

PRELIMINARY INTERPRETATION REPORT  
AIRBORNE MAGNETOMETER SURVEY  
OF  
SOUTHERN IOWA

(Adapted from Report of Airborne Magnetometer Survey  
by Lockwood, Kessler and Bartlett, Inc.)

IOWA GEOLOGICAL SURVEY

Iowa City, Iowa

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January, 1973

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INTRODUCTION

This report describes an aerial magnetic survey performed for the Iowa Geological Survey by Lockwood, Kessler and Bartlett, Inc., Pasadena, California, during February and March 1972 covering that portion of Iowa lying south of latitude  $40^{\circ} 54'$  north and extending to its southern boundary. This area of about 5,200 square miles includes the entire southern tier of counties plus the southern portions of Henry and Des Moines Counties at the eastern end of the survey area (see index map).

The flight direction of the survey traverses was east-west, with an average distance of one mile between adjacent parallel traverses. The tie lines were flown north-south, normal to the traverses and at 10-mile intervals.

The magnetic survey data are available on two isomagnetic contour map sheets at a scale of 1:250,000 or one inch equals 3.95 miles. For this report the two sheets have been combined on one sheet at a scale of 1:500,000 or one inch equals 7.9 miles. The contour interval used for the delineation of the survey is 20 and 100 gammas. The base map used in the survey compilation is the U. S. Geological Survey Iowa Base Map, 1966 edition.

## INTERPRETIVE OBSERVATIONS

### A. REGIONAL GEOLOGY AND STRUCTURAL FEATURES

The regional geology of the survey area is displayed on the Geologic Map of Iowa (Reference 1). The sedimentary rocks of the area are almost all of Paleozoic age, and a fairly complete and continuous sequence is present. The regional dip is to the southwest.

The oldest exposed rocks in the survey area are in Des Moines and Lee Counties, along the Mississippi River (see index map). These rocks consist of the shales of the Upper Devonian Yellow Spring Group. Progressively younger rocks overlie the Devonian to the west. Mississippian age rocks are at the surface as far west as Davis County, and Pennsylvanian age rocks form the bedrock across the rest of the area with the exception of a few small outliers of Cretaceous age sediments in Page County. A mantle of unconsolidated glacial material that ranges in thickness from a few feet to a few hundred feet covers the entire region.

Precambrian basement topography and geology for the survey area is shown on the Basement Rock Map of the United States (Reference 2). The extreme western end of the survey is seen to lie over the midcontinent gravity and magnetic high. Near Bedford, Iowa the Forest City basin is present with a basement closure below -3,000 feet sea level. Near Coal City on the southern boundary of the State, the basement is shown rising to -2,000 feet sea level and then dropping again to the east to about -2,700 feet sea level at the Mississippi River.

Reference 2 also shows a triangularly shaped basement rock unit lying north of Iowa City and between Waterloo and Dubuque with basaltic and Precambrian



