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EXPLORATION SERVICES DIVISION

3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

October 7, 1971

RECEIVED

OCT 8 1971

EXPLORATION DEPT.

Mr. W. L. Kurtz
Tucson Office

POLICY CONSIDERATIONS
GEOPHYSICAL FOLLOW-UP OF
AEROMAGNETIC ANOMALIES
SOUTHERN ARIZONA

Dear Bill:

In my letter to Mr. John Collins of September 14 on the above subject, a copy of which was sent to you, I recommended that a program of geophysical work be organized to follow up the aeromagnetic study which we have been pursuing in the Southwest.

In the intervening time since that letter I have been preparing the attached report in support of my ideas. This report is necessarily brief, but it contains the essential points I would make.

It is my belief that, after considering the factors of geological permissibility and property availability, many miles of the magnetic zones will remain which will have mineral potential great enough to justify the cost of I. P. coverage.

As part of the program, prior to I. P. coverage, usage would be made of geological information and of interpretations of special aeromagnetic and/or gravity profiles to determine which portions of the zones would be sufficiently shallow that I. P. effects from bedrock would be dominant over effects from the fill. Also, other considerations being equal, the factor of accessibility would carry important weight in the interest of obtaining the most rapid and efficient coverage.

Needless to say, those areas which have favorable geologic indications, in addition, would be given priority.

Yours very truly,

C. K. Moss

C. K. MOSS

CKM:am
Enc.

cc: J. J. Collins, w/enc.
J. H. Courtright "
J. Balla "

THE SIGNIFICANCE OF AEROMAGNETIC DATA
IN COPPER EXPLORATION IN ARIZONA

PART I

C. K. Moss

EXPLORATION SERVICES DIVISION
AMERICAN SMELTING AND REFINING COMPANY

October 1971

THE SIGNIFICANCE OF AEROMAGNETIC DATA IN
COPPER EXPLORATION IN ARIZONA - PART I

INTRODUCTION

Over the past four years the Geophysical Section has been engaged in a study of the magnetic patterns in southern Arizona. This study has had the objective of finding correlations between magnetic features and the occurrence of copper mineralization; it has involved work on both regional and detail scales.

Earlier work by other individuals in the field has been concerned essentially with only interpretations of magnetic patterns related to the geology in the immediate vicinity of individual deposits. From such studies a correlation between hydrothermal alteration and magnetic "lows" has been suggested as one guide to mineralization; a correlation between tactite mineralization and local magnetic "highs" has been recognized as another.

In addition, interpretations of magnetics have been used to map igneous geology and structural patterns.

The special objective at the outset of the present project was to search for threads in the magnetic picture which would interconnect separate copper deposits; and thereafter to seek distinctions in the magnetic fabric in the vicinity of these deposits which would help identify such localities.

Over the years a variety of computer treatments of the data have been studied. Such treatments have included dimension filters (high pass, low pass, band pass) and directional filters. Also, analyses of magnetic lineaments, and upward continuation of data have been made. However, the bulk of the above work will not be discussed in this report.

The specific work herein discussed is concerned with the significance of "magnetic gradient bands" relative to the occurrence of copper deposits. A review of results of other aspects of the magnetic study will be given in a later report. Whereas that work has shown interesting results with possible exploration significance, the implications are of a less tangible nature than implications of the gradient bands.

Five areas of detail magnetic coverage over well known mining districts have been taken to serve as examples from the work which has been completed to date. Regional magnetic coverage is included for all of southern Arizona.

CONCLUSIONS

A comparison of magnetics, geology and copper occurrence leads to the following conclusions.

The distribution of copper deposits shows strong alignment with the magnetic grain. This can be seen on a regional scale involving distances of hundreds of miles; and the correlation is even more definite when viewed on a detail scale.

More particularly, the deposits consistently occur along the flanks of magnetic highs, near a line which would correspond to the contact between the rocks of contrasting magnetic susceptibilities which give rise to the magnetic variations. On a magnetic map this line would follow a zone of strong magnetic gradient, and in the following discussion the term "gradient band" is applied to this zone.

To date, no distinctive character in the bands in the vicinity of copper occurrences has been recognized which could be used as a favorable magnetic criterion to localize interest along the band.

The dominant source of the regional magnetic highs is interpreted to be a pre-Cambrian granite of the basement complex. Explanations as to why the contact of this rock should have particular importance in mineralization would include the concept that the contact (either fault or intrusive) represents a zone of weakness which could extend to great depth and provide access for Tertiary intrusion and mineralizing solutions. The strong correlation of copper with the granite suggests that the roots of the granite (or a particular phase, thereof) might be the source of the copper.

In regard to exploration applications, whereas one might argue that gradient bands are universally present in all magnetic coverage, and would therefore be too abundant to restrict effectively the potential area of exploration, a study of the evidence on a detail scale shows that particular bands interconnect multiple deposits and thereby accrue special importance over their length and breadth. Such special bands present much-restricted target areas for follow-up exploration methods.

In general, portions of bands which interconnect known deposits should be considered as having high mineral potential, as should extensions of bands passing through separate deposits.

The significance of the above correlations are, in the writer's opinion, great enough that many areas can be selected from the magnetics which have sufficient mineral potential to justify follow-up surveys with induced polarization for indications of sulfides. The use of geological information, both positive and negative would of course be used to further optimize chances of concentrating work over fruitful areas. The utilization of preliminary auxiliary geophysical methods would also be important to ascertain depths to premineral bedrock, and thereby to help avoid areas having excessive depth of cover.

PROCEDURES AND RESULTS

The regional magnetic data were derived from a high level aeromagnetic survey -- coverage was flown 7000' \pm above terrain with a three-mile line spacing. The detail magnetic data were taken in surveys in which

coverage ranged from 500' to 2000' above terrain, with a half-mile line spacing.

Figure 1 shows a magnetic contour map for southern Arizona. Here the original data (regional coverage) have been filtered by computer to suppress magnetic features having dimensions smaller than twelve miles, (approximately). The filter treatment has served to remove "hash" from the picture and thereby to allow broadscale features to show through more clearly.

Figure 1 Overlay shows the "ridge lines" of the major magnetic highs and also the gradient bands which frame the highs. These features were derived through simple visual study of patterns in the underlying contour map. It is evident that particular lithologic patterns in the basement rocks can be traced for hundreds of miles, as is exemplified by the length of the ridge lines and corresponding gradient bands.

The overlay also shows the locations of notable copper occurrences, which, in turn, show clearly to be related to the gradient bands.

This particular figure is not cited as convincing evidence of close correlation between magnetics and mineralization. It does, on the other hand, show a general regional relationship in that regard, and it further serves to frame the detail results within the regional scheme.

Figure 2 shows how the Tertiary host intrusive appears to be related to older intrusives, as interpreted from the magnetics and observed geology. The overlay shows the corresponding hypothetical magnetic picture. Two variations in the intrusive relationships are shown, Figures 2A and 2B.

Experience has shown that the pre-Cambrian granite and other pre-Tertiary intrusives will usually show positive magnetic effects. This may be true also of the less acid Laramide intrusives; however, the quartz-monzonite Laramide intrusives (those most commonly related to copper mineralization) are typically only weakly magnetic. The latter rock, consequently will not normally show a recognizable magnetic expression, Figure 2A.

Plates 1 through Plate 5 show the interpretations from the detail magnetics. Again, the significant copper occurrences are shown. The gradient bands which are marked are those that exhibit the most direct correlation with known copper mineralization. No reference has been made to geology at this point, except in connection with the locations of the particular mineral occurrences.

On Plate 1, only one copper occurrence is involved; Plate 2 shows two occurrences; Plates 3, 4, and 5 show increasing numbers of copper occurrences within the respective areas.

From an examination of Plates 1, 2, and 3, only, the case in favor of the mineral-magnetic correlation might be dismissed as a chance relationship. Further consideration of Plates 4 and 5 adds enough

weight that, in the writer's opinion, little doubt is left as to the over-all validity of the correlation.

The interpretation presented on the attached plates is essentially self-explanatory. A few comments especially pertinent to some areas are given below.

Plate 1 covers the area around the New Cornelia mine at Ajo. From the magnetic pattern we have proposed that the fault shown in the magnetics has offset the Ajo East Anomaly from the Ajo Anomaly. The source of the Ajo East Anomaly is hidden by post mineral cover, and it was selected as a subject for a special study using magnetic and gravity data with computer-assisted interpretational techniques. The results of the interpretation have been submitted under separate report and will be discussed only briefly here.

From a cursory appraisal of the "East" anomaly, there is obvious evidence of volcanic effects which confuse the pattern on the west portion. The computer work was able to separate the volcanic effects and show the target source to be made up of two intrusive-type forms lying at somewhat greater than 1000 feet in depth.

The magnetics of Plate 2 show the two deposits (Reward and Lakeshore) to lie on bands which do not interconnect. Possibly a northwest structural feature exists which cuts the gradient bands at the respective locations and connects the two, yet does not show in the magnetics.

The magnetic picture in the northeast part of Plate 5 suffers from two effects. First, the volcanics in the area are producing considerable hash in the magnetic pattern; second, the magnetic trend entering the area from the southwest is merging with a strong magnetic high having an east-west trend. The result of the two extraneous factors is to prevent satisfactory resolution of the body, or bodies, which produce the significant southwest-northeast pattern.

An improved picture would be obtained by re-flying the area with greater terrain clearance, and by using computer modeling to further separate and resolve the sources of the mineral-related pattern.

C. K. Moss

C. K. MOSS

CKM/mb
Enc.

MAJOR "RIDGE LINES" IN "MAGNETIC TOPOGRAPHY"

