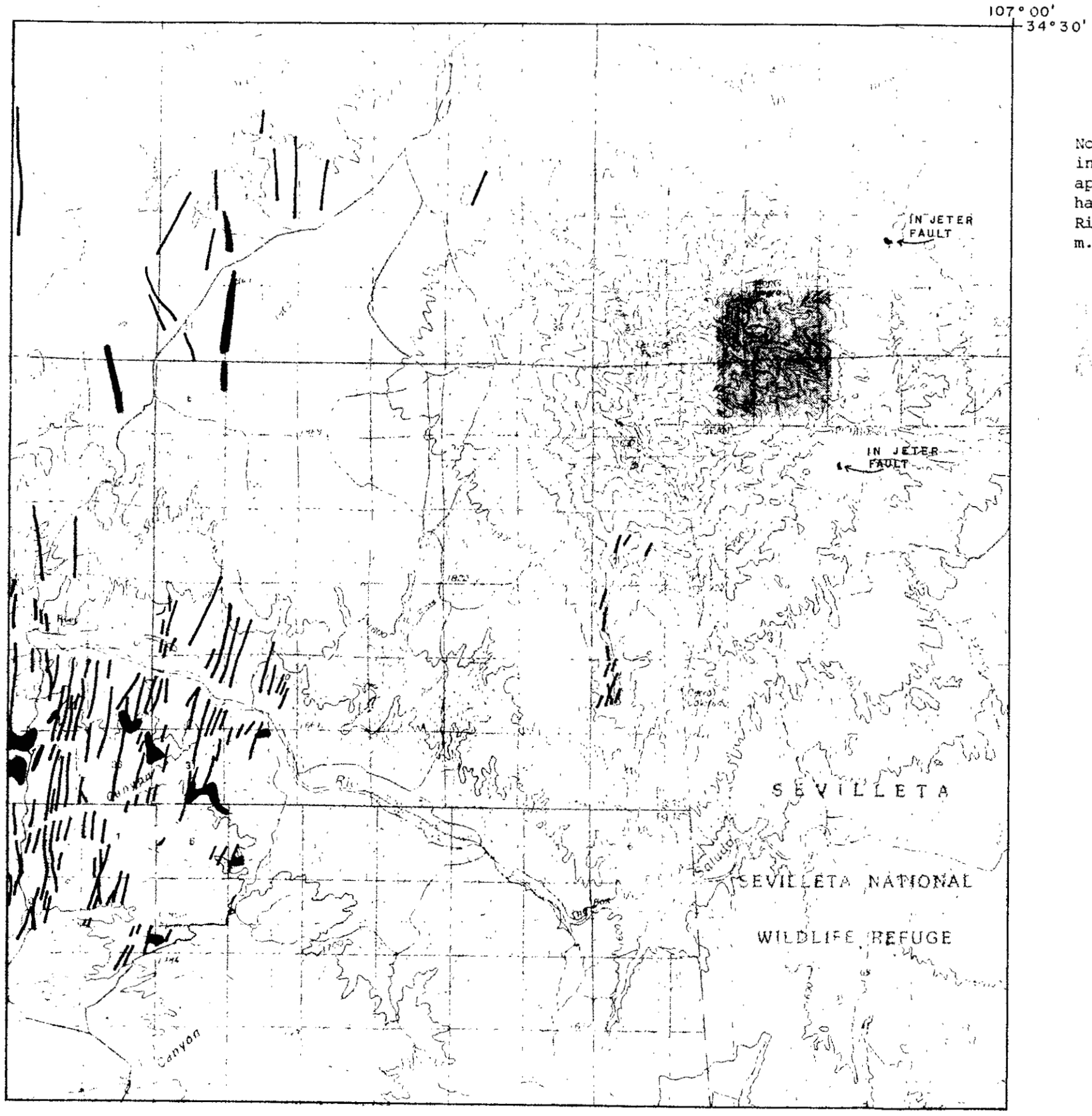
1) Black, 1964 (modified from Condie, 1976)
2) Kelley and Wood, 1946
3) Denny, 1940
4) Bruning, 1973
5) Massingill, 1979
6) Bachman, ca. 1977 (see Machette, 1978)
7) Reconnaissance, this report (9/81-10/81)

1 mi. 1 km

1:100,000

Topographic base from Magdalena 30'x60' quadrangle (USGS)
contour interval = 20 meters

Figure 3. BASALTIC DIKES AND SILLS IN THE LADRON AREA



Note: Most dikes and sills are basaltic in composition, with textures ranging from aphanitic to diabasic. Some wider dikes have monzonitic cores. Several dikes in Riley area have been dated as 24 to 27 m.y. old (C.E. Chapin, oral commun., 1982).

North-trending diabase dikes cutting Precambrian rocks are common in this area (Black, 1964). These dikes may be Tertiary or Precambrian in age.

1 mi. 1 km

1:100,000

TABLE 3. STRATIGRAPHIC AND ROCK UNITS OF THE LADRON AREA.

Map Symbol in Figure 2	
Qs	SURFICIAL DEPOSITS (Holocene and upper Pleistocene): Alluvial fan deposits, valley fill, talus, soil, and pedimont-slope gravels. Generally less than 10 m thick.
	UNCONFORMITY
QTt	TRAVERTINE (Pleistocene and Pliocene?): Crusted, banded, and fragmental travertine deposits related to ancient springs. Locally interbedded in QTs south of WSA Sec. 35, T. 1 N., R. 3 W.); unconformably overlaps Paleozoic rocks northeast of Riley. 1-8 m thick.
QTs	SIERRA LADRONES FORMATION (Pleistocene and Pliocene): Alluvial fan and piedmont-slope deposits; intertongues with alluvial flat and river-channel deposits east of study area. Piedmont facies is as much as 150 m thick. Clasts of Paleozoic and Precambrian rocks dominant.
	ANGULAR UNCONFORMITY
Tp	POPOTOSA FORMATION (Miocene): Bolson deposits; purplish-gray, buff, and tan; heterolithic; moderately to well indurated, coarse fanglomerate; grading into light-red to brown muddy siltstones and playa-facies mudstones. Playa facies at Silver Creek contains numerous lithium-rich ash beds altered to bentonite. As much as 1500 m thick. Clasts of volcanic rocks dominant.
Ti	BASALTIC, DIABASIC AND MONZONITIC DIKES AND SILLS (Oligocene and early Miocene; 24-27 m.y.): Basaltic dikes and sills with textures from aphanitic to diabasic. A few relatively wide (50-100 m) dikes have monzonitic cores. Several basaltic dikes in Riley area yield K/Ar ages of 24 to 27 m.y. old, which strongly suggests that they were feeder dikes to the La Jara Peak Basaltic Andesite (see Tv).
Tv	ROCKS OF DATIL VOLCANIC FIELD, UNDIVIDED (Oligocene to early Miocene): Includes La Jara Peak Basaltic Andesite. La Jencia Tuff, Hell's Mesa Tuff, and Spears Formation. Thicknesses of Tv units estimated from exposures in Sec. 22 (uns.), T. 2 N., R. 2 W. Ages of volcanic rocks from unpublished data of C.E. Chapin.

Table 3 (continued)

La Jara Peak Basaltic Andesite (24-32 m.y.)--Dark red to black, dense to vesicular, aphanitic lava flows with abundant small ferromagnesian phenocrysts altered to hematite and iddingsite. More than 300 m thick.

La Jencia Tuff (32 m.y.; new name, previously A-L Peak Tuff)--Moderately to densely welded, light gray, crystal-poor (sanidine, quartz) rhyolite ash-flow tuff. 30-50 m thick.

Hell's Mesa Tuff (32-33 m.y.)--Densely welded, crystal-rich, quartz-rich, two-feldspar, rhyolite ash-flow tuff. 15-25 m thick.

Spears Formation (33-37 m.y.)--Andesitic to latitic sandstones, conglomerates, and mudflow deposits. Approximately 200 m thick.

Tb BACA FORMATION (Eocene): In Riley area (250 m thick), consists of red-brown and grayish-red mudstones and siltstones. East of Ladron Mts (10-20 m thick), consists of coarse fanglomerates and debris flows with abundant sandstone clasts (Sec. 22, T. 3 N., R. 2 W.) and granitic clasts (NE/4, Sec. 15, T. 2 N., R. 2 W., uns.). Along eastern front of Ladron Mountains, "Tb" lies unconformably on Permian Abo and Yeso formations (Pay); west of the Ladrons, "Tb" rests unconformably on Cretaceous rocks (K).

UNCONFORMITY

K CRETACEOUS ROCKS, UNDIVIDED: Includes Crevasse Canyon Formation, Mancos Shale, and Dakota Sandstone.

Crevasse Canyon Formation (Upper Cretaceous)--Generally nonmarine sequence of yellowish-brown and greenish channel sandstones separated by gray to black shales, siltstones, and thin coal beds. Ironstone concretions common. Approximately 300 m thick.

Mancos Shale (Upper Cretaceous)--Interbedded light-gray to dark-gray marine shales and light-gray to yellowish-gray marine sandstones; includes minor limestones and silty sandstone. 250 to 330 m thick.

Dakota Sandstone (Upper Cretaceous)--Light-gray to yellowish-brown sandstone, locally bioturbated or cross-bedded and ironstained; interbedded at top with thin, carbonaceous shales. As much as 35 m thick.

UNCONFORMITY

TR CHINLE FORMATION (Upper Triassic): Red, pink, gray, and green shales and siltstones with minor gray, thin-bedded freshwater limestone and yellowish, arkosic channel sandstone. Locally includes a basal limestone pebble conglomerate. 350-380 m thick.

Table 3 (continued)

UNCONFORMITY

Pgs SAN ANDRES LIMESTONE AND GLORIETA SANDSTONE, UNDIVIDED (Permian):

San Andres Limestone (Permian)--Includes an upper limestone member of gray, medium-bedded limestone, gypsum, gray shale and sandstone, and a lower evaporite member of gypsum, gypsiferous sandstone, massive sandstone, and thick-bedded gray limestone. 120-145 m thick.

Glorieta Sandstone (Lower Permian)--Includes upper buff-white, massive, cross-bedded sandstone, middle gypsum and shale, and lower buff-white, massive, cross-bedded sandstone. As much as 25 m thick.

Pay YESO AND ABO FORMATIONS, UNDIVIDED (Lower Permian):

Yeso Formation (Lower Permian)--Includes upper member of gypsum and tan-brown sandstone, and lower member of tan-brown sandstone. 250-350 m thick.

Abo Formation (Lower Permian)--Nonmarine, reddish-brown, fine- to coarse-grained sandstone, siltstone, and shale with minor limestone. Locally contains chert-pebble conglomeratic sandstone (SE1/4, Sec. 15, T. 2 N., R 2 W., uns.). Approximately 250 m thick.

PM MADERA AND SANDIA FORMATIONS (Pennsylvanian) AND KELLY LIMESTONE (Mississippian), UNDIVIDED:

Madera Limestone (Middle to Upper Pennsylvanian)--Gray, thin- to thick-bedded, locally cherty limestone with gray and reddish-gray siltstone, shale and conglomeratic sandstone. 690-820 m thick.

Sandia Formation (Middle Pennsylvanian)--Upper slope-forming unit of yellowish-brown siltstones and shales; middle unit of gray to brown, medium- to thin-bedded sandy limestone; and lower unit of light gray, quartz sandstones, locally crossbedded. 120-125 m thick.

UNCONFORMITY

Kelly Limestone (Lower Mississippian)--Includes an upper gray, crinoidal, medium-grained limestone (Ladron Member of Armstrong and others, 1979) and a lower member (Caloso Member of Armstrong and others, 1979) which includes a basal sandstone-arkose-shale sequence followed by a series of fine-grained, cherty, algal and massive limestones. Quartz pebble conglomerates occur locally at base in Cerro Colorado area. 0-25 m thick.

Table 3 (continued)

UNCONFORMITY

p€l LADRON PLUTON (Precambrian, approx. 1300 m.y. old): coarse-grained, nonfoliated, light-gray to buff, two-mica (muscovite, biotite) quartz monzonite; and a late-stage, white-colored, two-mica, quartz monzonite. Intrudes p€c and p€m. Not strongly deformed.

p€m METASEDIMENTARY AND METAVOLCANIC ROCKS UNDIVIDED (Precambrian): Includes arkosic and siliceous metaarenites, metaconglomerates, porphyritic metarhyolites, amphibolites, phyllites, and mica schists. Metaarkose appears to unconformably overlie the Capirote Granitoid in NE1/4 Sec. 36, T. 3 N., R. 3 W. and in SE1/4 Sec. 6, T. 2 N., R. 2 W. Probably isoclinally folded; stratigraphy uncertain.

UNCONFORMITY(?)

p€c CAPIROTE GRANITOID (Precambrian): Heterogeneous unit of red to greenish-gray, medium-grained to coarse-grained, nonfoliated to foliated, granitoid rocks ranging in composition from quartz diorite to granite. Large, lenticular bodies of metamorphic rock that occur within the Capirote Granitoid may represent remnants of isoclinal folds. Some small blocks are clearly xenoliths of sediments that predated the Capirote granitoid.

(with diabasic textures) have been reported to cut Precambrian rocks throughout the Ladron Mountains (Black, 1964, p. 27; Haederle, 1966, p. 37). Two small diabasic intrusions that occur along the Jeter fault (Fig. 3) are clearly of Tertiary age. Relatively wide dikes, located about 3 miles north of Riley, locally have monzonitic cores. Dikes in the Ladron area occur in conjugate sets averaging N20E and N10W; thus the average direction of early crustal extension is interpreted to about 5 degrees south of east. There is no evidence of significant thermal metamorphism or hydrothermal alteration-mineralization

in association with the basaltic dikes (Chapin and others 1979; reconnaissance, this report). However, some minor talc mineralization is associated with contacts of the wider monzonitic dikes (Duschatko and Poldervaart, 1955; R.H. Weber, oral comm., 1982).

South of the Ladron area, ductile extension of the crust at depth has been accommodated at the surface by progressive slipping and rotation of closely spaced normal faults, which in cross section look similar to a train of fallen dominoes (Chamberlin, 1978). An area of 50-60 percent crustal extension in the Lemitar Mountains is associated with Oligocene volcanic strata (Tv) and Miocene sedimentary strata (Popotosa Fm.; Tp, Fig. 2, Table 3) that have been tilted 40-60 degrees to the west and displaced by numerous low-angle normal faults dipping 20-30 degrees to the east. Different directions, or amounts, of rotation in the field of domino blocks have been accommodated by scissors-like movement along northeast-striking (occasionally northwest striking) high-angle faults. Many of these transverse scissors faults follow segments of older basement structures, such as the Morenci lineament (Chapin and others, 1978).

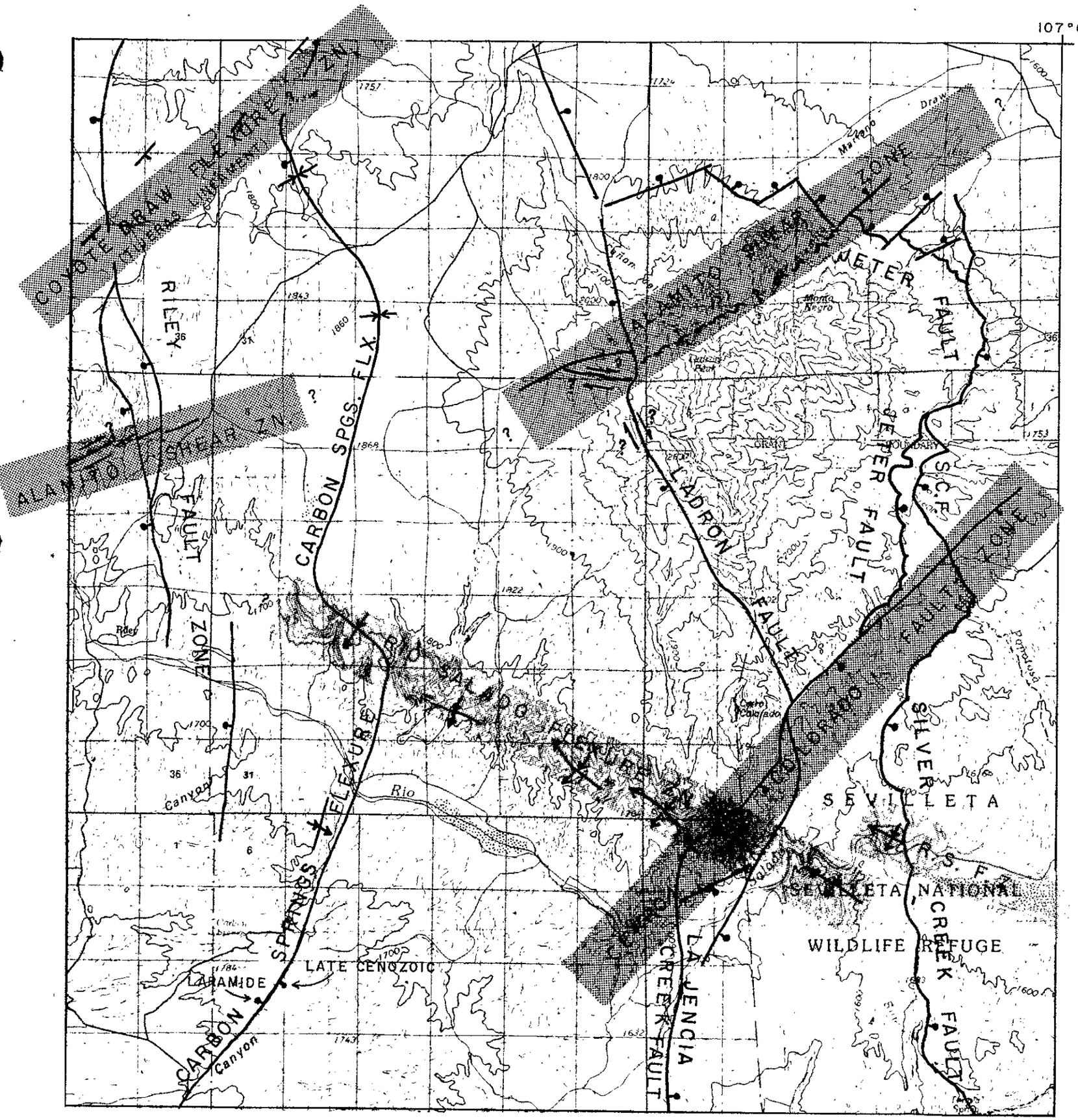
With this perspective, the Ladron Mountains appear to represent a resistant prong of the Colorado Plateau block that juts into the western side of the rift. Domino blocks bounded by the La Jencia Creek fault, the Silver Creek fault, and the Jeter fault (Fig. 4) have been rotated as much as 50 degrees to the west (Fig. 2), but the Ladron Mountain block cannot be rotated more than about 25 degrees to the west. This difference in block

rotation has been accommodated by scissors-like motions along the Cerro Colordo fault zone (Fig. 4). Thus a significant fraction of local crustal extension appears to have been deflected northeastward around the Ladron block. Down-to-the-east extensional movement along the southern end of the Carbon Springs flexure (Fig. 4) in Pliocene/Pleistocene time has apparently been transferred to (deflected along) the Rio Salado flexure (Fig. 4) as down-to-the-south movement. This deflection of late-stage extension around the south end of the Ladron block has created a sag-like basin filled in by as much as 150 m of the Sierra Ladrones Formation (QTs, Fig. 2, Table 3). The northern flank of the Ladron Mountains is apparently bound by northeast-trending scissors faults that parallel the Alamito shear zone (Fig. 4) of probable Precambrian ancestry.

Thus overall, the Ladron Mountains block has the appearance of a northeast-trending transverse horst block, which is superimposed on a westerly rotated fault-block uplift. A seismic reflection profile across the rift north of the Ladron Mountains (Brown and others, 1979, p. 174) has revealed the continuation of this transverse horst, where it plunges northeastward under the southern end of the Albuquerque basin.

Clast compositions, facies relationships, and paleocurrent directions in the Santa Fe Group (Fig. 2, Tp, QTs, QTt) south and east of the Ladron Mountains are consistent with the interpretation of episodic uplift and erosion of the Ladron Mountains-Riley block since early Miocene time (Denny, 1940; Bruning, 1973). However, the Precambrian/Paleozoic core of the Ladrons did not become a major topographic feature until late

Figure 4. MAJOR STRUCTURES OF THE LADRON AREA



Rift Faults:

- Jeter
- Silver Creek
- La Jencia Creek

} "domino" faults

- Carbon Springs (south of Rio Salado)

*Older structural grains:

- Northeast - Precambrian (pre-1.3 b.y.)
  Laramide
- Northwest - Late Paleozoic
  Laramide
- Northerly - Late Precambrian (∿ 1.3 b.y.)
  Late Paleozoic
  Laramide

*all older grains locally reactivated by rifting

Note: The Alamito shear zone, Rio Salado flexure zone, Carbon Springs flexure, Riley fault zone, and La Jencia Creek fault are new "names-of-convenience". They are tentative interpretations not found on maps predating this study.

1 mi. 1 km

1:100,000

Miocene or Pliocene time (Bruning, 1973). Coarse alluvial fan deposits of the Sierra Ladrones Formation (QTs, Fig. 2), which are rich in clasts of Paleozoic limestone and Precambrian granites, lie in angular unconformity on the Popotosa Formation (Tp, Fig. 2) in the area west of Silver Creek. Based on the well constrained age of the Popotosa Formation in the Socorro-Magdalena area (25-7 m.y.; Chamberlin, 1981a), the alluvial fan deposits shed from the rising Ladron Mountains are considered to be almost certainly less than 10 m.y. old and most likely are about 1-5 m.y. old.

The maximum aggradation of basins along the Rio Grande valley occurred prior to Middle Pleistocene time (Kottlowski, 1958). By Middle Pleistocene time, the Ladron Mountains were surrounded by an undissected apron of alluvial fan deposits as much as 150 m thick (QTS, Fig. 2). On the southwest side of the Ladrons the fan deposits lapped unconformably upslope onto Paleozoic limestones, and on the northeast side of the Ladrons the fans lapped upslope onto Precambrian granites and metamorphic rocks. Presumably, these alluvial fans graded eastward to the ancestral Rio Grande (Machette, 1978b).

This period of erosion, weathering and groundwater flow away from the core of the Ladron Mountains in Pliocene and Pleistocene times (ca. 5-1 m.y. ago) was clearly penecontemporaneous with the formation of several types of supergene mineral deposits on its flanks. Subsurface waters flowing to the south and west off the Ladrons carried significant amounts of calcium carbonate, iron, and manganese (Table 9), which were then precipitated in

discharge areas downslope.

The geometry and character of the travertine deposit (QTt, Fig. 2) on the west flank of the Ladrons indicates that it formed mostly from springs, which most likely issued from the toes of the limestone-rich alluvial fans where they overlapped less permeable rocks of the Abo Formation (Pay, Fig. 2). Thus the travertine deposit is thought to reflect a period of relatively high groundwater flux associated with a cool/wet climate at the onset of Quaternary continental glaciation (J.W. Hawley, oral comm., 1982). Some travertine mounds (spring vents) and high-grade manganese mineralization (Black Mask mine) were probably formed by waters locally rising along the Carbon Springs fault zone. Low-grade (iron-rich) manganese deposits, found near the Rio Salado Box, were probably associated with descending groundwater flow that entered solution caves and fractures in the underlying Pennsylvanian limestones.

Weathering (wetting and oxidation) of uranium oxide and copper sulfide-bearing Precambrian rocks along the crest of the Ladron Mountains during the past few million years most likely provided the uranium-copper rich ground waters that formed the Jeter uranium deposit (see Table 7). The extremely high uranium content (704 ppb) of well waters at the Lazy C Bar J Ranch (Pierson and others, 1981) strongly suggests ongoing weathering of high-grade uranium mineralization in Precambrian rocks west of the ranch.

Since middle Pleistocene time, the Rio Grande and its tributary, the Rio Salado, have cut downward through as much as 100 m of the upper Santa Fe Group (QTs) and, locally, into the

underlying formations. Lowering of the water table associated with this period of entrenchment has placed the uranium-copper deposits along the Jeter fault in an unstable position (in the zone of oxidation above the water table). Recent and present day activity of the Rio Grande rift is indicated by fault scarps that cut late Quaternary alluvium about 3 miles east of the Ladrons (Denny, 1940), and by swarms of microearthquakes on the northeast flank of the Ladrons (Sanford and others, 1979). The microearthquake activity has been interpreted as an expression of contemporaneous magma intrusion (A.R. Sanford, oral comm., 1982), which in turn suggests some geothermal potential exists in the Ladron area.

Pre-Rift Setting

Episodic uplift and erosion of the Ladron Mountains-Riley area over the past 30 million years has exposed the entire sequence of older strata and related structures that pre-date the rift. Obvious and subtle unconformities in the stratigraphic sequence (Table 3) separate and define major periods of crustal deformation in Precambrian, late Paleozoic, and late Cretaceous-early Tertiary time. However, the exact ancestry of major structures in the Ladron area (Fig. 4) is apparently masked by reactivation in different stress fields.

Precambrian rocks that form the core of the Ladron Mountains are about 1.6 to 1.3 billion years (b.y.) old (Condie and Budding, 1979). An older terrane of predominantly well foliated metamorphic rocks (pЄm) and foliated to non-foliated granitic rocks (Capirote granitoid pЄc) is generally recognized (Black,

1964; Condie, 1976) as being intruded by the relatively undeformed (non-foliated) Ladron pluton (p€l), which has been dated as 1.3 b.y. old (White, 1977).

Several features of the older terrane suggest that it was tightly to isoclinally folded prior to intrusion of the Ladron pluton. These features are: 1) lithologic layering and foliations are generally parallel (Black, 1964; Condie, 1976); 2) small amplitude isoclinal folds are visible in outcrops (Black, 1964; Haederle, 1966; Condie, 1976); 3) contacts of the Capirote granitoid that are parallel with foliations in the adjacent metamorphic rocks have been repeated many times at map scale and at outcrop scale (Black, 1964; Condie, 1976). Rocks of similar age and lithology in the Manzano-Los Pinos Mountains, are recognized as being isoclinally folded (Fulp and Woodward, 1981). Hobbs and others (1976, p. 252-264) point out that layering in isoclinally folded metamorphic rocks "closely resembles bedding, may contain genuine sedimentary structures, and appears to represent a simple stratigraphic sequence." If the older metasedimentary and metavolcanic rocks of the Ladrons are isoclinally folded, then the relatively simple stratigraphic relationships interpreted for these rocks by Condie (1976, 1980) may--in the words of Hobbs and others--"be entirely misleading". For this report, Black's (1964) interpretation of penetrative isoclinal folding of the Ladron metamorphic terrane is considered to be more likely and is presumed correct.

Broad warping of foliations in the older terrane, locally apparent northeast of Cerro Colorado and northwest of Ladron Peak

(Fig. 2), may represent another period of Precambrian deformation. The abrupt change from northeast to northwest striking foliations northwest of Ladron Peak is suggested here as the expression of a previously unrecognized shear zone formed in Precambrian time. The Alamito shear zone (Figs. 2, 4) presumably originated as a splay off the Tijeras lineament, a major northeast-trending basement structure of Precambrian ancestry (Chapin and others, 1979). The Alamito shear zone appears to have predated and locally influenced the boundaries of the Ladron pluton (Fig. 2).

Details of age relationships, pre-metamorphic character, and distribution of rock types in the older Precambrian terrane are not entirely clear (cf. Black, 1964; Condie, 1976; 1980). Black (1964) recognized two metasedimentary units, the Torres schist and the Blue Canyon Quartzite. Condie (1976) further subdivided the quartzite sequence, into units of feldspathic quartzite, arkosite, quartzite and conglomeratic quartzite; and subdivided the schistose rocks into phyllites, amphibolites, and siliceous metavolcanic rocks. Black (1964) had previously interpreted porphyritic textures in the "sericitic quartz schists" of his Torres Schist as porphyroblasts of metamorphic origin.

A reconnaissance traverse southwest of Canyon del Norte has confirmed the presence of rhyolitic metavolcanic rocks commonly containing rounded (resorbed) phenocrysts of quartz and euhedral phenocrasts of feldspar. However, neither Condie nor Black recognized that the Capirote granitoid here is separated from the schists and metavolcanic rocks by about 100 m of coarse-grained

meta-arkose that exhibits crossbeds and graded bedding (NE1/4, NE1/4, Sec. 36, T. 3 N., R 3 W.). Both Black (1964) and Condie (1976) reported that the Capirote granitoid intrudes the metamorphic rocks. Condie (1980) later reinterpreted the Capirote granitoid to be unconformably overlain by the metasedimentary sequence and to intrude the metavolcanic sequence. Observations in the Canyon del Norte area suggest that both the metasedimentary and metavolcanic rocks may unconformably overlie the Capirote granitoid. However, the Capirote granitoid clearly contains xenoliths of metasedimentary rocks about one mile southwest of Ladron Peak (NE1/4, SW1/4, Sec. 6, T. 2 N., R. 2 W.). The observed field relationships thus suggest a greater complexity for the older Precambrian terrane than described by either Black (1964) or Condie (1976, 1980).

Minor copper occurrences (oxides after sulfides) are reported to be scattered throughout the metamorphic terrane of the Ladron Mountains (Black, 1964, p. 77; Condie, 1976). Black interprets the copper sulfides to be of Precambrian age and describes them as occurring "along the schistosity or bedding planes". These known sulfide occurrences (Alamito Canyon prospect, Fig. 5) are the most likely source of supergene copper mineralization along the Jeter fault. Seemingly "minor" occurrences of this type, when placed in context with current geologic concepts (Gustafson and Williams, 1981; Meyer, 1981), suggest that a significant potential for economic deposits of stratiform polymetallic sulfides exists in the metamorphic terrane of the Ladron Mountains.

As mapped by Condie (1976), the "Capirote granite" consists

dominantly of quartz monzonite, but overall it has a wide range in composition from granite to quartz diorite (Cookro, 1978). Because of this heterogeneous character, it is referred to here as the "Capirote granitoid". Cookro's (1978) data indicate that disseminated fluorite occurs at several areas in the Capirote granitoid and at one location in the Ladron pluton (Fig. 5).

The Ladron pluton is a homogeneous quartz monzonite characterized by the presence of two micas, muscovite and biotite. In comparison, the Capirote granitoid contains only one mica, biotite. The presence of muscovite and biotite is a distinctive trait of the ilmenite-series granitoids (Ishihara, 1981). The so-called "two-mica granites" are often associated with tin-tungsten deposits and uranium deposits. The earliest indication of a north-trending structural grain in the Ladrons is expressed by aplite dikes and a northerly elongated stock related to a late stage of the Ladron pluton (Condie, 1976; Black, 1964).