# INDEX TO AIRBORNE MAGNETOMETER SURVEYS IN IOWA

## BEDROCK OF IOWA

### LEGEND

#### CRETACEOUS

**Ku** Undifferentiated

#### JURASSIC

**Jfd** Fort Dodge Beds

#### PENNSYLVANIAN

**Pv** Virgil

**Pm** Missouri

**Pdm** Des Moines

#### MISSISSIPPIAN

**Mu** Undifferentiated

#### DEVONIAN

**Du** Upper

**Dm** Middle

#### SILURIAN

**Su** Undifferentiated

#### ORDOVICIAN

**Ou** Undifferentiated

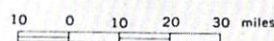
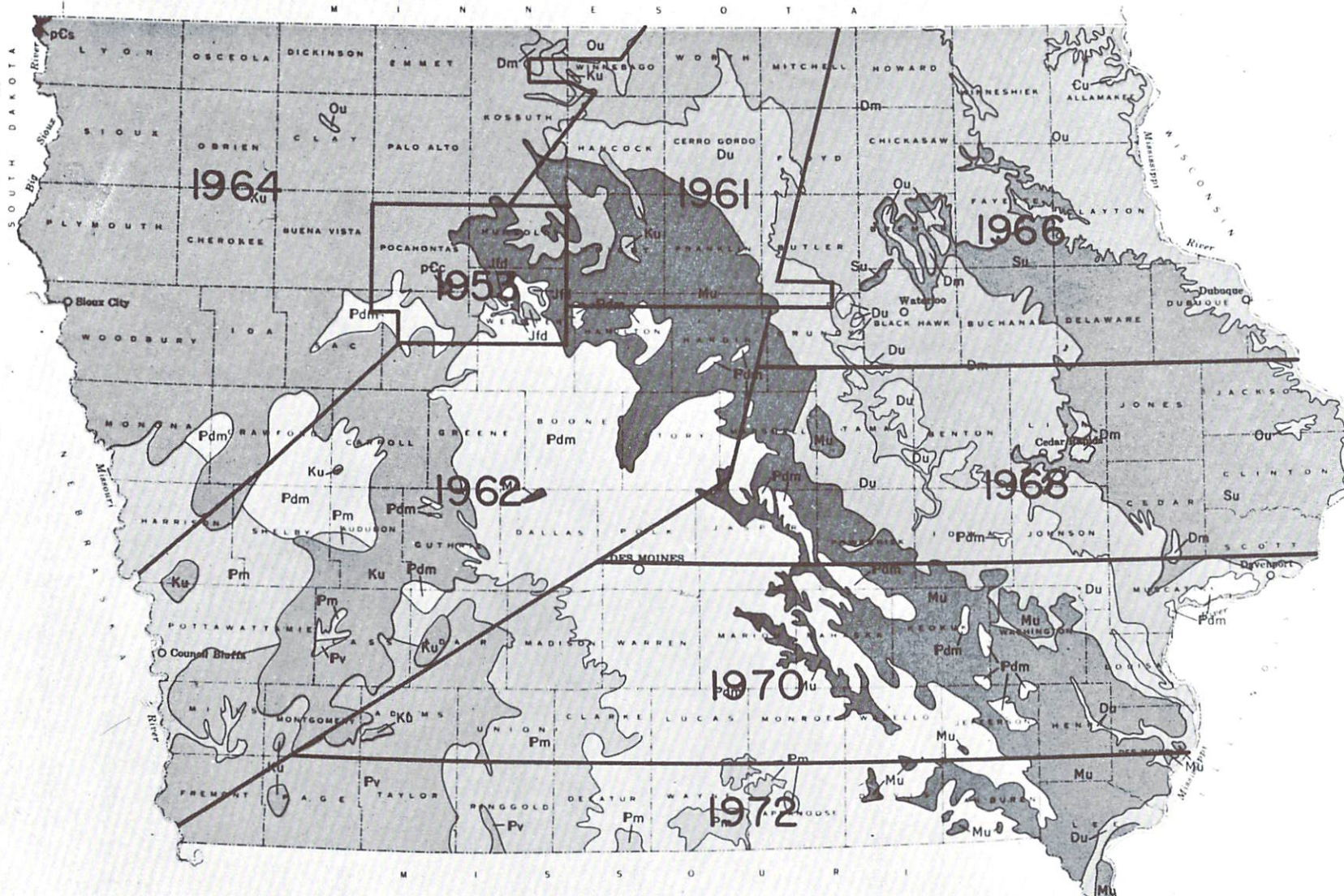
#### CAMBRIAN

**Cu** Undifferentiated

#### PRECAMBRIAN

**pCc** Crystalline

**Sioux**



IOWA GEOLOGICAL SURVEY

H. GARLAND HERSHEY

DIRECTOR AND STATE GEOLOGIST

1969

Williams & Heintz Map Corporation, Washington, D.C.

1966-Dates of Previous Surveys

1972-This Survey



clastic composition. As such, it is similar to the indicated composition of the rock units within and flanking the midcontinent gravity high.

From well data, the Precambrian basement composition is identified as "felsic" in the Bedford area to the west and in the Burlington area to the east over the Mississippi River arch.