+ 113°
+ 33°

+ 110°
+ 33°
Morenci
San Juan ● Lone Star

See Plate 1
for detail →

See Plate 4
for detail →

See Plate 5
for detail →

See Plate 2
for detail →

See Plate 3
for detail →

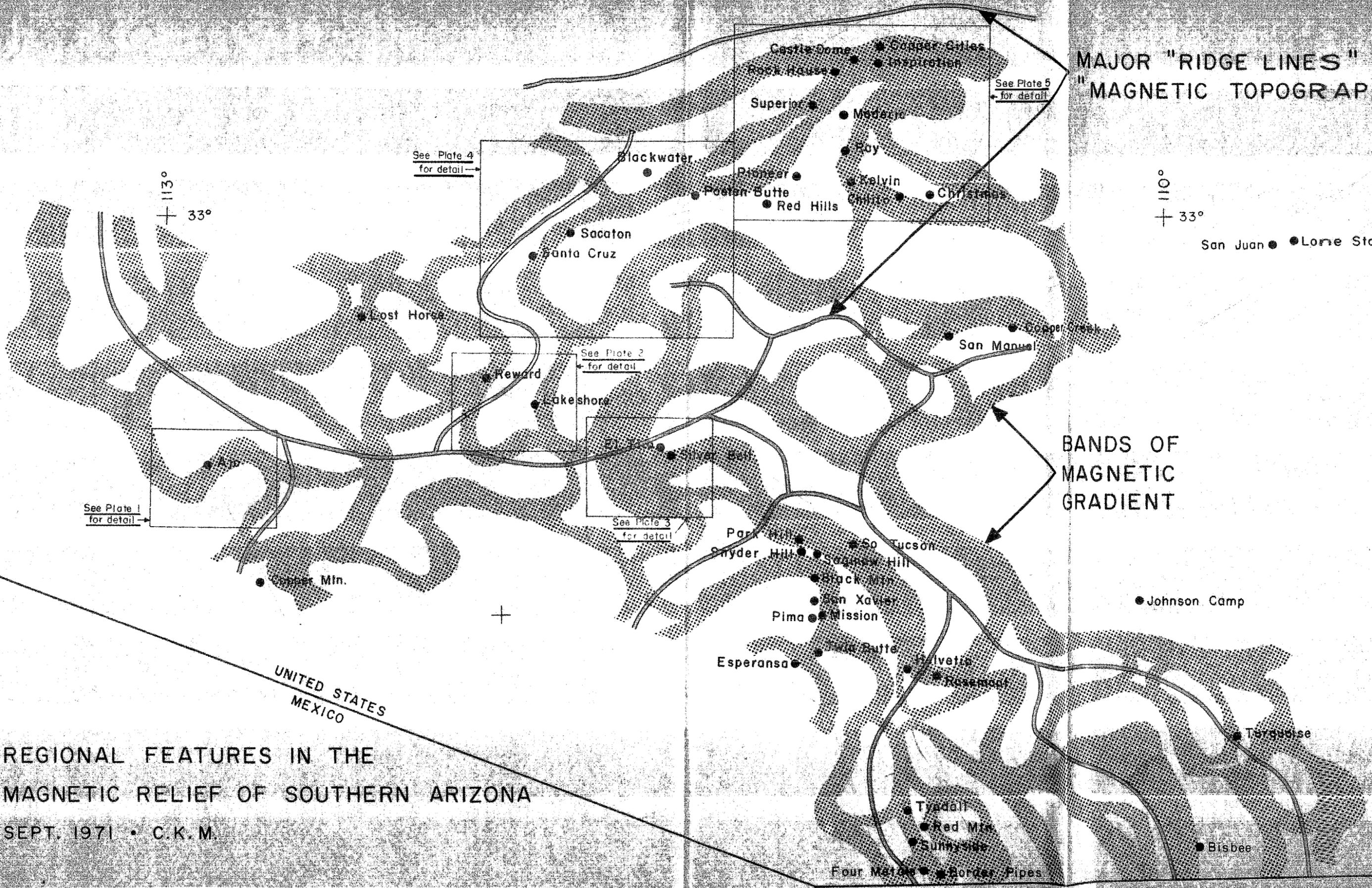
BANDS OF
MAGNETIC
GRADIENT

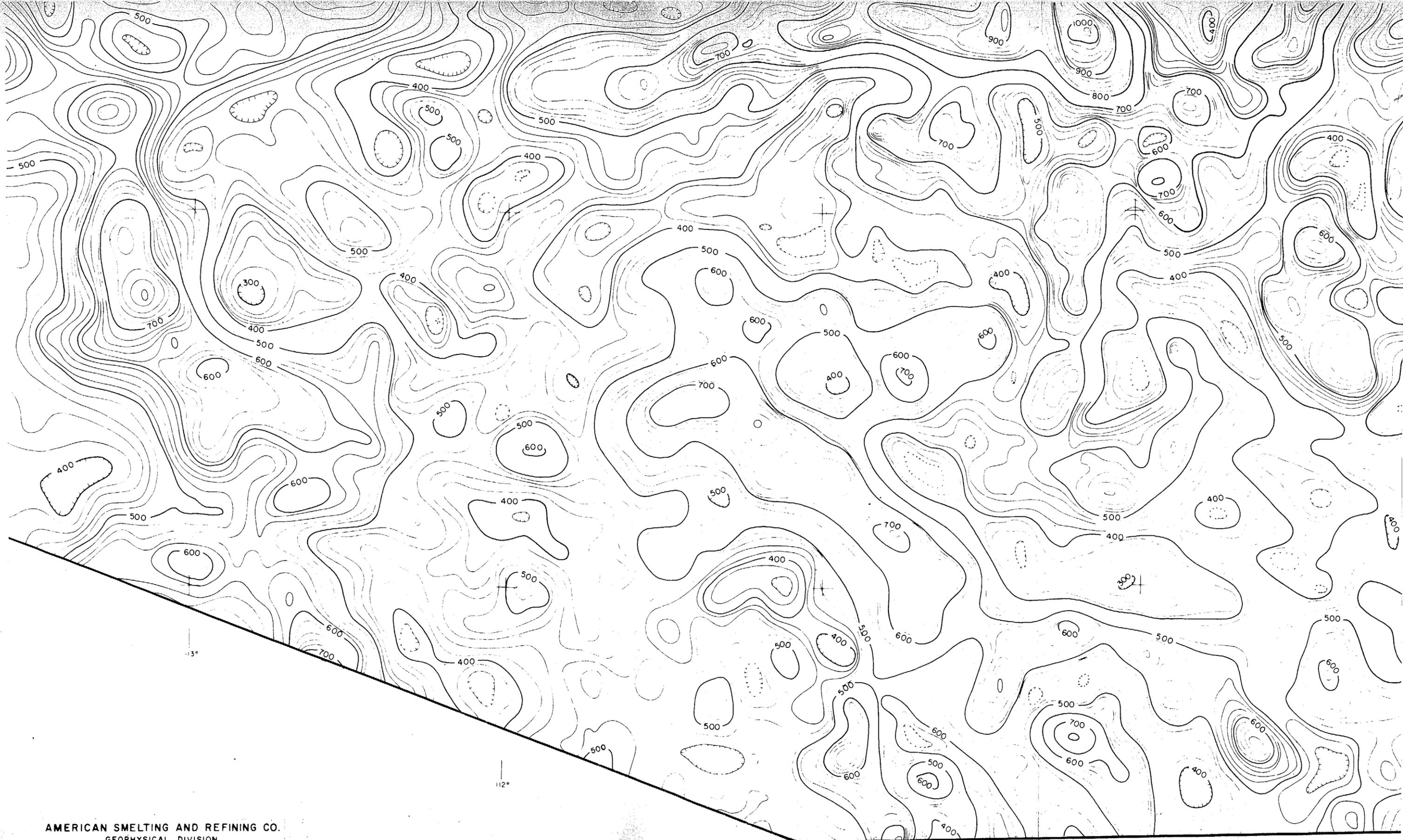
UNITED STATES
MEXICO

REGIONAL FEATURES IN THE
MAGNETIC RELIEF OF SOUTHERN ARIZONA

SEPT. 1971 • C.K.M.

Scale
1: 1,000,000





AMERICAN SMELTING AND REFINING CO.
GEOPHYSICAL DIVISION
SALT LAKE CITY, UTAH

ARIZONA AEROMAGNETICS
12.5 MILE REGIONAL FILTER
CONTOUR INTERVAL 20 GAMMAS
SCALE 1:1,000,000

FIGURE 1

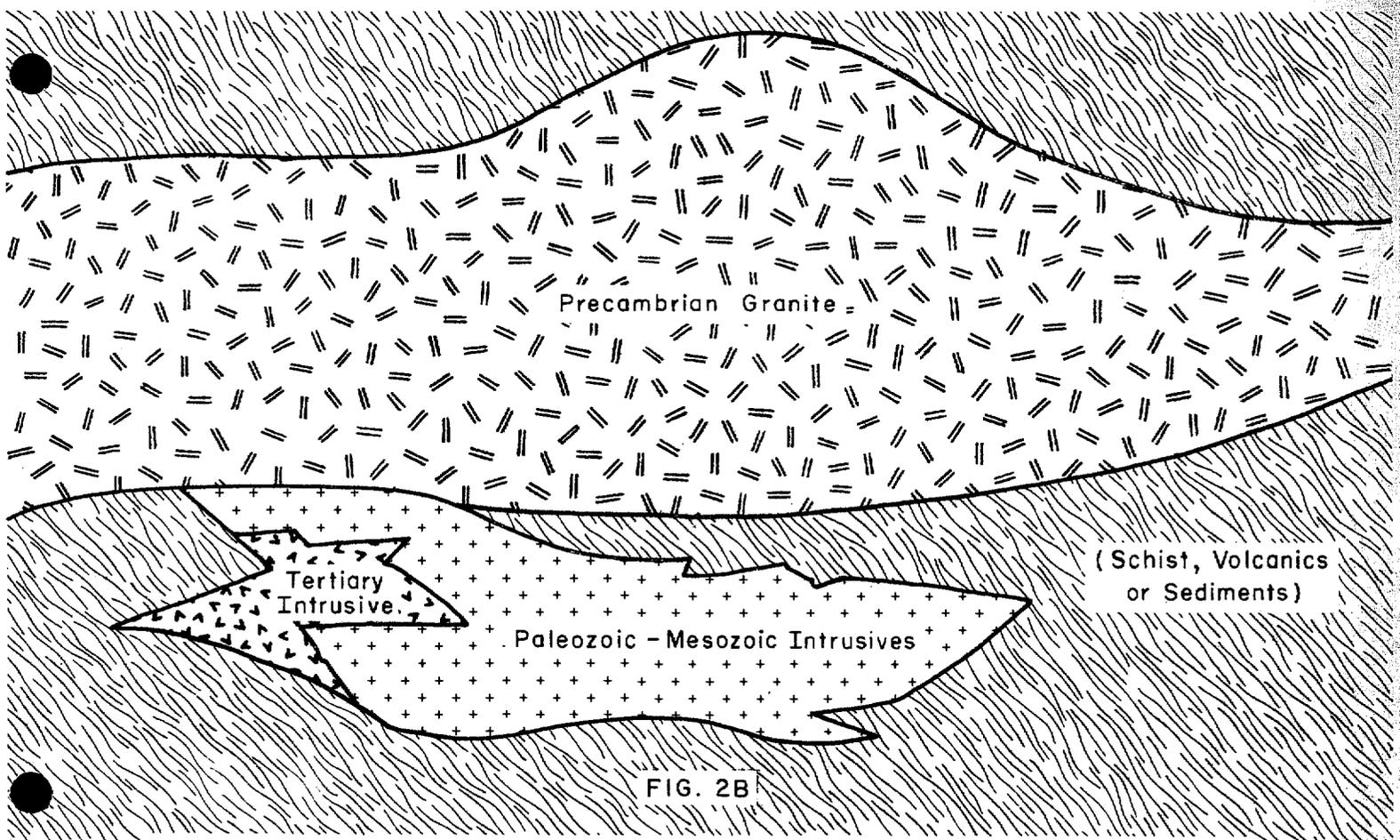
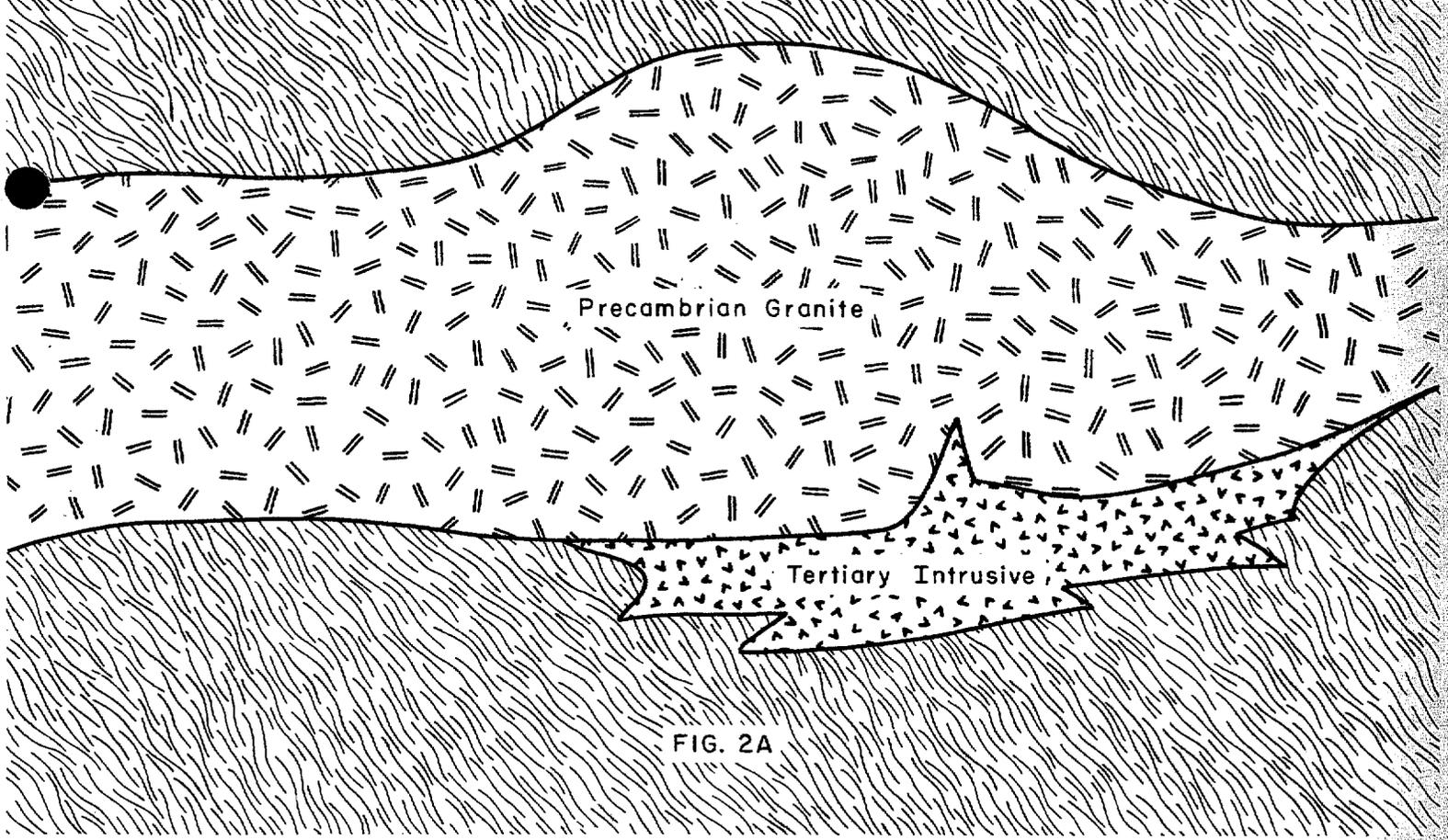