The western portion of the Ladron WSA is underlain by 1480-1740 m (4850-5700 ft) of marine and continental sedimentary rocks deposited in late Paleozoic basins about 330-230 m.y. ago (Fig. 2, Table 3). Regional syntheses (RMAG, 1972; Kottlowski, 1963) indicate that central New Mexico was on the southern end of a northeasterly trending structural high of Precambrian ancestry that formed the backbone of the continent in early Paleozoic time. This persistent highland, known as the Transcontinental arch, was flanked by broad shelves, which were periodically inundated by transgressions of shallow seas. Region-wide transgressive-regressive cycles of sedimentation are respectively

attributed to epeirogenic (continent-wide) subsidence and uplift (Gross, 1972). However, numerous embayments and a few seaways across the arch in Cambrian time suggest some localized development of west-northwest trending and some northeast-trending structural troughs (Lochmann-Balk, 1972). By middle Paleozoic time, erosion had beveled the New Mexico portion of the Transcontinental arch to a surface of low relief. Early Paleozoic transgressions may have reached northward to the Ladron area, but presumably a thin Silurian-Devonian sedimentary cover was removed by minor uplift and erosion in the late Devonian to early Mississippian time (Kottlowski, 1963).

In conjunction with the block uplifts of the Ancestral Rocky Mountains (Kluth and Coney, 1981), Mississippian and Pennsylvanian seas moved northward into central New Mexico along a deepening trough between the Pedernal uplift on the east and the Zuni-Defiance uplift on the west. The Ladron area lies near the axis of an interior sub-basin, the Lucero basin, where Pennsylvanian rocks are 610-820 m (2000-2700 ft) thick (Kottlowski, 1963; Siemers, 1978). It is suggested here that the eastern side of the Lucero basin, which has a dog-leg geometry, may have been defined by episodic movement of north- and northwest-trending submarine fault blocks contemporaneous with deposition of the Sandia and Madera formations. Armstrong (1958, p. 14) recognized that some flexures and faults in the Cerro Colorado area deform only lower Mississippian strata and are unconformably overlain by middle Pennsylvanian strata of the Sandia Formation. Reconnaissance west of Cerro Colorado has revealed a series of small amplitude (1-10 m) monoclinal

flexures, (N60W, 45°SW), which preferentially downwarp the Mississippian strata to the southwest. A major high-angle reverse fault (150 m throw) of lower Mississippian to middle Pennsylvanian age, which originally had a northwest strike (similar to the structures near Cerro Colorado), has been mapped in the Lemitar Mountains (Chamberlin, 1982, Section C-C"). Much of the uplift of the Joyita Hills, relative to downwarped areas in the Ladrons and Lemitar Mountains, must have occurred in latest Pennsylvanian to early Permian time (Kottlowski and Stewart, 1970; Siemers, 1978). In this framework of regional and local observation concerning late Paleozoic structures, it appears reasonable that the en echelon pattern of northwest trending folds, west of the Ladron fault (Fig. 2), and the apparent oblique slip (down-to-west, right-lateral?) on the Ladron fault may have originated in Mississippian to early Permian time by generally northward directed compression. However, northeasterly directed compression during the Laramide orogeny (Chapin and Cather, 1981) may have reactivated these structures in a sense much like their inferred late Paleozoic movement.

Late Paleozoic rocks in the Ladron area have been divided into seven formations (Table 3). Overall, these formations represent an intertonguing sequence of shallow marine deposits (limestones, dark shales, and sandstones) interbedded with continental sediments (red beds) deposited in a hot/dry climatic regime (red mudrocks, sandstones, and gypsum). Terrigenous sediments of late Paleozoic age were derived primarily from

highlands to the north and east of what is now central New Mexico.

In Mesozoic time, the regional sediment source shifted to a highland in what is now southern Arizona and New Mexico, the Cordilleran highland. Triassic red beds of the Chinle Formation were deposited unconformably on the San Andres Limestone (upper Permian). Late Cretaceous sediments consist of intertonguing marine/nonmarine sandstones, shales, and minor coals. Coals and abundant carbonized plant debris in coastal plain deposits of the Mesaverde Group indicate that the prevailing Late Cretaceous climate was warm and wet. In central New Mexico, unconformities at the bottom and top of the Cretaceous sequence are associated with lateritic soils and weathering profiles apparently related to the waxing and waning of this warm and wet climatic period (Leopold, 1943; Chamberlin, 1981b). Some sandstone uranium deposits are spatially, and maybe genetically related to these hydrochemical weathering profiles.

In early Tertiary time the Ladron area (east of the Carbon Springs flexure) was upwarped as part of a Laramide highland (Chapin and Cather, 1981, figs. 1, 5). Near Riley, at the east end of the Laramide Baca Basin, the Baca Formation (Eocene) rests unconformably on Cretaceous rocks. However, on the north and east flanks of the Ladron Mountains, Baca-type sedimentary rocks (red sandstone-clast conglomerates and limestone-granite-clast conglomerates) rest unconformably on the Abo and Yeso formations (Permian). In both areas the Baca Formation is conformably overlain by a thick pile of Oligocene volcanic rocks, including ash-flow tuffs erupted from the Socorro-Magdalena area. Thus,

the Precambrian rocks of the present Ladron Mountains were most likely covered by an incomplete late Paleozoic section and a thick volcanic pile prior to the onset of rifting about 30 m.y. ago.

KNOWN SURFACE MINERAL OCCURRENCES

Conceptual Significance

Like links in a chain, both rocks and mineral resources within them are formed in stages by very normal (presumably simple, but complexly interacting) geologic processes (Meyer, 1981; Ohle and Bates, 1981). Surface mineral occurrences are the best indication that the genetic chain is complete and unbroken. Natural ore-forming systems are unaware of mankind's economic system; thus, noneconomic and economic mineral occurrences are often intimately related.

Most (90-99 percent?) metallic ore deposits (including uranium) are formed when water (universal solvent) is forced to flow through rocks (Cathles, 1981; White, 1981; Gustafson and Williams, 1981; Nash and others, 1981). Three situations are common: 1) cold/hot water convection cells around shallow igneous intrusions (porphyry's), 2) lateral expulsion of waters (warmed by earth's internal heat) originally trapped in basal strata of compacting (filling) sedimentary basins, and 3) infiltration of low-temperature ground waters moving down gradient to discharge areas (springs, rivers, oceans). Convection cells may also form around uranium-thorium-potassium-rich granites through periodic buildup of heat generated by radioactive decay (Cathles, 1981). These four hydrologic systems and related ore deposits may be respectively termed: magmatic hydrothermal, sedimentary hydrothermal, supergene, and radiogenic hydrothermal. Clearly, the boundaries of these systems are gradational, and other systems may be involved (metamorphism, resurgent boiling, etc.).

Most commercial geothermal systems are essentially active convection cells (some grade to lucrative vapor systems) around sites of recent or contemporary magma intrusion (White, 1981). In geothermal waters, the concentration of dissolved silica increases exponentially with the temperature of the rocks at depth (Levinson, 1974, fig. 8-8). Intense silicification and abundant siliceous veins are therefore considered to be distinctive traits of hydrothermal deposits (fossil geothermal systems; e.g., porphyry copper deposits), which are notably absent in low-temperature supergene deposits (e.g., sandstone uranium deposits).

The age of mineralization is often a key, but disputable, constraint on the origin of ore deposits. Nearly all ore deposits must be of the same age or younger than the enclosing host rock. Stratiform and stratabound mineral deposits (mostly parallel to layering), even though they may have clearly invaded the host rock after deposition, may have formed so shortly after deposition of the enclosing strata that they would be essentially of the same geologic age as the host rocks (Meyer, 1981; Gustafson and Williams, 1981). Deposits that are spatially associated with geologic structures (intrusions, unconformities, faults) are usually considered to be penecontemporaneous with the formation of the associated structures. Remobilization of ore deposits (by metamorphism, weathering, etc.), reactivation of structures, multiple episodes of related mineralization, and super position of unrelated mineralization events are theoretically viable (and sometimes demonstrated) processes that mask the true (original) age of ore deposits.

Distribution Patterns and Ages of Mineralization

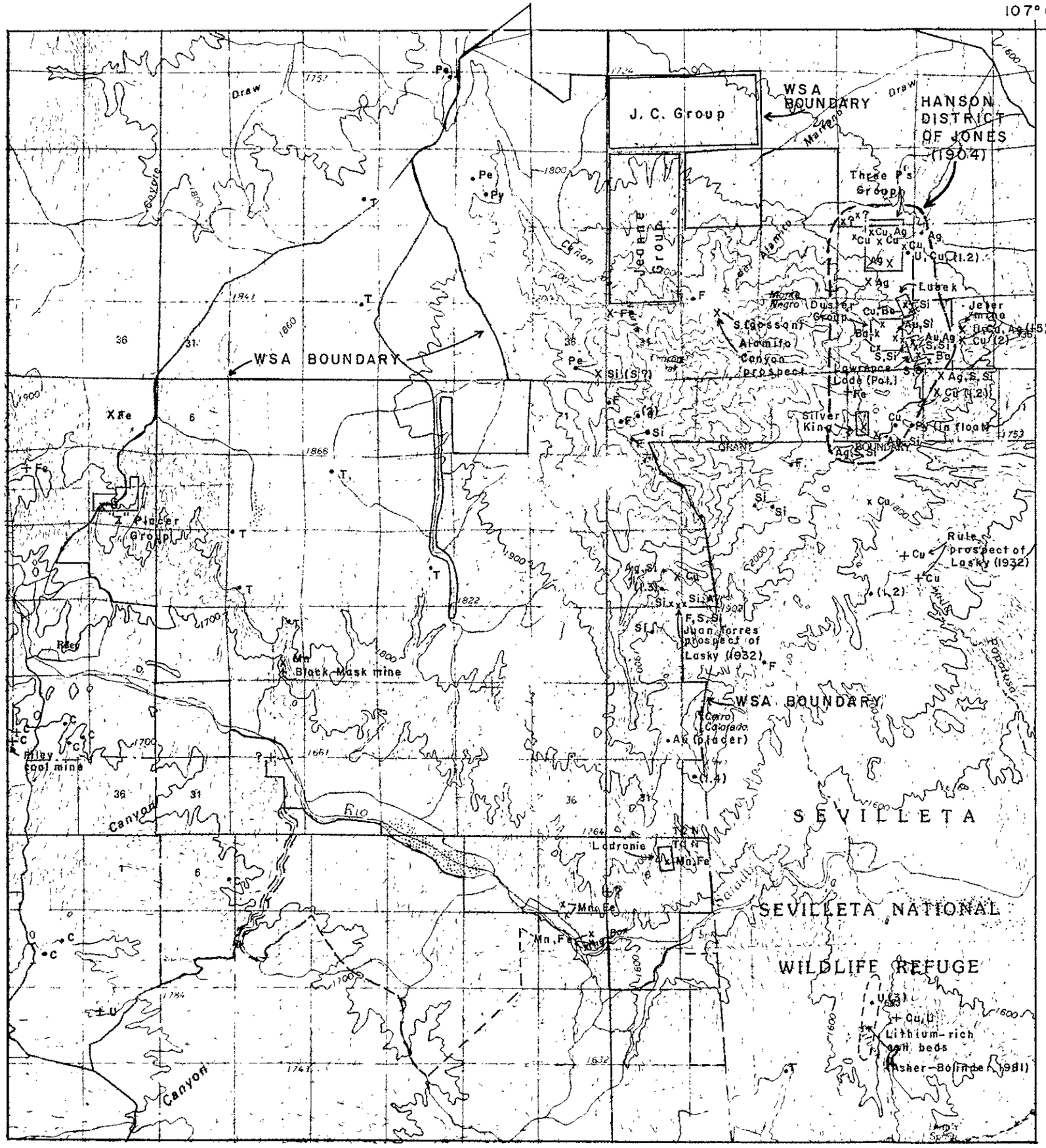
Locations and types of known surface mineral occurrences in the Ladron area are plotted in Figure 5. If all areas of surface mineralization were mapped in detail, and ocurrences accurately plotted, this map could easily show twice as many control points. For example, Black (1964, p. 77) and Condie (1976) report that copper occurrences (oxides after sulfides) are scattered throughout the Precambrian metamorphic rocks of the Ladron Mountains, but do not give exact locations.

If the mineral occurrence map (Fig. 5) is superimposed on the geologic map (Fig. 2), several important patterns of mineral distribution become apparent. The most obvious pattern is that the overwhelming majority of metallic (Cu, U, Ag) and nonmetallic (barite, fluorite) occurrences are found within Precambrian rocks forming the core of the Ladron Mountains.

Numerous occurrences of oxidized copper sulfides, described as being parallel to foliations and layering in metamorphic rocks (Black, 1964), probably represent the oldest known mineralization in the Ladron Mountains. Interpreting the copper sulfide occurrences as sedimentary or volcanogenic deposits of pre-metamorphic age (i.e. stratiform) seems to be the most reasonable explanation of Black's observations. The Alamito Canyon prospect (Fig. 5) is presently the only verified copper occurrence that appears to fit Black's descriptions.

Numerous quartz veins and silicification, indicative of hydrothermal mineralization, occur only in Precambrian rocks, with one notable exception. Silicified Pennsylvanian limestones

Figure 5. MINERAL OCCURRENCES IN THE LADRON AREA



Explanation

Type of Occurrence
- x Verified prospect
- + Unverified prospect
- · Unprospected mineral occurrences

Metal or Mineral

A	Amethyst
Ag	Silver
Au	Gold
Ba	Barite
C	Coal
Cu	Copper oxides and carbonates
F	Fluorite
Fe	iron
G	Gypsum
Mn	Manganese
Pe	Petroliferous limestone
Py	Pyrite
S	Base metal sulfides
Si	Silicification; quartz veins
T	Travertine (sampled locations)
?	Unknown
U	Uranium
(1.2)	Gamma radiation anomaly (hundreds of counts per second)

Note: Copper sulfide occurrences are scattered throughout Precambrian metamorphic rocks (Black, 1964, p. 77)

Active Mineral Claim or Group (location approximate)

Unverified occurrences from:
1) Black, 1964, p. 57, 77 (sulfides)
2) Cookro, 1978 (fluorspar)
3) Massingill, 1979 (coal)
4) Pierson and others, 1981 (uranium)
5) R.H. Weber, oral commun., 1982 (copper at Rule Prospect)

1 mi 1 km

1:100,000

occur along the Ladron fault, about one mile west of Ladron Peak. The siliceous vein networks (southern two-thirds of Hanson District, Juan Torres prospect area, etc.) are not associated with any known porphyritic intrusions. Siliceous veins locally carry economically interesting amounts of silver (10 oz/ton) along with base-metal sulfides, barite, fluorite, and subeconomic gold (0.02 oz/ton). Siliceous veins in the Hanson district locally extend up to, but do not cross, the range bounding the Jeter fault of Cenozoic age. Since the hydrothermal silicificaion and vein networks may be as young as Pennsylvanian, but not as young as late Cenozoic, they are tentatively interpreted to be of late Paleozoic age (Laramide age possible, but less likely). These silica/sulfide systems may be of radiogenic/sedimentary hydrothermal origin (contemporaneous magma intrusions not required).

Known magmatic intrusions of the Ladron Mountains are Precambrian in age, equigranular in texture, and apparently deep-seated. Pegmatite and aplite dikes (hydrothermal features) are reported to grade laterally into massive quartz veins (Black, 1964). These magmatic hydrothermal veins of probable Precambrian age, presumably barren, could be confused with other siliceous veins.

Numerous copper-uranium occurrences along the Jeter fault, and copper mineralization at the Rule prospect (Lasky, 1932) are clearly of middle to late Cenozoic age. Silica veins and/or silification are <u>not</u> associated with any of these copper-uranium occurrences. Zonation of metals in the Jeter uranium deposit provides strong evidence of a supergene origin (Table 7).

Copper/uranium-rich ground waters that most likely formed the Jeter deposit could only have come from weathering (oxidation) of copper sulfide-rich and uranium oxide-rich Precambrian rocks in the core of the Ladron Mountains. Precambrian stratiform copper sulfides are the most likely source of base metals in the Jeter deposit. Uranium in the Jeter deposit may have been derived from high-grade mineralization peripheral to the copper sulfides, or from vein-type deposits in granites, or from uranium-oxides disseminated in granites. None of these possible uranium sources in the core of the range have been verified.

Travertine deposits (QTt, Fig. 2) and the commercial-grade Black Mask manganese mine, that occur on the west flank of the Ladrons, are clearly of late Cenozoic age. Noneconomic iron-manganese occurrences near the Rio Salado Box occur in limestones of the Madera Formation (Pennsylvanian), but only where overlying late Cenozoic conglomerates (QTs) have been removed by Quaternary erosion. The travertine/manganese/iron-manganese occurrences most likely represent a cogenetic, supergene mineralization system formed by ground waters flowing off the western flank of the Ladron Mountains.

Several other types of mineral occurrences in the Ladron area represent accumulations at the time of sedimentation. One occurrence of placer-type gold (subeconomic, 0.01 oz/ton) was found in a basal conglomerate of Mississippian age near Cerro Colorado. In the Navajo Gap area, limestone beds of the upper Madera Formation (Pennsylvanian) have a weak petroliferous odor, indicating that they were originally rich in organic material.

Permian formations northeast of Riley contain thin gypsum beds. Nonmarine sandstones and shales of Cretaceous age are known to contain thin coal beds (southeast of Riley).

Two types of known mineral occurrences on the periphery of the WSA do not project (geologically) into the WSA. These are sandstone uranium occurrences in the Baca Formation (south of Riley) and lithium-rich ash beds in the Popotosa Formation (Silver Creek area).

In summary, known mineral occurrences in, or adjacent to, the Ladron WSA represent economically interesting concentrations of copper, uranium, silver, barite, fluorite, manganese, and travertine (high-calcium limestone used to make cement). Known occurrences of placer gold (late Paleozoic), gypsum, coal, iron-manganese, and amethyst (Condie, 1976) are not likely to be of economic significance. Multiple episodes of metallic mineralization probably took place in Precambrian, late Paleozoic, and late Cenozoic time.

INTERPRETATION OF "NURE" GEOCHEMICAL DATA

As part of the National Uranium Resource Evaluation, samples of stream (arroyo) sediments, ground waters, and bedrock were collected in the Ladron area. These samples were then chemically analyzed to determine concentrations of uranium and a large suite of other elements (Planner, 1980a; Pierson and others, 1981). Except for recognition of uranium anomalies (in sediment and ground water) on the northeast flank of the Ladron Mountains (Pierson and others, 1981, p. 51-59), the NURE data for the Ladron area has not been utilized as a guide to evaluating mineral resource potential. Our interpretation of the NURE data is based on principles of exploration geochemistry, provided by Levinson (1974, p. 193-222). Levinson (1974, p. 210) recognizes three possibilities for a geochemical anomaly (value above "normal" background values): 1) it may reflect an economic mineral deposit--real anomaly, 2) it may reflect a subeconomic mineral deposit-false anomaly, 3) it may reflect contamination, sampling, analytical errors, or some other feature not related to mineralization--false anomaly. There is no guaranteed way to distinguish a real anomaly from a false anomaly. Also noteworthy is the fact that economic mineral deposits have been discovered in geochemical survey areas where the values were essentially normal--a phenomenon known as "blank out" (Levinson, 1974, p. 209).

Table 4 and Figure 6 summarize analytical data (Planner, 1980a) for 24 elements in 63 arroyo sediment samples collected in the Ladron area. Anomaly thresholds for each element were chosen

TABLE 4. Summary of stream sediment geochemical data for 24 elements in 63 samples from the Ladron area (data from Planner, 1980a). Values in ppm. See Fig. 6 for sample locations.

Element	Detection[1] Limit	Range in[2] Common Rocks	Range in Ladron Sediments	Anomaly[3] Threshold	Number of Anomalies
Ag	5	.04-1	all < 5	.5	? + 0
Au	.04-.1	.004-.005	all < .04-.1	.03	? + 0
Ba	∿110	100-700	359-998	900	4
Be	1	.5-5	<1-5	4	4
Bi	5	.1-.18	one value: 6	.4	? + 1
Ce	5	10-50	26-129	95	4
Co	∿1.1	1-50	3.8-38	30	1
Cr	∿7	4-200	25-308	190	2 *
Cu	10	10-100	11-163	45	2
La	7-10	6-36	<10-51	45	2
Li	1	10-60	12-99	75	3
Mn	∿90	500-2200	290-1506	750	5 *
Nb	20	∿20	all < 20	20	0
Ni	15	.5-150	<15-51	60	0
Pb	5	5-20	<5-43	30	4
Sb	1-2	.2-1	one value: 1	1	1
Sn	10	1-4	one value: 12	5	? + 1
Ta	1-2	.5-3.5	three values: 2,2,3	2	3
Th	∿1.3	2-17	4.1-36.6	21	4
Ti	∿880	400-9000	2282-11760	10,000	2 *
U	.01	.6-4.8	1.93-6.62	4.5	7
V	∿20	15-250	34-358	225	1
W	15	.5-2	four values: 15,16,16,24	4	? + 4 *
Zn	10-120	25-100	37-246	150	3 *

[1]lowest detectable concentration of element for given analytical method

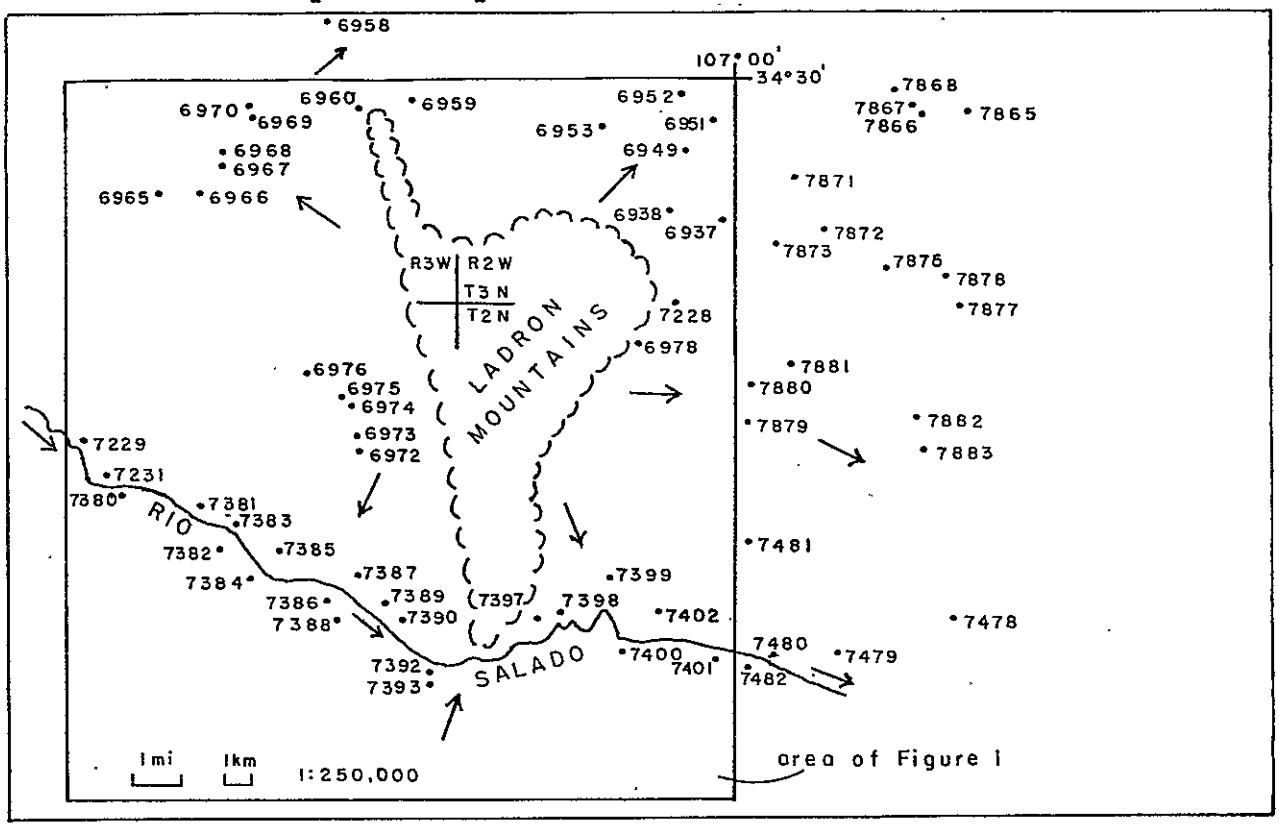
[2]range of average concentration in basalt, granodiorite, granite, shale, and limestone; from Levinson (1974, Table 2-1)

[3]visual inspection of data sets indicates that these thresholds eliminate the lower 95 percent of the total 1384 sediment samples collected in the Socorro $1^{\circ} \times 2^{\circ}$ quadrangle (Planner, 1980a)

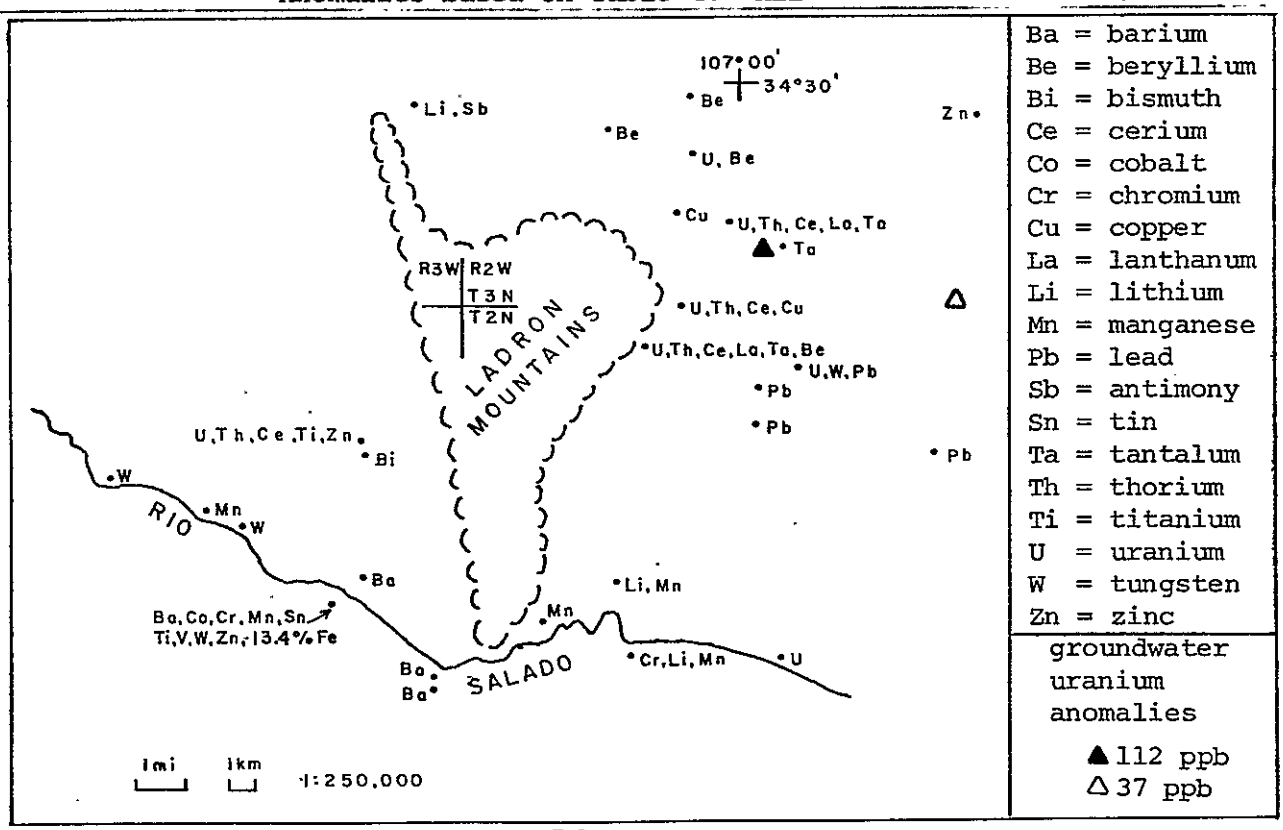
*highest Cr, Mn, Sn, Ti, V, W, Zn, (also Co, Ni) in the Ladron area are all in sample no. 7386

Figure 6. Stream sediment sample locations and geochemical anomalies in the Ladron area.

A. Location and identification number for 63 stream sediment samples in the Ladron area (from Planner, 1980a). Arrows indicate general downstream direction of drainages in the area. Base map from 1° x 2° Socorro quadrangle. All samples have prefix "0-N1".



B. Location of stream sediment anomalies in the Ladron area. Anomalies based on Table 4. All data from Planner (1980a).



by visual inspection to eliminate the lower 95 percent of the total 1384 sediment samples in the Socorro quadrangle. Gold and silver thresholds are based on surveys in the Mogollon Mountains (Gila Wilderness), an area of known precious metal mineralization (Rattè and others, 1979). The distribution of stream sediment anomalies in the Ladron area is shown on Figure 6A. The possible significance of this map (and Table 4) is as follows.

Gold - Silver - Antimony

Detection limits of analytical methods used in the NURE survey (Table 4) are too high to "see" economically significant distribution patterns of gold and silver (see Rattè and others, 1979). Although minor in volume, silver-gold-bearing veins (Table 9) along the northeast flank of the Ladron Mountains are not revealed in sediments emanating from this area. In other words, economic gold-silver mineralization in the Ladron WSA could easily go undetected on the basis of the NURE stream sediment data. One slightly anomalous value of antimony (1 ppm), a pathfinder element for gold (Levinson, 1974), is located southeast of Navajo Gap.

Uranium - Copper

Stream sediments emanating from the northeast flank of the Ladron Mountains are distinctly anomalous in uranium (4.57 - 5.39 ppm) and copper (46-163 ppm). Based on their own stream sediment data, Pierson and others (1981, p. 52) state that:

> "The uranium anomaly associated with the area of the Jeter Mine is real, in that it is not a false anomaly due to a generally higher uranium background in the Precambrian rocks. This is confirmed by the

consistently lower stream-sediment uranium concentrations associated with all other Precambrian terranes in the Socorro quadrangle. The highest uranium concentration is located up-drainage from the Jeter Mine [in Precambrian terrane], implying that more ore-bearing terrane may be in the vicinity".

Ground waters emanating from the northeast flank of the Ladron Mountains are also highly anomalous in uranium content: 37-112 ppb -- parts per billion (Planner, 1980a); and in a more detailed survey 17-704 ppb (Pierson and others, pl. 4B, app. B-2)[1]. Water from a well (windmill) collared in Precambrian rocks at the Lazy C Bar J ranch house contains an extremely anomalous concentration of 704 ppb (0.7 ppm) uranium.

For comparison, most ground waters in the Socorro quadrangle contain about 0.2 - 10.0 ppb uranium; and ground waters from uranium mines in the Grants area contain 1 - 26 ppm uranium (1000-26,000 ppb) (EPA, 1975). In subsurface waters uranium concentrations of greater than 100 ppb are rare, and have generally been found only in aquifers containing high-grade uranium mineralization (Rich and others, 1977). Based on their groundwater data, Pierson and others (1981, p. 59) concluded that:

"These results strongly suggest that there is considerably more uranium ore in the area than has been removed from the Jeter deposit. This area demands considerably more fieldwork and a detailed water and stream sediment survey; this should help delineate the favorable ground in more detail".

---

[1] See Appendix of this report for maps (Figures 8A-8C) showing plots of ground-water uranium and sulfate data of Pierson and others (1981).