King and Zietz (Reference 3) give a detailed description of the midcontinent gravity high describing it as originating from Keweenawan flows flanked on the east and west by major faults of steep dip, and lying within a trough in the Precambrian basement rocks.

Reference 2 shows what is the presumed location of the eastern fault of the midcontinent gravity high. Reference 3 also gives theoretical cross sections across the midcontinent gravity high; one such profile, B-B1, extending off the east side of the high and continuing southeastward to the southern state boundary, shows a computed basement profile.

Reference 4, Future Petroleum Provinces of the United States, gives a profile of the basement rocks extending from the southwest corner of the State in Page County northeastward to Allamakee County constructed from data from some 14 wells drilled across the State.

Reference 5, Structural Significance and Analysis of the Midcontinent Gravity High, discusses the gravity and magnetic implications of the midcontinent high as well as the flanking basinal structures along its eastern flank.

Details of the magnetic field over the midcontinent gravity high and flanking basins are shown on U.S.G.S. Map GP-476, (Reference 6).

## B. INTERPRETIVE PRESENTATION

The interpreted features of this survey are available on two map sheets at a scale of 1:250,000. For this report these have been combined on one sheet at a scale of 1:500,000. These maps show certain annotations discussed below relating to the interpreted geologic significance of the magnetic contours, along with numbered locations of magnetic anomalies where "depth to basement" determinations have been made.

## C. MAGNETIC SIGNATURES

Three general magnetic signatures, representative of three zones of depth to basement, are recognized. These signatures also relate to lithologic units found in or above basement rocks. These three signatures are:

D = "Deep" basement areas

M = "Medium" depth basement areas

S = "Shallow" depth igneous rock areas

These areas are differentiated by dashed lines on the interpretation map and have been determined after inspection of magnetic surveys done in 1970 and 1969 lying to the north of the present survey, and of the U. S. Geological Survey survey of 1965 over the midcontinent gravity high which overlaps the western end of the present survey in Fremont County (Reference 6).

The approximate basement sea level (S.L.) elevation limits of the three magnetic signatures are:

D = lower than -5,000 feet S.L.

M = -3,000 to -5,000 feet S.L.

S = -3,000 feet S.L. or higher

## 1. Deep Basement

At this point it is appropriate to comment on this classification since several published sources do not recognize what is clearly interpretable from the magnetic maps as deep crystalline basement in some areas of the State.

This is perhaps not surprising since only a limited number of wells in the southern part of the State have penetrated crystalline basement. For example, Reference 7 states concerning the Forest City basin, (the major recognized basin in the State):

"The Cambrian and Lower Ordovician section essentially is untested as only three wells have been drilled that completely penetrate this section in the lowa portion of the Forest City basin."

and also states:

"The deepest well (in the lowa portion of the Forest City basin) reached crystalline basement at a depth of 5,205 feet."

Also, two other sources indicating the presence of deeper rock are available. The first is Reference 3 wherein a theoretical profile showing basement depth in the flanking basin southeast of the midcontinent gravity high indicates a depth of about 13,000 feet below surface.

The second source indicating deep basement is Reference 5 where the following statements appear referring to the flanking basins along the midcontinent gravity high:

"The marginal gravity lows have very flat gradients which support the interpretation of 8,000 - 15,000 feet of clastic sediments in these basins."

and later:

"The marginal clastic sediments may be 8,000 - 16,000 feet thick--near Clarinda (Page County)."

Hence, there is substantial evidence that deep crystalline basement areas do exist in the vicinity of the Forest City basin and northward along the eastern flank of the midcontinent gravity high.