FIG. 2 GENERALIZED PLANIMETRIC DIAGRAMS SHOWING TYPICAL INTER-RELATIONSHIPS OF INTRUSIVE ROCKS AS INTERPRETED FROM MAGNETICS

GEOPHYSICAL DIVISION

3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

December 16, 1970

JAN 4 1971

R. J. L.
DEC 21 1970

RECEIVED

DEC 23 1970

S. W. U. S. EXPL. DIV.

MEMORANDUM TO R. J. LACY:

RECOMMENDATIONS FOR ADDITIONAL AEROMAGNETIC COVERAGE, SOUTHERN ARIZONA

Within a few days I will prepare a resume of the past year's aeromagnetic work as per John Collins' request of November 23. At the present time I would like to recommend additional aeromagnetic coverage in the Southwest.

With the accumulation of snow cover in the northern states, the problems of flight line recovery become serious. This fact coupled with the favorable mineralogic-magnetic correlations exhibited on recent survey results in the Southwest, a sample of which is attached, support the advisability of directing further attention to the Southwest.

For the past several weeks we have been assembling a mosaic of magnetic maps of southern Arizona. Sources for this have been surveys by the Geophysical Division, surveys by aeromagnetic contractors, and surveys by the U. S. G. S. These maps all represent low-level coverage. They have been reduced to a mosaic scale of 1:250,000 (A. M. S.).

Figure 1 attached shows magnetic contours for a sample strip running from the Casa Grande area to the Superior area. Figure 1 Overlay shows the location of copper occurrences together with the location of bands of high magnetic gradient. I believe the manner with which the gradient bands interconnect the known copper deposits is quite significant. Such patterns could be of strong importance in guiding exploration.

Figure 2 shows areas which I recommend for coverage in the immediate future in relationship to past surveys. I would welcome additional recommendations from the Southwest Division if their interests lie in different directions than those indicated.

I consider the prime objective of this work would be to trace out the gradient bands in detail, for future reference. I would not consider that complete comprehensive interpretations of the magnetics would be an immediate objective of the undertaking.

C. K. Moss

C. K. MOSS

CKM:am
Encls.

cc: J. J. Collins, w/enc.
✓ J. H. Courtright "
W. E. Saegart "
W. G. Farley "

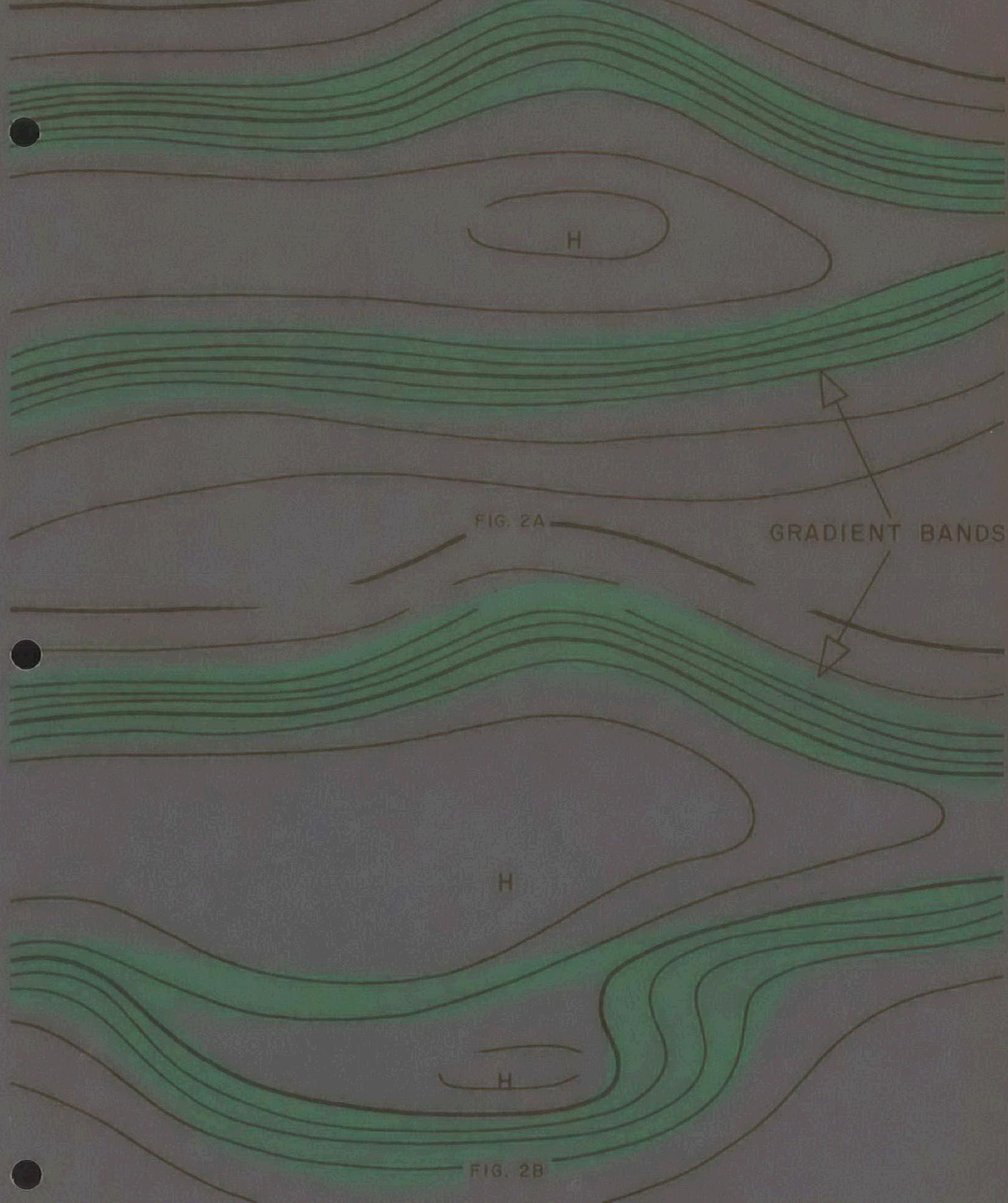
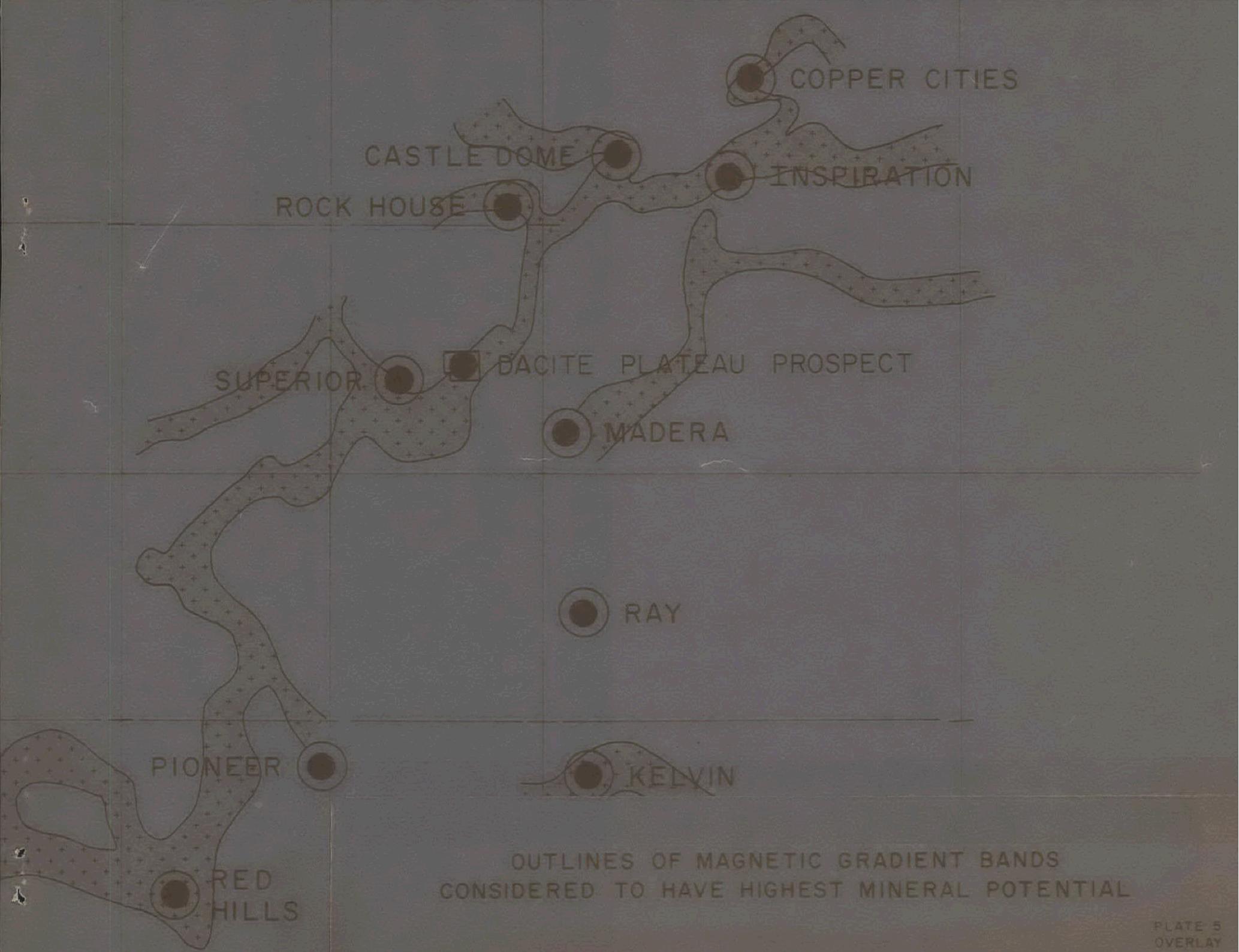
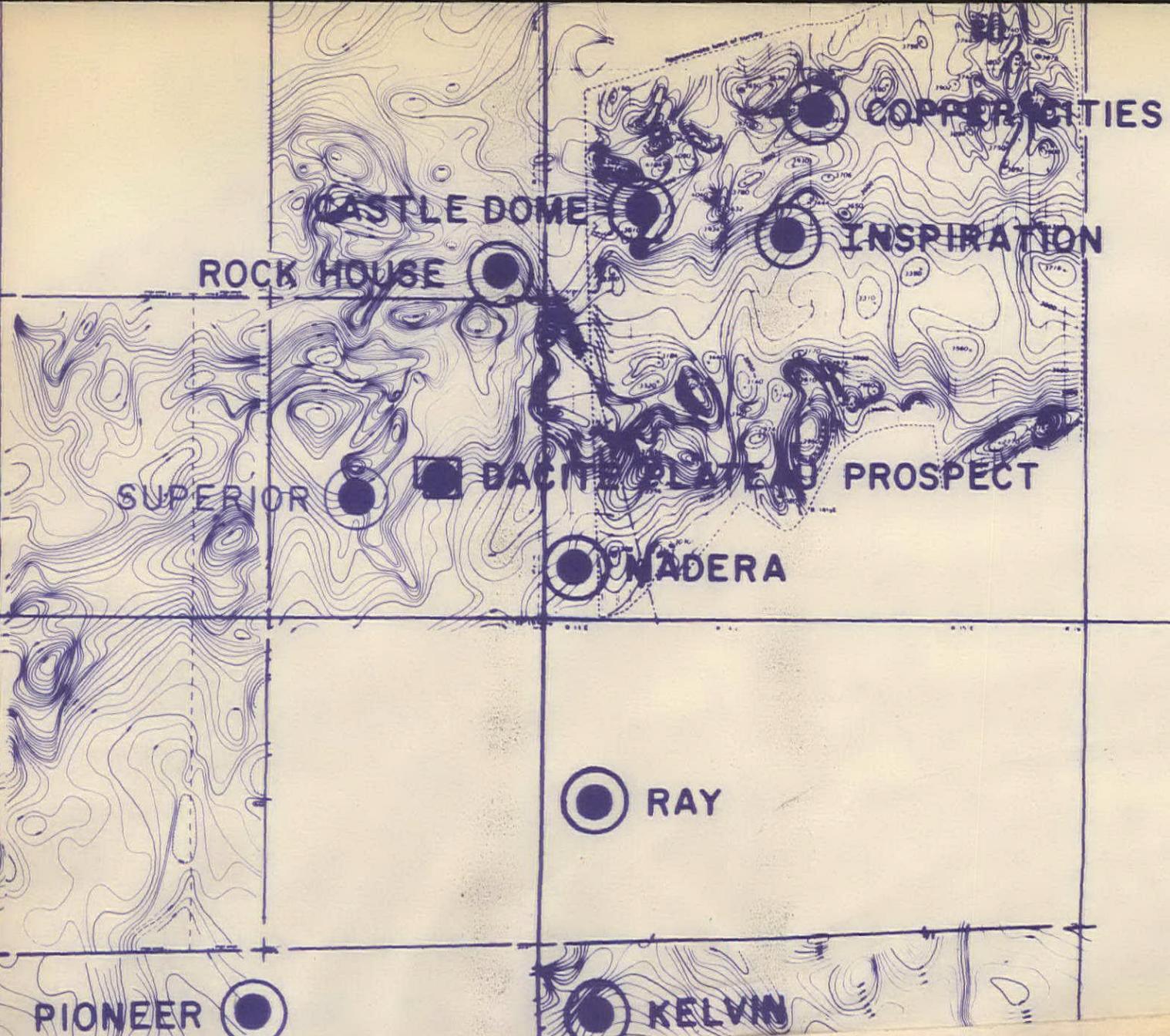


