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Gary B. Glass, State Geologist

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STREAM-SEDIMENT SAMPLE RESULTS IN SEARCH OF KIMBERLITE INTRUSIVES IN SOUTHEASTERN WYOMING

by

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This report has not been reviewed for conformity with the editorial standards of the Geological Survey of Wyoming.

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Introduction

Since 1977, the Geological Survey of Wyoming has been searching for barren and diamondiferous kimberlite in the Laramie Mountains of southeastern Wyoming. Many of the exploration methods used by the Geological Survey of Wyoming to locate kimberlite were described by Hausel and others (1979a, 1979b, 1980, 1981). The procedure for testing for diamond mineralization was discussed by Hausel and others (1985).

The most effective technique used to isolate regions that may contain kimberlitic intrusives or some other related ultramafic or ultrabasic rock is stream-sediment sampling surveys for minerals indicative of kimberlite. Essentially, stream-sediment sampling surveys, if designed properly, can isolate regions that may contain kimberlite intrusives and associated diamond deposits.

The area sampled covers more than 800 square miles of dominately Precambrian terrane, including Proterozoic eugeoclinal rocks to the south and Archean cratonic rocks to the north. The major rock units are the 1.42 billion-year-old (Ga) Sherman Granite, the 1.435 Ga Laramie Anorthosite Complex (ages from Subbarayudu, 1975), Archean granite gneiss, Archean supracrustal rocks including a portion of the Elmers Rock greenstone belt, and Proterozoic metaigneous and metasedimentary rocks in the Silver Crown mining district.

This report summarizes eight years of stream-sediment sampling surveys by the Metals and Precious Stones Division of the Geological Survey of Wyoming.

To date, about 1,000 samples have been collected in the Laramie Mountains. Results are presented on **Plates 1** and **2.** In brief summary, the Geological Survey of Wyoming has discovered dozens of heavy mineral anomalies and has isolated three regions of considerable size that should be considered for detailed diamond exploration. These areas are (1) Happy Jack-Eagle Rock (**Plate 3**), (2) Middle Sybille Creek-Sheep Rock (**Plate 4**), and (3) Halleck Canyon-Elmers Rock. The boundaries of the latter region are still being defined and therefore no large-scale sample map was prepared for this report.

Procedures

Three indicator minerals -- pyrope garnet, chromian diopside, and picroilmenite -- were sought in the sample survey. The stream-sediment sampling program was designed to sample all major drainages for the indicator minerals in the Laramie Mountains on a sample spacing of one mile. But, because of access difficulties and other problems, it was not always possible to adhere to this sample spacing. Where possible, specific sample sites were selected for their likelihood of trapping heavy minerals. Where mineral anomalies were found, many were resampled to verify the results.

Each sample collected was screened and panned at the sample site to increase the heavy mineral concentration and to reduce the bulk of the sample. Material that would not pass through a fly screen (4-square-millimeter openings) into a gold pan was rejected at the sample site, and only the fine fraction was recovered. Initial total sample weight of the coarse, medium, and fine fractions was probably much greater than 100 pounds and resulted from two to four hours of panning by two individuals at each site. The final sample concentrate varied in weight from 200 to 500 grams.

In the lab, these samples were passed through a magnetic separator to remove the magnetic mineral fraction. The nonmagnetic portion of the sample was then processed on a Wilfley table to further concentrate the heavy fraction and separate heavy-, medium-, and light-weight mineral fractions. The light-weight fractions were predominately composed of minerals with low and average specific gravity, including quartz, feldspar, and mica. This fraction was discarded.

The heavy- and medium-weight sample fractions, which together weighed between 40 and 200 grams per sample, were optically scanned under a binocular microscope to search for pyrope garnet (specific gravity about 3.5), chromian diopside (specific gravity about 3.2), and nonmagnetic ilmenite (specific gravity about 4.2) as well as any other anomalous heavy minerals such as gold, ruby, sapphire, and fluorite. Some minerals required additional laboratory tests for identificiation including refractive index measurements, x-ray diffraction determinations, spectrographic tests, and electron microprobe analyses.