Four areas in the present survey are interpreted from the magnetic map as having deep crystalline basement. These are:

D-1 in Fremont and Page Counties

D-2 in Decatur County

D-3 in Appanoose and Davis Counties

D-4 in Lee County

## 2. Shallow Igneous Rocks

Shallow igneous rock anomalies are apparent in the survey in areas labeled S-1, S-2, S-3 and S-4. Area S-2 is the largest and is clearly defined. An examination of the areas showing



shallow igneous rock anomalies leads to another point of interpretation. This is whether these anomalies arise from "basement" or mafic flows within the sedimentary section above crystalline basement. Anomaly shapes in the S areas are typical of those resulting from "flows" or tabular rock as distinct from anomalies present in the Forest City basin which resemble those arising from theoretical vertical prisms of deeply buried rock units. Furthermore, the S areas occur in areas of Iowa where reported drilling has been minimal or is non-existent. In many respects, the S anomalies are similar in shape and amplitude to those observed over the midcontinent gravity high and to those occurring over the buried basalt area identified in Reference 2 lying between Waterloo and Dubuque. It is therefore quite possible that filtering of the present survey data in these areas to remove near surface effects could reveal a deeper magnetic basement not readily apparent in the present data in the S areas.

### 3. Medium Depth Basement

Localities intermediate in depth between the shallow and deep magnetic signatures occur in the survey; such localities being labeled as M-1, M-2, M-3, M-4 and M-5. Frequently, these areas lie between the D and S areas.

## D. MAGNETIC FEATURES AND SURFACE DRAINAGE

In several locations within the present survey, magnetic features shown on the contour map show excellent correlation in trend and length with surface drainage



patterns. Although the survey area is mantled with unconsolidated glacial material that ranges up to a few hundred feet in thickness and effectively masks most bedrock structural features, it is possible that structurally controlled preglacial drainage patterns are reflected in the present day drainage patterns. Hence, a structural significance to the magnetic patterns may be presumed as discussed later in this report.

#### E. DISCUSSION BY AREAS

##### 1. Western Portion of the Survey: Fremont, Page and Taylor Counties

The western portion of the survey is dominated by the "deep" magnetic character. Area D-1 is coincident with the western edge of the known Forest City basin. Depth determination shows minimal elevation of crystalline basement of -9,000 feet S.L. (anomaly 3) near Nyman and of -7,000 feet S.L. (anomaly 4) southeast of Clarinda in Page County. This deep basement area apparently rises to the south to about -4,000 feet S.L. (anomaly 2) near Coin thus being in agreement with the profile shown in Reference 4 where basement depth from well data is reported as -4,750 feet S.L. This area is designated as M-1. Area D-1 also overlaps the postulated clastic filled trough on the eastern edge of the midcontinent gravity high.

The eastern boundary of area D-1 is strikingly coincident with the course of the west branch of the One Hundred and Two

River, where its course changes from N-S to NE-SW east of New Market in Taylor County.

This is but one example in the survey area where basement features revealed by the magnetic survey correlate closely with surface drainage indicating basement control of structure within the overlying sedimentary rocks. The western boundary of D-1 occurs in Fremont County where the mafic flows of the midcontinent gravity high manifest themselves in the shallow area S-1 with a sea level basement elevation calculated at anomaly 1 as -1,300 feet S.L.

Based on magnetic evidence, reported well depths, and surface drainage, major crystalline basement fractures or faults have been designated as shown in the western area.

In Taylor County, the "shallow" area S-2 becomes apparent in the magnetic contours with a western limit at the One Hundred and Two River, the area extending eastward into Wayne County.

This occurrence is significant when compared to the Basement Rock Map of the United States (Reference 2) which shows the Forest City basin with basement elevations lower than -3,000 feet S.L. extending nearly to longitude 94° on the east. Depth calculations at anomalies 5 and 6 in Taylor County give -1,700 feet S.L. and -1,100 feet S.L. elevations. Magnetic character is suggestive of mafic material mapped near Dubuque and over the midcontinent gravity high

(Reference 2). Hence, if the Forest City basin, in fact, is as deep and as extensive as mapped in Reference 2, then other igneous material occurs above it in the S-2 area, a conclusion which should be examined by drilling or other geophysical methods.

In northern Taylor County the S-2 zone disappears and the "medium" depth zone M-2 is designated with a calculated depth of -5,500 feet S. L. A thick tabular rock unit is suggested at point 7, but limited on the west by the zone D-1 and the possible fracture in the basement. Feature M-2 is not readily recognizable until the magnetic survey immediately to the north is examined concurrently with the present survey. However, the contrast is obvious; leading to the conclusion that the shallower igneous material does end in northern Taylor County revealing magnetic expression of other deeper igneous rock.