To the interpretations of Pierson and others, we would add that copper-uranium occurrences along the Jeter fault (including Jeter Mine) represent a "displaced geochemical anomaly" (Levinson, 1974, p. 13) formed by metal-rich ground waters flowing eastward off the Ladron Mountains about 1-3 m.y. ago (see Table 7). The metal-rich ground waters most likely formed through weathering (oxidation) of copper sulfide-rich and uranium oxide-rich Precambrian rocks situated under the crest of the range (see p. 70-80). Stream sediment copper anomalies are not as widespread as uranium, because copper is not mobile in the alkaline surface environment. In summary, strong uranium and copper anomalies emanating from the northeast flank of the Ladron Mountains could easily be "real" anomalies that reflect economic copper sulfide and uranium oxide deposits in the adjacent Precambrian terrane.

Thorium - Cerium - Lanthanum - Tantalum - Beryllium

Most uranium anomalies in stream sediments around the Ladron Mountains are associated with anomalous values of thorium (24.3-36.6 ppm), cerium (95-129 ppm), lanthanum (50-51 ppm), tantalum (2-3 ppm), and beryllium (4-5 ppm). Accessory minerals (e.g. allanite, zircon, etc.) in granitic rocks and/or pegmatites related to the Ladron pluton (Fig. 2) are the most likely source of this element association. Stream sediments high in uranium (often 5-15 ppm) and thorium (often 20-45 ppm) are associated with many Precambrian granitic plutons in central and southern New Mexico (compare data of Green and others, 1981, pl. 4; Berry and others, 1982, pl. 4; and Union Carbide, 1981, pl. 1; with

locations of Precambrian granitic plutons given by Condie and Budding, 1979). However, the Precambrian terrane of the Ladron Mountains appears to be unique as a source of soluble uranium, as expressed in the highly anomalous uranium content of associated ground waters, which is not typical of the other uranium-thorium rich granites of New Mexico. The exact source(s) of soluble uranium, presumably high-grade uranium oxides, cannot be determined at present. Both the Ladron pluton and the adjacent metamorphic rocks are reasonable (but unverified) sources of soluble uranium. Pegmatites in the Ladron Mountains are not strongly zoned (internally differentiated; Black, 1964) and therefore are probably not good candidates for economic tantalum or beryllium deposits.

Tungsten - Bismuth - Tin

Detection limits of analytical methods used in the NURE survey (Table 4) are too high to "see" all but the higher anomalous values of tungsten, bismuth, and tin. Two arroyo systems (east and west of the Ladrons) that radiate from a granite/metamorphic terrane, about one mile south of Ladron Peak, carry anomalous values of tungsten (16 ppm) and bismuth (6 ppm).

Another possible source for the high tungsten value could be the fluvial facies of the ancestral Rio Grande (Sierra Ladrones Formation). However, Planner's data (1980a) along this portion of the Rio Grande Valley do not show other tungsten anomalies that could be derived from the ancestral river deposits.

An exposure of unusually coarse-grained granite (plug-like?) mapped in the area southwest of Ladron Peak (Condie, 1976) is

reported to contain "primary" disseminated fluorite, 0.1 - 0.6 volume percent (Cookro, 1978). The possible derivation of anomalous tungsten and bismuth values from a fluorite-bearing granite suggests that a greisen or vein-type tungsten-bismuth-tin(?) occurrence may be present in the Ladron WSA. Anomalous tungsten and tin values near the Rio Salado could reflect mineralization outside the WSA, in the Magdalena and/or Bear Mountains. Surface occurrences of tungsten and bismuth have not been reported in the Ladron Mountains. Additional geochemical sampling and mapping are needed in this area to locate the tungsten-bismuth source(s).

Manganese

Manganese values in stream sediments of the Ladron area are highest (783-1506 ppm) in the general area of known manganese occurrences along the Rio Salado. However, the high manganese values are not very conclusive. One of the lowest anomalous values (789 ppm Mn) occurs in a drainage less than a mile downstream from the commercial grade manganese deposit at the Black Mask mine. This value (789 ppm Mn) is a borderline anomaly, not clearly above regional background.

Chromium - Cobalt - Nickel

The highest values of chromium (308 ppm, 198 ppm) and cobalt (38 ppm) are found south of the Rio Salado, in drainages emanating from basaltic terrain (La Jara Peak Basaltic Andesite, Table 3). Higher, but not clearly above background, values of nickel (51 ppm, 37 ppm) are associated with elevated chromium and cobalt. A

flow near the base of the La Jara Peak Basaltic Andesite in the Bear Mountains is known to contain as much as 468 ppm chromium, 50 ppm cobalt, and 168 ppm nickel (Bornhorst, 1980, p. 972-985). The highest values of chromium, cobalt, nickel, manganese, vanadium, titanium, tin, tungsten, and zinc in the entire Ladron area are all found in one sample, number 7386 (Fig. 6, Table 4). This sample also contains unusually high iron (13.4 percent, vs. about 5 percent for most samples), which explains the high overall metal content. Iron and manganese oxides have a high capacity to attract metals by adsorption (Levinson, 1974, p. 205). The high chromium-cobalt values are considered to reflect uneconomic concentrations in basaltic rocks, exposed on the southwestern periphery of the Ladron WSA.

Barium - Lead - Zinc

Weakly to moderately anomalous values of barium (905-998 ppm), lead (30-43 ppm), and zinc (157-246 ppm) are present in drainages emanating from the Ladron Mountains (Fig. 6A). However, the source of these metal values need not be strictly from the Ladron Mountains. Lead values on the southeast side of the Ladrons could be related to underlying playa deposits of the Popotosa Formation. Barium values along the Rio Salado have several possible sources: 1) the travertine caprock (QTt, Fig. 2, Table 9), 2) unusually barium-rich basaltic rocks (1148-1974 ppm Ba; Bornhorst, 1980, p. 972-985) of the La Jara Peak Basaltic Andesite in the Bear Mountains, or 3) undiscovered barite mineralization in Pennsylvanian limestones along the Rio Salado. The latter does not seem likely since the Rio Salado area has

been extensively prospected for manganese. Some barite mineralization is known to occur in fault gouge of the Silver Creek fault south of the Rio Salado (R.H. Weber, oral commun., 1982), but the high barium values along the Rio Salado are upstream from the Silver Creek fault. Therefore, these observations are probably not related. Known barite veins, albeit minor, on the northeast flank of the Ladron Mountains (Fig. 5), are not revealed by the NURE stream sediment data. One weakly anomalous zinc value (157 ppm) may be associated with the bismuth-tungsten anomaly previously described.

In conclusion, the barium and lead anomalies occur in isolated clusters that are not likely to represent economic mineralization. Weak zinc anomalies are of uncertain significance.

SUMMARY OF MINERAL RESOURCE POTENTIAL

Favorable areas for thirteen different types of mineral deposits within (and adjacent to) the Ladron WSA have been identified on the basis of geologic concepts combined with: 1) known surface mineral occurrences (Fig. 5), 2) stream-sediment geochemical anomalies (Fig. 6A), 3) ground-water geochemical anomalies (Fig. 8 in Appendix), 4) trace-element zonation in the Jeter uranium deposit (Table 7), 5) microearthquake data (Sanford and others, 1979, fig. 6), and 6) known petroleum source beds (Wengerd, 1959) at favorable depths (Fig. 2, Table 3). The locations of these favorable areas with respect to the Ladron WSA, their respective types of deposits, the probable hosts (Fig. 2), the indicated depth range for possible discoveries, and judgments of their economic potential are all summarized in Figure 7.

Geologic constraints on the possible geometry, volume, and grade (i.e., value) of the different types of deposits range from well known (identified), to partially known (hypothetical), to poorly known (speculative). As appropriate for undeveloped federal lands, the Ladron WSA contains no well known (identified) mineral deposits of commercial value. That is, the Ladron WSA contains no outcropping ore deposits. However, five areas favorable for discovery of concealed mineral deposits with commercial potential have been delineated on a hypothetical or speculative basis (Fig. 7; II-B, III-A, III-B, III-C, and III-F). That areas favorable for discovery of commercial mineral deposits are hypothetically or speculatively constrained should not be

MAP SUMMARIZING MINERAL RESOURCE POTENTIAL OF THE LADRON AREA

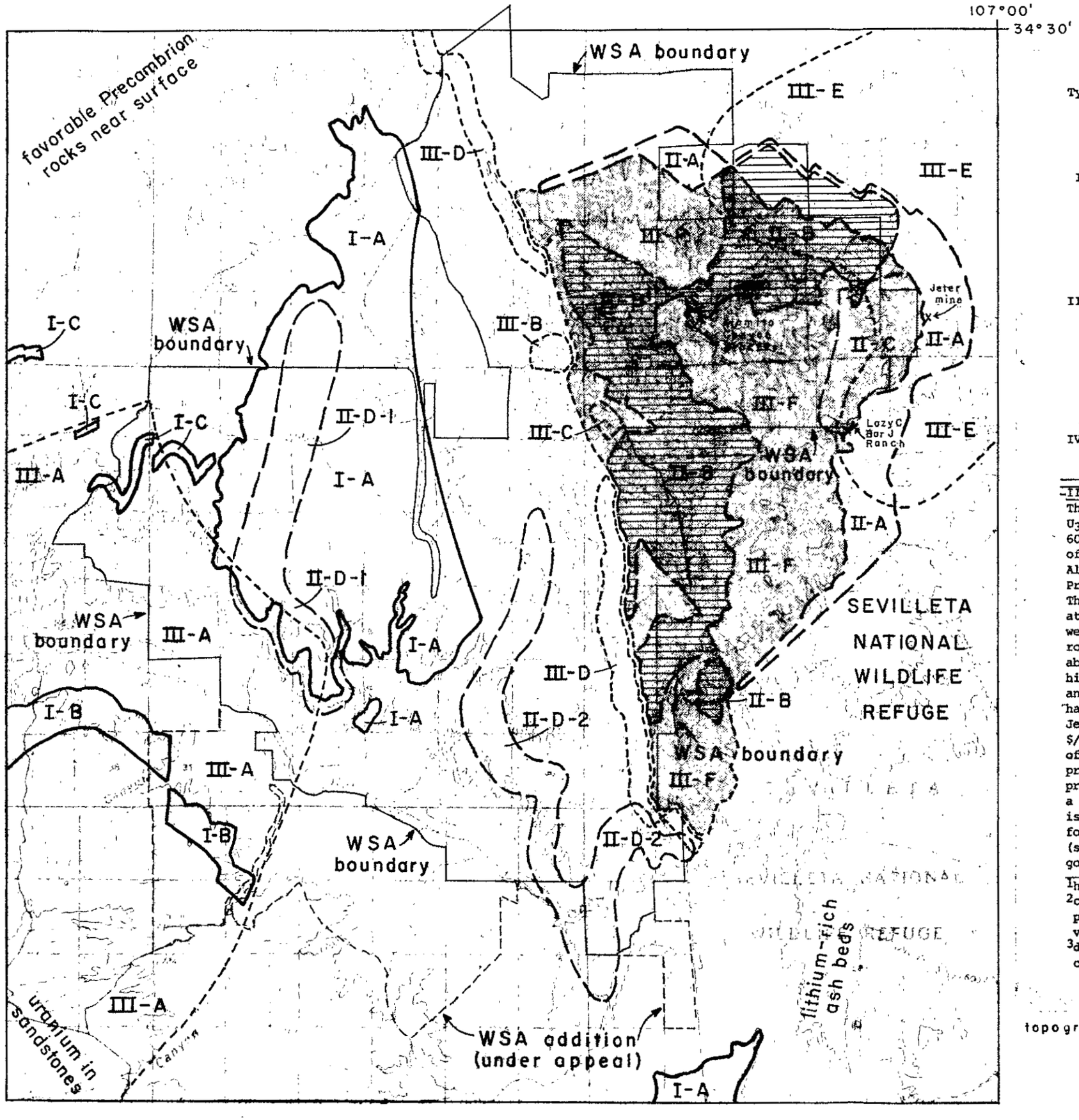


Figure 7.

EXPLANATION

Type of Deposit/Host[1]/Depth/Probability of Commercial Deposit[2]

I. Well Known Deposits (Identified) ————————
- A. High-calcium limestone[3](cement)/QTt/0-10m/ 10^{-2}
- B. Coal/K/0-30m/10^{-6}
- C. Gypsum/Pay/0-30m/10^{-6}

II. Partially Known Deposits (Hypothetical) —— — —
- A. Supergene Uranium-Copper/Jeter fault/0-300m/10^{-4}
- B. Stratiform Polymetallic Sulfide with Copper-Lead-Zinc —Nickel*-Cobalt*/pЄm/0-1500m/10^{-2}
- C. Siliceous Veins with Silver-Gold-Lead-Zinc-Copper-Barite-Fluorite*/pЄ/0-300m/10^{-5}
- D-1. Supergene Manganese*/QTs/0-30m/10^{-4}
- D-2. Supergene Manganese*-Iron/PM/0-100m/10^{-6}

III. Poorly Known Deposits (Speculative)– – – – – – – – – –
- A. Oil-Natural Gas/PM/2900-3600m/10^{-3} (Carbon dioxide=10^{-5})
- B. Mississippi Valley-type Lead-Zinc —Barite/PM/300-600m/10^{-3}
- C. Tungsten*-Bismuth (Tin*?)Greisen/pЄ granite/0-900 m/10^{-5}
- D. Late Paleozoic Gold Placers/basal PM/0-300m/10^{-5}
- E. Geothermal Energy/pЄ /5000m/10^{-5}
- F. Uranium/pЄ/0-1500m/10^{-2}

IV. *Strategic Minerals Potential (* mark = strategic mineral) Probability for discovery of commercial chromium or platinum deposit in Ladron WSA is nil (10^{-6})

II-B— III-F AREAS OF HIGH ECONOMIC POTENTIAL

The Jeter uranium-copper deposit (production = 58,500 lbs U_3O_8; estimated reserves plus production = 120,000 lbs U_3O_8, 60,000 lbs Cu) was almost certainly derived from weathering of preexisting polymetallic sulfide mineralization (like Alamito Canyon prospect) and uranium oxide mineralization in Precambrian rocks that form the core of the Ladron Mountains. The extremely high uranium content (704 ppbU) in well waters at the Lazy C Bar J Ranch is a strong indication of ongoing weathering of high-grade uranium mineralization in Precambrian rocks west of the ranch. The Jeter deposit probably represents about 1/200th of the metals weathered from the adjacent highland. Therefore, as much as 24 million pounds of uranium and 18.6 million pounds of base metals (Cu-Zn-Pb-Ni-Co) may have been mobilized by weathering during formation of the Jeter deposit. At current to foreseeable uranium prices (17-45 \$/lb U_3O_8), this is equivalent to 0.4 to 1.1 billion dollars of uranium, and to 30 million dollars of base metals (current prices). Similar metal values may be preserved below the present zone of weathering. The probability for discovery of a commercial uranium deposit (type uncertain) in area III-F is judged to be relatively good (10^{-2}) and the probability for discovery of a commercial polymetallic sulfide deposit (stratiform geometry) in area II-B is judged to be relatively good (10^{-2}).

[1]host identified by symbol in Fig. 2 or name in Fig. 4.
[2]commercial deposit worth \$25 million in place; relative probabilities: high=10^{-1}, good=10^{-2}, fair=10^{-3}, low=10^{-4}, very low=10^{-5}, nil=10^{-6}
[3]deposit is of commercial size (225 million tons), 10^{-2} chance of sufficient future demand to become commercial.

topographic base from Magdalena 30'X 60' quadrangle (USGS, 1979)

1 mi 1 km

1:100,000

surprising in a preliminary evaluation of mineral resource potential. Obviously, the areas of commercial mineral potential defined here should simply be regarded as foci for future detailed evaluations.

Hypothetical Area of Commercial Mineral Potential

One hypothetically defined favorable area (Fig. 7, II-B) is judged to have a relatively good probability (10^{-2}) for discovery of an economic mineral deposit of commercial significance (gross value of at least $25 million). Precambrian metamorphic rocks in area II-B are judged to be favorable for the discovery of stratiform polymetallic (Cu-Zn-Pb-Co-Ni) sulfide deposits, which may be associated with peripheral uranium mineralization. The envisioned stratiform deposits may be similar to the very large deposits of the Zambian Copper Belt or to the smaller massive sulfide deposits common in Precambrian metamorphic rocks of Canada (Meyers, 1981; Gustafson and Williams, 1981).

Speculative Areas of Commercial Mineral Potential

Four speculatively constrained favorable areas within the Ladron WSA are judged to have a good to very low probability (10^{-2} to 10^{-5}) for discovery of an economic mineral deposit of commercial significance (gross value of at least $25 million).

1) Area III-A: An area of about 5 square miles near the southwest margin of the WSA (northeast of Riley) is favorable for discovery (probability = 10^{-3}) of oil and/or natural gas reservoirs in late Paleozoic

rocks at a depth of about 2.9 - 3.6 km (5900-7300 feet).

2) Area III-B: Silicified Pennsylvanian limestones (along the Ladron fault) about one mile west of Ladron Peak may reflect lead-zinc-barite replacement deposits (discovery probability = 10^{-3}) in limestones at depths of 300 to 600 m (1000 to 2000 feet).

3) Area III-C: A coarse-grained plug(?) of fluorite-bearing granite about one mile southwest of Ladron Peak is a likely source for tungsten (16 ppm) and bismuth (6 ppm) anomalies in stream sediments emanating from this area, which suggests the possibility (probability = 10^{-5}) of a greisen or vein-type tungsten-bismuth deposit.

4) Area III-F: Extremely high uranium values (704 ppb) in well waters at the Lazy C Bar J Ranch strongly suggest ongoing weathering of high-grade uranium mineralization in Precambrian rocks west of the ranch. Possible (but unverified) sources of this soluble uranium are: 1) high-grade uranium mineralization peripheral to stratiform sulfide deposits (see II-B), 2) high-grade uranium veins associated with the Ladron pluton, 3) disseminated uranium oxides in the Ladron pluton, and 4) high-grade uranium vein mineralization associated with a possible unconformity developed on the Capirote granitoid. Thus the entire Precambrian terrane of the Ladron Mountains is considered overall to have a relatively good probability (10^{-2}) for discovery of a

commercial uranium deposit.

Areas of Low Mineral Potential

Six favorable areas are judged to have a low (noncommercial, but possibly mineable) economic potential within the Ladron WSA.

1) Area II-A: Small (~10^4 tons) Jeter-type uranium-copper deposits (~120,000 lbs U_3O_8; ~ 60,000 lbs Cu) have a high probability for discovery (10^{-1}) where Paleozoic rocks are exposed along the Jeter fault (Fig. 2); probability for discovery of an economic deposit is fair (10^{-3}), but this potential lies mostly outside the Ladron WSA.

2) Area II-C: Siliceous veins along the northeast flank of the Ladron Mountains (Hanson district of Jones, 1904) are known to carry economic silver (10 oz/ton), subeconomic gold (0.02 oz/ton), and locally appreciable amounts of barite and base-metal sulfides; veins are mostly thin, discontinuous, and mineable grades are not coincident with mineable widths. Probability for discovery of economic deposit is very low (10^{-5}).

3) Area II-D-1: Small (~10^5 tons), high-grade (40-50% Mn) Black Mask-type manganese deposits have a good probability for discovery (10^{-2}) where concealed at shallow depths below the travertine cap north of the Black Mask mine; low probability (10^{-4}) for discovery of commercial manganese deposit.

4) Area I-A: Travertine caprock northeast of Riley contains commercial quantities, 225,000 metric tons

(150,000 mt in WSA), of high-calcium limestone suitable for making cement, but distance to market and lack of transportation facilities make it presently uneconomic.

5) Area III-D: Subeconomic (0.1 oz/ton) gold values in basal Mississippian conglomerates (~0.3 m thick) west of Cerro Colorado indicate some placer gold potential along basal late Paleozoic unconformity, probability for discovery of an economic placer gold deposit is very low (10^{-5}).

6) Area III-E: An area of microearthquake activity on the northeast flank of the Ladron Mountains has a signature of magma injection; a geothermal reservoir near the average focal depth of earthquakes (5 km) is possible, but commercial geothermal reservoirs of this type are not known, and have a very low (10^{-5}) probability for discovery here.

Noneconomic Mineral Deposits

Three types of mineral deposits in the Ladron WSA are clearly noneconomic. These include: thin coal beds southeast of Riley (I-B), thin gypsum beds northeast of Riley (I-C), and low-grade iron-manganese deposits in Pennsylvanian limestones near the Rio Salado Box (II-D-2).

Narratives discussing all thirteen types of mineral deposits listed on Figure 7 follow. The discussions of economic potential are generally arranged in order of decreasing geologic

understanding; that is, as well-known, partially-known, and poorly-known types of deposits.

POTENTIAL OF WELL-KNOWN (IDENTIFIED) DEPOSITS

The Ladron WSA contains three types of syngenetic, strata-bound mineral deposits; they are high-calcium limestone, coal, and gypsum. Because these commodities are strata-bound, their thickness and lateral extent in outcrop provide a good measure of near surface volume and tonnage. Approximate strippable tonnages may then be taken as an indication of their resource potential.

High-Calcium Limestone (Fig. 7, area I-A) by M.J. Logsdon

High-calcium limestone (>95% $CaCO_3$) is present in the Sierra Ladrones WSA as an extensive blanket of late Cenozoic travertine (QTt). Within the WSA the travertine blanket covers approximately 25 km^2 (10 mi^2). Another 12 km^2 (5 mi^2) lies on the northwest perimeter of the WSA. The travertine ranges in thickness approximately from 1.5 to 8 m. Although the travertine has not been sampled systematically for quantitative chemical analysis, one chip-channel sample contains 99.0% $CaCO_3$ (Table 5). It is highly probable that virtually all of the travertine is greater than 95% $CaCO_3$. Assuming an average thickness of 3 m, an average density of 2.7 g/cm^3, and an average porosity of 30%, the entire travertine deposit totals approximately 225 million metric tons of limestone. Approximately 150 million metric tons of travertine are within the WSA. The travertine is essentially flat-lying and typically has less than 50 cm of unconsolidated alluvial, colluvial, or eolian overburden. Using the thickness given above, the travertine would have an average stripping ratio (cover: target rock) of 1:6. Clearly, the travertine is an enormous resource of

easily surface-mined, high-calcium limestone.

A second high-calcium limestone resource (not shown on Fig. 7) is probably present in the Pennsylvanian Madera Formation (upper part of Ꝑ M, Fig. 2), in the central part of the WSA. As part of another study, three samples of upper Madera limestones were collected from sections 14 and 15, T. 3 N., R. 3 W., just outside the WSA; all three contained approximately 95% $CaCO_3$ (Table 5). Although Madera limestones from inside the WSA were not analyzed, the high-calcium units sampled can be traced into the WSA in sections 23 and 26. Precise estimates of the amount of high-calcium limestone present in the Madera Formation cannot be made without detailed mapping and chemical analyses of samples, but another 25 - 50 million metric tons is possible within sections 23 and 26 alone. The extraction of these limestones would be more difficult than that of the travertine, since the Madera limestones are tilted and interlayered with sandstones and shales.

Chapin and others (1979) suggested the possibility of using coal from the Riley-Puertecito area to fuel a cement plant in the Riley area, using locally derived limestone as the principal cement raw material. The quality of either the travertine or of high-calcium units within the Madera Formation is certainly high enough to produce cement or even chemical lime. The principal obstacle to development of high-calcium limestone in the WSA will be transportation. From the center of the travertine deposit, the nearest railhead is the Atchison, Topeka, and Santa Fe Railroad at Bernardo, approximately 40 km by gravel road to the

Table 5. Analyses of High-Calcium Limestones from the Sierra Ladrones Area

	CaO	McO	SiO_2	Al_2O_3	Fe_2O_3	CO_2	$CaCO_3$	$MgCO_3$
FEK-1	NA	NA	0.11	0.04	0.04	43.80	99.00	0.46
ℙm-N-1	54.71	0.48	0.67	0.38	0.26	42.27	94.77	1.14
ℙm-N-2a	53.47	0.76	1.96	0.26	0.27	42.85	95.84	1.56
ℙm-N-2b	53.56	0.35	2.06	0.38	0.15	42.43	95.64	0.73

FEK-1 from Kottlowski, 1962. ℙm-N-1, ℙm-N-2a,b from M.J. Logsdon, personal communication, 1981.

east; part of the road is subject to flash-flooding during the summer rainy season. Transporting either limestone or cement/lime 40 km over marginal roads would be an economic disadvantage of considerable magnitude for any producer relative to transportation costs for other high-calcium limestones in central New Mexico. However, if predictions of population growth in the "Sun Belt" States materialize, then there may be sufficient future demand for cement to exploit this large travertine deposit.

Coal (Fig. 7, area I-B) by G.H. Roybal and J.C. Osburn

Cretaceous coal-bearing rocks are present in a proposed addition to the Ladron WSA that lies south of the Rio Salado and southeast of Riley (sections 5, 6 and 7, T. 1 N., R. 3 W., and sections 31 and 32, T. 2 N., R. 3 W.). The coal beds are in the Crevasse Canyon Formation of the Mesaverde Group. Numerous dikes, sills, and faults cut across the Crevasse Canyon beds in this area (Massingill, 1979). Coal beds in the Ladron WSA lie at the extreme eastern edge of the Datil Mountain coal field.

Coal beds in the Ladron WSA are generally less than a foot thick and have very little lateral extent. These coals occur in the lower half of the Crevasse Canyon Formation, which is considered to be correlative to the Dilco Member. Coals in the Riley Quadrangle are generally of poor quality, averaging subbituminous A in rank (Table 6). The coals are commonly found near basaltic dikes. Some coals have been observed to grade into coaly shales a short distance from the dikes. Significant thermal maturation of the coals is limited to within a few feet

Table 6. Analyses of coal samples from the Riley Quadrangle (unpublished U.S.G.S. and U.S.B.M. data).

Source and ID No.: USGS, D184621

Sample Location: SE¼, SE¼, Sec. 11, T. & R.: 1N., 4W

Proximate Analysis (%)

Moisture: 16.70 Ash: 36.6 Volatile Matter: 24.30 Fixed Carbon: 22.40

Ultimate Analysis (%)

Moisture: 0.00 Carbon: 30.50 Hydrogen: 3.80 Nitrogen: 0.80

Sulfur: 0.30 Ash: 36.6 Oxygen: 28.20 BTU: 4578.0

Moist Mineral Matter Free BTU: 7566.29 Rank: Lignite A

Source and ID No.: USGS, D184619

Sample Location: NE¼, NE¼, Sec. 4, T & R: 1N., 4W.

Proximate Analysis (%)

Moisture: 8.40 Ash: 32.7 Volatile Matter: 31.90 Fixed Carbon: 27.00

Ultimate Analysis (%)

Moisture: 0.00 Carbon: 41.70 Hydrogen: 3.80 Nitrogen: 0.80

Sulfur: 0.40 Ash: 32.70 Oxygen: 20.60 BTU: 6854

Moist Mineral Matter Free BTU: 10601.27 Rank: Subbituminous A

Source and ID No.: USGS, D184620

Sample Location: NE¼, NE¼, Sec. 4, T.& R.: 1N., 4W.

Proximate Analysis (%)

Moisture: 14.30 Ash: 23.2 Volatile Matter: 30.00 Fixed Carbon: 32.50

Ultimate Analysis (%)

Moisture: 0.00 Carbon: 44.40 Hydrogen: 4.20 Nitrogen: 0.90

Sulfur: 0.40 Ash: 23.20 Oxygen: 26.80 BTU: 7280

Moist Mineral Matter Free BTU: 9715.75 Rank: Subbituminous B

Sample and ID No.: USBM

Sample Location: Sec. 26, T. & R.: 2N., 4W.

Proximate Analysis (%)

Moisture: 1.4 Ash: 28.1 Volatile Matter: 31.50 Fixed Carbon: 39.00

Ultimate Analysis (%)

Moisture: 0.0 Carbon: 56.2 Hydrogen: 4.4 Nitrogen: 1.0

Sulfur: 2.2 Ash: 28.1 Oxygen: 8.1 BTU: 10080

Moist Mineral Matter Free BTU: 14567 Rank: High volatile A bituminous

of the dike margins (Chapin and others, 1979, p. 30).

The best coal outcrops are located in the NE1/4, SE1/4 of section 6, T. 1 N., R. 4 W. At this location there are two coal beds; they are approximately 0.4 m thick and separated by 0.9 m of siltstones. The coals are highly lenticular, extending only 9 meters along the outcrop.

In conclusion, coals observed in the Ladron WSA are thin, lenticular, appear to be of poor grade, and contain a large amount of shaley material. By standards of the U.S. Geological Survey, calculation of the tonnage of strippable coal in the Ladron WSA is not appropriate because of structural complexities and the lenticularity of the coal beds. At best, the two coal seams that crop out in section 6 contain less than 100,000 tons of strippable coal. Chapin and others (1979, p. 19) have estimated a resource of about 1,000,000 tons of strippable coal about one mile southwest of Riley and two miles west of the WSA boundary. They suggest that the best use for relatively minor coal resources in the Riley-Puertecito area would be to fire a cement plant using travertine, gypsum, shale, and water resources, all available near Riley.

Gypsum (Fig. 7, area I-C) by M.J. Logsdon

In the United States gypsum is used primarily in the manufacture of construction materials. Of the 18.3 million metric tons of crude gypsum consumed in the U.S. in 1980, 67% was used to manufacture wallboard, 19% was used as retarder in portland cement, and 4% was used to produce building and industrial plaster. Of the remaining 10%, almost all was used in

agriculture as a soil conditioner, with only a fraction of one percent consumed in miscellaneous industrial applications. All of New Mexico's 1980 production of 189,000 metric tons was used to produce construction materials: 91% for gypsum wallboard and 9% as portland cement retarder. The economic performance of gypsum is, and will continue to be, tied closely to that of the construction industry.

Within and adjacent to the Ladron WSA, gypsum beds crop out near the top of the Yeso Formation and near the base of the Glorieta Sandstone, both of Permian age. The gypsum exposed at the "Z Placer" claim (Fig. 5) and east of the BLM road from Riley to Navajo Gap in section 12, T. 2 N., R. 4 W. probably belongs to the Los Vallos (or Torres) Member of the uppermost Yeso Formation (Kelley and Wood, 1946). Gypsum in the Los Vallos (Torres) Member is typically interbedded with limestone, dolomite, and sandstone. The principal gypsum bed in section 12 is 1-2 m thick.

The gypsum beds north of Riley are not amenable to strip-mining because they occur just below the cuesta-forming San Andres Limestone. Assuming an average thickness of 1.5 m, a strippable outcrop width of 25 m, an outcrop length of 3.0 km (Fig. 7), an average density of 2.3 gm/cm^3, and an average porosity of 25 percent; then the Ladron WSA contains approximately 194,000 metric tons of near-surface gypsum. Recent activity (October, 1981) at the "Z Placer" claim involved using a bulldozer to strip gypsite and colluvial overburden from the gypsum. It is not known if any gypsum was removed from the site in October 1981; total tonnages mined are very small, probably less than two metric tons. The end-use of this gypsum is

uncertain, but it is probably being used locally as a soil conditioner. Gypsum in the Yeso Formation also crops out west of the WSA boundary in section 1, T. 2 N., R. 4 W. There is no evidence that gypsum in section 1 has ever been mined.