Pyrope garnets were identified primarily by color and grain morphology, followed by optical tests including refractive index measurements. Colors varied from deep purple to lavender and red-orange to orange. Grains varied from well rounded with pitted orange-peel texture, suggesting relatively great transport distances, to angular and less pitted, suggesting relatively minimal transport distances. Many grains were crushed and optically tested for isotropism and for the characteristic refractive index for pyrope (less than 1.76). Only a few garnets were examined by an electron microprobe. These garnets yielded relatively high Ca/Cr ratios.

Chromian diopside grains were identified by their distinct bright emerald-green color and pyroxene cleavage and parting. Most of the recovered grains were small, elongate, and rounded and had a finely pitted surface texture. The roundness of many of the grains suggest significant stream transport distances from their source rock.

Nonmagnetic ilmenites were identified by their metallic grey luster, morphology, and lack of magnetism. Grains tend to be round to tabular. The lack of magnetism is apparently important for identifying picroilmenite (see Leighton and McCallum, 1979), however, some nonmagnetic ilmenites tested by the Survey proved to be ferroilmenite, indicating that magnetism is not diagnostic of picroilmenite. No picroilmenites were positively identified in this study. Positive identification of picroilmenite should be done, when possible, on a microprobe.

Results

Three main areas contain concentrations of indicator minerals. These are Happy Jack-Eagle Rock, Middle Sybille Creek-Sheep Rock, and Halleck Canyon-Elmers Rock.

Most of the Happy Jack-Eagle Rock area (**Plate 3**) is located within the Precambrian Sherman Granite. The primary indicator mineral found in this area is pyrope garnet, which was identified in 32 samples, with three samples exhibiting between five and ten pyropes. Chromian diopside was identified in only three samples, and nonmagnetic ilmenite was identified in 18 samples. No source rock was found for these indicator minerals although one 120-footdiameter circular structure was located on a major north-northwesterly trending lineament on aerial photos. This structure, tentatively named the Eagle Rock structure (sec. 5, T.15N., R.71W.), was sampled by shovel and only one yellow-orange pyrope was recovered.

The Middle Sybille Creek-Sheep Rock area (**Plate 4**) is underlain by the Precambrian Laramie anorthosite, and includes the Radichal kimberlite intrusive in the center of the area. A total of 29 samples from this area yielded pyrope garnet. Nine sample sites produced more than five indicator minerals each, with pyrope counts ranging from seven to twelve. The largest numbers of pyropes occur within 2 miles downstream from the Radichal kimberlite intrusive. Eight samples showed chromian diopside, only one of which was downstream from the Radichal kimberlite. Thirteen sites scattered across the area showed non-magnetic ilmenite.

The Halleck Canyon-Elmers Rock area lies along the northern edge of the Elmers Rock greenstone belt (see Graff and others, 1982). This area is characterized by Archean mafic amphibolites and minor ultramafic schists of the greenstone belt, Archean granitic intrusives, and an Archean gneissic basement. This area lies north of Sybille Canyon and Highway 34 (**Plate 2**). Indicator minerals found in these samples are a mixture of pyrope garnets and chromian diopsides. Nonmagnetic ilmenite was identified in only two samples in this area, with pyrope found at 13 sites, and chromian diopside found in 17 samples. Indicator mineral counts range downward from a high of 30 at site DR-1 (containing 28 pyropes); seven sites showed ten or more indicators. A few pyropes in this region exhibit good angularity. The source(s) of these indicator minerals has not been located.

Interpretation

The identification of one or more of the indicator minerals suggests the possible presence of kimberlite or a similar ultramafic or ultrabasic source rock. Indicator minerals can be derived from nonkimberlitic sources containing upper mantle material, thus caution must be exercised in the interpretation of the anomalies.

Pyrope garnets are a relatively good indicator of kimberlite or other mantle-derived rocks. Pyrope garnets occurring in kimberlite and its host xenoliths have high MgO contents as well as variable amounts of other oxides. The relative amounts of CaO and Cr_2O_3 may be an important indicator of diamond mineralization according to Gurney (1984). After studying garnet inclusions in diamonds, Gurney designated subcalcic pyrope garnets as G10 and calcic pyrope garnets as G9. Gurney's G10 designation was contrived to separate diamond-inclusion garnets from the nondiamond-bearing calcium-rich lherzolite garnets of the G9 group. The G10 garnets contain greater than 4 weight percent Cr_2O_3 and are depleted in CaO compared to the G9 garnets. G10 garnets appear to be associated with diamonds. The degree to which the G10 garnets are subcalcic appears to directly correlate with the diamond content of the kimberlite (Gurney, 1984). That is, the more subcalcic the garnet, the greater the potential diamond content of the host kimberlite.