## 2. West Central Area: Ringgold, Decatur and Wayne Counties

Shallow classification S-2 is the dominant magnetic feature in the west central portion of the survey over Ringgold, Decatur and Wayne Counties.

Tabulated elevations of "basement" in this area are:

<u>Point No.</u>	<u>Sea Level Elevation</u>
8	-3,000 feet
9	-3,000 feet
10	-1,900 feet
12	-3,000 feet
13	-1,800 feet

The boundary between the S-2 shallow area and the M-3 medium depth area to the north is readily drawn after inspection of the magnetic contours in this survey along with those from the previous survey to the north. Likewise, at the extreme northern edge of Decatur County a deep area, D-2, has been designated. Although no calculated depth is shown, it is clear that, magnetically, an area of deeper basement expression extends from the northwest portion of the State to the edge of the present survey in Decatur County.

The area M-3, which is recognizable across the State to the east, yields a depth calculation of -4,900 feet S.L. at point 11.

A drainage pattern correlation with magnetics is again seen in the S-2 area where the Weldon River flows south in the vicinity of High Point and Woodland in Decatur County. Hence, a fracture in the S-2 igneous rock has been indicated.

3. East Central Area: Appanoose, Davis and Van Buren Counties

Magnetic features dominating the East Central area of the survey are the M-3 zone previously mentioned and a third "deep" zone D-3. D-3 is readily traceable from the magnetic contours. With a southern boundary trending roughly northwest-southeast, it is characterized by a broad series of magnetic lows of large dimension with a more or less continuous magnetic flank rising on the south side. It is readily projectable on the magnetic contour map of the survey to the north, but transected by medium



depth anomalies there. Depth calculations on the magnetic gradient are tabulated as follows:

<u>Point No.</u>	<u>Sea Level Elevation</u>
14	-9,000 feet
17	-10,000 feet
18	-9,000 feet

Over part of its length, the south boundary of D-3 is coincident with the Fox River including a change of drainage direction west of Bloomfield. Hence, a basement fracture on the south edge of D-3 has been inferred. Soap Creek also flows parallel to the length of D-3 which direction is unusual for the area, the stream direction being more easterly than the general northwest-southeast stream patterns. An apparent structural relationship between D-3 and the overlying sediments is postulated here.

The M-3 trend is characterized by medium depth anomalies as follows:

<u>Point No.</u>	<u>Sea Level Elevation</u>
16	-3,100 feet
19	-5,000 feet
20	-5,600 feet
21	-5,000 feet

In postulating the D-3 and M-3 depth zones in the East Central area, it must be recognized that the Basement Rock Map of the United States shows no such feature. However, as this is an area where published

well data is lacking, it is preferred at this time to accept interpretation of a deep crystalline basement in the area.

The Des Moines River parallels magnetic patterns in eastern Van Buren County. Likewise, its tributary, Chequest Creek, follows the edge of the indicated shallow magnetic zone S-4 west of Keosauqua. This gives further evidence to the postulated igneous control of sedimentary structure in the area.

Shallow zones S-3 and S-4 also have been identified in the east central part of the survey. In each, the characteristic short wave length anomalies of near-surface igneous rocks are seen. Point 15 produces a basement elevation of -2,700 feet S.L. and point 19A gives -1,300 feet S.L. These depths are therefore in agreement with the basement elevations shown in Reference 2.

#### 4. Eastern Portion of the Survey: Lee County

In Lee County, anomalies at points 22, 23, 24 and 25 tend to confirm basement rock depths shown in Reference 2; e.g., on the order of -2,000 to -3,000 feet S.L. Areas S-5 and M-4 include these points. Tentatively, a deep area, D-4, is identified as a location where the mafic rock characteristics seen in the S and M zones are lacking.

Surface drainage patterns in the eastern portion of the survey do not correlate with magnetic patterns as in the western areas.

Medium basement depth zone M-4 is shown by point 25 giving an elevation of -3,000 feet S.L.



