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Regional gravity and aeromagnetic studies applied to uranium exploration in northeastern Washington and Wyoming

by

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In this report regional gravity and aeromagnetic maps are used in an attempt to elucidate regional geology in the vicinity of the Midnite Mine in Washington and the uranium districts surrounding the Sweetwater uplift in Wyoming. They are the first step in a project to develop geophysical techniques to discover new uranium deposits elsewhere in the country, in frontier areas.

Other investigators report successful test of ground geophysics, especially magnetic, induced polarization, and VLF (very low frequency electromagnetic) methods, in small study areas to locate roll fronts or other detailed geological features associated with uranium ore. These same techniques can be used in frontier areas once a small enough target area has been chosen by other means.

Abstract for this paper was previously released in Open-File Report No. 75-595 "Abstracts of the 1975 Uranium and Thorium Research and Resources Conference." This report is based on talk given at the U.S. Geological Survey Uranium and Thorium Research and Resource Conference held December 8-10, 1975 at Golden, Colorado.

These other means are mainly regional geological, geochemical, and aeroradioactivity studies. The geophysics I do is intended to assist the regional geological studies - to make geological models on a provincial or regional scale in which we can identify targets for detailed exploration. Successful application of regional geophysics to uranium exploration will provide an important tool for resource assessment, especially in areas of the country lacking good regional syntheses of geologic mapping.

I would like to stress that data of the kind used in these studies are readily available to the public. Ninety-five percent of the gravity data were obtained free from the Department of Defense gravity library. About 7 person-weeks were expended collecting 475 additional gravity stations in critical areas (Cady and O'Connor, 1975; Meyer and Wilson, 1975). Aeromagnetic data were obtained from open-file reports (USGS 1973, 1974) and a published map by Hunting Geophysical Services (1960).

The first slide (Fig. 1 in the open-file report) is an index map outlining the Okanogan, Sandpoint, Ritzville, and Spokane $1^{\circ} \times 2^{\circ}$ quadrangles in northeastern Washington and northern Idaho containing about 2000 gravity stations.

The second slide is a colored gravity map of the outlined area. Major geologic features are superimposed in black. Data exists over the entire map area, but to save drafting time, only the central area was colored in detail. The major features on this map are a large high to the south due to the Columbia River basalts, a central high roughly associated with plutonic rocks, and a low to the east over the Belt series Precambrian rocks. Note the peculiar east-northeast high-low pair in the center near the Midnite Mine near the southern edge of the Togo Formation. Mesozoic and Tertiary plutons are indicated by check symbols. The Late-Cretaceous Purcell Trench marks the approximate east boundary of the Kootenai mobile belt (Yates and others, 1966), but runs oblique to the boundary of the central gravity high.

Black lines indicate the Precambrian-Paleozoic boundary and the boundary between Paleozoic eu- and mio-geosynclines. These north-northeast-trending boundaries are not reflected in the gravity data. A prominent correlation between gravity and known geology is the gravity low associated with, but much wider than, the Republic Graben, a trough in the plutonic rocks partially filled with Tertiary volcanics.

The major question raised by this slide is: What is the cause of the central gravity high? Several lines of evidence suggest that the plutonic rocks have insufficient density contrast to cause a gravity high. Density measurements by Dean Kleinkopf (Harrison and others, 1972) show that near the Purcell Trench, granodiorite and other plutonic rocks have an average density of 2.66 gm/cm^3, whereas low-grade metamorphic rocks of the Belt Supergroup have an average density of 2.72 gm/cm^3. Quartz monzonite from the Midnite Mine has an average density of 2.64 gm/cm^3, whereas metamorphic rocks of the Togo Formation near the Midnite Mine have an average density of 2.71 gm/cm^3. A detailed gravity profile across the Midnite Mine (Appendix Fig. 1b) showed Bouguer anomaly values 2 to 4 mgal lower over the quartz monzonite than over the Togo Formation.

The lobe of the gravity high west of the Republic Graben overlies the Okanogan gneiss dome (Fox and other, 1973), and Robert Pearson (oral commun., 1975) reports another gneiss dome under the lobe of the gravity high east of the Republic Graben. Kenneth Fox, Jr. and Dean Rinehart (written commun., 1975) report that the Okanogan gneiss dome can be divided into a central portion of partially migmatized Permo-Triassic metamorphic rocks with an average density of 2.75 gm/cm^3 and a range of 2.61 to 3.05 gm/cm^3. Surrounding this high-density core is a completely granitized border zone with an average density of 2.67 gm/cm^3.

These data suggest that a densely-cored gneiss dome causes the gravity high west of the Republic Graben. The central gravity high is about 40 mgal higher than the gravity field over the Belt series Precambrian rocks to the east, which have an average density of 2.72 gm/cm^3. A 10 km thick slab with a density contrast of 0.1 gm/cm^3 causes a 42 mgal gravity anomaly. Hence, a possible model for the source of the central gravity high is a huge gneiss dome with a 10 km thick core of density 2.82 gm/cm^3. This density is higher than the average density, but well within the range, of densities of rocks in the exposed core of the Okanogan gneiss dome.