The Yeso Formation comprises the largest geologic resource of gypsum in New Mexico. However, the principal gypsiferous unit is the Cañas Gypsum Member, not the Los Vallos (Torres) Member (Hunter and Ingeroll, 1981; Logsdon, 1981). The principal economic resource of gypsum is the Jurassic Todilto Formation of north-central New Mexico (Logsdon, 1981). Relative to the active gypsum mines in the Todilto Formation north of Albuquerque, the gypsum in and near the Sierra Ladrones WSA is remote from the principal construction markets, has poor access, and is unfavorable for mining because of thick overburden, interbedding with clastic and carbonate units, and structural complexity. The only use for the gypsum in and near the Ladron WSA under foreseeable economic conditions would be as soil conditioner in the Riley area. If a cement plant were constructed in the Riley area (see p. 65), then the gypsum in and near the WSA would find a ready market as retarder for portland cement.

POTENTIAL OF PARTIALLY KNOWN (HYPOTHETICAL) DEPOSITS

Favorable areas for four types of metallic mineral deposits (Fig. 7: IIA, II-B, II-C, II-D) have been hypothetically defined on the basis of surface mineral occurrences for which there is some data on grade of mineralization (indirect evidence for grade of II-B), probable geometry of mineralization, and geologic relationships constraining possible origins of the mineralization. All four types of deposits are either known, or appear, to contain ore-grade material. However, exposures of apparent mineable grade are generally not coincident with a mineable thickness. Working genetic models (not unequivocal) are used to constrain possible subsurface geometry and extent, which in turn allows a preliminary estimate of maximum economic potential and probability for discovery of an economic mineral deposit.

Plio-Pleistocene Uranium-Copper Deposits in Jeter Fault (Fig. 7, II-A)

Area II-A of Figure 7 represents the subsurface projection of the gently dipping (~25 degrees) Jeter fault to a depth of about 1000 feet (300 m). Narrow northeast-trending portions of the favorable area represent high-angle transverse faults of the Cerro Colorado and Alamito Canyon fault zones (Fig. 4), across which the Jeter fault is locally deflected (see p. 33-34).

Eight occurrences (Fig. 5) of secondary copper minerals (mostly carbonates), locally associated with uranium minerals (or radiometric anomalies indicative of uranium mineralization), have been verified along the footwall of the Jeter fault. Occurrences

of this type are known to be present from near the mouth of Alamito Canyon to about one mile south of the Lazy C Bar J Ranch, a distance of about 11 km. The most significant of these uranium-copper occurrences along the Jeter fault is the Jeter uranium mine, which produced 58,562 pounds of U_3O_8 at an average grade of 0.33 percent U_3O_8 (DOE records, W.L. Chenoweth). At $20.75/lb U_3O_8 (Engineering and Mining Journal, 5/82), the Jeter deposit would have produced about 1.2 million dollars worth of uranium oxide.

The most detailed description of the geology and mineralogy of the Jeter deposit is presented in an exploration drilling report of Collins and Nye (1957). In the following excerpts from Collins and Nye (1957, p. 11-12), comments or alternatives to some problematic statements are presented in brackets:

> "Uranium mineralization at the Jeter Mine has occurred along a 500-foot section of a low-angle fault [Jeter fault of Black, 1964] which follows [forms] the contact between Precambrian granite and overlying sedimentary and volcanic rocks of Tertiary age [volcanic rocks exposed south of Jeter Mine].
>
> The footwall of the fault zone is commonly a highly altered [bleached and kaolinized] granite but in some places includes a variety of metamorphic rocks, predominantly schist. The granite has been intruded by a host of fine-grained gray andesitic dikes ["andesitic dikes" not recognized by later investigators; Black, 1964; Condie, 1976; reconnaissance, this report]. Many dikes are exposed on outcrops [Condie, 1976, mapped numerous amphibolite dikes west of Jeter Mine; diabase dikes known to cut granite in this area may be of late Precambrian or early Miocene age, Black, 1964; Fig. 3 in this report]. The dikes apparently were intruded during the widespread volcanism of middle Miocene time [now known to be Oligocene; Table 3 in this report]. Some of these dikes dip eastward at low angles [may be fault slivers of andesitic Spears Formation, Table 3 this report], while others are nearly vertical. The dikes on the surface trend

north. Along the fault, the dikes [and other rock types] have been kaolinized and altered to a light buff [bleached] color [indicating that dikes predate alteration and mineralization]. This alteration along with shearing and fracturing has made the dikes a fair host for uranium deposition [high phosphate content, which is common in mafic igneous rocks, would tend to precipitate hexavalent uranium from solution; this explains presence of secondary meta-autunite and meta-torbernite at Jeter mine; see following description].

Overlying the granite in the fault zone is a layer of light gray to dark gray [manganese oxides may add to gray color; see Table 7 in this report] carbonaceous tuffaceous mudstone with thin interbedded quartzite [Hilpert, 1969, p. 55, correlates this "gray clayey material and bleached tuffaceous sandstone" with the Popotosa Formation of Denny, 1940; however, carbonaceous mudstones are not commonly recognized in Popotosa playa facies, and well-cemented "quartzite" beds have not been reported in the Popotosa Formation by Bruning, 1973; thus the gray mudstone and quartzite are more likely to be a fault sliver of the Pennsylvanian Sandia Formation]. This carbonaceous layer is a very favorable host and contains most of the known ore at the Jeter mine [carbonaceous material is a well known chemical trap in sandstone uranium deposits]. The quartzite consists of medium sized grains of quartz cemented by opal and sericite. The attitude of the mudstone unit appears to be the same as the fault plane [this geometry, coupled with a following description of ore shoots, is suggestive of mullion-shaped fault slivers of Sandia Formation elongated parallel to dip of fault]. The unit varies from 2 to 15 feet in thickness in the vicinity of the mine.

The mudstone is overlain by a zone of sheared red clay which varies in thickness from 2 to 25 feet. The clay has been derived from alteration and shearing of andesitic flows [bonifide andesites in this position could only be fault slivers of the Oligocene Spears Formation, Table 3]. These flows were deposited on the mudstone unit and apparently had a similar attitude [andesitic conglomerates of Spears Formation predate Ladron uplift and Jeter fault by 10 to 20 million years; geometry must be structurally induced]. Andesitic fragments in varying stages of alteration to clay are found throughout the red clay zone [red clay zone also contains fragments of altered granite, Black, 1964]. The zone can be traced for about two miles south along the strike and is known by drilling to extend more than 1200 feet down the

fault plane [along dip to depth of 400 feet]. Southward from the drilling area the clay grades into slightly altered andesitic flows which attain a thickness of about 100 feet along the fault east of the Jeter ranch house [juxtaposed slivers of Spears Formation and Oligocene ash-flow tuffs form a structural wedge between the Jeter fault and the "overlying" low-angle Silver Creek fault in the area east of the Lazy C Bar J ranch house, Fig. 2 in this report; minor bleaching also occurs here along footwall of Silver Creek fault].

The red clay zone usually shows anomalous radioactivity [i.e. low-grade uranium mineralization is essentially continuous along the Jeter fault] and in places at the Jeter Mine contains sufficient uranium to approach ore grade [see Table 7 of this report].

The hanging wall of the fault, directly overlying the red clay is a fanglomerate. It is a heterogeneous mixture of pebbles, cobbles, and boulders of granite and schist [minor] in a coarse sandy matrix. It is moderately well [to poorly] cemented, poorly sorted and in most outcrops is mosaic [?] in appearance [generally forms rounded hills mantled with clasts of Precambrian-type rock units]. At the south end of the drilling area the fanglomerate shows poorly developed bedding and appears to be flat lying [flat lying beds mentioned here are probably a late Quaternary terrace deposit exposed along road to Lazy C Bar J ranch; crudely bedded fanglomerates at Jeter Mine and a few other rare exposures clearly dip about 20-30 degrees westward; Black, 1964; Fig. 2 in this report]. The fanglomerate in the easternmost drill holes is more than 400 feet thick. The lower [stratigraphic] contact of the fanglomerate is very irregular [?]. [Figure 5 of Collins and Nye shows only a planar fault contact below the fanglomerate, dipping 25° to the east and intercepted by 4 drill holes]. The material composing the fanglomerate was derived from the main mass of the Ladron Mountains immediately to the west and was formed as an alluvial rock fan in the last stages of Popotosa deposition [These alluvial fan deposits, rich in clasts of Precambrian rocks, are now correlated with the Sierra Ladrones Formation of Machette, 1978b; see Bruning, 1973; Fig. 2 of this report].

The principal primary uranium mineral at the property has been identified as coffinite [common in sandstone uranium deposits] (J.W. Gruner, June 13, 1957, written communication). A number of types of secondary uranium minerals are abundant along outcrops of the fault zone at the mine. These include: para-schoepite, meta-autunite,

> meta-torbernite; and soddyite (R.G. Anderson, July 9, 1956, written communication). Associated with these minerals are malachite, azurite, barite, limonite, and manganese oxides. Pyrite is present in minor amounts in fractures in core samples of unaltered [?] andesite dikes [pyrite most likely represents a mineralization event in Precambrian host rocks that predates bleaching and kaolinization along Jeter fault]. Uranium mineralization [ore grade] has occurred principally in a 500-foot section along the strike of the fault. Most of this section has been mineralized but two main ore bodies or shoots are present. At the southern end of the zone a 100-foot wide low-grade body two to eight feet thick of secondary uranium minerals is found in sheared and contorted carbonaceous mudstone. The ore body has an apparent trend N 60-70°E, and has an average thickness of possibly four to five feet. Maximum thickness is about 15 feet. At the outcrop secondary uranium minerals were present but in unoxidized material coffinite is the principal uranium mineral.

Although Collins and Nye's description has needed some updating with regard to correlation of rock units and structural relationships, the fundamental alteration/mineralization patterns described are supported by later reports (Black, 1964, Hilpert, 1969; Condie, 1976) and our own reconnaissance.

Since its discovery in 1954, the Jeter uranium-copper deposit has been described in terms of a hydrothermal origin (Collins and Nye, 1957, p. 17; Black, 1964, p. 67-80; DOE, 1980, microfiche--Basin and Range assessment report no. 76) or as a vein-type deposit in sedimentary rocks, implicitly linked to a hydrothermal origin (Hilpert, 1969, p. 119; Pierson and others, 1981, p. 32). However, we suggest that: 1) the asymmetry of alteration and mineralization at the Jeter Mine (restricted to footwall), 2) the type of alteration (bleaching and kaolinization), and 3) the absence of silicification, all argue against a hydrothermal origin. Known rock types that could fit

the description of "andesite dikes" (Collins and Nye, 1957) consist of Precambrian (or mid-Tertiary) diabase dikes and fault wedges of the andesitic Spears Formation, which predate the Jeter deposit deposit by tens to hundreds of millions of years.

Strong evidence of a supergene origin (descending low-temperature ground waters) for the Jeter uranium deposit is found in trace element analyses of vertically oriented samples from outcrop of the Jeter ore zone (Pierson and others, 1981), which are summarized here in Table 7. In Wyoming-type sandstone uranium deposits, of widely accepted supergene origin, uranium consistently accumulates down-dip (down-flow path) from an oxidation-reduction boundary, and molybdenum consistently accumulates further down-dip (down-flow path) from the peak uranium values (Harshman, 1974). Table 7 illustrates the strong vertical zonation of metals in the Jeter ore body. Relative positions of the key peaks of uranium (at the top of the ore zone) and molybdenum (in the middle of the ore zone) indicate deposition from waters flowing <u>downward</u> and laterally along the permeable Jeter fault zone (as appropriate for low-temperature ground waters).

Uranium-copper mineralization and alteration concentrated along the Jeter fault must be penecontemporaneous with, or younger than, the fault itself. Granitic conglomerates that form the hanging wall at the Jeter Mine are the youngest formation cut by the Jeter fault. The age of these granitic conglomerates, which are alluvial fan deposits derived from erosion of the emerging Ladron Mountains, is not clearly established. However,

TABLE 7. Trace elements anomalies and their vertical distribution in the ore zone (footwall of the Jeter fault) at the Jeter mine; data from Pierson and others (1981, App. B). Values in ppm, anomalies underlined.

	Field No.[1] (MDQ-)	U	Ba	Co	Cu	Mn	Mo	Ni	Pb	Sn	Sr	V	Zn
top } ore	135	3080[3]	240	27	1600	620	22	40	140	23	310	110	83
middle } zone	136	521	150	19	1400	620	82[3]	32	54	<10	270	100	100
bottom }	137	79	670	19	530	1300	<10	27	<10	<10	57	26	230
below ore zone	012	21	1800	<1	47	<200	<10	8	<10	<10	700	98	50
ore on stockpile	134	4000	1200	230	2000	<5000	20	300	?	22	210	69	500
high values in common rocks[2]		4.8	700	50	100	2200	3	150	20	4	500	250	100

1. Samples 135, 136, 137 and 012 are reported to be from outcrop of ore zone and the footwall of Jeter fault at the Jeter mine. General vertical relationship of samples, lithologies, and relation to the Jeter Fault are as follows:

	Sample No.	Description
hangingwall	—	granitic boulder conglomerate (QTs, Fig. 2)
	—	low-angle fault contact (Jeter fault)
footwall	MDQ-135	top of 3 samples in place, red mudstone
	MDQ-136	middle of 3 samples in place, purple mudstone
	MDQ-137	bottom of 3 samples in place, clayey arkose
	MDQ-012	metamorphic rock, gouge from fault contact zone

2. Highest value for average content of given element in either basalt, granodiorite, granite, shale, or limestone; from Levinson (1974, Table 2-1).

3. Relative position of peak uranium and molybdenum values demonstrates mineralizing solutions flowed downwards (Harshman, 1974). Thus mineralization is interpreted to be supergene.

they must be younger than the underlying Popotosa Formation, which is reliably dated in the Socorro-Magdalena area as ranging from 25 to 7 m.y. in age (Chamberlin, 1981a). Therefore, the granitic conglomerates and uranium mineralization at the Jeter Mine are both considered to be younger than about 7 m.y.

Stratigraphic relationships on the west flank of the Ladron Mountains (Qs/QTt/QTs, Fig. 2, Table 3) indicate two periods of accelerated erosion and alluvial fan deposition (Qs, QTs) separated by a period of accelerated chemical sedimentation (QTt). The latter apparently reflects a period of high ground-water flux. This period of high ground-water flux may have been associated with a relatively cool/wet climate during the onset of continental glaciation in late Pliocene to early Pleistocene (J.W. Hawley, oral comm., 1982). The Jeter deposit most likely formed by ground waters flowing eastward off the Ladron Mountains during this relatively wet climatic period about 1-3 m.y. ago.

Given a Plio-Pleistocene age, the only reasonable source of metal-rich ground waters was precipitation on the highlands of the Ladron Mountains. Thus the Jeter ore metals must have been weathered from Precambrian rocks underlying the crest of the range. Since copper is not soluble in alkaline waters (Levinson, 1974, p. 143), its presence in the Jeter ore (0.05 - 0.2 percent Cu) requires transport and precipitation from acidic ground waters. Sample MDQ-012 (Table 7), a metamorphic rock below the ore zone, is unusually low in manganese (<200 ppm) and iron (9400 ppm) (Pierson and others, 1981, app. B-1). Leaching of ferrous iron and manganese by acidic ground waters at a pH less than 5.5 is a likely explanation for this relationship (Levinson, 1974, p.

128).

The above constraints virtually require that the Jeter uranium-copper deposit was formed by acidic, metal-rich ground waters derived from chemical weathering (wetting and oxidation, Levinson, 1974, p. 77) of copper sulfide-rich and uranium oxide-rich Precambrian rocks situated under the crest of the Ladron Mountains. The extremely high uranium concentration in ground water at the Lazy C Bar J ranch (704 ppb uranium; see Appendix III, Fig. 8B) strongly suggests ongoing weathering of high-grade uranium mineralization in Precambrian rocks west of the ranch. In the vernacular of exploration geochemists, the Jeter deposit, and numerous supergene copper deposits all along the east flank of the Ladrons, represent a "displaced geochemical anomaly" (Levinson, 1974, p. 13), which has been laterally shifted from its source area. Since the Jeter deposit is about 200-300 feet above the present water table (assuming the perennial portion of Rio Salado is representative of present water table east of the Ladrons), a more appropriate classification would be a "fossil" displaced geochemical anomaly.

Given a supergene origin for the Jeter deposit, similar mineralization may be expected along any past, or present, zone of ground-water flow on the east flank of the Ladrons. The Rule prospect of Lasky (1932)--a malachite-azurite-chalcocite occurrence in Tertiary rocks--is a likely candidate for supergene mineralization outside the Jeter fault zone. Ore grade uranium-copper mineralization apparently required interaction of metal-rich ground waters with a highly reducing (carbonaceous) zone, as

at the Jeter mine (Collins and Nye, 1957). Subeconomic copper-uranium mineralization, which is virtually continuous along the Jeter fault, probably formed at a relatively weak oxidation-reduction boundary near the interface of the vadose zone (unsaturated zone) and the water table (saturated zone) (Levinson, 1974, fig. 1-3). An upward increase in alkalinity (carbonate/bicarbonate) across this interface (near the top of the saturated zone) would explain the more widespread occurrence of copper carbonates in comparison to uranium mineralization. Uranium would not precipitate with an increase in pH, but rather it would continue on in solution as uranyl carbonate complexes (Levinson, 1974, p. 128).

Discovery of additional Jeter-type uranium-copper deposits is virtually assured at points where high paleoground-water flux was intercepted by highly reducing environments along the mountain front. Fault slivers of late Paleozoic carbonaceous shales (Sandia Formation) are the most likely candidates for the necessary reducing environments. Fault blocks of late Paleozoic rocks exposed about 2 miles south and 2 miles north of the Jeter Mine (Fig. 2) are considered to be highly favorable areas to find small Jeter-type deposits; both of these areas are outside the Ladron WSA.

The maximum economic potential of the Jeter deposit (and the economic potential of its source area--the adjacent Precambrian terrane) can be evaluated by estimating the total metal content of the original Jeter ore body. The Jeter deposit produced 58,562 pounds of U_3O_8 from 8,826 short tons of ore, which yields an average grade of about 0.33 percent U_3O_8. However, an

unpublished mine map (DOE files, see Appendix) indicates that only about 50 to 75 percent of the ore-grade material was actually removed from the Jeter deposit. Based on the unpublished mine map, the original tonnage of the Jeter ore body is estimated to have been a minimum of 11,300 tons and a maximum of 15,400 tons. An original 15,000 ton ore body, with grades equivalent to stockpiled ore (Table 7), would have contained about (±25 percent): 120,000 lbs U_3O_8, 60,000 lbs Cu, 15,000 lbs Zn, 9,000 lbs Ni, 6,000 lbs Co, and 3,000 lbs Pb. At recent prices (Engineering and Mining Journal, 5/82) the original Jeter deposit would have contained about 2.5 million dollars worth of uranium oxide and about 150 thousand dollars worth of cobalt, copper, nickel, zinc, and lead (calculations in Appendix). Recoverable metal values would be about 15 to 25 percent less than bulk metal values.

In the Department of Energy assessment of uranium potential in the Ladron area (DOE, 1981, microfiche--Basin and Range report no. 76), Pierson and others (1981) rated the probability for discovery of a second deposit approximately equivalent to the Jeter production (54,000 lbs U_3O_8) at 50 percent. Probability for discovery of a deposit about 5 times larger (256,000 lbs U_3O_8) was rated at 5 percent. By extrapolation of Pierson and others' probability estimates (in DOE, 1980), the probability for discovery of a deposit 25 times larger (1,450,000 lbs U_3O_8), which would be a commercial deposit worth about 30 million dollars (at \$20.75/lb U_3O_8), should be about 0.5 percent, or 1/200. The DOE estimate of favorable ground for a Jeter-type

deposit was 36.9 square miles, equivalent to the projection of the Jeter fault to a depth of 1500 m (4900 ft). Since we interpret the Jeter deposit as supergene, as opposed to magmatic hydrothermal (DOE, 1980), the favorable area assigned here is restricted to a zone of shallow ground-water flow presumably within 300 m of the present surface. Using the supergene model, we estimate the probability for discovery for a commercial Jeter-type deposit to be about 1/1000. This potential for a commercial Jeter-type deposit lies mostly to the east of the Ladron WSA. Based on the size of potential host rocks (Paleozoic fault blocks) along the Jeter fault, the maximum economic potential of a Jeter-type deposit is judged to be about 20 to 30 million dollars.

Precambrian Stratiform Polymetallic Sulfide Deposits in Metamorphic Rocks (Fig. 7, II-B)

Area II-B of Figure 7 outlines the major outcrops of Precambrian metamorphic rocks in the Ladron Mountains, which are judged to be highly favorable for the discovery of stratiform polymetallic (Cu-Pb-Zn-Ni-Co) sulfide deposits. Uranium oxide mineralization may be associated with the periphery of the envisioned polymetallic sulfide deposits. Small portions of this favorable area on the north and northeast flank of the Ladron Mountains represent subsurface projections of metamorphic rocks under alluvium and under the hanging wall of the Jeter fault to a depth of about 1000 feet. Favorable metamorphic rocks should project at relatively shallow depths under Paleozoic sedimentary rocks in the area southwest of Ladron Peak and west of the Ladron

fault (not shown in Fig. 7; see Figs. 2, 4).

Two detailed studies of the Ladron Mountains (Black, 1964, Condie, 1976) report that numerous copper occurrences (oxides and carbonates after sulfides) are scattered throughout the metamorphic terrane. Unfortunately, exact locations of these occurrences are not given. However, a small copper prospect (1.2 x 2.4 x 4.6 m shaft parallel to dominant foliation) in quartz-feldspar-muscovite-amphibole schist (Torres Schist of Black, 1964) near the head of Alamito Canyon (NW1/4, Sec. 32, T.3 N., R. 2W.) has been exactly located by our reconnaissance (Fig. 5; App. I, sample LAD-64; App. III).

Dump material at the Alamito Canyon Prospect (Fig. 5) consists of schistose rocks, some of which are gradational into a boxwork-type limonite gossan indicative of high-grade sulfide mineralization. Trace element analysis of the gossan material (LAD-64A) yielded: 700 ppm copper, 700 ppm lead, 600 ppm zinc, 80 ppm nickel, and less than detection limit of 100 ppm cobalt. Assuming the host rock to be a metamorphosed argillaceous sandstone--with the above metals typically in 1-100 ppm range (Mason, 1966, table 6.5)--then copper, lead, and zinc are clearly anomalous. Nickel is well above average values found in sandstones (2-10 ppm), and cobalt is presumably above average (1-10 ppm) since it is typically concentrated along with nickel (Hawkes and Webb, 1962). The copper-lead-zinc-nickel-cobalt content of the gossan material probably represents about 1/10th to 1/100th of the original metal content of the sulfide ore. Iron oxides formed during weathering have the ability to adsorb significant amounts of trace metals that would otherwise be

completely removed by weathering (Levinson, 1974, p. 83).

Analysis of the same gossan material (LAD-64A) also yielded 1000 ppm uranium. However, the absence of radioactivity of the Alamito Canyon prospect strongly suggests that this uranium was weathered from a nearby source and then adsorbed by the iron oxides (as opposed to being a primary constituent of the sulfide ore). Geologic and topographic relationships at the Alamito Canyon prospect would allow the inferred nearby uranium mineralization to occur in metamorphic rocks peripheral to the prospect, or in the adjacent Ladron quartz monzonite (see Fig. 2).

Another fragment of gossan material on the dump was found to be largely encased in quartz veinlet material (sample LAD-64B, App. I). Traces of chalcopyrite and bornite are visible in this gossan material. Malachite is abundant as fracture fillings in the quartz. In thin section, the limonite boxwork forms irregular (broken?) masses within the coarse-grained quartz. In the pit walls, thin quartz veinlets and granitic dikelets cut the schist at a small angle to foliation, but sulfide type mineralization (expressed as gossan) does not extend into the pit walls. Thus, the thin section and megascopic observations suggest that the quartz veinlets are not intimately associated with the original sulfide mineralization (i.e. quartz veining may postdate the sulfide mineralization). Mapping of trace-element distribution in sample LAD-64B with a scanning electron microscope shows that copper is disseminated in the iron oxides of the gossan.

Although the geometry of the original sulfide body in the schist is not known, the geometry of the prospect shaft would allow it to have been a tabular or rod-shaped body parallel to the dominant layering. Black (1964, p. 77) indicates that copper sulfide mineralization parallel to layering or foliation is common in the metamorphic rocks he mapped as the "Torres Schist". In his discussion of the economic geology of the Ladron Mountains Black (1964, p. 77) makes the following statements, with our comments added in brackets:

> Mineralization in the northern and eastern Ladron Mountains has taken place in two distinct periods, the first Precambrian, the second Tertiary [sedimentary hydrothermal veins of late Paleozoic age are also possible, see p. 49-51]. Apparently, neither of these mineralizing periods was of sufficient intensity to produce economically feasible deposits[?], although considerable prospecting has been done.
>
> The first period of mineralization undoubtedly[?] accompanied Precambrian intrusion of the metasediments and is principally represented by oxidation products of original hypogene copper sulfide fissure veins [Black's terminology implies a magmatic hydrothermal origin, which was the prevailing concept for metallic sulfide deposits in 1964]. These deposits are scattered throughout the Torres Schist and are generally controlled by fissures along the schistocity or bedding planes [Black is clearly describing weathered copper sulfide mineralization that is dominantly parallel to foliation or layering in metamorphic rocks]. The dominant minerals are malachite, azurite, and chrysocolla.

An alternative working hypothesis proposed here is that "copper sulfide fissure veins" of Black and the Alamito Canyon prospect are more likely to represent stratiform copper sulfide occurrences of pre-metamorphic age, which would explain why mineralization parallels the dominant layering or foliation.

The proposed stratiform metallic sulfide deposits of the Ladron Mountains would be similar in age (late Proterozoic, 1600-

1300 m.y. old), geochemistry (copper-lead-zinc-nickel-cobalt association of Alamito Canyon gossan) and geologic setting (metamorphosed continental sandstones and marine sediments)[1] to stratiform deposits of the Zambian Copper Belt (Gustafson and Williams, 1981). Zambian deposits are very large ore bodies (1-10 million metric tons of contained Cu) worth about 1.6 to 16 billion dollars at current prices ($0.75/lb Cu). Over half of the world's cobalt (strategic metal) is produced as a byproduct from stratiform copper deposits in Zaire and neighboring Zambia (Silbey, 1979). Alternatively, these stratiform sulfide deposits could be similar to the smaller, but higher grade, massive sulfide deposits found in metavolcanic/metasedimentary rocks of the Canadian Shield (Meyer, 1981).

The favorable area for stratiform polymetallic sulfide deposits presently includes all metamorphic rock types, since there is no known reason why such deposits should be restricted to the relatively pelitic rocks of the Torres Schist (Black, 1964). Gustafson and Williams (1981) report that stratiform copper deposits in sedimentary rocks are not restricted to a particular sedimentary facies. Black (1964, p. 17) has described color variations in Ladron quartzites, which indicate the presence of both oxidized and reduced arenaceous rocks capable of having trapped copper and uranium at redox boundaries. Also, it is possible that the copper sulfide occurrences are of volcanogenic

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[1] Condie (1976, 1980) interprets clastic sediments (quartzite unit, etc.) to have been deposited in a continental rift. (Black, 1964, p. 98) indicates that some hornblende schists of the Torres Schist probably formed through metamorphism of a calcareous sediment (possibly an impure limestone of marine origin).

origin, since metavolcanic rocks are known to be present (Condie, 1976). However, there is no reported indication of a submarine eruptive environment for these metavolcanic rocks (op. cit.), which is considered to be a prerequisite in the formation of volcanogenic massive sulfides (Fulp and Woodward, 1981).

Given recent metal prices (Engineering and Mining Journal, 5/82) for copper ($0.75/lb), zinc ($0.35/lb), lead ($0.26/lb), nickel ($3.00/lb), and cobalt ($12.50/lb), and assuming nominal grades for an Alamito Canyon-type sulfide body (preweathering) of 3.0% copper, 2.0% zinc, 2.0% lead, 0.1% nickel, and 0.1% cobalt then an Alamito Canyon ore would have an approximate value of $100.40 per short ton. Assuming the ore minerals (7.2%) are disseminated in schist (2.7 gm/cc), then the ore density would be about 2.8 gm/cc or about 3.0 tons/m^3. Thus if half the volume (6.8 m^3) of the Alamito Canyon prospect (13.6 m^3) was originally ore, then it would have had an original (preweathering) value of about 2,050 dollars. This 20.4 tons of hypothetical ore would have contained about 1224 pounds of copper, 316 pounds of zonc, 816 pounds of lead, 41 pounds of nickel, and 41 pounds of cobalt.

If all of the copper in the Jeter deposit (60,000 pounds, see p. 89) was derived from Alamito Canyon-type deposits, then it would require about 49 Alamito Canyon-size bodies to have produced the Jeter deposit. A small tabular sulfide deposit, 1 x 10 x 33 m, could also have provided all the copper in the Jeter deposit. However, the strike length of the Jeter ore zone (55 m) represents only about 1/200th of the strike length of the Jeter fault (11,200 m), which shows essentially continuous alteration and low-grade mineralization by metal-rich groundwaters.

Therefore the 60,000 pounds of copper in the Jeter deposit could easily represent only about 1/200th (or less) of the total copper content weathered from Alamito Canyon-type sulfide mineralization in the adjacent Precambrian terrane.

If the above assumptions are reasonable, then the copper in the Jeter deposit could have been derived from a stratiform sulfide deposit containing 12 million (200 x 60,000) pounds of copper, 3 million pounds of zinc, 1.8 million pounds of nickel, 1.2 million pounds of cobalt, and 0.6 million pounds of lead. The gross metal value of such a deposit (200 times that of Jeter deposit) would be about 30.6 million dollars. From these rough calculations (see Appendix for details) it is apparent that there should be a relatively good probability (1/100) for discovery of a commercial stratiform polymetallic sulfide deposit in the metamorphic terrane of the Ladron Mountains. Of course, this conclusion would require stratiform sulfide bodies, equivalent to those redistributed by weathering, to be preserved in the Precambrian metamorphic rocks below the present zone of weathering.

It should be noted that at grades previously assumed for the Alamito Canyon "ore", the envisioned 30-million-dollar source for the Jeter deposit would have to be a large tabular body measuring, for example, 1 x 100 x 666 meters. Black's (1964) description of weathered sulfide mineralization does not suggest that gossans of such magnitude are present in the Ladron Mountains. Alternatively, the extensive alteration and mineralization along the Jeter fault could represent weathering

of hundreds of small Alamito Canyon-size bodies. Stratiform sulfide mineralization commonly pinches and swells along the mineralized horizon. The apparent small volume of weathered sulfides presently exposed in the Ladron Mountains could thus easily be associated with much larger stratiform sulfide deposits concealed at depth and much larger stratiform deposits completely removed by prior weathering and erosion.