## F. SUMMARY AND CONCLUSIONS

This report presents geologic inferences based on the magnetic contour maps and profile data of the 1972 aeromagnetic survey of southern Iowa. These inferences are supported by the reference material available at this time, particularly published well data and theoretical models of basement areas flanking the midcontinent high. In several ways, the inferences presented here appear to differ from other published work in Iowa.

The principal points made here are:

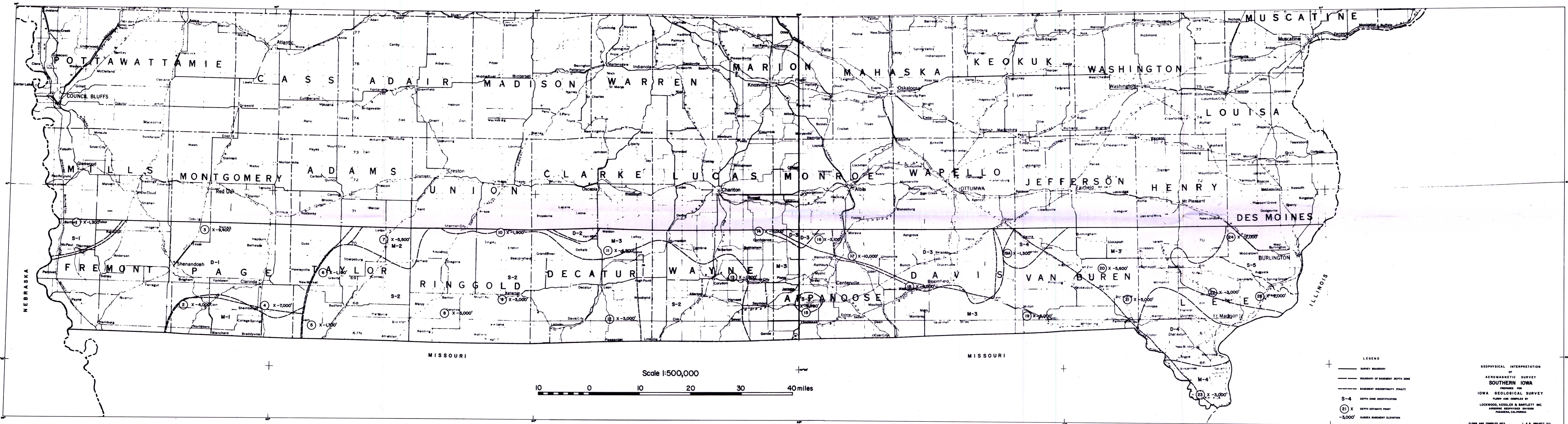
1. From the magnetic data it is possible to infer "deep" basement areas not only in the vicinity of the midcontinent gravity high and the Forest City basin, but in other areas surveyed. Moreover, depth estimates in the "deep" areas result in basement elevations which exceed those shown on the Basement Map of the United States, but are not inconsistent with theoretical depths calculated from gravity data and with several reported well records.
2. Areas of relatively "shallow" igneous rock occur beneath the surface. The most significant of these is the area designated S-2, where the calculated depth estimates from the magnetic data and the published sea level elevations of the Forest City basin do not necessarily agree. One might conclude therefore that shallow igneous rock overlies the crystalline basement in certain areas and that the zone S-2 anomalies may not necessarily reflect "basement" anomalies.

3. None of the magnetic anomalies shown are identified as representing unusual concentrations of magnetite, but represent mafic rock units discussed in other published data.
4. Basement discontinuities (possibly faults or fractures) have been tentatively identified across the survey.