The Midnite Mine lies in a gravity low adjacent to a gravity high near the center of the inferred central gneiss dome. The high-low pair suggests an east-northeast-trending fault north of the Midnite Mine. Possibly the central gravity low indicates a downfaulted block in the center of the gneiss dome. The fault model is denied, however, by the continuity of mapped northerly-trending geologic units across the inferred location of the fault; therefore I conclude that the high is a composite high due to Paleozoic rocks in the west and Precambrian rocks in the east, and the low is caused by a major pluton southeast of the Togo Formation.

The third slide is a closeup of the geology and gravity in the center of the map. The pen points to the Midnite Mine, at the boundary between a quartz monzonite pluton and a roof pendant of Precambrian argillite and phyllite of the Togo Formation. Around the periphery of the map, gravity lows roughly correlate with plutons and highs with the Columbia River basalts.

The fourth slide shows selected aeromagnetic anomalies superimposed on the gravity map. A magnetic low coincident with the west side of the central gravity high shows that eugeosynclinal Paleozoic rocks of the Covado group are moderately dense but nonmagnetic. Magnetic highs over 250 gammas are shown in solid black, over 150 gammas by ruling, while important closures of lesser amplitude are simply outlined.

About 10 km northwest of the Midnite Mine is a magnetic high coincident with a gravity low. Much of the anomaly area is covered by Tertiary volcanic and sedimentary rocks, but outcrops of the Loon Lake Granodiorite are frequent. I infer that the anomalies are caused by a granodiorite pluton. The peculiar pattern of the peaks of the magnetic high, which wrap around just inside the north and east borders of the inferred pluton and cut across its center, might be explained by igneous zonation within the pluton or stoping of country rock into the pluton.

Several small magnetic highs occur southeast, east, and northeast of the Midnite Mine. The high centered 8.5 km southeast of the mine occurs over a contact between porphyritic quartz monzonite and Loon Lake Granodiorite. Wildcat drilling of this high (J. T. Nash, oral commun., 1975) revealed metasedimentary rock, perhaps a foundered roof pendant, at a depth of 300 metres. No uranium was found. I entertain two working hypotheses about the source of the small magnetic highs. One is that they are due to foundered roof pendants. The other is that they represent centers of zoned plutons or centers of anatexis. The second hypothesis provides an empirical model for exploring for uranium in a belt northeast of the Midnite Mine. The fifth slide adds geology to the gravity and aeromagnetic data of the last. Note the three small magnetic highs in close proximity to the Togo Formation. If these highs represent the center of zoned plutons, and if the juxtaposition of such a pluton to the Togo Formation has led to uranium deposition at the Midnite Mine, then two exploration targets exist to the northeast, where the magnetic highs lie close to the Togo.

Another target lies 3 km east and 7 km north of the Midnite Mine on the border of the Turtle Lake and Hunters quadrangles, where a small magnetic high coincides with a mapped shear zone (Becraft and Weiss, 1963).

We now shift to Wyoming for a study of gravity anomalies over the entire state. The sixth slide, based upon some 9000 gravity stations, shows that Bouguer anomalies are low to the southwest over the Rocky Mountains and high to the northeast over the Great Plains. Note the northwest-trending anomalies in the north and west, a northeast-trending high in the east, and an east-west high-low pair in the center of the map.

Major physiographic features are superimposed in black on the gravity map. The northwest-trending features are caused by northwest-trending basins and ranges formed during the Laramide orogeny. Most notable are the high over the Wind River uplift and the parallel low over the Green River Basin. The northeast-trending high in the east suggests a connection between the Black Hills and the Laramie Range. The prominent east-west high is caused by the Sweetwater uplift, and the parallel low, by the Wind River Basin.

This study began with the purpose of using gravity to look for structure in the Precambrian basement rocks in the Sweetwater uplift. To do so, it was first necessary to remove the broad east-west high due to the uplift of the range above the adjacent basins. The seventh slide shows a fifteenth degree polynomial surface fit to the Bouguer anomaly. The surface captures most of the long-wavelength features of the previous map which are caused by basins and ranges.

The eighth slide shows the residual obtained by subtracting the polynomial surface from the original data. The striking effect obtained by this trend surface removal is the suppression of the long-wavelength east-west anomalies due to the Sweetwater uplift and the adjacent basins, and the enhancement of shorter-wavelength northwest-trending anomalies in the center of the map which cut across the Sweetwater uplift.

These crosscutting anomalies lie parallel with the gravity high over the Wind River Range and coincide approximately with Laramide folds shown in 1:250,000 scale geologic maps open-filed by ERDA (Texas Instruments, Inc., 1974). According to Love (1970), the initial latest Cretaceous Laramide uplifts in Central Wyoming trended northwest. It was not until late-early Eocene time that the present east-west-trending uplift was initiated.

A second form of data processing, band-pass filtering using the fast Fourier transform, was used to insure that the emergence of northwest-trending anomalies across the Sweetwater Arch was not a spurious artifact of the polynomial surface fitting. The ninth slide shows the results of filtering designed to suppress long-wavelength anomalies due to basins and uplifts as well as short-wavelength noise. Most of the features coincide with features on the polynomial residual map. Features peculiar to the filtered map are prominent medium-wavelength anomalies that trend northeast between the Laramie Range and the Black Hills.