To locate specific high-favorability areas (i.e. drilling targets) for stratiform sulfide deposits in the metamorphic terrane of the Ladron Mountains will require a considerable investment of time and money. Detailed geologic mapping (1:12,000) and a stratigraphic-structural analysis similar to that of Holcombe and Callender (1982) should provide sufficient structural-stratigraphic data to predict the geometry of potential stratiform deposits. Multi-media geochemical surveys and petrologic studies of the Precambrian rocks should help identify favorable stratigraphic horizons. Detailed geophysical surveys[1], especially helicopter-borne electromagnetic surveys, could detect concealed sulfide bodies that may be preserved below the zone of weathering. Detailed studies of this nature would probably require an investment of several hundred thousand dollars and several field seasons for mapping.

Government agencies such as the U.S. Geological Survey, the U.S. Bureau of Mines, and the New Mexico Bureau of Mines and

[1]An aeromagnetic intensity map of the Ladron area (Geometrics, 1973 shows two elliptical magnetic highs (amplitude: 50-100 gammas) over exposures of metamorphic terrane at Monte Negro and at the ridge south of Ladron Peak. The magnetic highs could reflect iron sulfide (pyrrhotite) concentrations associated with stratiform copper sulfide deposits (Wright, 1981), but detailed studies are needed to exclude other possibilities.

Mineral Resources could certainly assist in such a detailed study. However, actual drilling of specific targets--if located--should be left to private industry.

A tabular body of high-grade copper ore in chlorite schist at the Sulphur Canyon mine (central San Andres Mountains) was mined from a metasedimentary terrane similar to that found in the Ladron Mountains (Lasky, 1932; Condie and Budding, 1979; Fulp and Woodward, 1981). Therefore, it is suggested here that Precambrian metamorphic terranes throughout central New Mexico be considered to have a significant potential for stratiform polymetallic sulfide deposits hosted by metasedimentary or metavolcanic rocks.

Late Paleozoic(?) Silver-Base Metal-Barite Veins (Fig. 7, II-C)

Numerous northwest- and northeast-trending fractures in Precambrian rocks on northeast flank of the Ladrons are occupied by a complex network of siliceous and carbonate veins. Area II-C of Figure 7 contains most of the siliceous veins, which are believed to represent the "Hanson district" (silver) of Jones (1904).

Reconnaissance observations suggest at least two different ages of silver-bearing veins on the northeast flank of the Ladron Mountains. Siliceous veins are common in Precambrian rocks just west of the Jeter fault, and at least one northeast-trending siliceous vein appears to be truncated by the Jeter fault (Table 8, LAD-28). Siliceous veins have not been observed in post-Precambrian rocks east of the Jeter fault. However, silver-bearing carbonate veinlets have been observed in middle or late

TABLE 8. Gold and Silver values of siliceous (S) and carbonate (C) vein materials exposed along the northeast flank of the Ladron Mountains (Hanson district of Jones, 1904). See Appendix I for sample descriptions and locations.

Sample No.	Vein Type	Au(oz/ton)	Ag(oz/ton)	Associated Metals[1]	Remarks
LAD-28	S	0.0	1.0	Cu, Ba	vein truncated by Jeter fault
LAD-42	C	0.0	0.0	Ba, Cu	barite dominant
LAD-44	S	0.02	0.0	Ba, Fe	vein approximately 2 m wide
LAD-45	S	0.0	0.0	Pb	silicified breccia zone
LAD-48B	C	0.0	0.0	Fe, Mn	Lawrence Lode vein (south end)
LAD-49	S	0.0	0.0	Cu, Fe	offset of Lawrence vein
LAD-51	S	0.02	1.5	Pb, Mn	Lawrence Lode vein (central)
LAD-52	S	0.0	0.6	Fe	Precambrian (?) mineralization
LAD-54	S	0.0	10.0	Cu, Pb, Zn	sorted material, Silver King shaft
LAD-56	C	0.0	1.2	Fe	Tertiary volcanic host rock
LAD-58	C	0.0	6.4	Cu	Emma Lode claim area
LAD-62	C	0.0	0.6	Fe	----
LAD-63	C	0.0	1.0	Fe	----

[1]based on visual identification of associated minerals, Appendix I

Tertiary volcanic conglomerates about one mile north of the Jeter mine (Table 8, LAD-56). Siliceous veins and iron-rich carbonate veins also locally occur side-by-side within the Lawrence Lode claim area. Distribution patterns of siliceous veins around the Ladron Mountains indicate that they may be as young as Pennsylvanian but not as young as middle Tertiary (see p. 46). Therefore, the siliceous silver-bearing veins in the Hanson district are tentatively interpreted to be sedimentary hydrothermal veins of late Paleozoic age. Some silver-bearing carbonate veins are clearly of Tertiary age and may be supergene. In either case, there is no requirement for a hidden magmatic source.

The siliceous vein outcrops range in width from about 1 cm (Silver King shaft, Fig. 5) to nearly 2 m in width (Lawrence Lode claim). Siliceous veins have been verified (Table 8) to contain minor amounts of lead-zinc-copper sulfides, moderate amounts of barite, as much as 10 oz/ton of silver (economic), and sub-economic gold values of as much as 0.02 oz/ton. Carbonate-dominated veins (mostly north of area II-C) locally carry economic grades of silver (6.4 oz/ton, probably as halides) and some barite. Coarsely crystalline galena, sphalerite, and chalcopyrite, which are common in the siliceous veins, have not been observed in the carbonate veins.

Although some silver values are economic, surface veins of mineable width do not appear to be of economic grade, and veins of known economic grade are not of mineable width. Because they are mostly thin and discontinuous, silver-bearing veins of the Hanson district are judged to be of relatively low economic

potential; that is, non-commercial. Based on similar observations and reasoning, quartz-fluorite veins near the Juan Torres prospect (Fig. 5) are also considered to have no commercial potential. However, an area of silicification and silicified limestones along the Ladron Fault--also possibly of sedimentary hydrothermal origin--occurs in a more favorable geologic setting (see p. 110).

Plio-Pleistocene Manganese Deposits (Fig. 7, II-D-1, II-D-2)

Favorable area II-D-1 represents a swath along the Carbon Springs fault zone (Fig. 4), where it is covered by a travertine caprock (QTt, Fig. 2). This swath is considered to be favorable for discovery of small high-grade manganese deposits similar to that at the Black Mask Mine (production 566 tons Mn, avg. grade 42%; Farnham, 1961). Area II-D-2 represents: 1) the shallow subsurface projection of a late Cenozoic (Plio-Pleistocene) unconformity where limestones of the upper Madera Formation (PM, Fig. 2) are overlain by limestone-cobble conglomerates of the Sierra Ladrones Formation (QTs, Fig. 2), and 2) a contiguous narrow band of Madera Limestone once buried by this Sierra Ladrones Formation. Small subeconomic-grade (22% Mn) manganese deposits, which occur in the Madera Limestone adjacent to the unconformity, have produced minor amounts of iron-rich manganese "oxides" (see Table 1, p. 23). Similar sub-economic manganese deposits are likely within area II-D-2 (northward from Rio Salado Box).

Ore-grade manganese at the Black Mask Mine has been verified to occur in limestone conglomerates of the Sierra Ladrones

Formation and is clearly of Plio-Pleistocene age. Low-grade manganese deposits of the Rio Salado Box area are also reasonably interpreted to be of Plio-Pleistocene age because of their proximity to the late Cenozoic unconformity. Anomalous iron and manganese contents (Table 9) in the Plio-Pleistocene travertine (QTt, Fig. 2), which overlies the manganese deposits at the Black Mask Mine, suggest that it was genetically tied to the contemporaneous manganese mineralization. Therefore, the two classes of manganese deposits and the travertine caprock are interpreted to represent cogenetic products of a shallow ground-water system (carbonate-manganese-iron-rich) that flowed southwesterly off the Ladron Mountains in Plio-Pleistocene time (ca. 1-3 m.y. ago; see p. 37, 52).

Separation of iron from manganese in sedimentary (i.e. supergene) manganese deposits is believed to occur where oxygen-poor ground waters (capable of dissolving iron and manganese) enter a progressively oxygenated environment, which causes iron to precipitate before manganese (Hewett, 1966; Levinson, 1974). Thus, manganese-iron-rich ground waters, locally rising along the Carbon Springs fault zone, could have mixed with more oxygenated waters in the limestone conglomerate to produce the high-grade Black Mask deposit. In comparison, the low-grade iron-rich deposits near the Rio Salado Box were probably deposited by laterally flowing (generally descending) ground waters that only mixed with more oxygenated waters along the unconformity.

Manganese is a relatively low value mineral commodity used primarily in the manufacture of iron alloys. The current price

TABLE 9. Summary of trace element anomalies (underlined) vs. iron content in four samples of the travertine (QTt) northeast of Riley. All values in parts per million (ppm). See Appendix I for descriptions, complete analyses, and locations.

Sample No.	Fe/Mn	Fe	Mn	V	Be	Co	Ni	Ag	Ba	Sr
LAD-7	13.3	20,000	1500	200	20	15	30	2	200	500
LAD-9	7.5	1,500	200	10	1	<5	15	2	50	1000
LAD-12C (middle)	30	30,000	1000	70	15	15	30	.5	1000	700
LAD-12D (top)	2.5	500	200	<10	2	<5	20	3	500	1500
average limestone[1]	3.5	3800	1100	15	1	4	12	1	100	500

[1]Average Fe content from Mason (1966, Table 6.5); other elemental abundances from Levinson (1974, Table 2-1).

of 48% manganese ore is $1.75/metric ton (Eng. & Min. Journ. 5/82). A description of the Black Mask manganese deposit (Neuschel, 1943) indicates that it was a flat-lying, tabular body (2 x 75 x 80 feet) truncated by erosion along its western margin. The now apparently mined out ore body produced two carloads (approximately 10 tons) of manganese during 1941-46, and 566 metric tons of manganese during 1952-55 (Farnham, 1961), which would be worth about $1008 at current prices. Nueschel (1943, p. 5) reported one sample of the Black Mask ore to assay 51.4% manganese and 1.7% iron. The average grade of the Black Mask deposit was about 42% manganese (Farnham, 1961).

Based on a supergene model for the origin of the Black Mask deposit, we estimate that there is a good probability (10^{-2}) for discovery of a small (10^5 metric tons) Black Mask-type manganese deposit at a shallow depth (<30 m) in area II-D-1. A small manganese deposit of this type could be recoverable at a profit, but would be too small to be considered a commercial resource. Assuming an ore density of 4.0 mt/m^3 (i.e. one m^3 = $7.00 worth of ore), a commercial manganese deposit (gross value = $25 million) would require a volume of 3.57 x 10^6 m^3. A tabular manganese deposit measuring 1 x 500 x 7140 m would equal this commercial volume and would fit snugly within the favorable area (II-D-1). A commercial manganese deposit of such dimensions seems to be inappropriately large in comparison to the volume and geometry of the inferred ground-water mineralization system. Therefore, the probability for discovery of a commercial

manganese deposit in the Ladron WSA (below the travertine cap) is judged to be low (10^{-4}.)

POTENTIAL OF POORLY KNOWN (SPECULATIVE) DEPOSITS

Favorable areas for 6 types of mineral commodities within the Ladron WSA (Fig. 7, III-A, III-B, III-C, III-D, III-E, III-F) have been tentatively outlined on the basis of indirect, in some cases very limited, evidence; therefore, both their existence and their economic potential are speculative. Conceptual models are again employed in outlining the favorable areas and making tenuous estimates of economic potential. These preliminary estimates of speculative economic potential may be used as a guide in deciding where more work is needed.

Oil and Gas (Carbon Dioxide) (Fig. 7, III-A) by R.A. Bieberman and R.M. Chamberlin

Commercial oil and/or gas production has not, as yet, been found in Socorro County, New Mexico. The nearest commercial production to the Ladron area is located about 86 miles to the northwest at the southeastern margin of the San Juan Basin (McKinley County; T. 15 N., R. 10 W.).

Pennsylvanian strata are the most favorable target for oil and gas exploration in the Lucero region of central New Mexico (Wengerd, 1959), which includes the Ladron WSA. Pennsylvanian rocks, which continuously underlie the western two thirds of the Ladron WSA, are as much as 2700 feet (1650 m) thick (Kottlowski, 1960).

The Sandia and Madera formations comprise the Pennsylvanian system in the Ladron Mountains. The Sandia is made up of interbedded shales, sandstones, and a few limestones. The Madera consists dominantly of limestone interbedded with shales and

sandstones. Dark gray limestones in the upper Madera Formation, which are exposed south of Navajo Gap, have a faint petroliferous odor (Fig. 5).

In 1947, White and Mangels drilled the #1 State test well (NE1/4, SW1/4, sec. 32, T. 4 N., R. 3 W.), which is located about 4 miles northwest of the Ladron WSA. This is the only oil and gas test in the vicinity of the Ladron area. Drilling started in the lower Sandia and encountered Precambrian rocks at a depth of 122 feet. The test was plugged and abandoned at a total depth of 201 feet.

On their map of New Mexico showing areas favorable for oil and gas exploration, Foster and Grant (1974) place the area around the Ladron Mountains in a "Class 4" ranking, which is the least favorable in a system where "Class 1" is most favorable. Exploration criteria employed by Foster and Grant include: 1) the number of favorable zones (i.e., potential petroleum source and reservoir beds), 2) maximum thickness of the sedimentary section, 3) structural setting, and 4) possible unconformities in the sedimentary section.

It is generally recognized in petroleum exploration that generation of petroleum and natural gas requires two factors: 1) the presence of organic-rich sediments (usually black shales and limestones of marine origin), and 2) progressive burial to a depth where the earth's internal heat causes thermal maturation of the organic material. Empirical observations indicate that typical geothermal gradients allow formation of petroleum at depths of about 2 to 4 kilometers and natural gas at depths of about 3 to 7

kilometers (Dow, 1978; Heroux and others, 1979).

By the criteria of Foster and Grant and the above genetic concepts, we consider a portion of the Ladron WSA (Fig. 7, III-A) just northeast of Riley to be favorable for oil and gas exploration. In our view, the Riley area may be considered to be a "Class 3" extension (continuation) of the "Class 2" Acoma Basin of Foster and Grant (1974).

In the Riley area, a thick sequence of Pennsylvanian marine rocks (ℙM, Fig. 2, Table 3) is inferred to be present at a depth of 2.9 to 3.6 km, which is within the normal "window" of oil and gas generation. The downwarped Pennsylvanian beds are structurally isolated from their exposed equivalents west of Ladron Peak by the Rio Salado flexure, the Carbon Springs flexure, and the Alamito Shear zone. These major basement structures (Fig. 4) locally form the eastern margin of the Laramide Baca basin (Chapin and Cather, 1981). Probable late Paleozoic movements along the Rio Salado flexure (see p. 40-41) may have created stratigraphic and structural traps that could now act as small reservoirs for oil and gas. Marine sandstones in the upper Madera Formation and fluvial sandstones in the lower Abo Formation could form suitable reservoir horizons.

The time of maximum burial of Pennsylvanian rocks in the Riley area was most likely in the late Oligocene to early Miocene. The maximum depth of burial at that time is estimated to be 3.2 to 3.6 km (Tv = 545-575 m, Tb = 250 m, K = 585-665 m, Triassic = 350-380 m, Pgs = 145-170 m, Pay = 500-600 m, ℙM = 835-970 m; see Table 3 for description of stratigraphic units).

Assuming nominal conditions (5% porosity, expansion

correction = 1.2 reservoir bbl/stock tank bbl, and oil saturation = 1.0) and a price of $34/bbl, then the necessary volume for a commercial(?) reservoir of oil ($25 million) is calculated to be $2.0 \times 10^5 m^3$ (Ron Broadhead, written comm., 1982). A reservoir horizon approximately 1 m thick, 100 m wide, and 670 m long would satisfy this commercial volume. This calculation simply shows that commercially significant amounts of petroleum could easily be present within the relatively small portion of the favorable area (about 5 square miles) that overlaps the southwestern flank of the Ladron WSA.

In conclusion, the available information indicates a high probability (10^{-1}) for the generation of petroleum and natural gas in Pennsylvanian rocks below the Riley area. However, numerous basaltic dikes and normal faults in the Riley area may have allowed oil and gas to leak from reservoirs, which significantly reduces the present probability for discovery of an undepleted reservoir. The probability for discovery of a relatively small oil and/or gas reservoir in the Riley area is judged to be fair (10^{-3}).

Carbon Dioxide: Carbon dioxide has a great many uses in addition to its use in soft drinks, fire extinguishers, and dry ice, and is becoming increasingly important in the enhanced recovery of oil. Carbon dioxide is highly soluble in crude oils and water at reservoir pressures and temperatures. When oil and water contain a substantial amount of dissolved carbon dioxide, their viscosities, densities, and compressibilities are modified in a direction which helps to increase the oil-recovery efficiency.

At present, oil companies are eager to have under contract a supply of carbon dioxide. The increasing price of crude oil will make it economically more attractive in the coming years to inject carbon dioxide to recover additional oil.

Carbon dioxide fields are being developed in northeastern New Mexico and southwestern Colorado. Pipelines will transport the carbon dioxide to oil fields in west Texas and southeastern New Mexico.

The formation of carbon dioxide accumulations beneath the surface of the earth is not clearly understood. One theory suggests that it might be generated through thermal action (contact metamorphism) when limestones are intruded by granitic igneous rocks. If this theory is correct, the Ladron WSA may have a speculative potential for carbon dioxide production. Basaltic to monzonitic dikes and sills are known to occur along the western part of the Ladron WSA (Fig. 3) and must cut Madera limestones in the subsurface. However, the basaltic-monzonitic dikes are associated with only minor baking of adjacent sediments at the surface. Significant contact metamorphism of Madera limestones at depth is therefore considered to be unlikely. The probability for discovery of commercial volumes of carbon dioxide in the Ladron WSA is judged to be very low (10^{-5}).

Mississippi Valley-type Lead-Zinc-Barite (Fig. 7, III-B)

Mississippian and Pennsylvanian limestones are historically productive hosts for replacement and vein deposits of lead-zinc-barite (± fluorite, ± silver, ± copper) in the Magdalena (Kelly) and Hansonburg mining districts of Socorro County (Lasky, 1932;

Kottlowski, 1953). Ores of the Hansonburg district have isotopic fingerprints and many other aspects similar to Mississippi Valley-type lead-zinc deposits (Slawson and Austin, 1960; Roedder and others, 1968; Allmendinger, 1975). Many geologists consider Mississippi Valley lead-zinc deposits to be of sedimentary hydrothermal (stratafugic) origin (Hanor, 1979; Gustafson and Williams, 1981). Although clearly epigenetic on a mine scale, Gustafson and Williams (1981) suggest that on a basin-wide scale, Mississippi Valley-type deposits may be viewed as diagenetic deposits formed by contemporaneous expulsion of sedimentary brines from basin floor strata during progressive filling and compaction. By the reasoning of Gustafson and Williams, the Hansonburg lead-zinc-barite-fluorite ores are more likely to be of late Paleozoic age than of the Tertiary age previously suggested (Allmendinger, 1975).

An area favorable for Mississippi Valley-type lead-zinc-barite deposits in limestones has been tentatively outlined (Fig. 7, III-B) on the basis of hydrothermally silicified limestones and silicified fault breccia along the Ladron fault, about one mile west of Ladron Peak. Black (1974, p. 78) reported triangular boxworks suggestive of copper sulfides in this silicified zone. Silicified limestones and dump material from an adit on this zone (Fig. 5; Appendix I, LAD-21 A, B, D, E) yielded no detectable gold or silver content by fire assay. However, siliceous hydrothermal veins of possible late Paleozoic age (see p. 46) in the Hanson district (Fig. 7, II-C) and the Juan Torres area do contain appreciable amounts of lead-zinc-barite-fluorite

and silver. These metalliferous hydrothermal veins occur in Precambrian rocks, at a deeper erosion level than the silicified rocks along the Ladron fault. Therefore, it seems possible that the mostly barren silicification along the Ladron fault may be associated with Mississippi Valley-type replacement deposits at depth.

Regional stratigraphic relationships and local structural patterns (see p. 44) permit the Ladron fault to be reasonably interpreted as a submarine structure that controlled the east margin of the Lucero basin in Pennsylvanian time (Kottlowski, 1963). If so, stratafugic basin brines (Gustafson and Williams, 1981) may have been channeled laterally along basement fractures such as the Alamito shear zone (Fig. 4) and upwards along the Ladron fault.

It is recognized here that the speculative potential for a lead-zinc-barite deposit in the Ladron WSA (area III-B) is based on concepts that are not generally employed and essentially untested in central New Mexico. Nonetheless, the probability for discovery of a commercial lead-zinc-barite deposit in the Ladron area is judged to be fair (10^{-3}). For comparison, at current prices, the Magdalena (Kelly) district (Lasky, 1932) produced about $77.7 million dollars worth of zinc, $10.9 million of lead, $6.4 million of copper and $4.5 million of silver.

Tungsten-Bismuth-(Tin?) in Precambrian Granite (Fig. 7, III-C)

Condie (1976) has mapped a small body of "unusually coarse-grained granite" within the medium-grained Capirote granitoid in an area about one mile southwest of Ladron Peak. The contact

relationships of the coarse-grained granite are not described, but the map representation implies a small, plug-like cupola of coarse-grained granite. In her study of granitic rocks of the Ladron Mountains, Cookro (1978) collected six samples from the area of this coarse-grained granite. Three of these samples are reported to contain minor amounts (0.1 to 0.6 volume percent) of disseminated fluorspar, which Cookro interprets as "primary" on the basis of textural relationships visible in thin section.

Sediments in arroyos that generally emanate from this area southwest at Ladron Peak contain anomalous values of tungsten (15 ppm) and bismuth (6 ppm) (see Fig. 6 and p. 59-60). The apparent association of anomalous tungsten and bismuth with a fluorine-rich granite suggests that a greisen or vein-type tungsten-bismuth-tin(?) deposit (Peters, 1978, p. 46) is possible within area III-C of Figure 7.

This tungsten-bismuth potential is highly speculative and the favorable area needs additional study to verify this possibility. Other localities of fluorite-bearing granite in the Ladron Mountains (see Cookro, 1978) are generally associated with fault zones mapped by Black (1964). Conceivably the fluorite-bearing granites could be related to unrecognized hydrothermal veins such as those at the Juan Torres prospect. However, this still would not explain where the high tungsten and bismuth values are coming from. The two-mica Ladron pluton (Condie, 1976) should also be considered as a possible source, since tungsten-tin deposits are commonly associated with two-mica granitoids (Ishihara, 1981).

Placer Gold in Basal Paleozoic Conglomerates (Fig. 7, III-D)

Bedrock surfaces unconformably mantled by fluvial or littoral conglomerates are well-known sites for discovery of placer-gold deposits (Thompson, 1980). Thin quartz-pebble conglomerates are known to occur at the base of the Kelly Formation where it rests unconformably on Precambrian rocks near Cerro Colorado (Lasky, 1932). Siemers (1978) reports that conglomeratic sandstones at the base of the Sandia Formation, commonly fill broad troughs in the underlying Precambrian rocks. Cross sections of Armstrong (1958) show that the Kelley Formation, rests unconformably on Precambrian rocks in the southern Ladron Mountains and that the Sandia Formation rests on Precambrian rocks in the northern Ladron Mountains.

With these observations in mind, a sample of quartz-pebble conglomerate (LAD-59, App. I) was collected from a thin bed (0.3 m) at the base of the Kelly Formation west of Cerro Colorado. Fire assay of this conglomerate yielded a subeconomic gold value of 0.01 oz/ton.

Thus, the available information suggests a potential for placer-gold deposits along the basal late Paleozoic unconformity. Favorable area III-D represents the subsurface projection of this unconformity to a depth of about 1000 feet. Additional sampling and fire asays may be warranted if thicker conglomerates (amenable to subsurface mining) are found along this basal unconformity. Since known basal conglomerates are thin and contain only subeconomic gold values, the economic potential of placer-gold deposits in the Ladron WSA is presently judged to be very low (discovery probability = 10^{-5}).

Geothermal Energy (Fig. 7, III-E)

The association of geothermal resources--natural heat energy in the earth's crust--with crustal belts of geologically recent volcanism, recent faulting, and earthquake activity is well known (Krueger and Otte, 1973). In New Mexico, most "Known Geothermal Resource Areas" (KGRA's) are spatially and genetically associated with magmatism along the Rio Grande rift (Chapin and others, 1978; Hatton, 1981).

In the Socorro segment of the rift, a deep (19-22 km) sill-like magma body has been identified and mapped using microearthquakes and seismic reflection profiling (see summary report by Sanford, 1978). The Socorro geothermal area lies at the south end of this deep magma body (Chapin and others, 1978). Several small, shallow (4-5 km) magma bodies, probably dike-like, have been geophysically mapped above the southern terminus of the deep magma body. These shallow magma bodies are a likely heat source for thermal waters and high geothermal gradients in the Socorro Peak area. The termination of the deep magma body and locus of shallow magma intrusion at Socorro is apparently controlled by a major transverse basement structure, the Morenci lineament (Chapin and others, 1978).

The east flank of the Ladron Mountains lies above the western margin of the deep sill-like magma body, which extends from Socorro to north of Bernardo (Sanford, 1978, fig. 1; Rinehart and others, 1979). A map of contemporary seismicity (microearthquake epicenters) around the Albuquerque Basin shows a tight cluster of microearthquakes on the northeast flank of the Ladron Mountains

(Sanford and others, 1979; fig. 6). This microearthquake activity is similar in character (average depth of focus at 5 km, occurs in swarms, tight cluster in space and time) to that in the Socorro area, which is attributed to shallow magma intrusion (A.R. Sanford, oral comm., 1982). Chapin (Chapin and others, 1978) has recognized that many geothermal areas in New Mexico are associated with major structural intersections between deep-seated crustal flaws (lineaments) and major north-trending fault zones of the rift. Appropriately, the Ladron microearthquake cluster lies along a northeast-trending transverse horst between the Cerro Colorado fault zone and the Alamito shear zone (Fig. 4). The center of the microearthquake cluster occurs at the intersection of these transverse basement structures with the late Pleistocene (10,000-150,000 years old) Loma Pelada fault (Machette, 1978).

Based on the available geophysical data, an area of speculative geothermal potential has been outlined on the northeast flank of the Ladron Mountains (Fig. 7, III-E). No thermal springs are known in the area and no heat-flow tests have been made. The average depth of microearthquake foci (~5 km) suggests a potential heat source, and geothermal reservoir may be present near this depth. Deep geothermal reservoirs of this nature have not yet produced commercial energy, and would certainly test the limits of current technology. Based on available data and concepts, the probability for discovery of a commercial geothermal energy source within the Ladron WSA is judged to be very low (10^{-5}).

Uranium in Precambrian Rocks (Fig. 7, III-F)

In surface and subsurface waters uranium concentrations of greater than 100 ppb are quite rare, and have generally been found only in aquifers containing high-grade uranium mineralization (Rich and others, 1977). Therefore, the extremely high uranium content, 704 ppb U (see p. 58), of well water at the Lazy C Bar J Ranch is taken as a strong indication of ongoing weathering of high-grade uranium mineralization in Precambrian rocks west of the ranch.

Several observations argue strongly against deriving the uranium-rich groundwater in the ranch well from weathering of uranium mineralization along the Jeter fault. Since the ranch well lies in a major eastward draining canyon, there should be a relatively steep hydraulic gradient and dominant flow direction to the east. The ranch well is about 150 m west (i.e. upcurrent) from the trace of the Jeter fault. In addition, a stock well collared about 300 m east of the ranch well, or about 150 m east of the Jeter fault, yields a much less anomalous value of 74 ppb U. Thus the fault zone and rocks between the two wells appear to be acting as a local trap for uranium as opposed to acting as a local source of uranium.

Asymmetric zoning of metals and hydrochemical alteration in the Jeter uranium deposit provide strong evidence of a supergene origin (Table 7). Stratigraphic and structural relationships around the Ladron Mountains indicate that the uranium in the Jeter deposit (estimated reserves plus production equals 120,000 lbs U_3O_8; see p. 89) was derived from weathering of uranium-rich Precambrian rocks in the core of the range in late Pliocene to

early Pleistocene time (ca. 1-3 m.y. ago). Essentially continuous alteration and low-grade mineralization along the Jeter fault (Collins and Nye, 1957) allow the interpretation that the uranium in the Jeter deposit probably represents less than about 1/2ØØth of the total uranium weathered from the Ladron Mountains in Plio-Pleistocene time. The near-surface uranium potential in Precambrian rocks of the Ladron Mountains is thus estimated to be as much as 24 million pounds of U_3O_8. This estimate assumes an amount of uranium preserved below the present weathering profile equivalent to that lost during prior weathering. Present day uranium anomalies in groundwaters indicate that some of this uranium potential must exist as high-grade uranium mineralization (i.e. economic) as opposed to widely disseminated and/or low-grade uranium mineralization (i.e. subeconomic).

The price of uranium oxide is currently very depressed (spot market 17-2Ø $/lb U_3O_8) because of an oversupply and diminished demand, which is superimposed on a general economic recession. At present prices the gross dollar value of a potential uranium deposit in the Ladron Mountains could be as much as 4Ø8 to 48Ø million dollars (based on a 24 million lb deposit). Assuming a renewed demand for uranium materializes in the next 5 to 1Ø years, then at foreseeable uranium prices (35-45 $/lb U_3O_8, 1982 dollars) the uranium potential of the Ladron Mountains could exceed a billion dollars (84Ø to 1Ø8Ø million dollars). Because uranium mineralization within the Precambrian core of the Ladrons has not yet been recognized, this uranium potential lies somewhere between a hypothetical and a speculative

classification. Primarily based on the intensity of the uranium geochemical anomaly at the foot of the Ladron Mountains, the probability for discovery of a commercial uranium deposit in Precambrian rocks of the Ladron Mountains is judged to be good (1/100).

Possible, but unverified, sources for uranium in the Jeter deposit and groundwaters near the Lazy C Bar J Ranch are: 1) metamorphosed sandstone-type uranium deposits at a transition zone between black-colored (radiation damaged?) quartzites and schists, which would be peripheral to stratiform polymetallic sulfide mineralization (see Black, 1967, p. 17, 57; Appendix of Nash, 1978); 2) variable, high-grade to low-grade uranium mineralization disseminated in the "two-mica" Ladron quartz monzonite pluton[1] (Condie, 1976; Cookro, 1978); 3) contact metasomatic or hydrothermal hematite-uranium(?) veins associated with the "two-mica" Ladron quartz monzonite (see Black, 1964, p. 77; Condie, 1976); and 4) unconformity-type uranium veins associated with a possible unconformity developed on the Capirote granitoid and buried by arkosic metasediments (Condie, 1980). Verification of any (or all) of these possible types of uranium deposits will require detailed geologic mapping and geochemical sampling. Once the type (or types?) of high-grade uranium

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[1]Data of Cookro, 1978, suggest a potential "uranium-source rock" in the Ladron pluton about 1.6 km west of the Lazy C Bar J Ranch. This sample (LD-1) contains 0.7 volume percent opaque minerals and chemical analysis yields only 0.04 weight percent Fe_2O_3. The opaques clearly cannot be iron oxides. Should the opaques prove to be uraninite or urano-thorianite, then the rock could contain as much as 2.2 weight percent U_3O_8.

mineralization indicated by groundwater anomalies is known, then relatively specific targets for potential uranium deposits can be outlined with respect to the Ladron WSA.