FIG. 2, OVERLAY—APPROXIMATE MAGNETIC PATTERNS WHICH WOULD BE EXPECTED FROM GEOLOGY OF FIG. 2

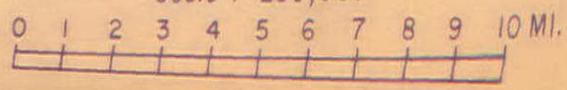


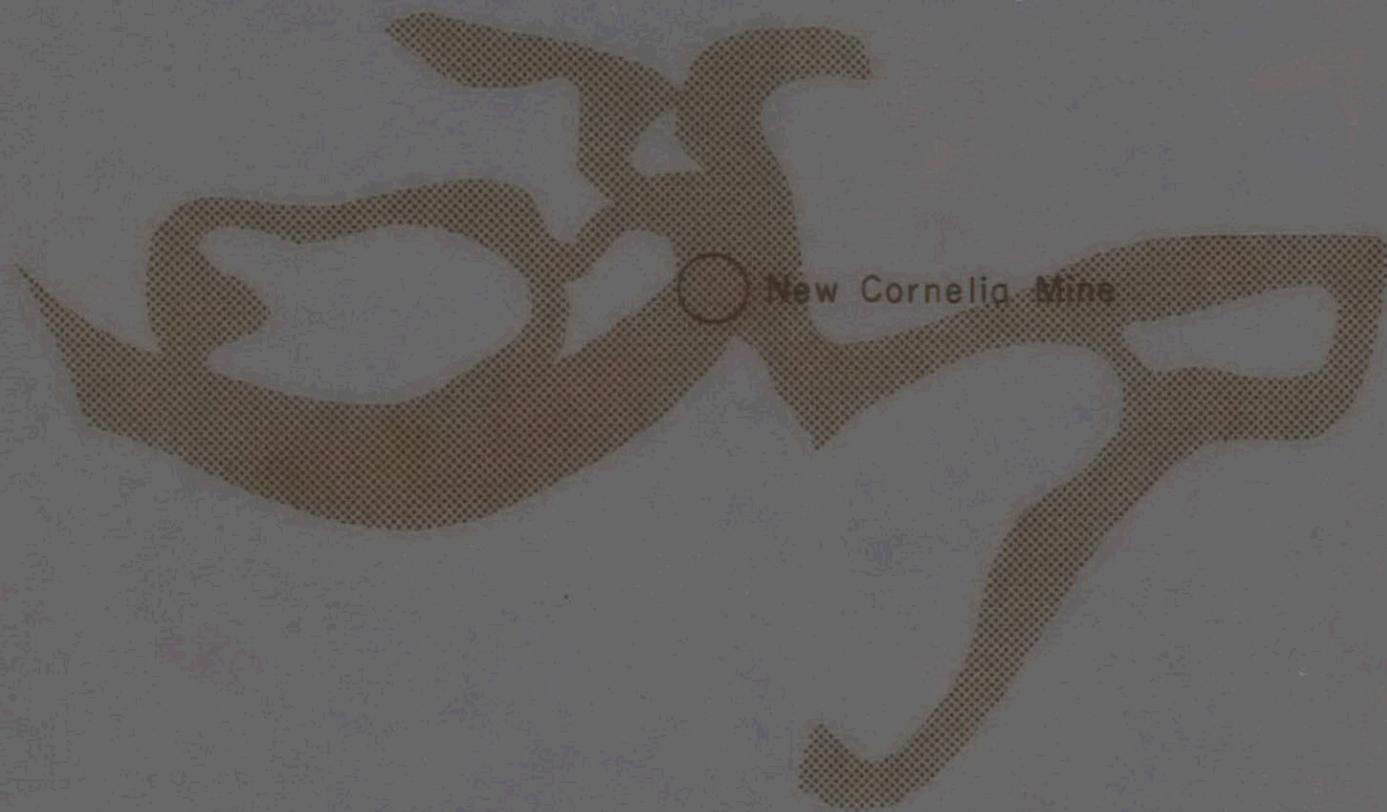


RED HILLS--COPPER CITIES AREA - DETAIL MAGNETICS

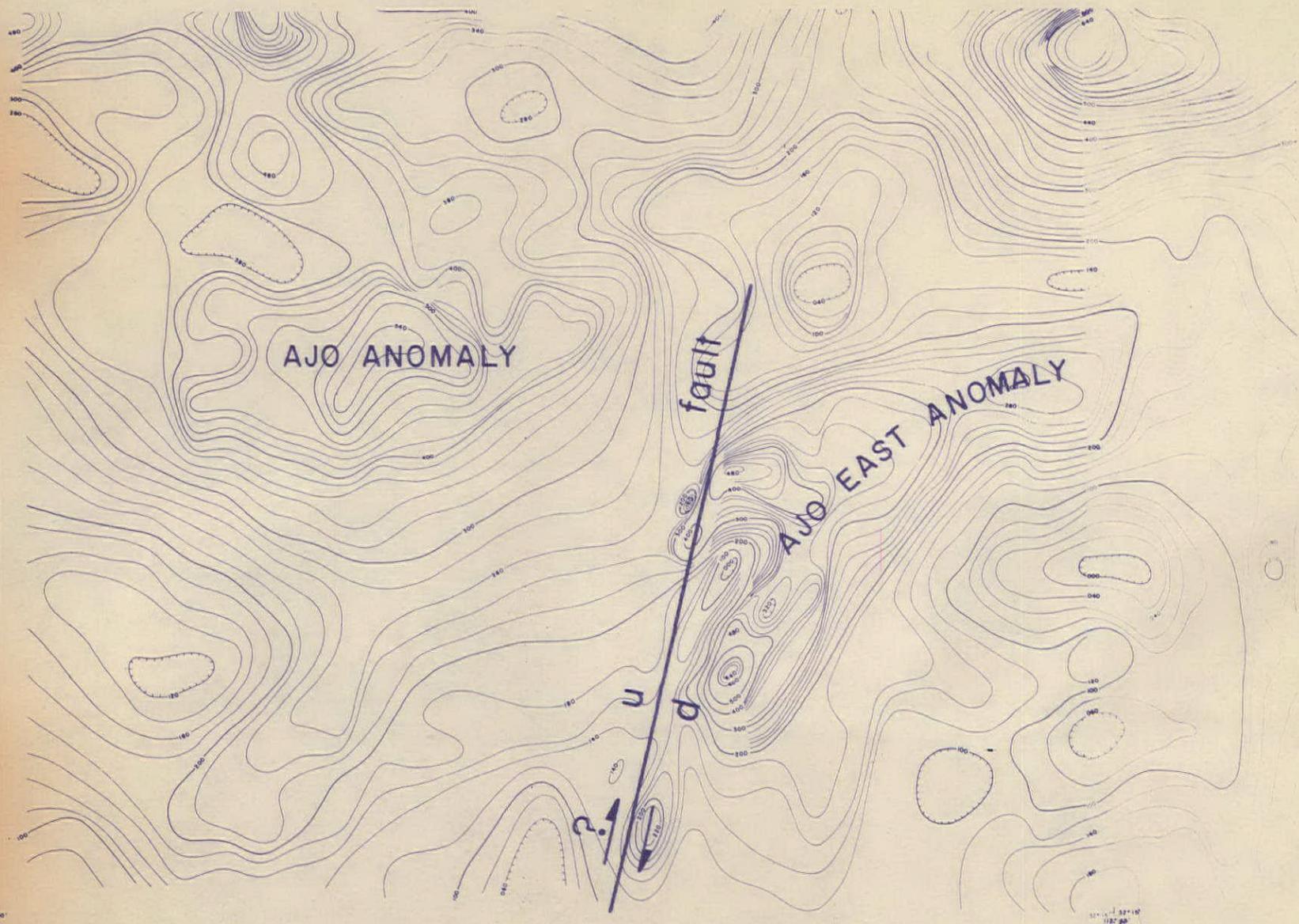


Scale 1:250,000





OUTLINES OF MAGNETIC GRADIENT BANDS
CONSIDERED TO HAVE HIGHEST MINERAL POTENTIAL



AJO ANOMALY