Three garnet samples recovered from stream sediment samples from the Happy Jack area (samples KP2, KP8, and KC19) were tested by microprobe to determine their chemistry. All three garnets fell within Gurney's (1984) G9 field. Three garnets tested from the Elmers Rock area are also G9 garnets. It should be noted that even though these garnets are not in the G10 field, they are chemically similar to some garnets from the diamondiferous Schaeffer kimberlites in the State Line District, Wyoming. It should also be noted that, in addition to G9 garnets, G10 garnets are also found in the Schaeffer diatremes (Gurney, 1984). More microprobe work is needed, because six garnets are not a sufficient sample.

Leighton and McCallum (1979) reported relatively short transport distances for indicator minerals eroded from kimberlite in the Sloan area of Colorado. They reported pyrope garnets are probably transported up to 1.5 miles, picroilmenites up to 2.5 miles, and chromian diopside only as far as 0.25 mile from a kimberlite source before they are completly disaggregated. Brink (1984) indicated that chromian diopside is seldom found more than 0.5 miles from a source kimberlite. Mannard (1968) related that in the arctic climate of Siberia, chromian diopside transport can be as far as 30 miles, garnet transport 95 to 125 miles, and ilmenite much farther. He also noted that in tropical occurrences these distances are on the order of 1 mile for chromian diopside, a few miles for pyrope garnet, and several miles for picroilmenite. McCandless (1982) suggested that climate may be a more important factor governing breakdown of the indicator mineral grains than is abrasion caused by transport. Intense chemical weathering in the tropics may severely limit transport distances. The widespread occurrences of indicator minerals in this sampling program suggests that either numerous kimberlite and/or alternate sources for the indicator minerals are to be found in the sampled area, or that the indicator minerals have survived transport distances greater than those cited for Wyoming's present climate.

All diamonds do not come from kimberlite, nor do all kimberlites host diamonds. Less than 10 percent of known kimberlites are diamond-bearing, and only part of those contain significant numbers of diamonds (Mannard, 1968). Other significant sources of diamond include highly potassic lamproites (such as those in Western Australia and Murfreesburo, Arkansas). These may lack picroilmenite and may contain only rare pyrope garnet. Diamonds can survive great transport distances because of their hardness, and may themselves indicate a kimberlite or lamproite source (Brink, 1984). However, the use of diamond as a kimberlite indicator is severely limited because of the rarity of diamond and because many kimberlites either contain no diamonds, or only contain microdiamonds. Most commercial diamond deposits yield diamond concentrations of less than 1 ppm.

Conclusions

The area of this sampling program straddles the projected trend of the northeast-southwest trending Mullen Creek-Nash Fork Shear Zone which separates the Archean basement (>2.5 Ga) to the north from the off-craton Proterozoic (<2.5 Ga) terrane to the south. All kimberlites so far identified are located south of the projected shear zone and intrude Proterozoic basement rocks and Proterozoic igneous intrusions. To date, kimberlite has not been identified in the Archean craton, however, several heavy mineral anomalies have been identified in the craton (**Plate 2**).

Craton-margin kimberlites and off-craton kimberlites of southern Africa are often barren of diamonds or poorly mineralized, whereas cratonic kimberlites include several commercial deposits. This suggests the terrane north of the Mullen Creek-Nash Fork shear zone may have the best possibilities for commercial diamond mineralization.

The results of samples collected by the Geological Survey of Wyoming in the search for heavy mineral indicators (pyrope garnet, chromian diopside, and picroilmenite) that may be indicative of kimberlite and potential diamond deposits are very encouraging. More than 100 heavy-mineral anomalies have been identified in the Laramie Mountains of southeastern Wyoming, including three highly anomalous regions. Similar stream-sediment sampling projects should be expanded throughout the Archean cratonic terrane of Wyoming, and the three highly anomalous regions identified in the Laramie Mountains should be investigated in detail.