STRATEGIC MINERALS POTENTIAL

As stated by Planner (1980b):

> "Strategic materials [includes minerals] are commodities essential to this country's economic welfare and military security that are in such short supply within the United States that they must be supplied from foreign sources or mined and processed at exorbitant expense."

Chromium, nickel, cobalt, and platinum group metals are among the most important and least available of strategic materials that are stockpiled by the U.S. government. Commercial deposits of chromium, platinum, and nickel are typically found in association with ultramafic igneous rocks such as layered dunite/peridotite complexes and podiform serpentinite bodies (Meyer, 1981). Since ultramafic rocks of the above type have not been reported in the Ladron area, it may be presumed that there is essentially no potential for chromium, platinum, or nickel deposits in the WSA.

Planner (1980b) indicates that in 1978 there were 19 strategic commodities for which the United States had to import over 50 percent of its consumption. In addition to chromium, nickel, and platinum group metals, the list includes (in order of decreasing import reliance): columbium, sheet mica, strontium, manganese, tantalum, cobalt, bauxite (alumina), asbestos, fluorine, tin, cadmium, zinc, potassium, selenium, mercury, gold, and tungsten.

The Ladron WSA is judged to have a good probability (1/100) for the discovery of a commercial polymetallic sulfide deposit in Precambrian metasedimentary rocks (Fig. 7, Area II-B). Geochemical data suggest that a large stratiform sulfide deposit

of this type could produce significant amounts of strategically important cobalt and nickel as byproducts. The Ladron WSA also has a good probability (1/100) for discovery of small (~105 metric tons), high-grade manganese deposits (Fig. 7, area II-D-1). The potential manganese deposits could be economically recoverable (i.e. mineable), but would probably be too small to be considered as a commercial resource. A speculative potential for tungsten exists in Precambrian granites southwest of Ladron Peak (Fig. 7, Area III-C). These areas, favorable for discovery of strategic minerals, have been delineated and discussed in previous sections of this report.

All Precambrian rocks (granites and metamorphic rocks) in the Ladron WSA (Fig. 7, Area III-F) are judged to have a good probability (1/100) for the discovery of a commercial uranium deposit. Although uranium is not considered to be a strategic mineral (primarily because it is not in short supply in the United States), it is an important "alternative" energy source, which will become increasingly important as supplies of fossil fuels are diminished.

RECOMMENDATIONS

The most significant conclusion of this preliminary evaluation is that Precambrian rocks within the Ladron WSA have a good (10^{-2}) probability for discovery of a commercial uranium deposit and/or a commercial deposit of polymetallic sulfides (Cu, Pb, Zn, Ni, Co). The probability for discovery of a large uranium deposit, worth as much as a billion dollars, is judged to be low ($\sim 10^{-4}$), but significant. Discovery and development of a large uranium deposit would certainly benefit the local population and economy, society in general, and all levels of government.

This recognition of commercial mineral potential is based primarily on recently obtained geochemical analyses (NURE data). The NURE data provide <u>indirect</u> evidence of abundant high-grade uranium mineralization and high-grade polymetallic (Cu-Pb-Zn-Ni-Co) sulfide mineralization (apparently as two different types of deposits) in Precambrian rocks within the Ladron Mountains. Detailed geologic mapping (e.g. Holcombe and Callender, 1982), detailed multi-media geochemical surveys (e.g. Rattè and others, 1978), and detailed geophysical surveys (e.g. Wright, 1981; Hohmann and Ward, 1981) will be necessary to delineate the most favorable targets for potential uranium deposits and/or polymetallic sulfide deposits. Proper testing of our preliminary conclusions will require an investment of several hundred thousand dollars and several field seasons of mapping time. If such detailed studies locate potential uranium deposits or sulfide deposits of commercial size, then the ultimate testing (drilling) should be left to private industry.

The Bureau of Land Management is now faced with the difficult task of weighing our estimate of the invisible and intangible mineral values against relatively visible and tangible (but still hard to quantify) wilderness values, in order to make a preliminary estimate of the "price" of a "Sierra Ladrones Wilderness Area". We suggest, that in terms of "lost mineral production" this price could be as much as a billion dollars. We suggest the Bureau of Land Management considers the following options (listed in order of decreasing preference):

1) to place the Sierra Ladornes WSA in a "holding" status for a period of 10-20 years and open it to mineral exploration by private industry, which would allow testing the presently outlined areas of high economic potential at the least cost to the taxpayer;
2) to recommend the Sierra Ladrones WSA suitable for Wilderness status, with the stipulation that sufficient time (5-10 years) and money (300-500 thousand dollars) be budgeted to make detailed investigations (a cooperative USGS, USBM, NMBM&MR project?),which should provide a meaningful test of the commercial uranium and polymetallic sulfide potential presently recognized;
3) to recommend the Sierra Ladrones WSA unsuitable for wilderness status because of preliminary evidence for uranium and/or polymetallic sulfide deposits of commercial significance.

Another option, to remove the area of commercial mineral

potential (Fig. 7, II-B and III-F) from the WSA, does not seem appropriate, since it forms the visible core and scenic heart of the proposed wilderness.

Finally, if good for nothing else, the conclusions of this preliminary evaluation should allow application of the "First Law of Serendipity" to any future evaluation of mineral potential in the Ladron Mountains. The "First Law of Serendipity" is: "In order to discover anything, you must be looking for something" (Ohle and Bates, 1981).

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APPENDIX I: Chemical Analyses

A. Results of Fire Assays (oz/ton), Other Analyses, and Description of Samples.

Sample No.	Description - by R.M. North	Results
LAD-1	Sample from prospect pit in Madera Limestone (PM) on NW side of "The Box". Fe and Mn oxides and hydroxides. Some iridescent limonite coatings on botryodial surfaces. One surface shows considerable yellow-brown limonite with slickensides. Minor calcite coatings and quartz-feldspar sand in surface depressions. Broken surface shows irregular shaped cavities of up to 5 mm (most are 1-2 mm) lined with Mn-Fe oxide/hydroxide calcite crystals, with long dimension of crystals perpendicular to cavity surface. XRD indicates Mn-minerals are hollandite and/or cryptomelane.	
LAD-7*	Riley travertine (QTt). White, gray and brown banded travertine. "Limonite brown" is the dominant color. Some cavities up to 2 cm. Color due to iron and manganese staining of calcite.	Ag-2ppm
LAD-9*	Riley travertine (QTt). White calcite with some slight pink Fe coloration. Cavities common up to 2 mm. Cavities are aligned apparently parallel to surface of accumulation.	Ag-2ppm
LAD-11*	Sample from Mn-prospect pit in upper Santa Fe Group (Qts) rocks. Vuggy Mn-oxide with white calcite lining vugs. Yellow Fe-staining present. Minor red hematite staining. Mn-minerals are relatively hard (~5), especially where present as dense concentrations (up to 1 cm x 0.5 cm). These dense Mn areas make up ~10% of the total sample. Mn minerals are intimately mixed with calcite, giving appearance of being softer in about 70% of sample. Remaining 20% is pure calcite and Fe-oxides/hydroxides. XRD shows Mn-minerals to be cryptomelane and/or hollandite.	Au-0.0 oz/ton Ag-0.0 oz/ton
LAD-12A*	San Andres Limestone. Light pink limestone. Some small cavities, but relatively dense. Largest cavities are 2 mm, lined with calcite. Most cavities are less than 1 mm.	Ag-3ppm

* see Appendix I-B for complete analyses.

Sample No.	Description	Results
LAD-12B	Riley travertine. Banded travertine. Alternating bands of white and cream colored calcite. Difference in iron content is at least partially the reason for different color of bands. Cream bands also have slightly coarser calcite crystals. Crystals in white bands are orientated with long axis perpendicular to banding. Crystals in darker bands show no orientation. Bands ~5 mm wide.	--
LAD-12C*	Riley travertine (QTt). Iron-stained calcite. Varigated browns, yellows and reds. Some small (less than 1 mm) cavities. Some small, white calcite veins (healed fractures?).	Ag-Ø.5ppm
LAD-12D*	Riley travertine (QTt). Dense, banded travertine. Bands are 1 mm to 1 cm wide, white to cream colored. All bands appear to have calcite with long axis perpendicular to banding.	Ag-3ppm
LAD-13	Riley travertine. Light reddish brown calcite. Cavities up to 1Ø mm common.	--
LAD-16	Sample from outcrop 2 miles southwest of Mac Brown Ranch (Lazy C Bar J Ranch), described by Mr. Brown as an "oil shale". Rock is dark gray Precambrian schist consisting of fine-grained plagioclase, hornblende, quartz, biotite, and chlorite. No organic material is present.	--
LAD-17	Sample from outcrop at windmill about 1 mile northeast of Mac Brown Ranch described by Mr. Brown as "oil shale". Precambrian schist containing fine-grained mixture of plagioclase, hornblende, quartz and botite. No organic content.	--
LAD-19A	Juan Torres prospect. Grab sample from dump. Quartz vein material. Dominantly milky white quartz, with minor copper mineralization. Copper minerals are malachite and chalcocite. Chalcocite is seen altering to malachite in places. Some pale blue-green fluorite also is present. Mn and Fe stains common.	Au-Ø.Ø oz/ton Ag-Ø.Ø oz/ton
LAD-19B	Juan Torres prospect. Chip sample across vein. Dominantly clear to white fluorite with limonite staining. Some milky white quartz common. Minor specular hematite.	
LAD-2Ø	Sample from unnamed prospect at elevation of	Au-Ø.Ø oz/ton

Sample No.	Description	Results
	6,548 feet (north of Juan Torres). Quartz, microcline, chlorite, malachite, hematite, pyrite, chalcopyrite. Malachite lines fractures.	Ag-Ø.Ø oz/ton
LAD-21A	Samples from adit in silicified shear zone of Ladron fault (west of Ladron Peak). Partially silicified limestone. Mixture of calcite and quartz with limonite along fractures. May be dolomite, in part. No valuable mineralization is visible.	Au-Ø.Ø oz/ton Ag-Ø.Ø oz/ton
LAD-21B	Brecciated limestone, in part silicified. Considerable limonite staining of calcite. Iron staining gives sample brown and yellow coloration. 1-2 mm wide quartz veinlets common.	Au-Ø.Ø oz/ton Ag-Ø.Ø oz/ton
LAD-21D	Silicified granite, gray quartz and flesh-pink K-feldspar (probably microcline) are the dominant minerals. Minor limonite. Quartz veining of up to 7 mm is common, indicating healing of fractures. One such vein is offset ~1 cm, indicating further shearing after formation of the quartz veining. No valuable minerals observed under 3Ø power magnification, however, fine-grained gold-silver is possible.	Au-Ø.Ø oz/ton Ag-Ø.Ø oz/ton
LAD-21E	From silicified ls(?) at portal. Partially silicified limestone. Considerably fractured. Fractures are healed by white calcite, yielding crosscutting veinlets. Veinlets are Ø.1 to Ø.1 mm across. Some small dark gray veinlets, probably Mn-stained calcite. Minor limonite stain.	Au-Ø.Ø oz/ton Ag-Ø.Ø oz/ton
LAD-22	Milky-white quartz vein, strike N2Ø°E, dip vertical. No other appreciable mineralization present. Gold unlikely.	Au-Ø.Ø oz/ton Ag-Ø.Ø oz/ton
LAD-23A	Sample from Jeter mine. Altered Precambrian on footwall of fault about 2Ø feet below claystone. Bleached-white (kaolinized?) granitic rock. Quartz, feldspar and clays present. Feldspar is mostly plagioclase, partially altered. The rock is highly fractured. Iron stains line some fractures. Both hematite and limonite are present, probably as weathering products of magnetite.	Au-Ø.Ø oz/ton Ag-Ø.3 oz/ton U-Ø.Ø1%
LAD-23C	Dark greenish gray silty claystone (base of altered fault gouge). Finely layered, in part. Some limonite stain. Color and greasy	U-Ø.2%

Sample No.	Description	Results
	feel suggest chlorite is present. Considerable slickenside surfaces. Outcrop yields 400 cps.	
LAD-23D	Light purplish gray silty claystone (middle of altered fault gouge). Slightly mineralized with copper. Chrysocolla and pyrite abundant. Hematite and limonite staining common.	
LAD-23E	Red silty claystone (top of altered fault gouge?) Contains fragments of bleached pЄ rock (up to 3 mm). Slickenside surfaces are common.	
LAD-25B	Prospect pit in Permian Yeso Formation, north of Riley. Cellular limonite, with possibly minor Mn oxides. Calcite coats many surfaces. This may have been a Mn prospect, but visual examination reveals little Mn mineralizaion.	
LAD-28	Along road in canyon bottom about 1 mile northeast of Brown Ranch. Prospect pit on vein strike N60°E, dip 60°SE. Quartz vein material with malachite, azurite, pyrite, chalcopyrite, barite, and chrysocolla. Pyrite is altering to hematite.	Au-0.0 oz/ton Ag-1.00 oz/ton U-0.04%
LAD-32	Cobble from upper Santa Fe conglomerates (Qts) east of Mac Brown Ranch. Purplish-gray, medium-grained quartzite with discontinuous pyrite stringers. Weathered surfaces are reddish-brown with iron staining. Very dense, with conchoidal fracture.	Au-0.0 oz/ton Ag-0.0 oz/ton
LAD-33	Mineralized shear in Precambrian below Atrasado segment (Black, 1964) of Jeter fault. Malachite and limonite in a dominantly quartz rock. The quartz is highly fractured, with malachite filling the fractures. Mica and feldspar, mostly plagioclase make up some of the fragments, which also has malachite filled fractures. Patches of hematite are common.	
LAD-35A	Quartz stringers in brecciated granite. Strike N20°W dip 50°NE. Medium- to coarse-grained mixture of quartz, K-feldspar (microcline) and plagioclase stringers. Minor limonite and calcite as alteration products. Minor amounts of epidote and magnetite.	Au-0.0 oz/ton Ag-2.8 oz/ton
LAD-42	Shaft on barite vein, strike N20°W, dip 80° W, 1-1/2 miles northwest of Jeter mine. 1) Vein material: Barite with iron and manganese staining. 2) Altered host rock: Malachite in fine-grained mixture of quartz and plagioclase,	Au-0.0 oz/ton Ag-0.0 oz/ton

Sample No.	Description	Results
	probably altered metasediment.	
LAD-44	Five foot thick quartz vein. Strike N50°W dip 70°NE in Precambrian metasediments. Barite with limonite and manganese staining.	Au-0.02 oz/ton Ag-0.0 oz/ton
LAD-45	Sample from prospect pit about 1 mile west of Jeter mine. Silicified breccia material. Clasts up to 3 cm cemented by quartz. Some K-feldspar and chlorite. Galena present as small veinlets and in pods.	Au-0.0 oz/ton Ag-0.0 oz/ton
LAD-48B	Sample from south end of main vein on Lawrence Lode claim. Chip sample across vein. Iron and manganese stained carbonate, mostly calcite. Siderite possible, but very minor. Fracturing common, with fractures coated by limonite and calcite.	Au-0.0 oz/ton Ag-0.0 oz/ton
LAD-49	Sample at shaft south of Lawrence Lode claim (from dump). Quartz with disseminated malachite. Iron and manganese stains also common. Some slickenslide surfaces with malachite and dendritic manganese stain. Hematite and limonite, both after pyrite, are common.	Au-0.0 oz/ton Ag-0.0 oz/ton
LAD-51	Near center of Lawrence Lode claim. Vein material from west side of shallow 10 ft deep cut on main vein. Quartz-carbonate vein material. Carbonate is calcite with iron staining with possibly some siderite. Manganese dendrites and smears common. Pervasive limonite staining. Minor galena.	Au-0.02 oz/ton Ag-1.5 oz/ton
LAD-52	Sample from prospect cut on Silver King #3 claim. Quartz pod in Precambrian bioschist. Quartz with minor calcite and limonite. Quartz is fractured. With limonite and/or calcite along fracture surfaces.	Au-0 oz/ton Ag-0.6 oz/ton
LAD-54B	Sorted vein material from dump at Silver King shaft. Galena, chalcopyrite and sphalerite in a gangue of quartz and limonite with minor calcite. Hematite stains in quartz. Chalcopyrite occurs as small (less than 0.5 mm) blebs. Several particles up to 1.5 cm of chalcopyrite with malachite stain. Vein is in part zoned, with parallel bands of hematite-stained quartz and limonite-rich bands. Veins are near vertical, thin, and strike N30°E and N15°W.	Au-0.0 oz/ton Ag-10.0 oz/ton

Sample No.	Description	Results
LAD-55A*	Claystone gouge in Jeter fault. Gray silty-claystone with areas red hematite stain and minor calcite. Some small (~1 mm) areas of malachite. Fault slivers of Precambrian rock are intruded by Tertiary diabase here.	.01% U 3.9% organic C
LAD-56	Veinlets in volcanic conglomerate. Banded calcite with layers of light gray-white crystalline calcite and red layers of hematite stained calcite grains. Limonite staining common.	Au-0.0 oz/ton Ag-1.2 oz/ton
LAD-57	Brecciated and bleached Precambrian rock (silicified granite?). Limonite and manganese dendrites common. 1 mm-2 mm patches of malachite common. The quartz is gray and white, giving the rock a spotted appearance.	Au-0.0 oz/ton Ag-0.0 oz/ton
LAD-58	Highly oxidized calcite vein material. Pervasive limonite staining, with lesser manganese and copper stain (malachite). Some hematite.	Au-0.0 oz/ton Ag-6.4 oz/ton
LAD-59	Sample from west of Cerro Colorado. Basal Mississippian conglomerate. Quartz clasts up to 2 cm. Minor calcite and chlorite(?). Small clasts of weathered schist.	Au-0.01 oz/ton Ag-0.0 oz/ton
LAD-60	Sample from southwest side Cerro Colorado. Very coarse-grained granite. Mostly microcline and quartz. Highly fractured and oxidized. Fracture surfaces coated with calcite, limonite, and manganese oxide. Minor biotite. Outcrop yields 140 cps.	
LAD-61	Sample from pit on southwest side of Cerro Colorado. Old Bonanza Thunderbird claims. Limonite, calcitend manganese oxide. Considerable yellow-ochre limonite.	
LAD-62	Sample from shallow shaft near center Section 27, T 3N., R 2W. Iron stained calcite vein material in Precambrian metasediments.	Au-0.0 oz/ton Ag-0.64 oz/ton
LAD-63	Sample from prospect pit in saddle of spur ridge east of Monte Negro. Iron-stained calcite vein material in Precambrian schist.	Au-0.0 oz/ton Ag-1.0 oz/ton
LAD-64A	Cellular boxwork of iron oxide gossan (dark brown, reddish brown and yellowish brown) from dump at Alamito Canyon Prospect (NW/4, Sec. 32, T3N, R2W). Host rock is quartz, muscovite, amphibole, schist	

Sample No.	Description	Results
	of Torres Schist of Black (1964); presumably a metamorphosed argillaceous sandstone. Atomic absorption analysis of gosssan yields: 0.1% (1000 ppm) uranium, 0.07% (700 ppm) copper, 0.07% (700 ppm) lead, 0.06% (600 ppm) zinc, 80 ppm nickel, and a cobalt content below detection limit of 0.01% (100 ppm). Uranium analysis was double checked. High uranium value is surprising, since anomalous radioactivity was not detected at the prospect and the gossan is not radioactive in hand specimen.	
LAD-64B	Fragment of mostly oxidized sulfide material (gossan) largely encased in quartz veinlet material (minor in prospect) from dump at Alamito Canyon Prospect. Traces of megascopic chalcopyrite and bornite are closely associated with boxwork of iron oxides. In thin section, bands of goethite/hematite form cellular boxwork (dominant trend is subparallel to fractures in surrounding quartz). Boxwork filled with large hematite masses and malachite (chrysocolla?). Broken(?) bits of boxwork iron oxides are encased in coarsely crystalline quartz. Small euhedral quartz crystals project into, or float in, or form short strands in the iron oxide boxwork. Malachite fills fractures in quartz. Trace of muscovite associated with quartz. Element mapping with scanning electron microscope shows anomalous copper disseminated in iron oxide.	

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ANALYTICAL REPORT

Client New Mexico Bureau of Mines

Address Campus Station
Socorro, N. M. 87801

Date Received Nov. 10, 1981

Authorized By R. M. North

Analyzed By JFA

Date Nov. 19, 1981

Job Number MA-704

Sample Identification LAD-7

Semi-Quantitative Emission Spectrographic Scan

Gold (Au)	< 10	Zirconium (Zr)	20
Silver (Ag)	2*	Boron (B)	< 10
Copper (Cu)	< 5	Barium (Ba)	200
Lead (Pb)	< 10	Beryllium (Be)	20 *
Zinc (Zn)	< 200	Lanthanum (La)	< 20
Molybdenum (Mo)	< 5	Niobium (Nb)	< 10
Iron (Fe)	2.0 %	Scandium (Sc)	< 5
Tungsten (W)	< 50	Strontium (Sr)	500
Nickel (Ni)	30	Yttrium (Y)	< 10
Cobalt (Co)	15	Calcium (Ca)	> 20.0 %
Chromium (Cr)	10	Magnesium (Mg)	0.15 %
Cadmium (Cd)	< 20	Titanium (Ti)	0.02 %
Arsenic (As)	< 200	Sodium (Na)	0.15 %
Antimony (Sb)	< 100	Potassium (K)	< 0.5 %
Manganese (Mn)	1500*	Silicon (Si)	< 1.0 %
Vanadium (V)	200*	Aluminum (Al)	0.7 %
Bismuth (Bi)	< 10	Phosphorus (P)	< 0.1 %
Tin (Sn)	< 10	Other	

Fe, Mg, Ca, Ti, Na, K, Si, Al & P reported in %, all other elements reported in ppm.

*Anomalous value (see Table 8)

CORE LABORATORIES, INC.
3428 Stanford Dr., NE
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Date Nov. 19, 1981

Job Number MA-704

Sample Identification LAD-9

Semi-Quantitative Emission Spectrographic Scan

Gold (Au)	< 10	Zirconium (Zr)	20
Silver (Ag)	2*	Boron (B)	< 10
Copper (Cu)	< 5	Barium (Ba)	50
Lead (Pb)	10	Beryllium (Be)	1
Zinc (Zn)	< 200	Lanthanum (La)	< 20
Molybdenum (Mo)	< 5	Niobium (Nb)	< 10
Iron (Fe)	0.15 %	Scandium (Sc)	< 5
Tungsten (W)	< 50	Strontium (Sr)	1000 *
Nickel (Ni)	15	Yttrium (Y)	< 10
Cobalt (Co)	< 5	Calcium (Ca)	> 20.0 %
Chromium (Cr)	< 10	Magnesium (Mg)	0.3 %
Cadmium (Cd)	< 20	Titanium (Ti)	0.03 %
Arsenic (As)	< 200	Sodium (Na)	0.2 %
Antimony (Sb)	< 100	Potassium (K)	< 0.5 %
Manganese (Mn)	200	Silicon (Si)	1.0 %
Vanadium (V)	10	Aluminum (Al)	1.0 %
Bismuth (Bi)	< 10	Phosphorus (P)	< 0.1 %
Tin (Sn)	< 10	Other	

Fe, Mg, Ca, Ti, Na, K, Si, Al & P reported in %, all other elements reported in ppm.

* anomalous value (see Table 8)

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Sample Identification LAD-12A (eroded top San Andres Limestone)

Semi-Quantitative Emission Spectrographic Scan

Gold (Au)	< 10	Zirconium (Zr)	50
Silver (Ag)	3 *	Boron (B)	< 10
Copper (Cu)	< 5	Barium (Ba)	200
Lead (Pb)	< 10	Beryllium (Be)	1
Zinc (Zn)	< 200	Lanthanum (La)	< 20
Molybdenum (Mo)	< 5	Niobium (Nb)	< 10
Iron (Fe)	0.5 %	Scandium (Sc)	< 5
Tungsten (W)	< 50	Strontium (Sr)	700 *
Nickel (Ni)	15	Yttrium (Y)	10
Cobalt (Co)	< 5	Calcium (Ca)	> 20.0 %
Chromium (Cr)	10	Magnesium (Mg)	0.5 %
Cadmium (Cd)	< 20	Titanium (Ti)	0.07 %
Arsenic (As)	< 200	Sodium (Na)	0.5 %
Antimony (Sb)	< 100	Potassium (K)	< 0.5 %
Manganese (Mn)	200	Silicon (Si)	5.0 %
Vanadium (V)	20	Aluminum (Al)	3.0 %
Bismuth (Bi)	< 10	Phosphorus (P)	< 0.1 %
Tin (Sn)	< 10	Other	

Fe, Mg, Ca, Ti, Na, K, Si, Al & P reported in %, all other elements reported in ppm.

* anomalous value (see Table 8)

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Date Nov. 19, 1981

Job Number MA-704

Sample Identification LAD-12C (base of Travertine)

Semi-Quantitative
Emission Spectrographic Scan

Gold (Au)	< 10	Zirconium (Zr)	30
Silver (Ag)	0.5	Boron (B)	< 10
Copper (Cu)	10	Barium (Ba)	1000*
Lead (Pb)	< 10	Beryllium (Be)	15*
Zinc (Zn)	< 200	Lanthanum (La)	20
Molybdenum (Mo)	< 5	Niobium (Nb)	< 10
Iron (Fe)	3.0 %	Scandium (Sc)	< 5
Tungsten (W)	< 50	Strontium (Sr)	700*
Nickel (Ni)	30	Yttrium (Y)	< 10
Cobalt (Co)	15	Calcium (Ca)	20.0 %
Chromium (Cr)	< 10	Magnesium (Mg)	0.2 %
Cadmium (Cd)	< 20	Titanium (Ti)	0.02 %
Arsenic (As)	300	Sodium (Na)	0.15 %
Antimony (Sb)	< 100	Potassium (K)	< 0.5 %
Manganese (Mn)	1000	Silicon (Si)	< 1.0 %
Vanadium (V)	70	Aluminum (Al)	0.7 %
Bismuth (Bi)	< 10	Phosphorus (P)	< 0.1 %
Tin (Sn)	< 10	Other	

Fe, Mg, Ca, Ti, Na, K, Si, Al & P reported in %, all other elements reported in ppm.

* anomalous value (see Table 8)

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Analyzed By JFA

Date Nov. 19, 1981

Job Number MA-704

Sample Identification LAD-12D (top of travertine)

Semi-Quantitative Emission Spectrographic Scan

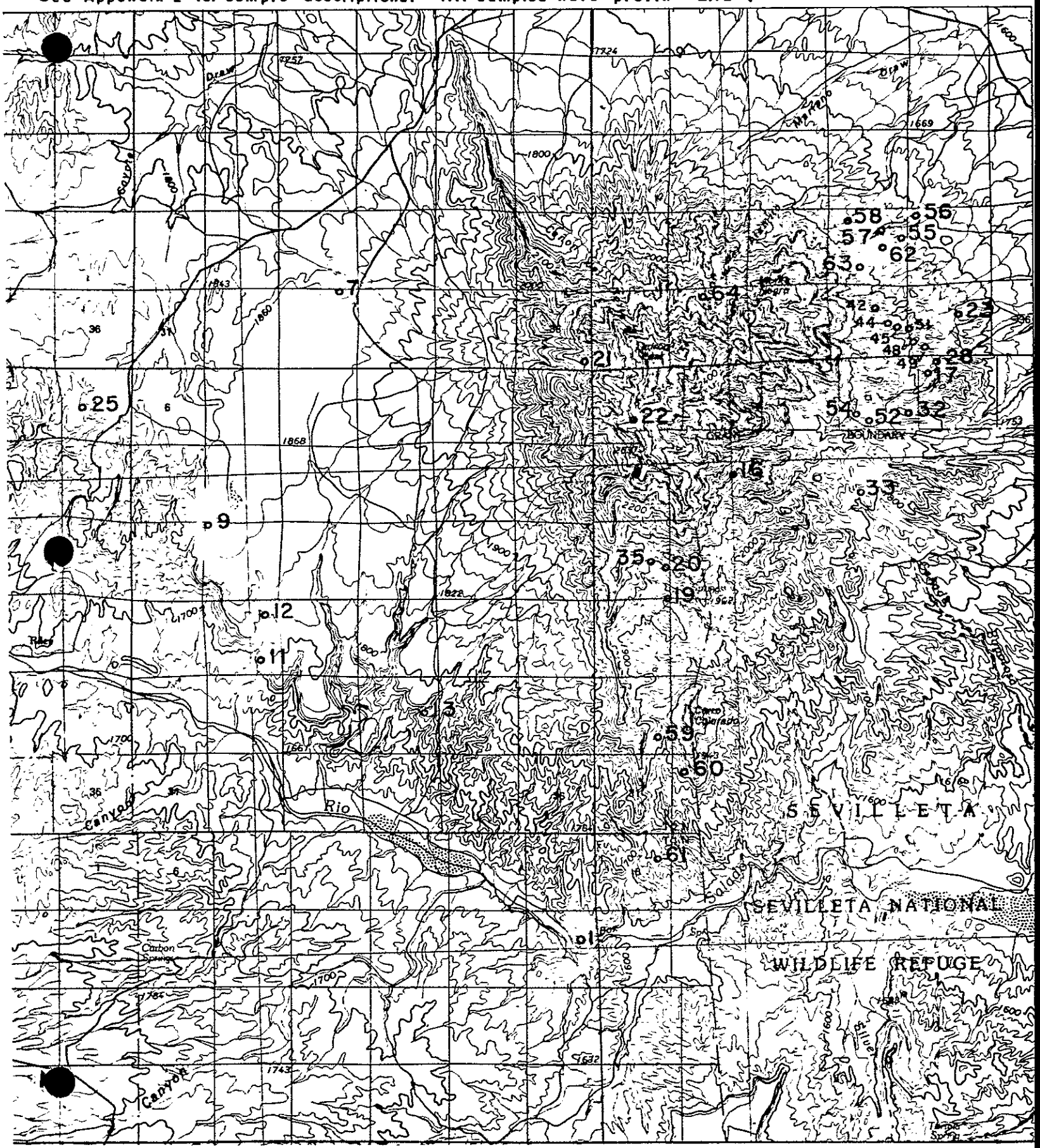
Gold (Au)	< 10	Zirconium (Zr)	20
Silver (Ag)	3.0 *	Boron (B)	< 10
Copper (Cu)	< 5	Barium (Ba)	500
Lead (Pb)	< 10	Beryllium (Be)	2
Zinc (Zn)	< 200	Lanthanum (La)	< 20
Molybdenum (Mo)	< 5	Niobium (Nb)	< 10
Iron (Fe)	0.05 %	Scandium (Sc)	< 5
Tungsten (W)	< 50	Strontium (Sr)	1500*
Nickel (Ni)	20	Yttrium (Y)	< 10
Cobalt (Co)	< 5	Calcium (Ca)	> 20.0 %
Chromium (Cr)	< 10	Magnesium (Mg)	0.5 %
Cadmium (Cd)	< 20	Titanium (Ti)	0.03 %
Arsenic (As)	< 200	Sodium (Na)	0.3 %
Antimony (Sb)	< 100	Potassium (K)	< 0.5 %
Manganese (Mn)	200	Silicon (Si)	< 1.0 %
Vanadium (V)	< 10	Aluminum (Al)	0.5 %
Bismuth (Bi)	< 10	Phosphorus (P)	< 0.1 %
Tin (Sn)	< 10	Other	

Fe, Mg, Ca, Ti, Na, K, Si, Al & P reported in %, all other elements reported in ppm.