fault

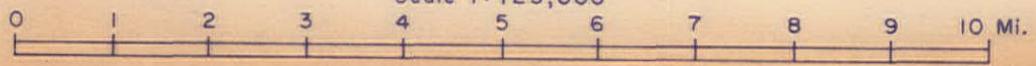
AJO EAST ANOMALY

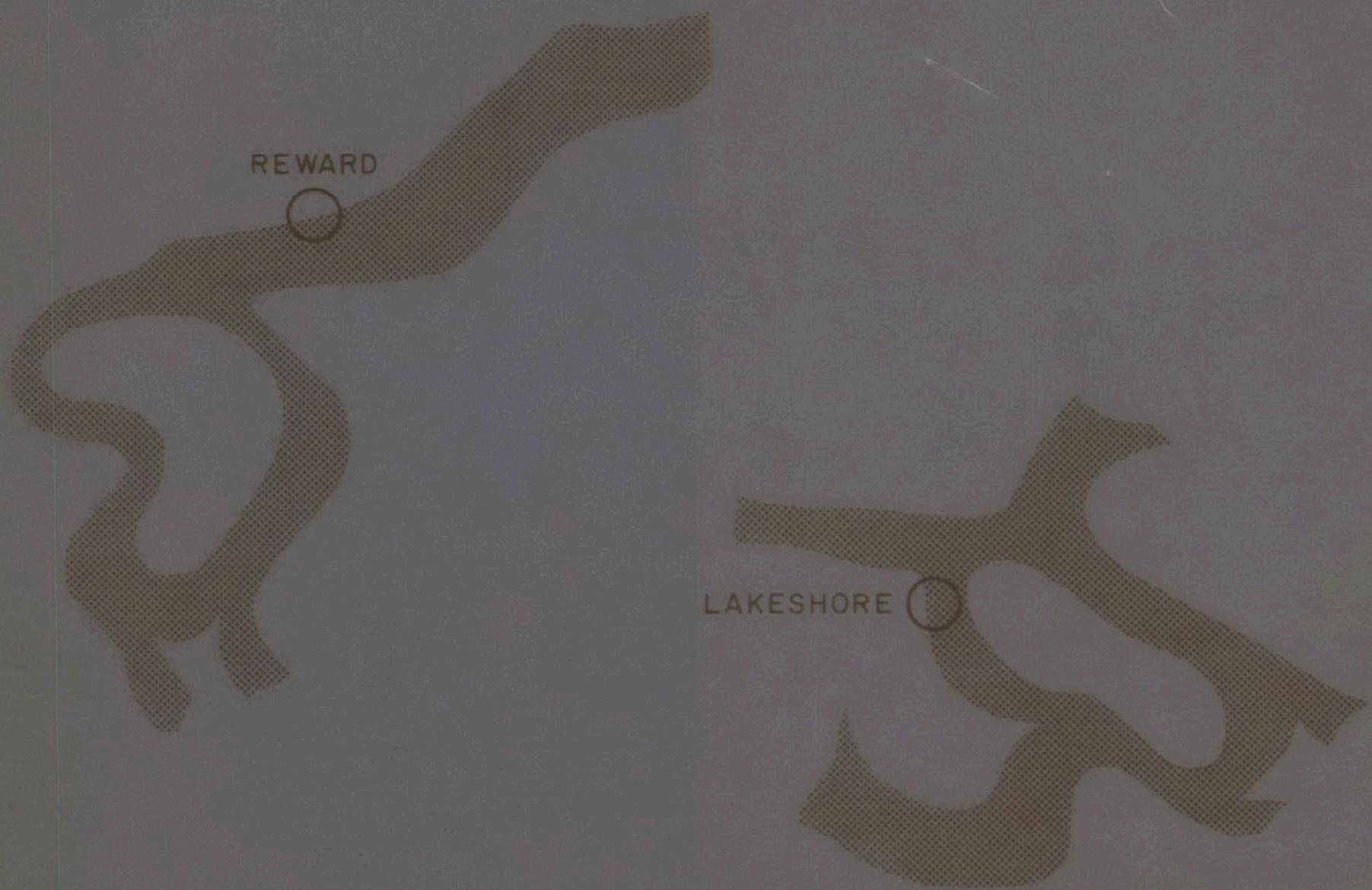
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AJO AREA - DETAIL MAGNETICS



Scale 1:125,000

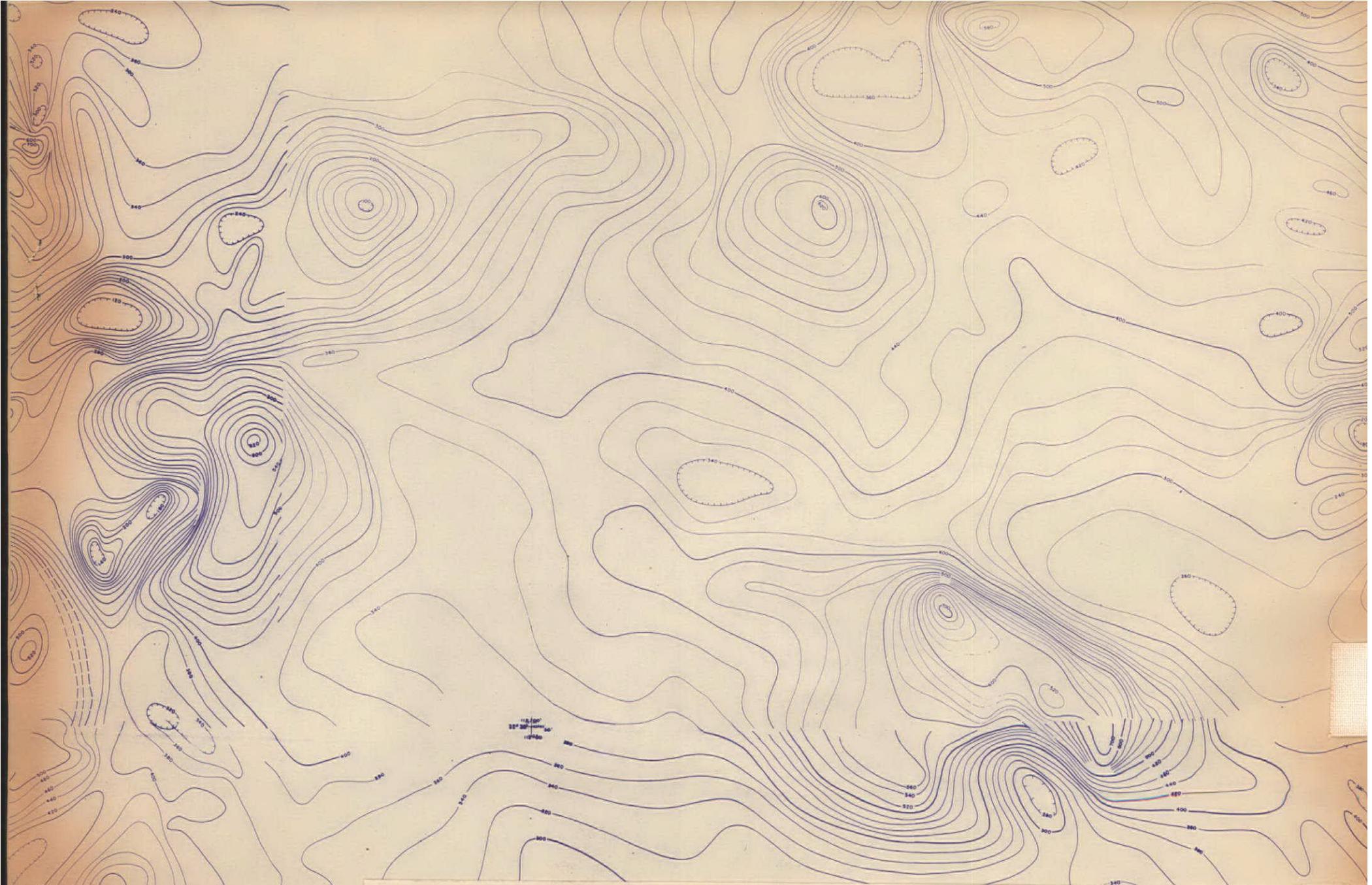




REWARD

LAKESHORE

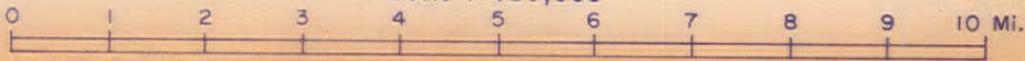
OUTLINES OF MAGNETIC GRADIENT BANDS
CONSIDERED TO HAVE HIGHEST MINERAL POTENTIAL