Acknowledgments

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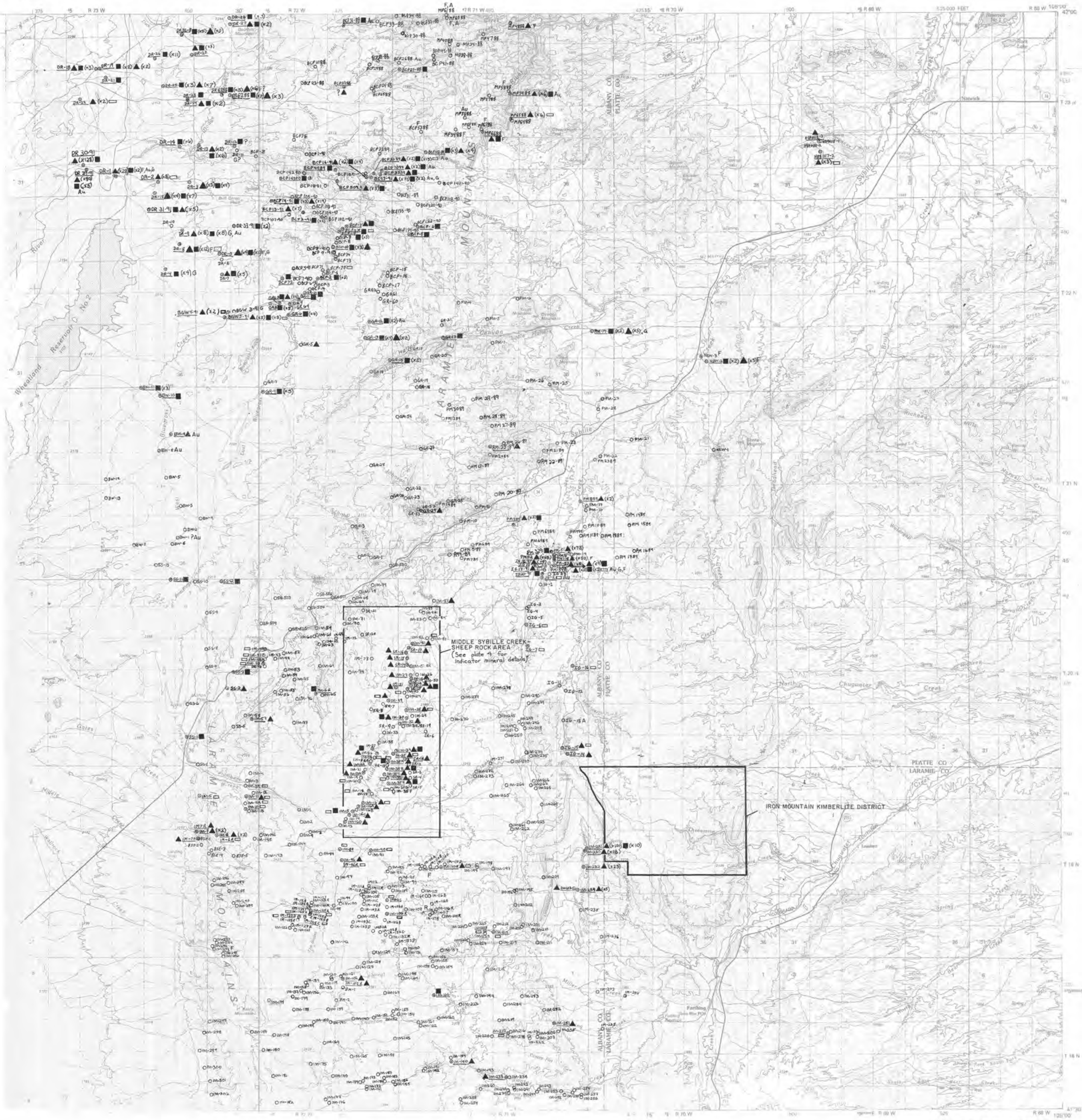

EXPLANATION

○ Sample site (underlined sample number implies indicator minerals were found)

The following symbols adjacent to a sample site imply one or more of the respective heavy minerals were recovered:

INDICATOR MINERALS

▲ Pyrope garnet: ▲(x10) indicates 10 pyrope garnets

■ Chromian diopside

OTHER HEAVY MINERALS

F Fluorite

Au Gold

G Sapphire

R Ruby

▭ Nonmagnetic ilmenite

0 1 2 3 miles

N

OTHER MINERALS

△ Amethyst

STREAM-SEDIMENT SAMPLING RESULTS IN THE ROCK RIVER 1:100,000-SCALE TOPOGRAPHIC MAP

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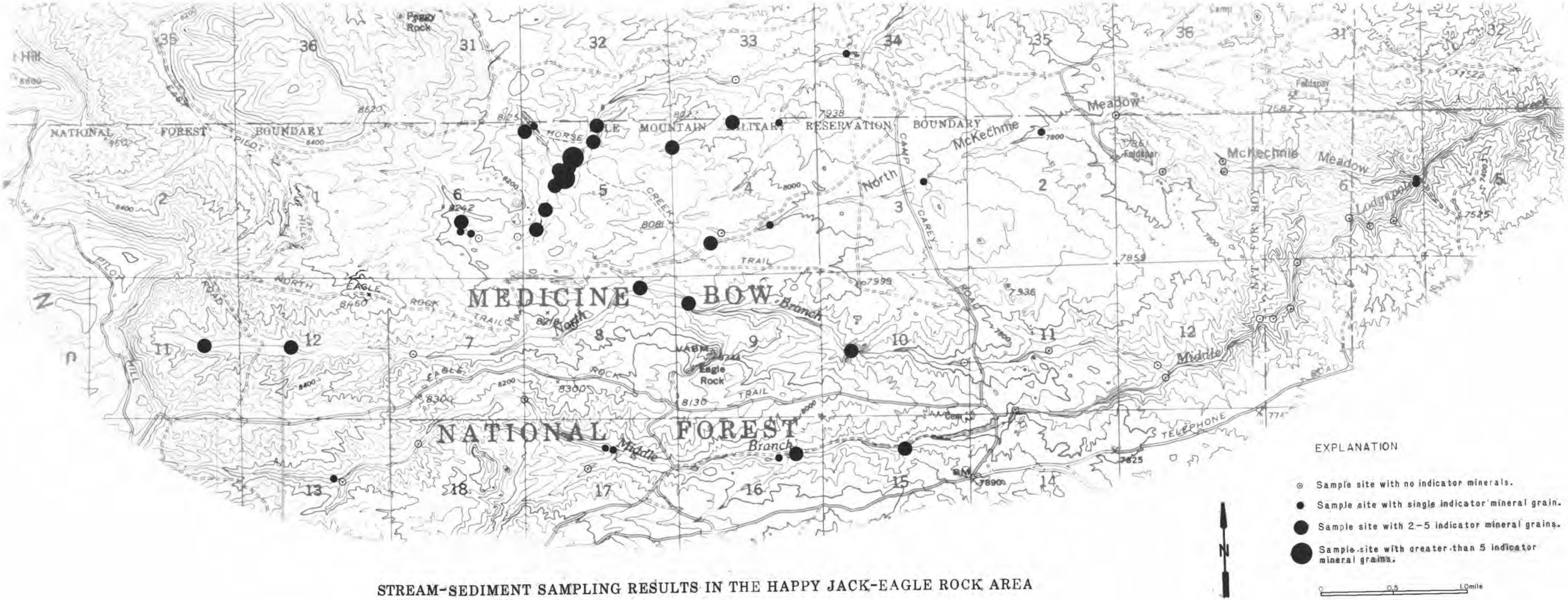

EXPLANATION

- Sample site with no indicator minerals.
- Sample site with single indicator mineral grain.
- Sample site with 2–5 indicator mineral grains.
- Sample site with greater than 5 indicator mineral grains.