* anomalous value (see Table 8)

Appendix II. SAMPLE LOCATIONS IN THE LADRON AREA

See Appendix I for sample descriptions. All samples have prefix "LAD".



APPENDIX III: Ladron WSA

ESTIMATE OF TOTAL METAL CONTENT IN JETER DEPOSIT

A) Known

1) Production of 8,826 tons of ore, which yielded 58,562 lbs of U_3O_8, for an average grade of extraction of 0.332% U_3O_8.

2) Mine maps indicate that only about 50 to 75 percent of the ore-grade material was recovered (see p.157).

3) Stockpiled ore grade:

0.4% U_3O_8	
0.2% Cu	
0.05% Zn	
0.03% Ni	
0.02% Co	
0.01% Pb	

4) Metal Prices (E&MJ 5/82)

U_3O_8	$20.75/lb
Cu	$ 0.75/lb
Zn	$ 0.35/lb
Ni	$ 3.00/lb
Co	$12.50/lb
Pb	$ 0.26/lb

B) Assume: the original ore body had a tonnage of 15,000 short tons (see tonnage calculations) with average grades equivalent to stockpiled ore.

C) Yields: (± 25%)	D) Worth: (± 25%)
120,000 lbs U_3O_8	2,490,000 $
60,000 lbs Cu	45,000 $
15,000 lbs Zn	5,250 $
9,000 lbs Ni	27,000 $
6,000 lbs Co	75,000 $
3,000 lbs Pb	780 $
	2,643,030 $

VOLUME AND TONNAGE OF JETER DEPOSIT

Volume estimates are based on the following map. Average thickness of ore zone assumed to be 2 m, except in stope area (thickness ~ 4.5 m). Density of claystone ore should be about 2.6 tons/m^3.

<u>Ore produced form triangular block in floor of open pit</u>

Volume = Area $[(P_1 + P_2)-(P_3 + P_4)]$ x thickness (2 m)

A of right triangle = 1/2 bh

V = [(430 + 752.5)-(26 + 52)] x 2

V = 1104.5 x 2

V = 2209 m^3

at 2.6 tons/m^3 = 5,743.4 tons from open pit

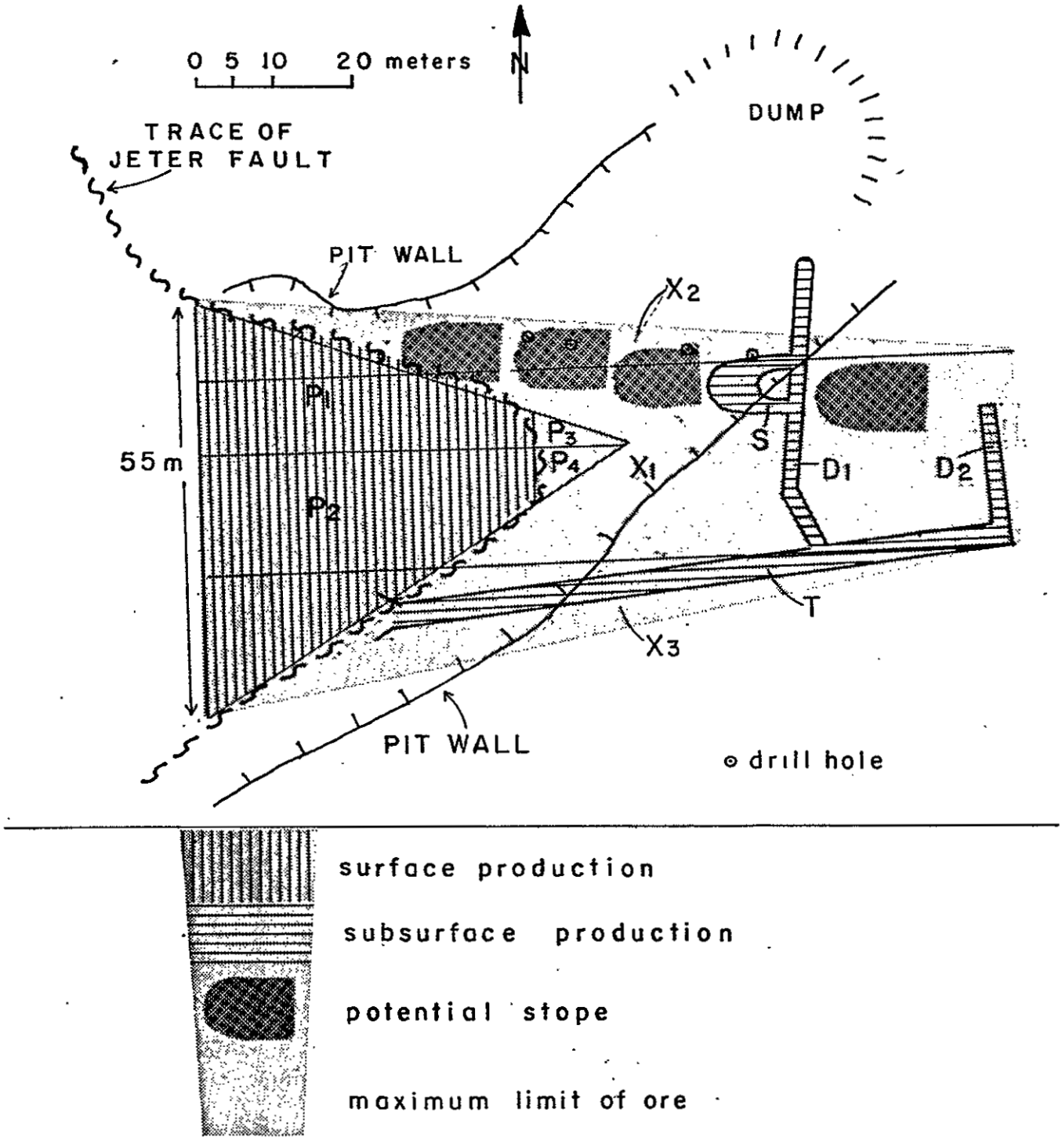
<u>Ore produced from underground workings:</u>

1) incline tunnel (T) = 80 x 3 x 2 = 480 m^3
2) upper drift (D_1) = 27.5 x 2 x 2 = 110 m^3
3) lower drift (D_2) = 15 x 2 x 2 = 60 m^3
4) stope (S) = 7 x 10 x 4.5 = 315 m^3
   minus pillar IP_1) = 4 x 4 x 4.5 = -72 m^3 } net = 243 m^3
   Total underground workings = 893 m^3
   at 2.6 tons/m^3 = 2,321.8 tons from underground

Total estimated production = 8,065 tons, which is within a reasonable error of 9 percent less than reported production. It appears that an additional 4 stopes could have been made along the main ore chute, thus an additional 2,527 tons of ore could have been produced (243 m^3 x 2.6 +/m^3 x 4).

Therefore the original mininum tonnage of the Jeter ore

JETER MINE



Appendix III Ladron WSA

Sketch map of the Jeter Mine. From unpublished U.S. Atomic Energy Commission map dated 11/1/57.

deposit was probably at least 11,353 tons (8,826 tons plus 2,527 tons).

The original maximum tonnage of ore in the Jeter deposit would have been in the wedge shaped (▱) area of $X_1 + X_2 + X_3$. This is not unreasonable since calculations indicate that all underground workings must have essentially been recovered as ore.

$$X_1 = 25 \times 106 = 2650 \text{ m}^2$$

$$X_2 = 1/2 \times 12 \times 106 = 636 \text{ m}^2$$

$$X_3 = 1/2 \times 18 \times 106 = \underline{954 \text{ m}^2}$$

$$4240 \text{ m}^2$$

Given an average thickness of 1.4 m (Collins and Nye, 1957) the maximum volume of ore at the Jeter deposit was about 5936 m^3

at 2.6 tons/m^3 = 15,433 tons <u>maximum</u>

For the purpose of estimating the <u>total</u> metal content of the Jeter deposit, 15,000 tons of ore is considered to be a reasonable estimate.

ESTIMATED METAL VALUE OF ORIGINAL (UNWEATHERED) SULFIDE BODY AT ALAMITO CANYON PROSPECT

Prospect dimensions: 4 x 8 x 15 ft = 480 ft^3 = 13.6 m^3

Assumptions:

1) Ore grades of 3% Cu, 2% Zn, 2% Pb, 0.1% Ni and 0.1% Co
2) Ore density = 3.0 tons/m^3
3) One-half of volume of prospect (6.8 m^3) was ore.

<u>Yields</u> (50%)	*<u>Worth</u> (50%)
1224 lbs Cu	$0.75/lb Cu = $ 918

816 lbs Zn	$0.35/lb Zn = $ 285
816 lbs Pb	$0.26/lb Pb = $ 212
41 lbs Ni	$3.00/lb Ni = $ 123
41 lbs Co	$12.50/lb Co = $ 512
from 20.4 tons of ore	$2050

= $100/ton ore

*metal prices from Engineering and Mining Journal 5/82

NOMINAL VOLUME OF RESERVOIR CONTAINING 25 MILLION DOLLARS IN OIL

by Ron Broadhead (6/25/82)

Need Reservoir volume for $\$25 \times 10^6$ of oil

1) Assume 5% porosity

2) Assume price of \$34/bbl

3) Assume FVF of 1.2 RB/STB

4) Assume oil saturation = 1.0

$$\frac{\$25 \times 10^6}{\$34/\text{bbl}} = 7.6 \times 10^5 \text{ bbl oil}$$

$$7.6 \times 10^5 \text{ bbl oil} \times 5.615 \text{ ft}^3/\text{bbl oil} = 4.2 \times 10^6 \text{ ft}^3 \text{ oil (stock tank)}$$

$$4.2 \times 10^6 \text{ stock tank ft}^3 \text{ oil} \times \frac{1}{1.2} \text{ FVF} = 3.5 \times 10^6 \text{ ft}^3 \text{ oil (reservoir)}$$

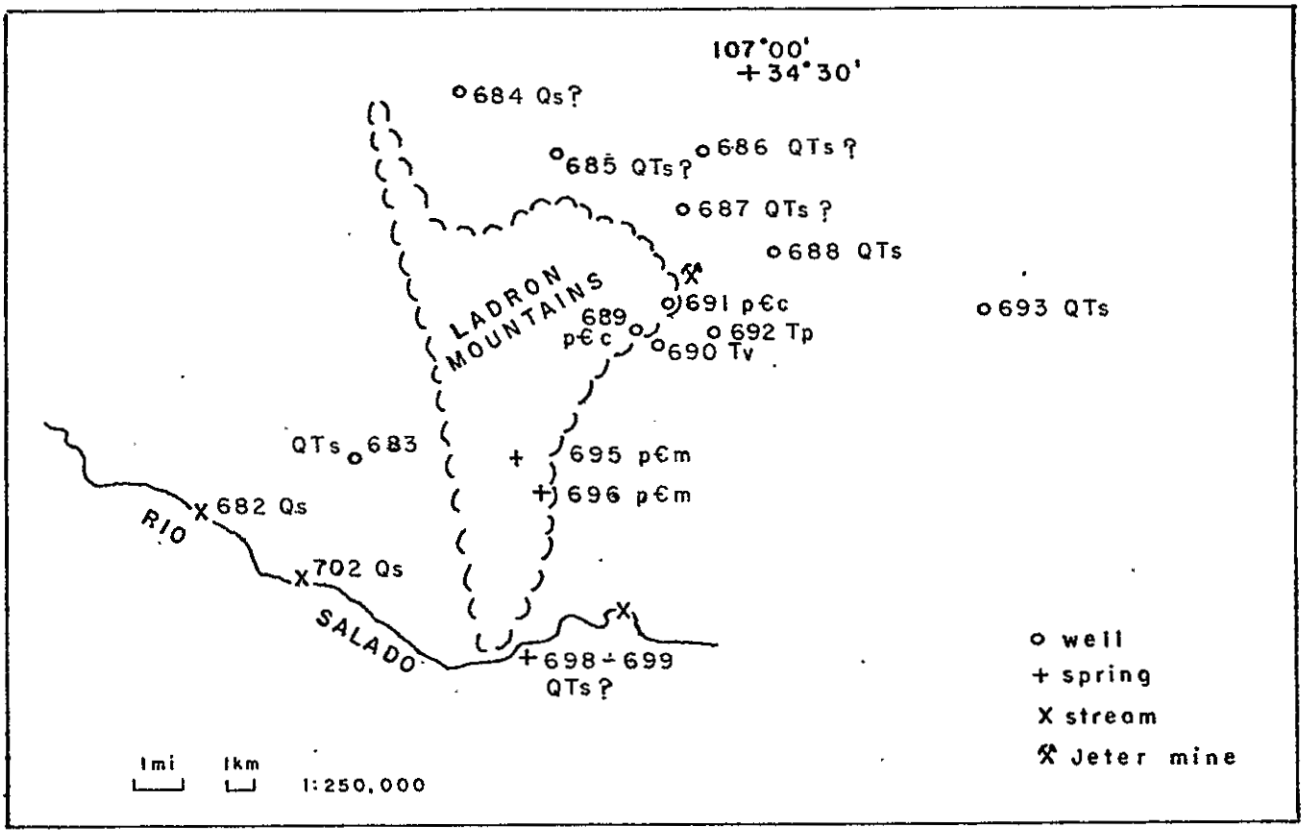
$$\frac{3.5 \times 10^6 \text{ ft}^3 \text{ oil (reservoir)}}{0.05 \text{ porosity}} = 7.0 \times 10^7 \text{ ft}^3 \text{ of reservoir}$$

$$7.0 \times 10^7 \text{ ft}^3 \text{ reservoir} \times \frac{1 \text{ m}^3}{35.316 \text{ ft}^3} = 2.0 \times 10^6 \text{ m}^3 \text{ reservoir}$$

assuming 3 m thick reservoir horizon: lateral extent for economic oil reservoir of above specifications would be ~258 m x 258 m (66,660 m^2)

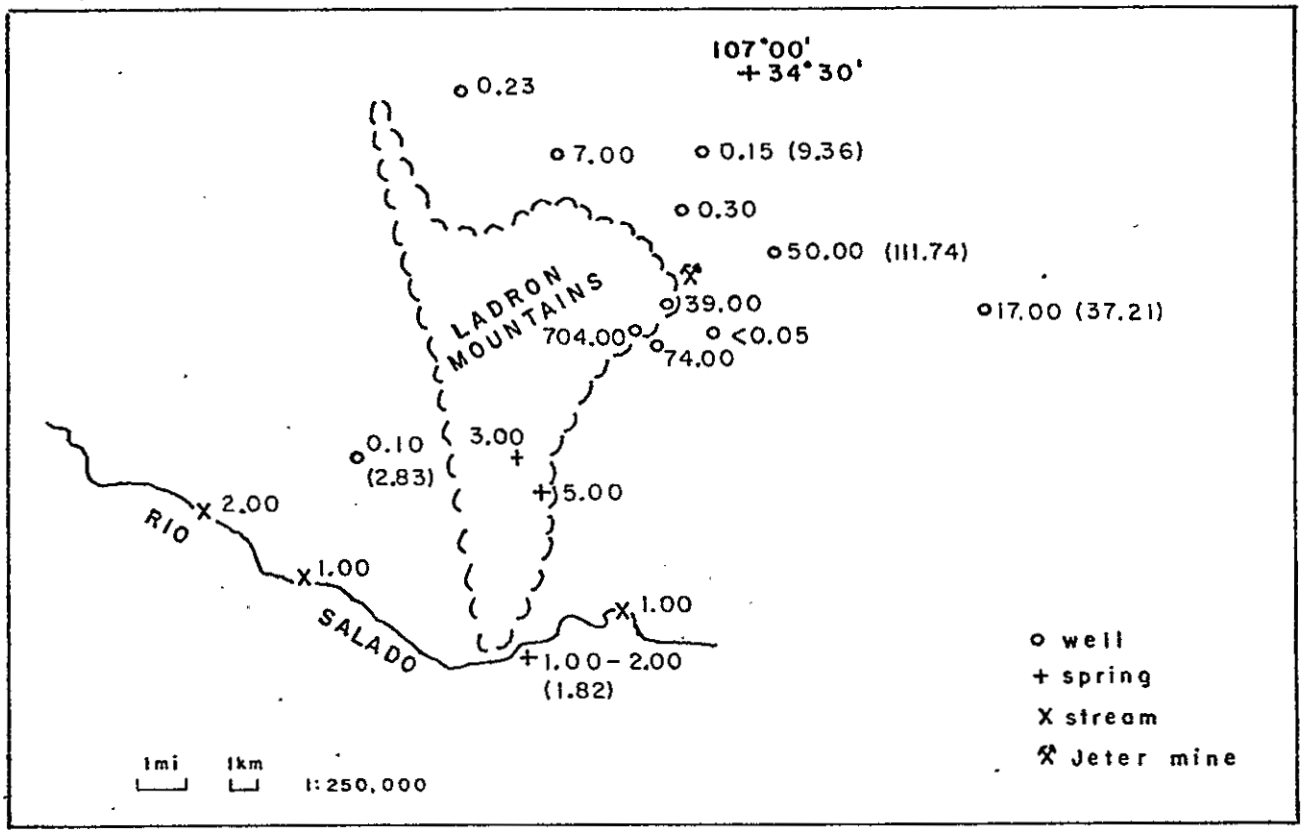
Statement of Opinion

The oil calculations require several assumptions which could greatly alter the results, e.g., what if porosity = 10%, then you only need 10^6 m^3 reservoir.



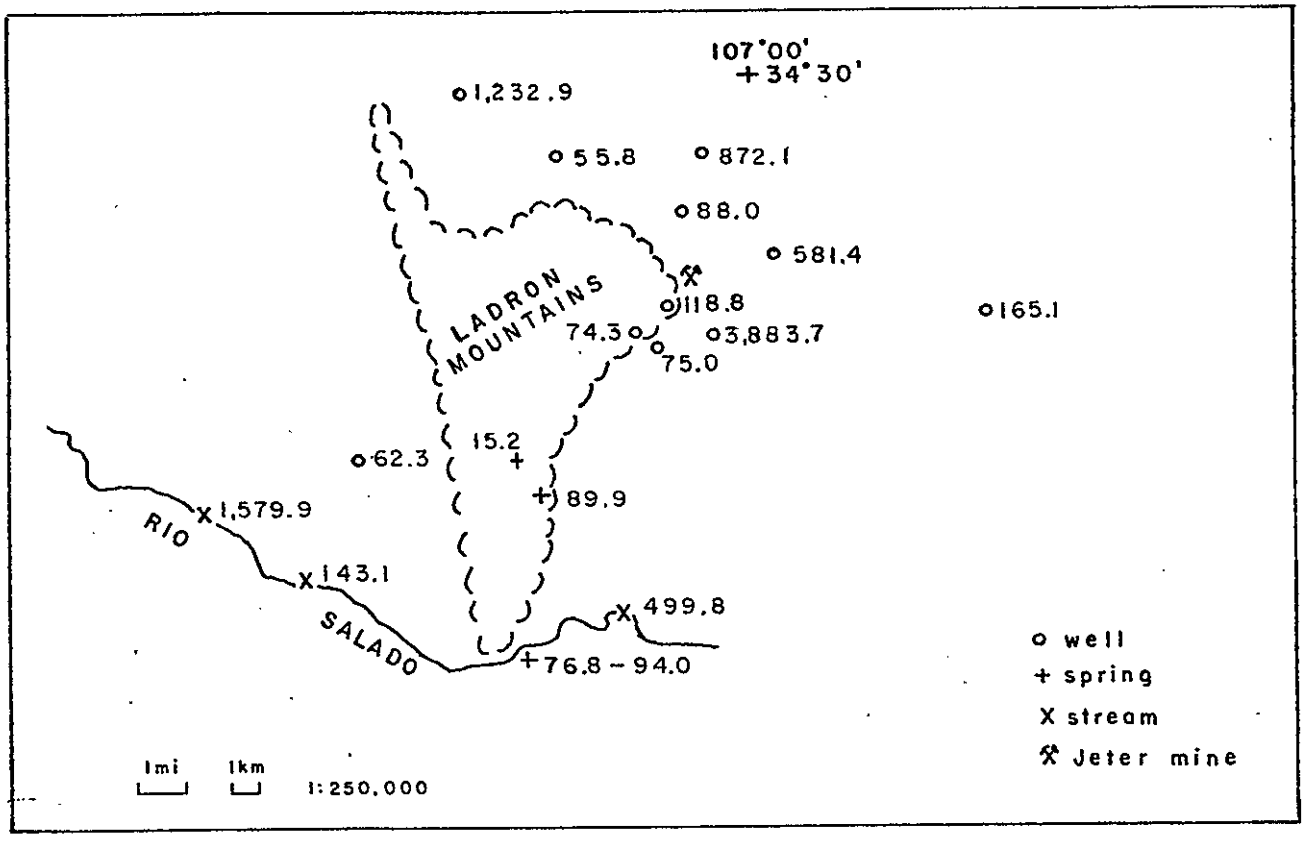
Appendix III Ladron WSA

Figure 8A Location of ground and surface water samples in the Ladron area, analysed by Pierson and others (1981, App. B-3). Probable aquifer for waters indicated by symbols used on Fig. 2.



Appendix III Ladron WSA

Figure 8B Uranium content in parts per billion (ppb) for ground and surface waters in the Ladron area (data from Pierson and others, 1981, App. B-3). Values above 10 ppb are considered anomalous. Values in parentheses from Planner (1980a).



Appendix III Ladron WSA

Figure 8C Sulfate content in parts per million (ppm) for ground and surface waters in the Ladron area (data-from Pierson and others, 1981, App. B-3). Values above 1000 ppm are considered anomalous. Highest value, 3884 ppm, from well collared in gypsiferous playa facies of the Popotosa Formation.

On April 28, 1982, I field checked a copper prospect within the Sierra Ladrones WSA. The prospect is located in NW1/4 sec. 32, T. 3 N., R. 2 W., at an elevation of approximately 7000 feet near the head of Canon del Alamito.

The workings consist of a single shaft, which is approximately 15 feet deep by 8 feet by four feet; there is a small dump on the downhill (northeast-facing) side of the shaft. The workings are in a mica schist unit of the Torres Schist (pЄ) of Black, near the contact with the Ladron Granite. The shaft was sunk parallel to the dominant foliation (and compositional layering) of the schist: N84E/78SE. On the southwest wall of the shaft, there are several small fold noses exposed; axial planes are parallel to foliation.

There is no indication in the shaft of the mineralization which was being prospected. On the dump there is some schistose rocks which has been altered to a limonite gossan, probably after sulfides, and small samples of schist which have the greenish colors of oxidized copper minerals. Also, on the dump I found a small piece of vein quartz with minor copper mineralization.

On the northwest wall of the shaft, small (5 cm - 25 cm) granitic veins, typically propyllitized and some with quartz veinlets, cut the schist at low angles. Whether the copper mineralization was associated with these veins or whether it was a podiform, stratabound occurrence is impossible to determine from the present exposure.

Mark J. Logsdon

NOTE: for description of samples from the above prospect (Alamito Canyon Prospect) see Appendix I, samples numbers LAD-64A, LAD-64B

New Mexico Bureau of Mines & Mineral Resources
Socorro, NM 87801

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

mation: 505/835-5420
Publications: 505/835-5410

October 7, 1981

MEMO

TO: Richard Chamberlin

FROM: Gretchen Roybal and JoAnne Osburn

SUBJECT: Cretaceous coal-bearing rocks in the Ladron WSA

We spent one day field checking the Crevasse Canyon Formation outcrops in sections 5, 6, and 7 in T. 1N., R. 3W., and sections 31 and 32 in T. 2N., R. 3W. This field work indicates that the dissertation map of G.L. Massingill, 1978 (Bureau OF-107) is generally adequate for the coal-bearing Crevasse Canyon Formation of the Mesaverde Group. Massingill did not map the Gallup (Gallegos) Sandstone in this area. We found cliffs of Gallup Sandstone, complete with the guide fossil Lopha sannionis about 40 feet thick in Baca Creek Canyon in section 31.

The coals in this area are generally less than 1 foot thick and lenticular. They are found in the lower ½ of the Crevasse Canyon Formation and are commonly associated with Tertiary dikes and sills. These coals grade to carbonaceous shales within 50 feet of the intrusive rocks. These shales are clearly lagoonal in origin.

We found that the southern-most outcrop belt in section 6 is probably more structurally complex than Massingill indicates. We found nearly flat-lying Santa Fe Formation (?) mudstones and siltstones overlying the Crevasse Canyon Formation exposures. We have not calculated resource estimates for this area because of the large amount of faulting and all the coals, with the exception of outcrop F, are too thin to be considered a resource.

A transcript of our field notes and reference map are included.

GR/JAO:sn

An Equal Opportunity/Affirmative Action Institution

CALCULATION OF VOLUME OF AN ECONOMIC MANGANESE DEPOSIT IN THE LADRON WSA

Current price of manganese ore containing 48% Mn is $1.75/metric ton.

A 48% Mn ore = 62.3% MnO_2 (pyrolusite)

Assuming ore = 62.3% MnO_2 (4.8 gm/cc)

37.7% lms. congl. (2.7 gm/cc)

Then ore density = (.623 x 4.8) + (.377 x 27) =

4.01 gm/cc = 4.01 mt/m^3

and 1 m^3 of ore = $7.02 (4.01 x 1.75)

An economic Mn deposit worth $25 x 10^6 would require a volume of 25 x 10^6/7.02 = 3.56 x 10^6 m^3

A tabular deposit 2 x 500 x 3,560 m would equal above volume

A more likely Mn deposit in the Ladron WSA might be 1 x 100 x 1000 m or 10^5 m^3 which would = 4.01 x 10^5 mt or $7.02 x 10^5 = $702,000.00

T. 2N., R. 3W.

A sec. 32, southwest corner, outcrop of Crevasse Canyon sandstone and shale, no coal.

T. 2N., R. 3W.

B sec 31, along tributary of Rio Salado, on south side, Gallup(?) present.

sec. 31 SW corner, southern side of river.

C Crevasse Canyon - dark carbonaceous shales but no coal, on south side of westernmost fault (Gallup).

1 sec. 31 SW corner northern side of stream 3" of coal under a 2 ft. sandstone.

2 Further north 6" coal (weathered) several coal outcrops around the dike - none of these have much lateral extent.

D Small coal outcrops of up to a foot occur along small dikes which show very little lateral extent. Generally, these are low grade coals and go into carbonaceous shales away from the dikes. Northern 1/2 of sec. 6, T. 1 N., R. 3W.

E NW corner of sec. 5, T. 1N., R. 3W., Crevasse Canyon sandstones and siltstones, no coals.

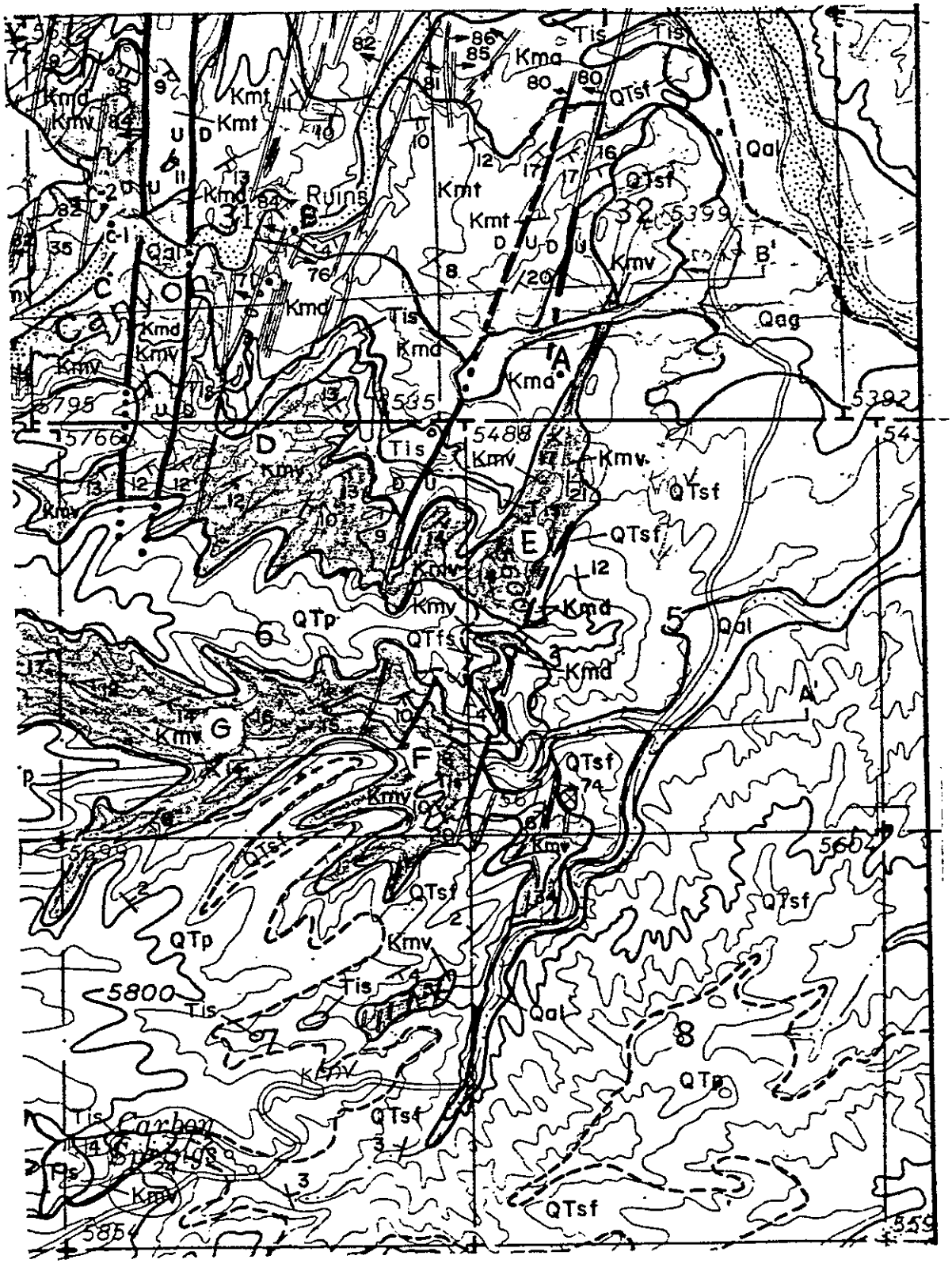
F SE corner sec. 6, T. 1N., R. 3W., 2 coals approx. 3 ft., apart-upper coal is 14" thick, the lower is 16". These coals have a lateral extent of 30 ft. and diminish in thickness. Coals are located on N side of tributary where the stream has been dammed.

G Further to the west in southern half of section 6, T. 1N., R. 3W. Some Crevasse Canyon sandstones and siltstones, shales, carbonaceous shales. No coal.