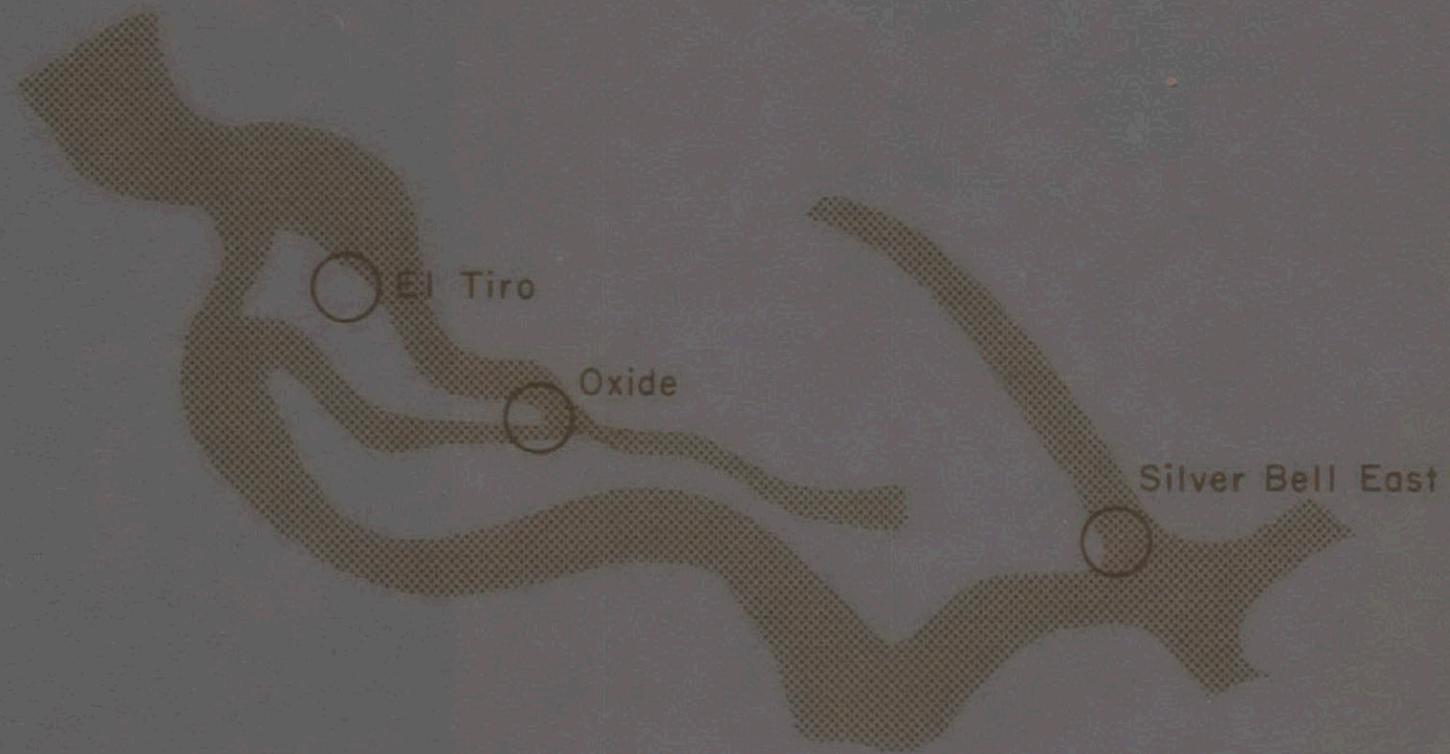


REWARD--LAKESHORE AREA - DETAIL MAGNETICS

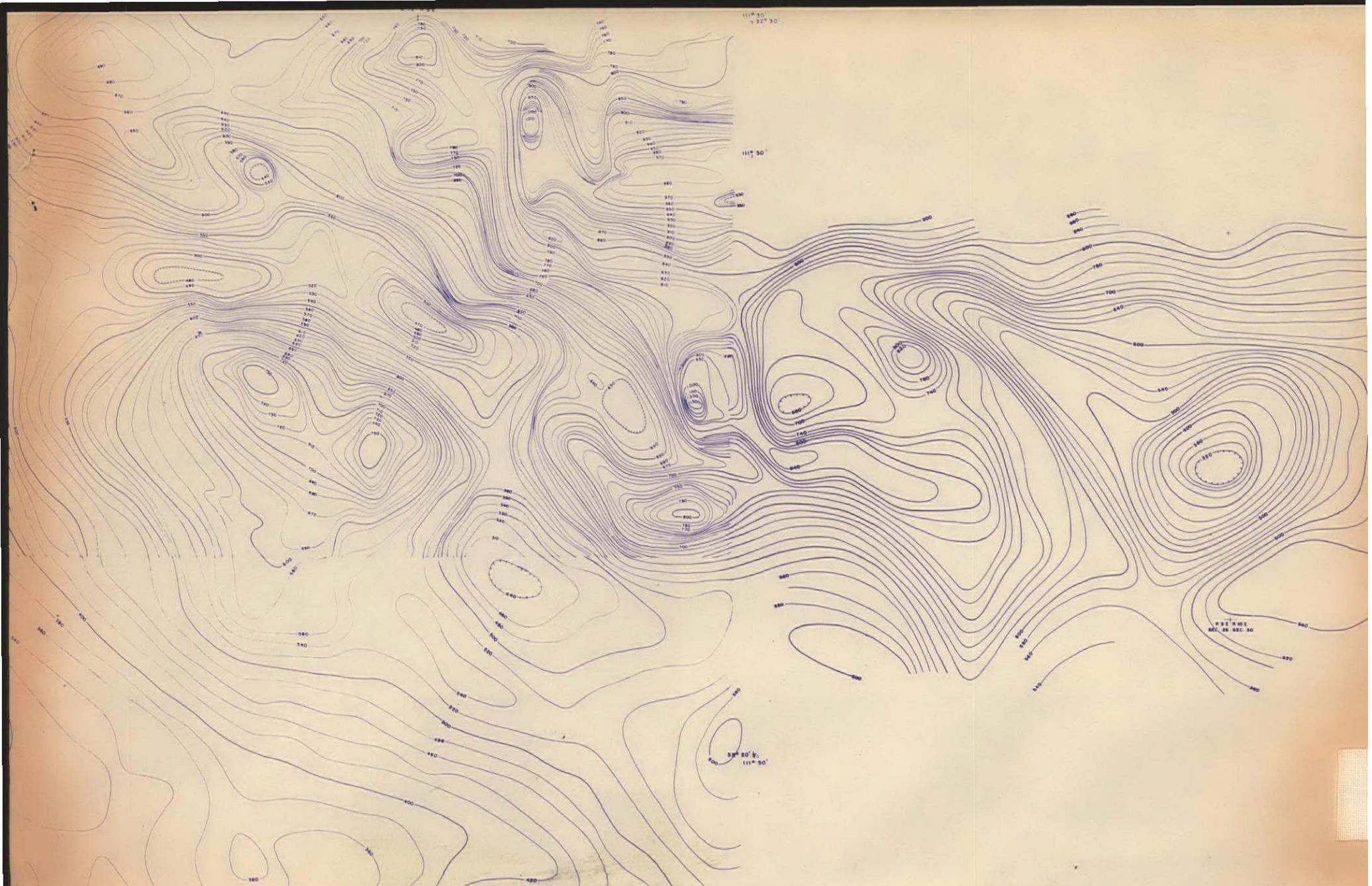


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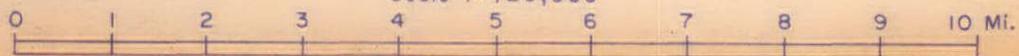


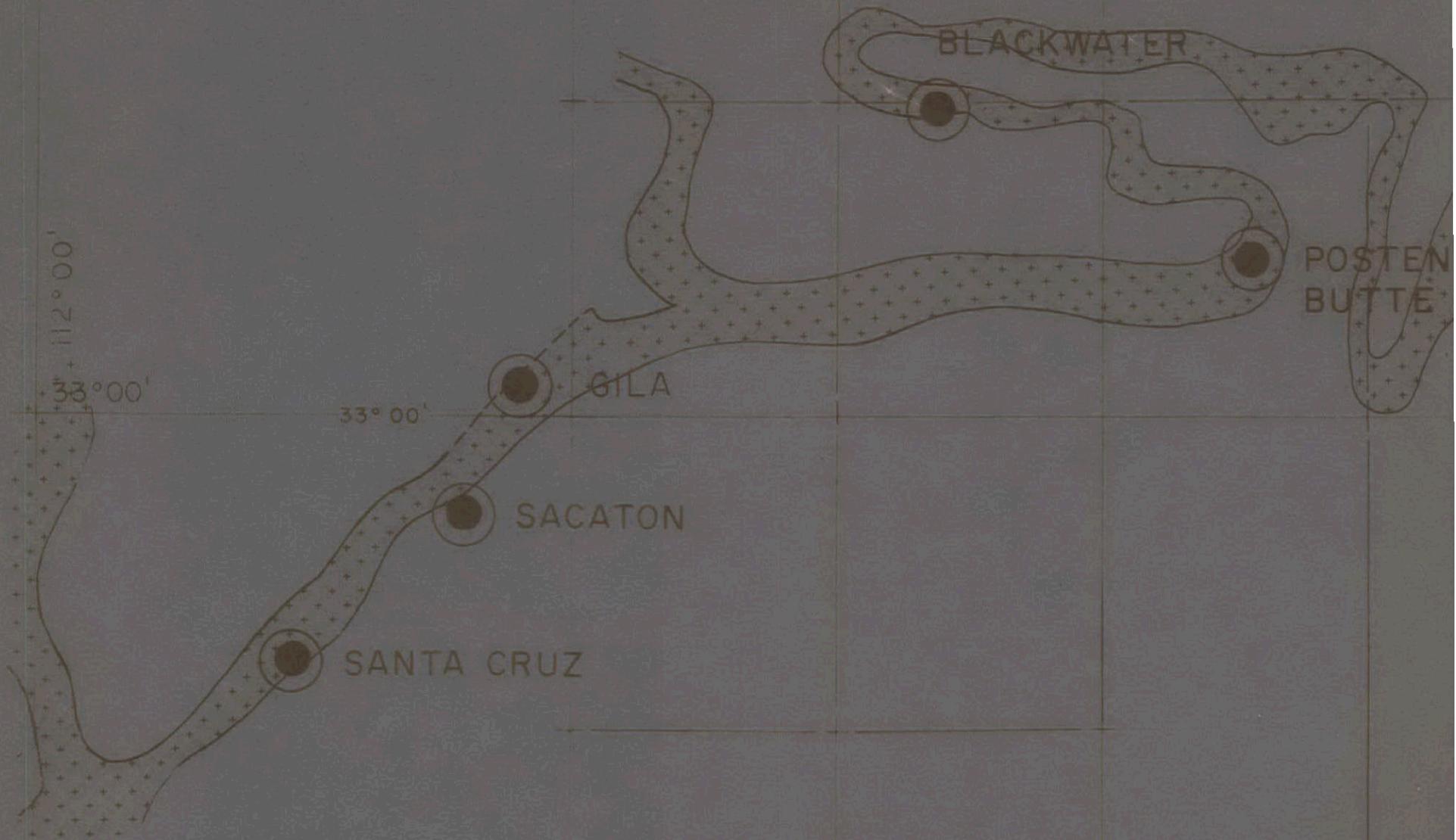
OUTLINES OF MAGNETIC GRADIENT BANDS
CONSIDERED TO HAVE HIGHEST MINERAL POTENTIAL