0 0.5 1.0 mile

STREAM-SEDIMENT SAMPLING RESULTS IN THE HAPPY JACK-EAGLE ROCK AREA

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Map originally compiled by Carl Brink

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Plate 4 of 4

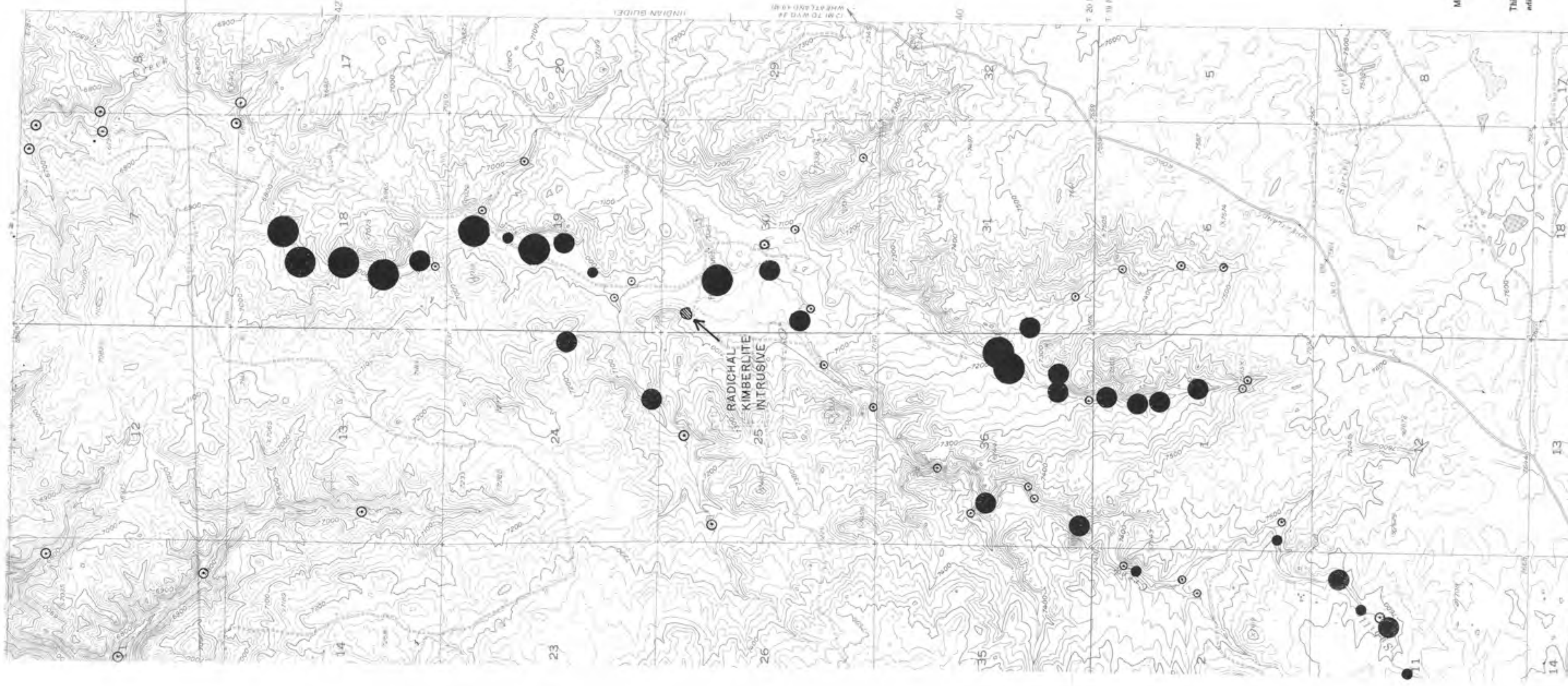
EXPLANATION

Sample site with no indicator minerals.

Sample site with single indicator mineral grain.

Sample site with 2-5 indicator mineral grains.

Sample site with greater than 5 indicator mineral grains.