See map that follows for locations of above observations

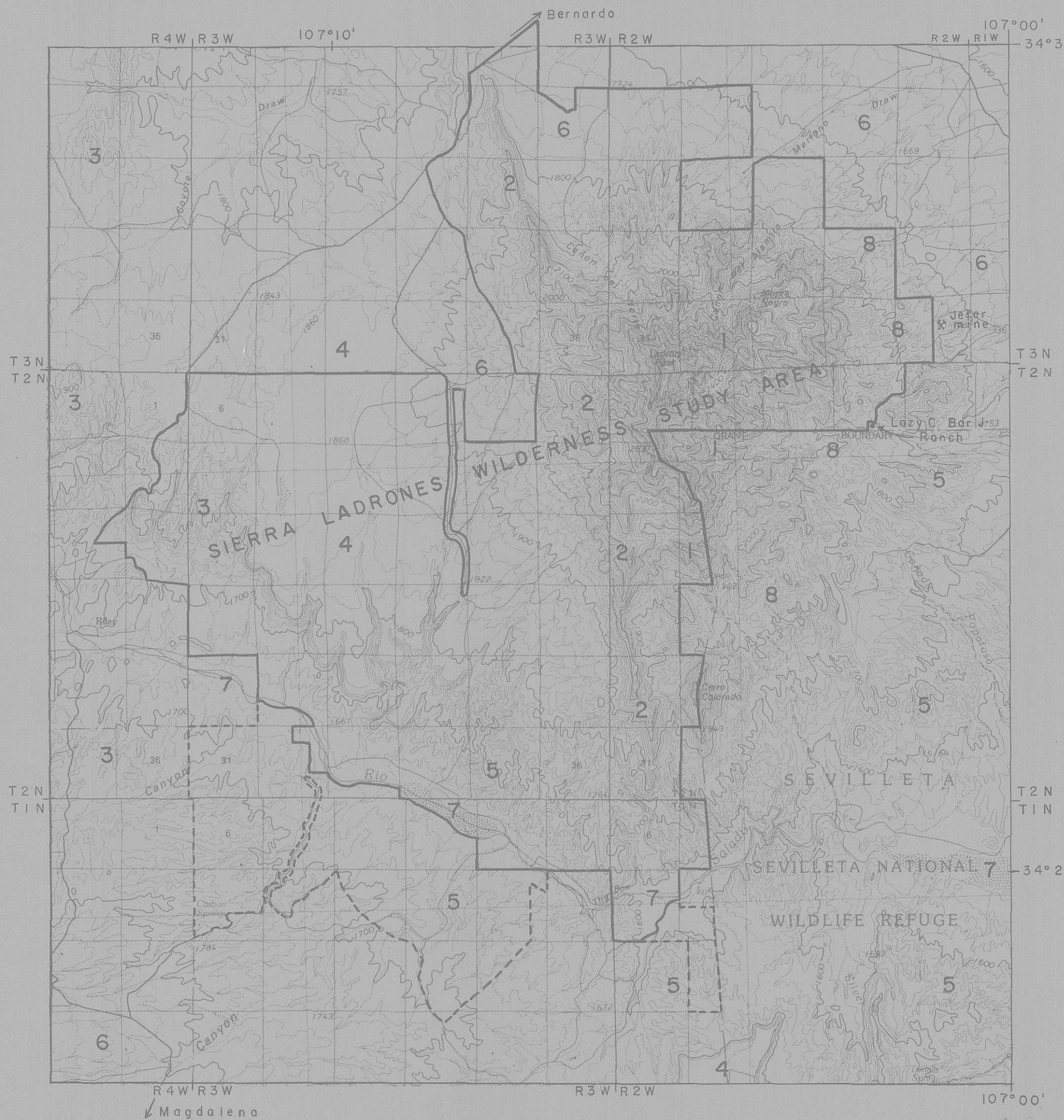
Cretaceous coal-bearing rocks in the Ladron WSA

from Massingill, 1979



trim line

Figure 1. TOPOGRAPHIC BASE MAP OF THE LADRON AREA



EXPLANATION

WSA boundary

proposed addition (under appeal)

Landforms:

1. mountain peaks and canyons
2. limestone hogback
3. limestone and sandstone cuestas
4. travertine capped mesa
5. hillslopes and dendritic drainages
6. alluvial fans and bajadas
7. channel and terraces of the Rio Salado
8. rounded foothills--sheared and altered Precambrian rocks (exhumed pediment?)

1 mi 1 km

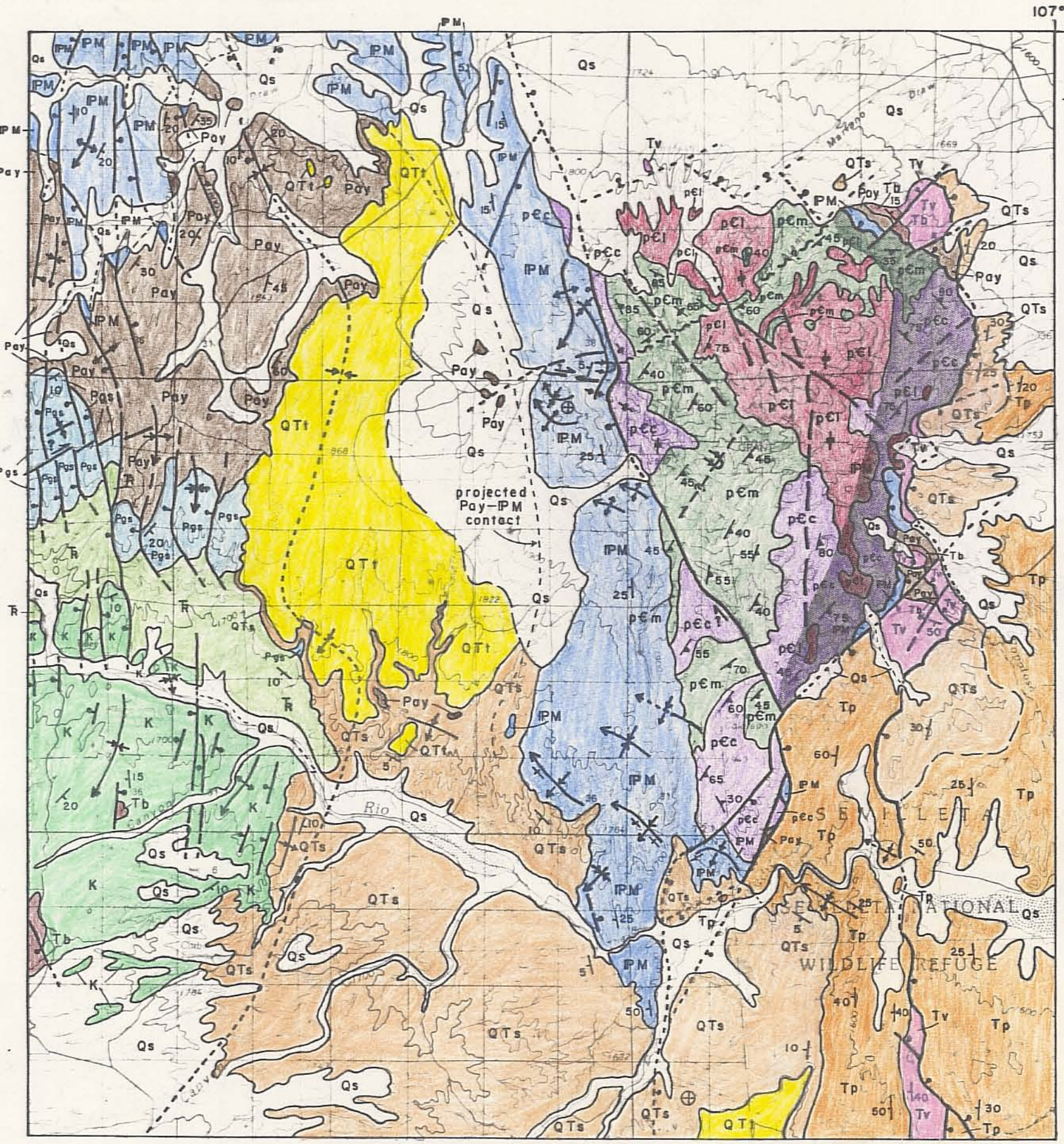
1:100,000

base from Magdalena 30'X 60' quadrangle (USGS, 1979)

contour interval = 20 meters

NMBM&MR OF-179

Figure 2. GENERALIZED GEOLOGIC MAP OF THE LADRON AREA



compiled by R.M. Chamberlin, 1982

Approximate age (m.y.)		MAP UNITS*	
<.5		Qs	Quaternary surficial deposits
1–3		QTt	Travertine
1–5		QTs	Sierra Ladrones Formation
7–25		Tp	Popotosa Formation
24–30		Ti	Basaltic dikes and sills (see Fig. 3)
24–38		Tv	Rocks of the Datil–Mogollon volcanic field
38–45		Tb	Baca Formation
85–105		K	Cretaceous rocks
195–210		Ꞧ	Triassic rocks
250–270		Pgs	Glorieta Sandstone and San Andres Limestone
270–280		Pay	Abo Formation and Yeso Formation
280–335		IPM	Pennsylvanian–Mississippian rocks
1300		p€l	Precambrian Ladron pluton
1600		p€m	Precambrian metamorphic rocks
?		p€c	Precambrian Capirote granitoid

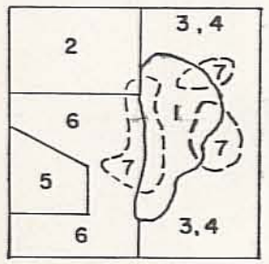
altered Precambrian rocks (Condie, 1976)

* See Table 3 for descriptions of map units

EXPLANATION

- contact
- fault, ball on downthrown side
- low-angle normal fault
- possible shear zone
- fold axes: anticlinal, synclinal, monoclinal
- strike & dip: bedding, foliation, joint plane

SOURCE INDEX



SOURCES:

1) Black, 1964 (modified from Condie, 1976)
2) Kelley and Wood, 1946
3) Denny, 1940
4) Bruning, 1973
5) Massingill, 1979
6) Bachman, ca. 1977 (see Machette, 1978)
7) Reconnaissance, this report (9/81–10/81)

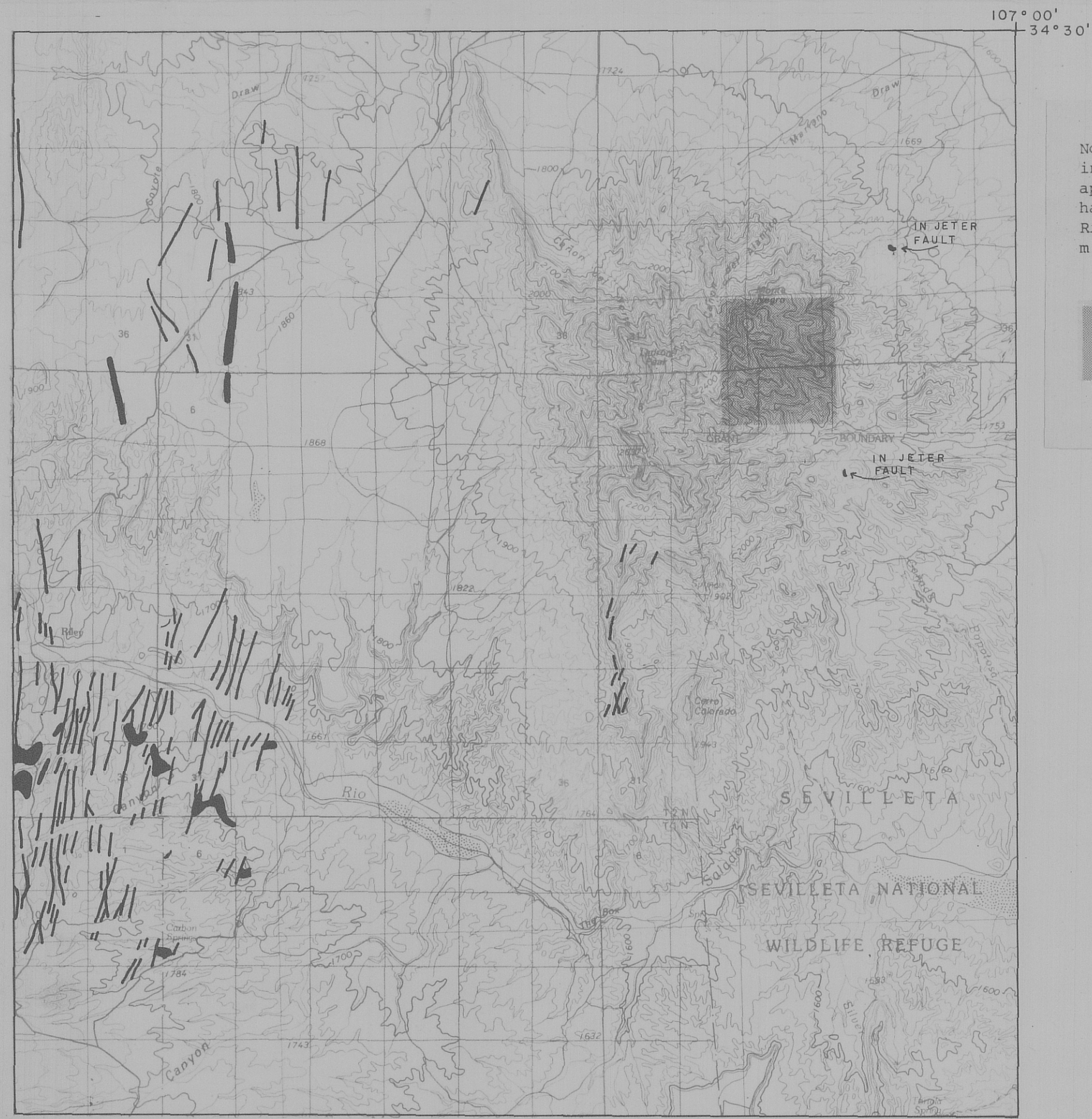
1 mi. 1 km

1:100,000

Topographic base from Magdalena 30'x60' quadrangle (USGS)
contour interval = 20 meters

trim line

Figure 3. BASALTIC DIKES AND SILLS IN THE LADRON AREA



Note: Most dikes and sills are basaltic in composition, with textures ranging from aphanitic to diabasic. Some wider dikes have monzonitic cores. Several dikes in Riley area have been dated as 24 to 27 m.y. old (C.E. Chapin, oral commun., 1982).

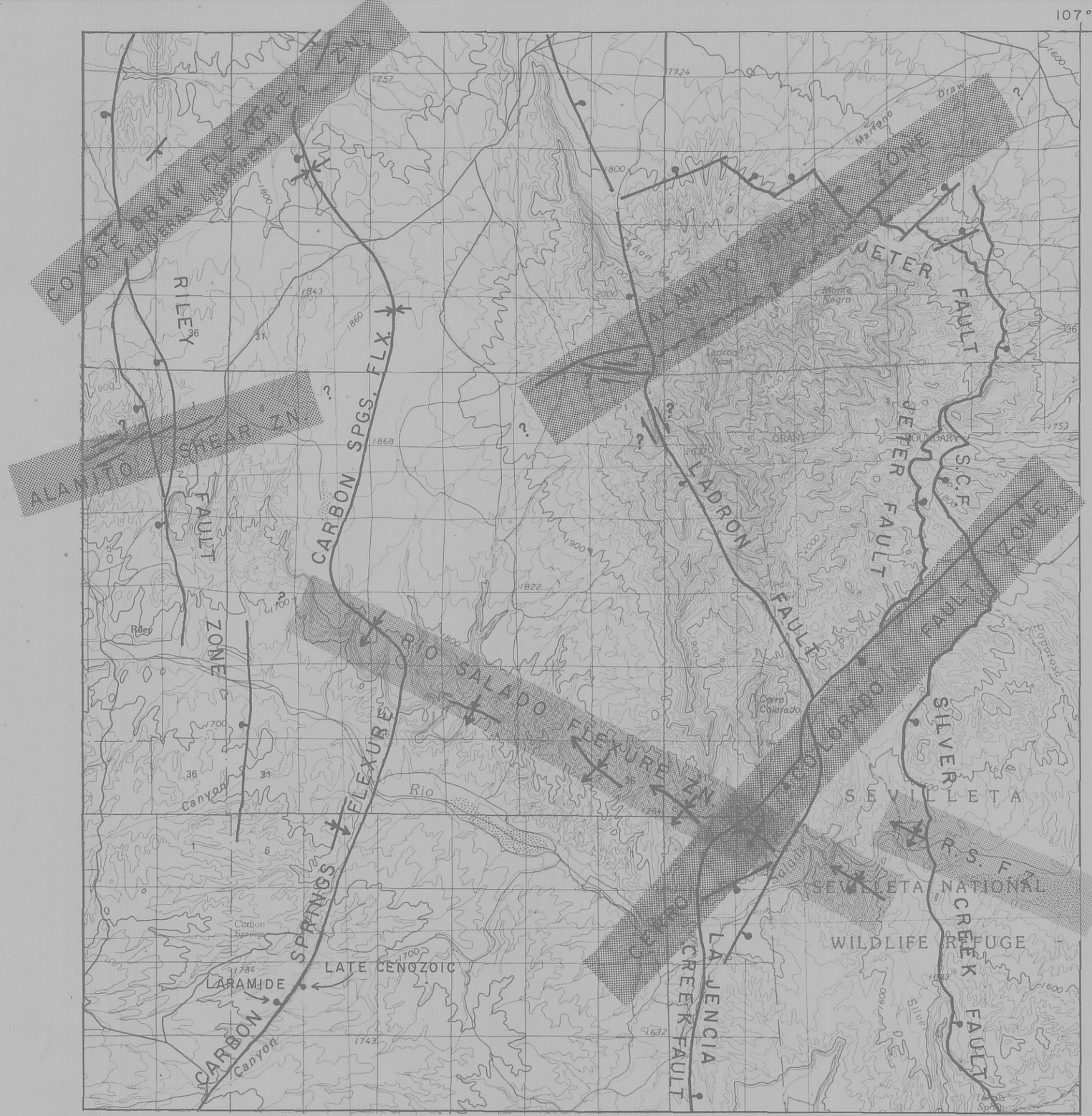
North-trending diabase dikes cutting Precambrian rocks are common in this area (Black, 1964). These dikes may be Tertiary or Precambrian in age.

1 mi. 1 km

1:100,000

trim line

Figure 4. MAJOR STRUCTURES OF THE LADRON AREA



Rift Faults:

- Jeter
- Silver Creek
- La Jencia Creek

} "domino" faults

- Carbon Springs (south of Rio Salado)

*Older structural grains:

- Northeast - Precambrian (pre-1.3 b.y.)
  Laramide
- Northwest - Late Paleozoic
  Laramide
- Northerly - Late Precambrian (∿ 1.3 b.y.)
  Late Paleozoic
  Laramide

*all older grains locally reactivated by rifting

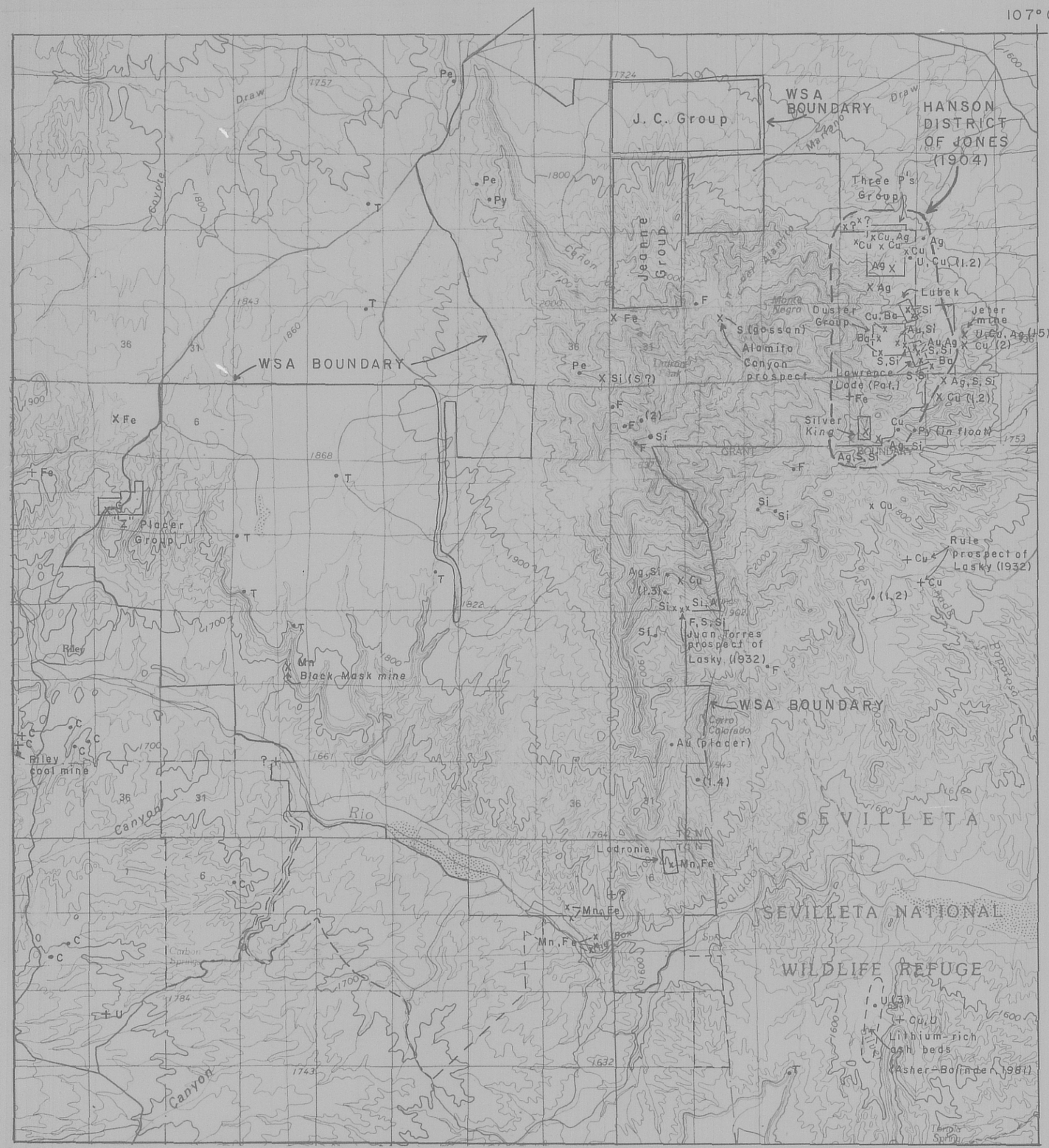
Note: The Alamito shear zone, Rio Salado flexure zone, Carbon Springs flexure, Riley fault zone, and La Jencia Creek fault are new "names-of-convenience". They are tentative interpretations not found on maps predating this study.

1 mi. 1 km

1:100,000

trim line

Figure 5. MINERAL OCCURRENCES IN THE LADRON AREA



Explanation

Type of Occurrence
- x Verified prospect
- + Unverified prospect
- · Unprospected mineral occurrences

Metal or Mineral
- A Amethyst
- Ag Silver
- Au Gold
- Ba Barite
- C Coal
- Cu Copper oxides and carbonates
- F Fluorite
- Fe iron
- G Gypsum
- Mn Manganese
- Pe Petroliferous limestone
- Py Pyrite
- S Base metal sulfides
- Si Silicification; quartz veins
- T Travertine (sampled locations)
- ? Unknown
- U Uranium
- (1.2) Gamma radiation anomaly (hundreds of counts per second)

Note: Copper sulfide occurrences are scattered throughout Precambrian metamorphic rocks (Black, 1964, p. 77)

Active Mineral Claim or Group (location approximate)

Unverified occurrences from:
1) Black, 1964, p. 57, 77 (sulfides)
2) Cookro, 1978 (fluorspar)
3) Massingill, 1979 (coal)
4) Pierson and others, 1981 (uranium)
5) R.H. Weber, oral commun., 1982 (copper at Rule Prospect)

1 mi 1 km

1:100,000

trim line

MAP SUMMARIZING MINERAL RESOURCE POTENTIAL OF THE LADRON AREA

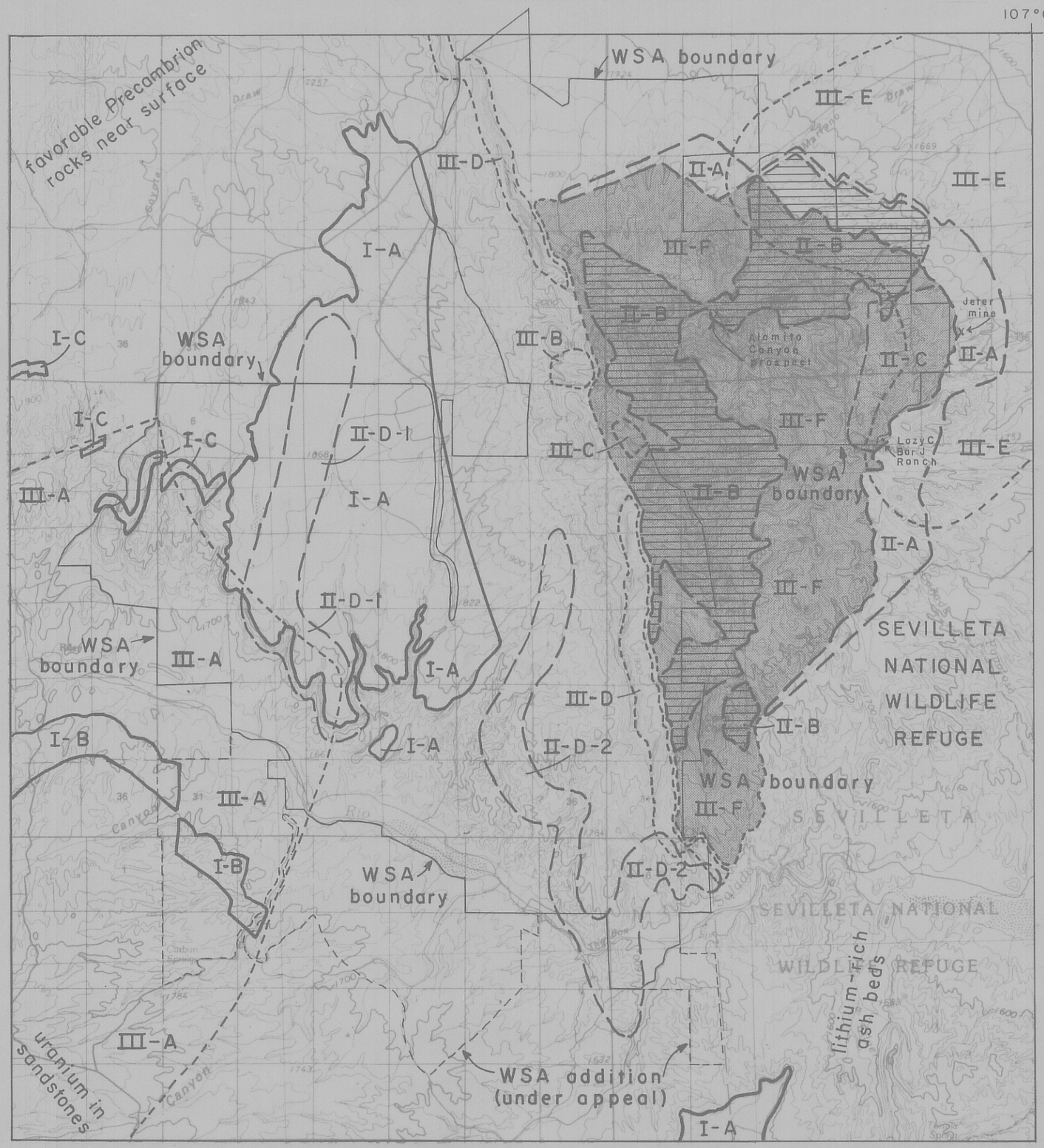


Figure 7.

EXPLANATION

Type of Deposit/Host[1]/Depth/Probability of Commercial Deposit[2]

I. Well Known Deposits (Identified) ————————
- A. High-calcium limestone[3](cement)/QTt/0-10m/ 10^{-2}
- B. Coal/K/0-30m/10^{-6}
- C. Gypsum/Pay/0-30m/10^{-6}

II. Partially Known Deposits (Hypothetical) —— —— ——
- A. Supergene Uranium-Copper/Jeter fault/0-300m/10^{-4}
- B. Stratiform Polymetallic Sulfide with Copper-Lead-Zinc -Nickel*-Cobalt*/p€m/0-1500m/10^{-2}
- C. Siliceous Veins with Silver-Gold-Lead-Zinc-Copper-Barite-Fluorite*/p€/0-300m/10^{-5}
- D-1. Supergene Manganese*/QTs/0-30m/10^{-4}
- D-2. Supergene Manganese*-Iron/PM/0-100m/10^{-6}

III. Poorly Known Deposits (Speculative) - - - - - - - - - -
- A. Oil-Natural Gas/PM/2900-3600m/10^{-3} (Carbon dioxide=10^{-5})
- B. Mississippi Valley-type Lead-Zinc -Barite/PM/300-600m/10^{-3}
- C. Tungsten*-Bismuth (Tin*?)Greisen/p€ granite/0-900 m/10^{-5}
- D. Late Paleozoic Gold Placers/basal PM/0-300m/10^{-5}
- E. Geothermal Energy/p€ /5000m/10^{-5}
- F. Uranium/p€/0-1500m/10^{-2}

IV. *Strategic Minerals Potential (* mark = strategic mineral) Probability for discovery of commercial chromium or platinum deposit in Ladron WSA is nil (10^{-6})

II-B, III-F AREAS OF HIGH ECONOMIC POTENTIAL

The Jeter uranium-copper deposit (production = 58,500 lbs U_3O_8; estimated reserves plus production = 120,000 lbs U_3O_8, 60,000 lbs Cu) was almost certainly derived from weathering of preexisting polymetallic sulfide mineralization (like Alamito Canyon prospect) and uranium oxide mineralization in Precambrian rocks that form the core of the Ladron Mountains. The extremely high uranium content (704 ppbU) in well waters at the Lazy C Bar J Ranch is a strong indication of ongoing weathering of high-grade uranium mineralization in Precambrian rocks west of the ranch. The Jeter deposit probably represents about 1/200th of the metals weathered from the adjacent highland. Therefore, as much as 24 million pounds of uranium and 18.6 million pounds of base metals (Cu-Zn-Pb-Ni-Co) may have been mobilized by weathering during formation of the Jeter deposit. At current to foreseeable uranium prices (17-45 \$/lb U_3O_8), this is equivalent to 0.4 to 1.1 billion dollars of uranium, and to 30 million dollars of base metals (current prices). Similar metal values may be preserved below the present zone of weathering. The probability for discovery of a commercial uranium deposit (type uncertain) in area III-F is judged to be relatively good (10^{-2}) and the probability for discovery of a commercial polymetallic sulfide deposit (stratiform geometry) in area II-B is judged to be relatively good (10^{-2}).

[1]host identified by symbol in Fig. 2 or name in Fig. 4.
[2]commercial deposit worth \$25 million in place; relative probabilities: high=10^{-1}, good=10^{-2}, fair=10^{-3}, low=10^{-4}, very low=10^{-5}, nil=10^{-6}
[3]deposit is of commercial size (225 million tons), 10^{-2} chance of sufficient future demand to become commercial.

topographic base from Magdalena 30'X 60' quadrangle (USGS, 1979)

1 mi 1 km

1:100,000