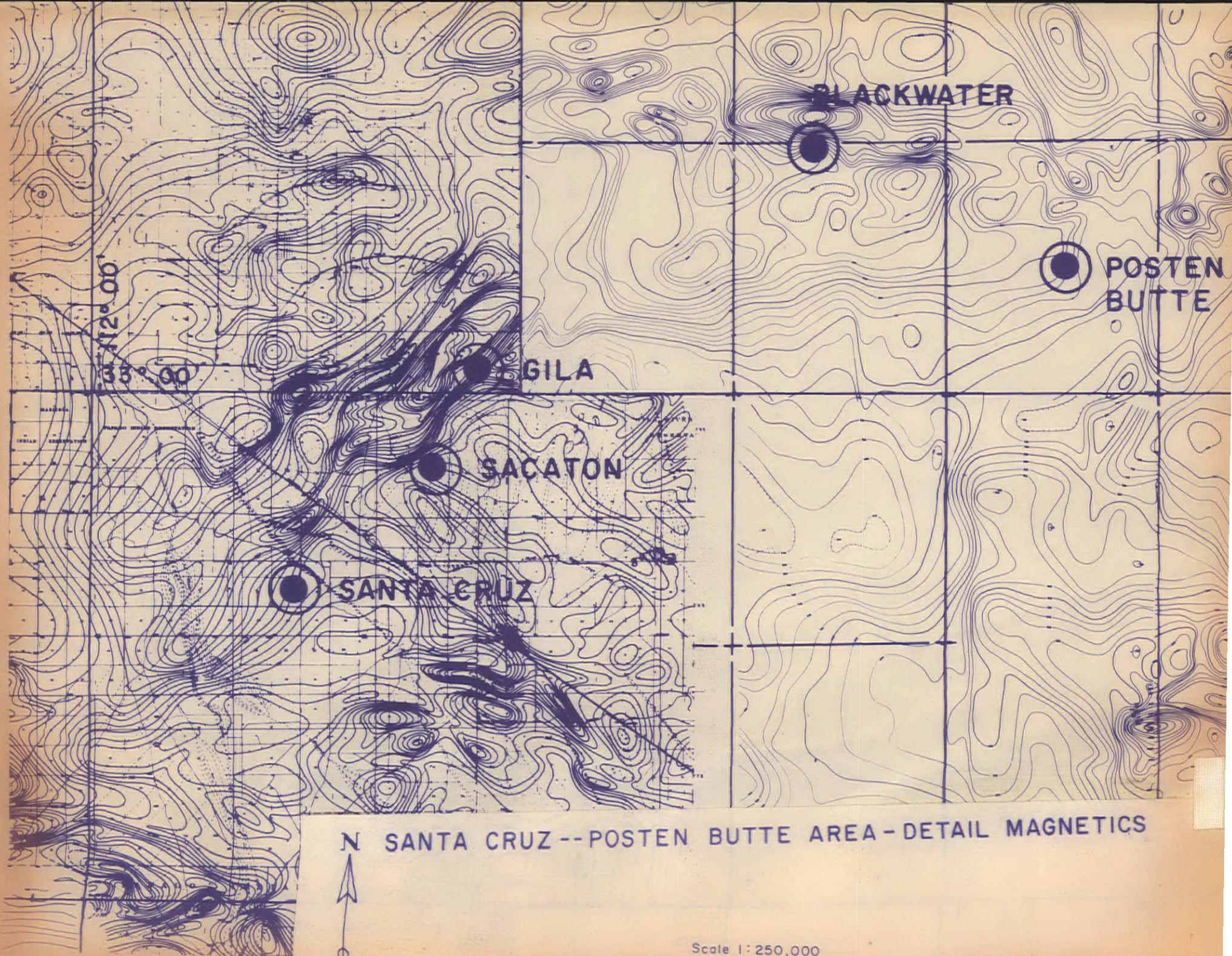
SILVER BELL AREA - DETAIL MAGNETICS

Scale 1:125,000





OUTLINES OF MAGNETIC GRADIENT BANDS
CONSIDERED TO HAVE HIGHEST MINERAL POTENTIAL



35° 00'

12° 00'

BLACKWATER

POSTEN BUTTE

GILA

SACATON

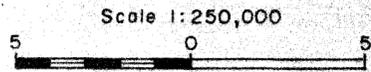
SANTA CRUZ

N SANTA CRUZ -- POSTEN BUTTE AREA - DETAIL MAGNETICS



Scale 1:250,000
0 1 2 3 4 5 6 7 8 9 10 MI.

FIG. 1
MAGNETIC CONTOURS
CASA GRANDE to SUPERIOR ARIZONA
C.K. MOSS



OVERLAY FOR FIG. 1
BANDS OF HIGH MAGNETIC GRADIENT
CASA GRANDE to SUPERIOR ARIZONA
C.K. MOSS

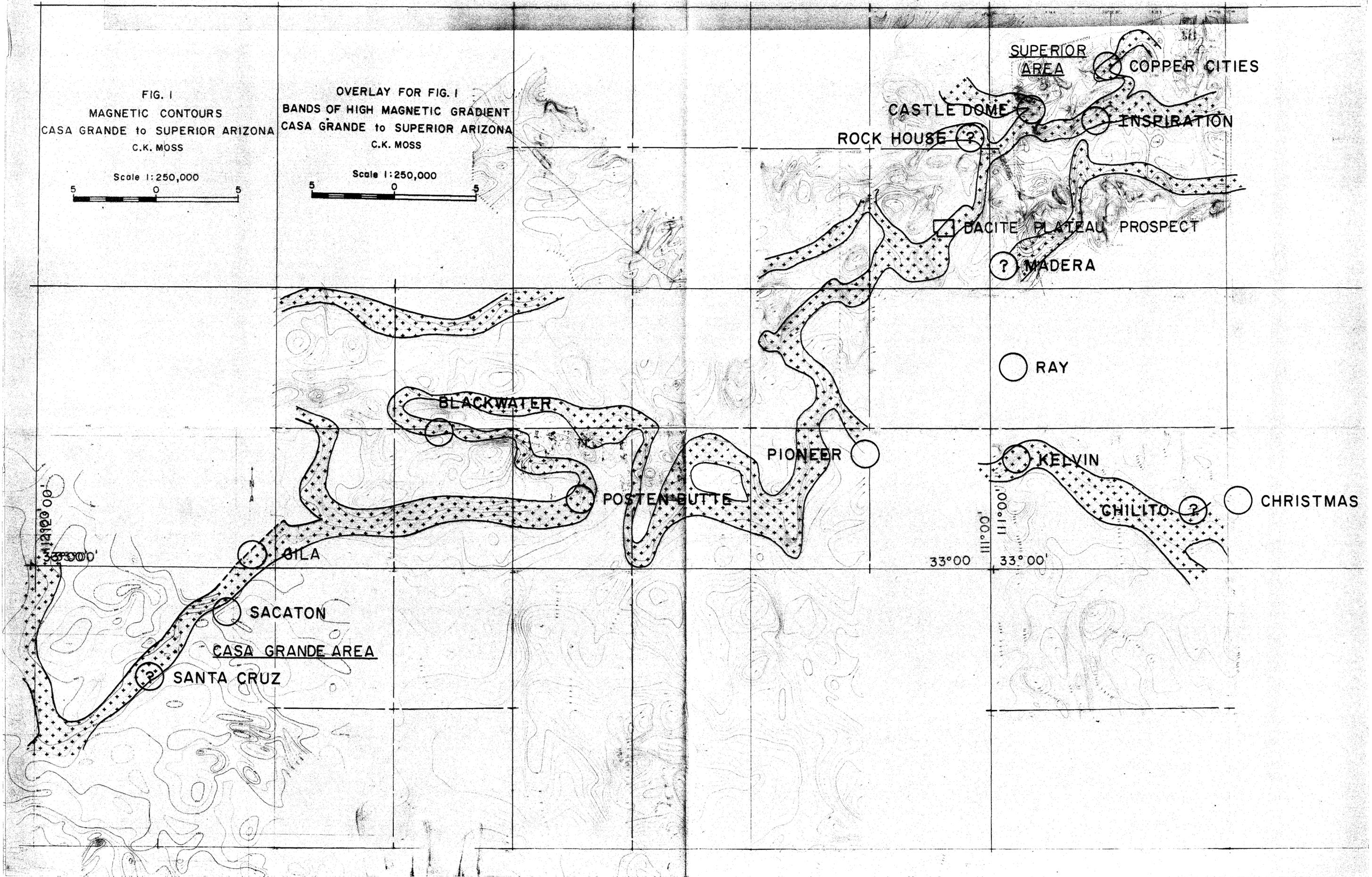
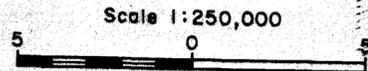
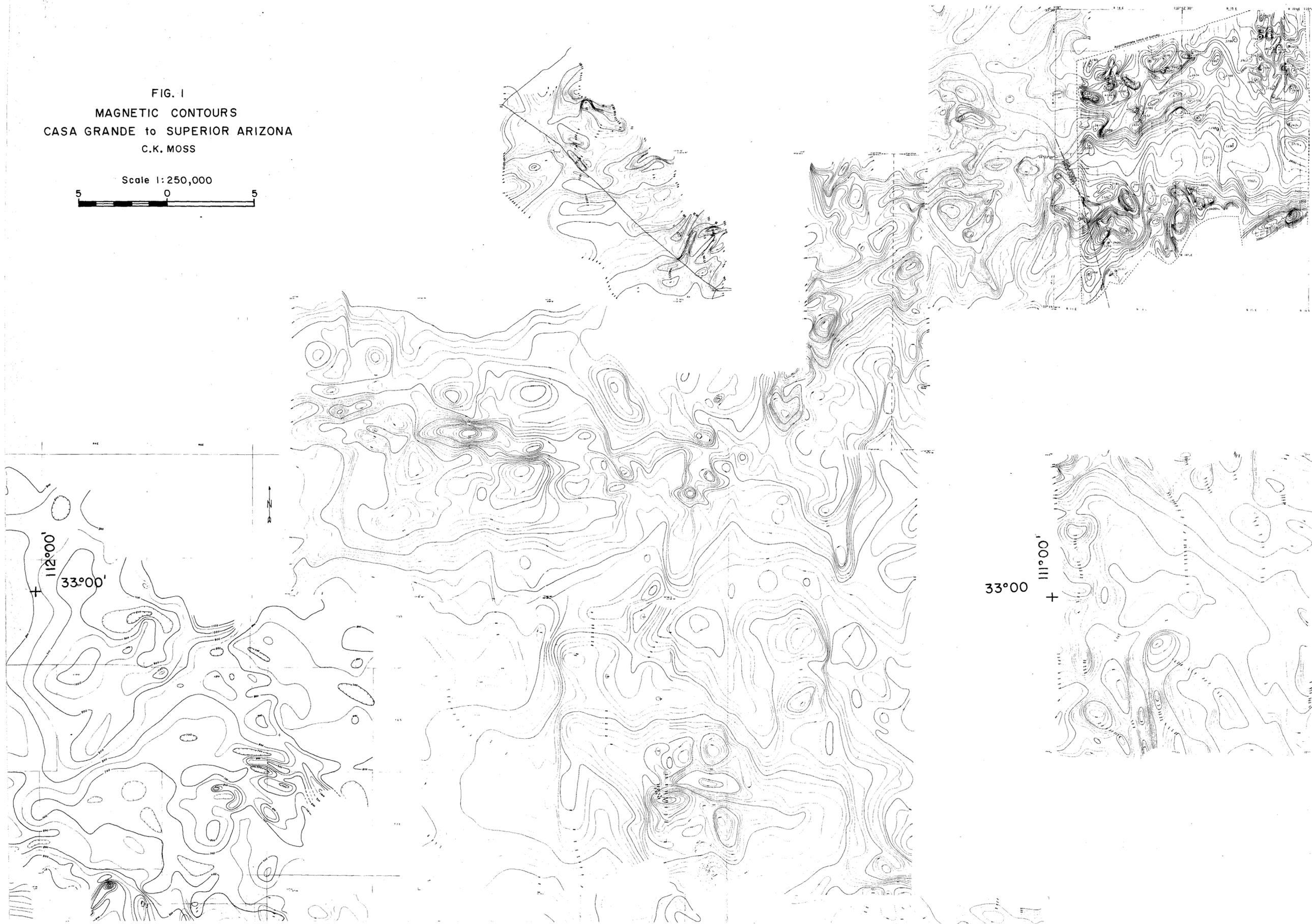
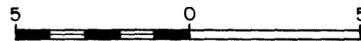
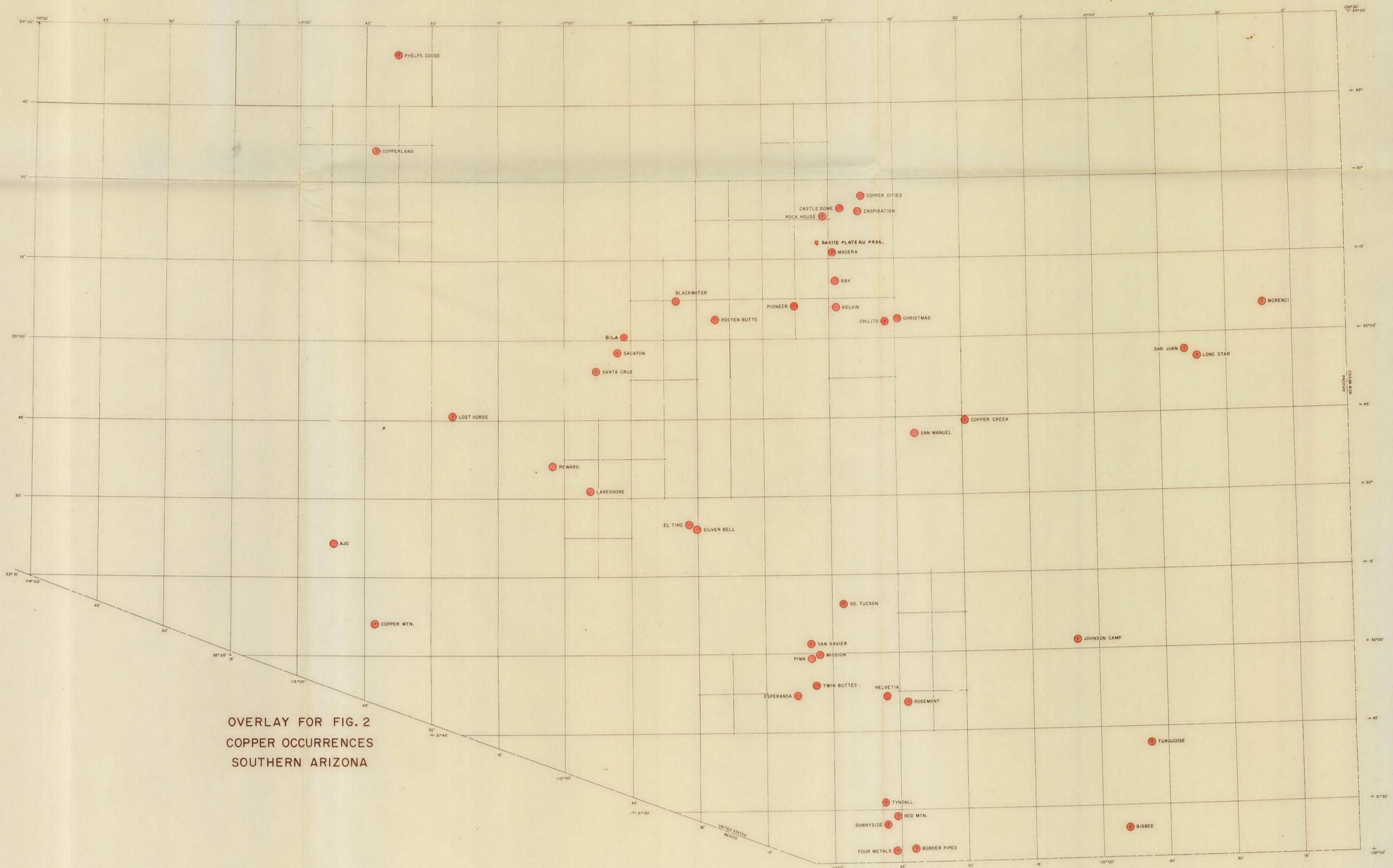