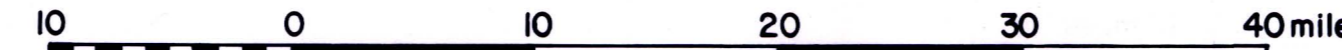
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Scale 1:500,000



**LEGEND**

- SURVEY BOUNDARY
- BOUNDARY OF BASEMENT DEPTH ZONE
- - - BASEMENT DISCONTINUITY (FAULT)
- S-4 DEPTH ZONE IDENTIFICATION
- ⊗ DEPTH ESTIMATE POINT
- ⊗ X SUBSEA BASEMENT ELEVATION

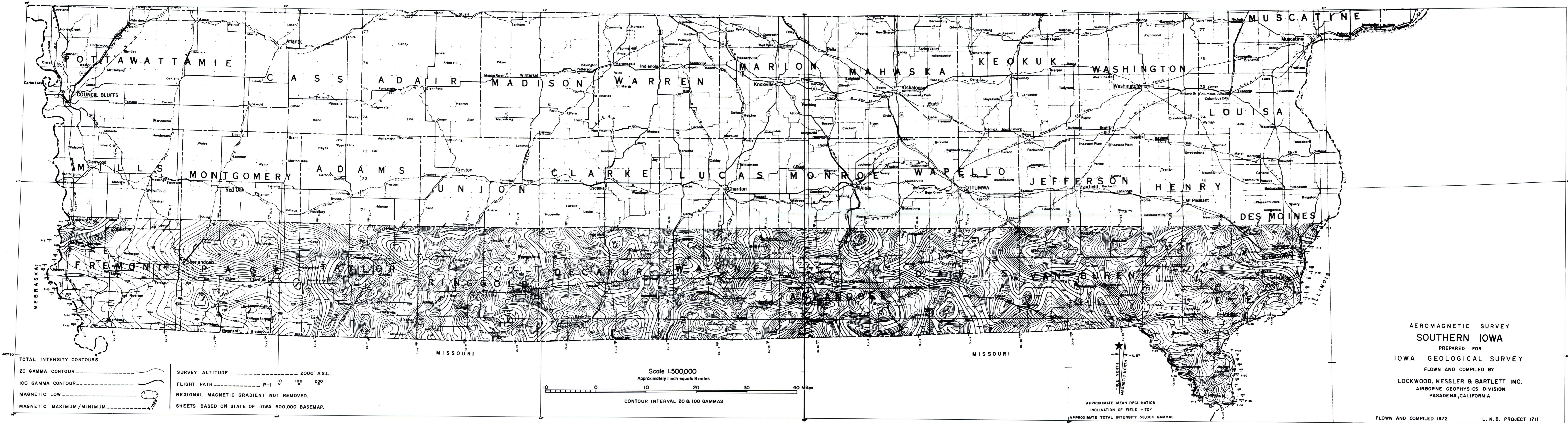
**GEOPHYSICAL INTERPRETATION OF AEROMAGNETIC SURVEY SOUTHERN IOWA**

PREPARED FOR IOWA GEOLOGICAL SURVEY

FLOWN AND COMPILED BY LOCKWOOD, KESSLER & BARTLETT, INC. ANAHEIM, CALIFORNIA

FLOWN AND COMPILED 1972. L. K. S. PROJECT 1711





TOTAL INTENSITY CONTOURS  
 20 GAMMA CONTOUR  
 100 GAMMA CONTOUR  
 MAGNETIC LOW  
 MAGNETIC MAXIMUM/MINIMUM

SURVEY ALTITUDE 2000' A.S.L.  
 FLIGHT PATH P-1  
 REGIONAL MAGNETIC GRADIENT NOT REMOVED.  
 SHEETS BASED ON STATE OF IOWA 500,000 BASEMAP.

Scale 1:500,000  
 Approximately 1 inch equals 8 miles  
 CONTOUR INTERVAL 20 & 100 GAMMAS

TRUE NORTH  
 MAGNETIC NORTH  
 APPROXIMATE MEAN DECLINATION  
 INCLINATION OF FIELD +70°  
 APPROXIMATE TOTAL INTENSITY 58,000 GAMMAS

AEROMAGNETIC SURVEY  
 SOUTHERN IOWA  
 PREPARED FOR  
 IOWA GEOLOGICAL SURVEY  
 FLOWN AND COMPILED BY  
 LOCKWOOD, KESSLER & BARTLETT INC.  
 AIRBORNE GEOPHYSICS DIVISION  
 PASADENA, CALIFORNIA

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