Map originally compiled by Carl Brink

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STREAM-SEDIMENT SAMPLING RESULTS IN THE MIDDLE SYBILLE CREEK-SHEEP ROCK AREA

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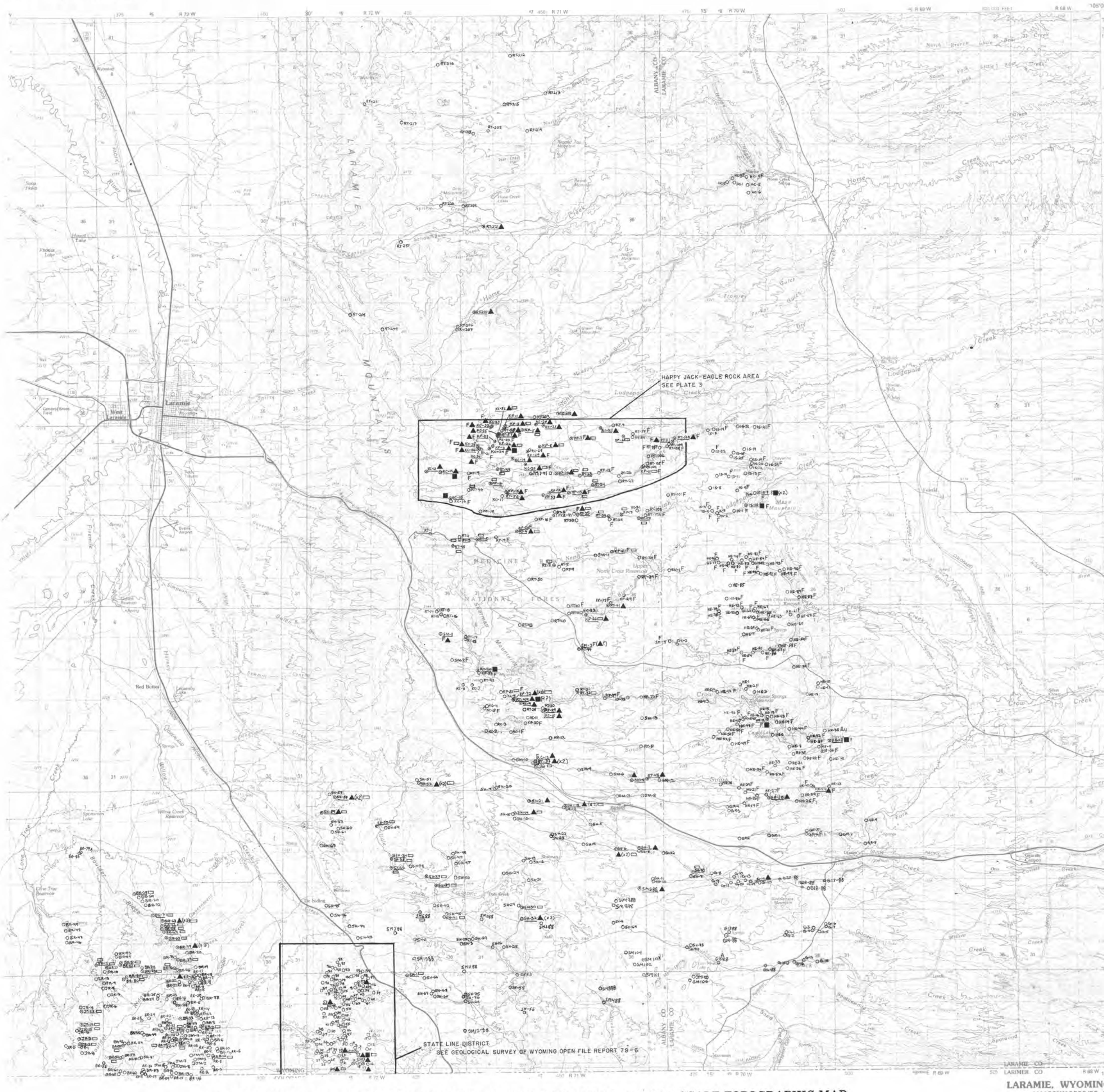
Plate 2 of 4



EXPLANATION

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INDICATOR MINERALS

▲ Pyrope garnet: ▲(x10) indicates 10 pyrope garnets

■ Chromian diopside

OTHER HEAVY MINERALS

F Fluorite

Au Gold

R Ruby

Nonmagnetic ilmenite

0 1 2 3 miles

OTHER MINERALS

Amethyst

LARAMIE, WYOMING

N4100W10500/30x60

1981

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STREAM-SEDIMENT SAMPLING RESULTS IN THE LARAMIE 1:100,000-SCALE TOPOGRAPHIC MAP

By

W. Dan Hausel, Wayne M. Sutherland, and Elizabeth B. Gregory

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