FIG. 1
MAGNETIC CONTOURS
CASA GRANDE to SUPERIOR ARIZONA
C.K. MOSS

Scale 1:250,000





OVERLAY FOR FIG. 2
 COPPER OCCURRENCES
 SOUTHERN ARIZONA

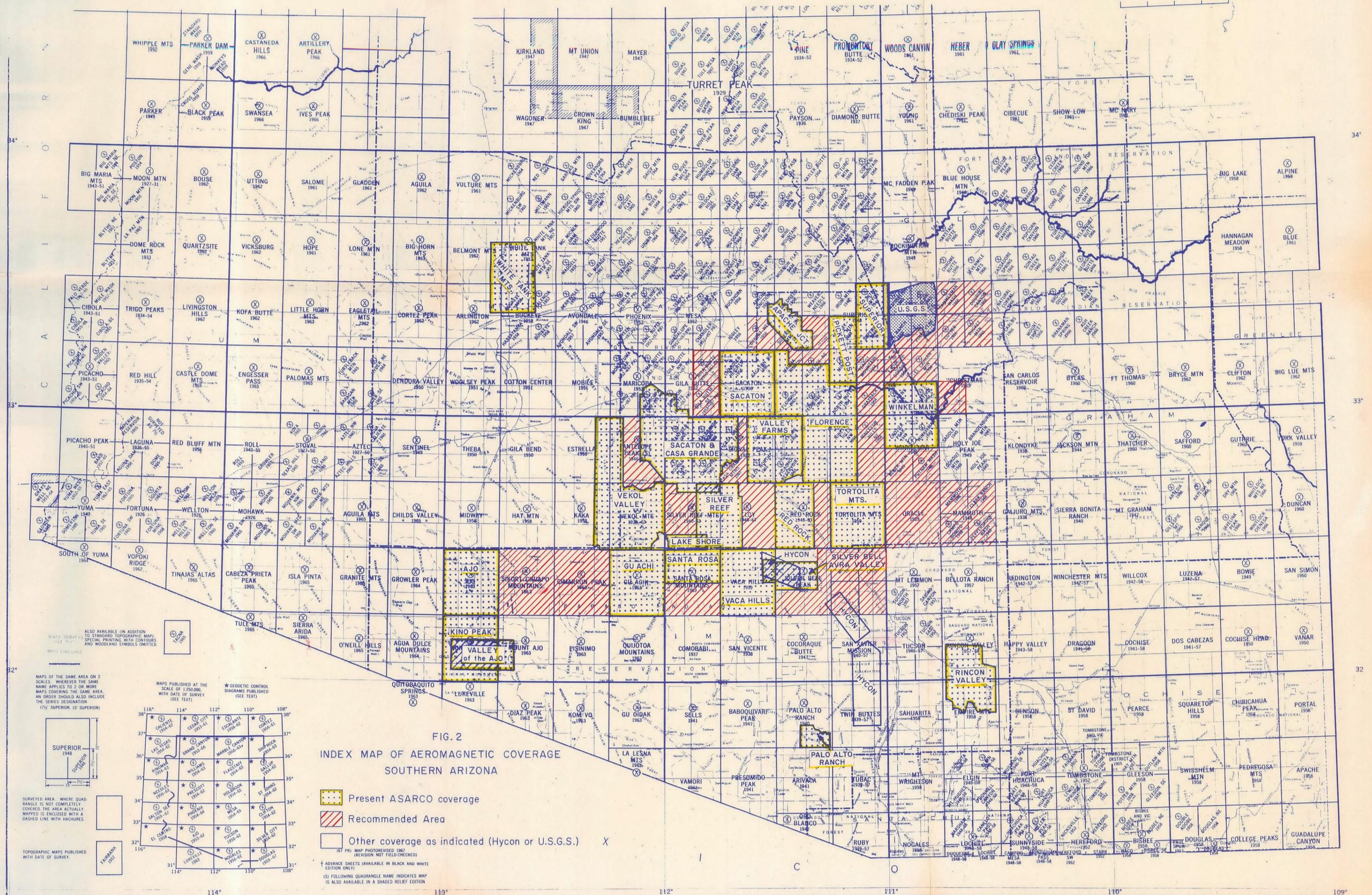


FIG. 2
INDEX MAP OF AEROMAGNETIC COVERAGE
SOUTHERN ARIZONA

- Present ASARCO coverage
- Recommended Area
- Other coverage as indicated (Hycon or U.S.G.S.)

(67 PR) MAP PHOTOREVISED 1967 (REVISION NOT FIELD-CHECKED)
 † ADVANCE SHEETS (AVAILABLE IN BLACK AND WHITE EDITION ONLY)
 (S) FOLLOWING QUADRANGLE NAME INDICATES MAP IS ALSO AVAILABLE IN A SHADED RELIEF EDITION

ALSO AVAILABLE (IN ADDITION TO STANDARD TOPOGRAPHIC MAPS) SPECIAL PRINTING WITH CONTOURS AND WOODLAND SYMBOLS OMITTED

MAPS OF THE SAME AREA ON 2 SCALES: WHENEVER THE SAME NAME APPLIES TO 2 OR MORE MAPS COVERING THE SAME AREA, AN ORDER SHOULD ALSO INCLUDE THE SERIES DESIGNATION (7 1/2" SUPERIOR, 15" SUPERIOR)

MAPS PUBLISHED AT THE SCALE OF 1:250,000, WITH DATE OF SURVEY (SEE TEXT)

* GEODETIC CONTROL DIAGRAMS PUBLISHED (SEE TEXT)

SURVEYED AREA WHERE QUAD RANGLE IS NOT COMPLETELY COVERED, THE AREA ACTUALLY MAPPED IS ENCLOSED WITH A DASHED LINE WITH HACHURES

TOPOGRAPHIC MAPS PUBLISHED WITH DATE OF SURVEY.