Studies are still underway to use more detailed residual gravity maps to elucidate the geology of the Sweetwater uplift. Pending these detailed results, I shall use the regional gravity study to identify possible exploration targets. The Sweetwater uplift is anomalous for several reasons. It trends east-west in a northwest-trending terrain. It is younger (Eocene) than the northwest-trending (latest Cretaceous) uplifts, and the gravity high over it has a longer wavelength. Most important for our purposes, it is flanked by major uranium deposits in Eocene rocks.

Let us assume that east-west-trending uplifts of Precambrian rocks accompanied by broad gravity highs are favorable source environments for uranium. Where do we turn? Just north of the Wind River Basin and parallel with the Sweetwater uplift is the Owl Creek uplift. Too late! Uranium has already been found there. The next candidate is the Uinta uplift. Rumor has it that the flanks of the Uintas have recently become a prime uranium exploration target. Perhaps if you do the reverse of what I have done - filter gravity data to suppress anomalies due to northwest-trending early-Laramide uplifts - you can discover anomalies due to younger, possibly buried, east-west-trending uplifts with possible uranium associations.

Appendix - Detailed Gravity Profile
Across the Midnite Mine

Appendix Figure 1a is an index map showing the location of a gravity profile across the Midnite Mine in the Turtle Lake quadrangle. Appendix Table 1 shows the principal facts for the 27 stations collected along this profile in July, 1975. Bouguer anomaly values along the profile are plotted in Appendix Figure 1b. Station numbers L3, L16, and L38 coincide with stations A00, B300, and D400E of Campbell and Flanigan (1976).

The gravity survey was tied to station SP162 of Meyer and Wilson (1975) at VABM 3870 on top of Spokane Mountain. Gravity reduction and terrain correction procedures are described by Meyer and Wilson. All stations were made with LaCoste and Romberg meter G-159.

A 0.56 mgal tare occurred in the gravity meter, probably between stations 17 and 18. Correction for the tare was made using ties to temporary base station L3. Station L17 was tied directly to L3, so possible errors due to the tare are restricted to the zone between stations L3 and L18. The tare cannot influence the conclusion that there is a 3 to 4 milligal increase in the Bouguer anomaly between stations over the quartz monzonite in the west and stations over the Togo Formation in the east.

Elevations were determined with a surveyor's level. A traverse from station L3 to station L18 and back closed with an error of 0.6 m. Level traverses west of L3 and east of L18 were not closed. Assuming that elevation accuracies were maintained on the unclosed traverses equivalent to those obtained on the closed traverse, maximum elevation error is 0.6 m, yielding a maximum error in Bouguer anomaly of 0.12 mgal.

Horizontal position was determined by pace and compass techniques and may be in error by up to 100 m. Estimated maximum error due to horizontal position error is 0.01 mgal.

The gravity profile (Appendix Fig. 1b) shows that the density of the quartz monzonite is very uniform. Density in the Togo Formation is higher and more variable. Limited sampling around the Midnite Mine shows an average density of 2.64 gm/cm^3 in the quartz monzonite and 2.71 gm/cm^3 in the Togo Formation. The difference is 0.07 gm/cm^3. For a 3 mgal gravity high to be caused by a slab-like roof pendant of Togo rocks in the quartz monzonite, the slab would have to be 1200 m thick.

Representative Bouguer anomaly values from the report by Meyer and Wilson are plotted in Appendix Figure 1a. The low of -109.5 mgal east of the detailed profile, in quartz monzonite east of the Togo roof pendant, shows that the eastward gravity increase seen in the detailed profile is a local effect of the Togo roof pendant. I conclude, therefore, that the pendant reaches a maximum thickness east of the Midnite Mine of at least 1000 m. Such a great thickness is surprising, for drilling near the mine shows a maximum thickness of the roof pendant of only 250 m (J. T. Nash, oral commun., 1975).

Figure Captions

Slide 1: (Shown as Fig. 1 in open-file report) Index map.

Slide 2. Gravity contour map of northeast Washington and northern Idaho with superimposed regional geology.

Slide 3. Detailed gravity map with superimposed geology.

Slide 4. Detailed gravity map with selected aeromagnetic features superimposed. Highs over 250 gammas are solid block; over 150 gammas are ruled; lesser highs are outlined. A single low is indicated by a check pattern.

Slide 5. Same as slide 4, with geology added.

Slide 6. Bouguer anomaly map of Wyoming with superimposed geology.

Slide 7. Fifteenth degree polynomial surface fit to Wyoming Bouguer anomaly map.

Slide 8. Fifteenth degree residual map of Wyoming gravity.

Slide 9. Band-pass filtered map of Wyoming gravity.

Appendix Figure 1a. Index map showing location of detailed gravity profile across the Midnite Mine and selected gravity stations outside the profile.

Appendix Figure 1b. Detailed Bouguer gravity profile across the Midnite Mine.

Appendix Table 1. Principal facts for gravity stations in a detailed profile across the Midnite Mine.

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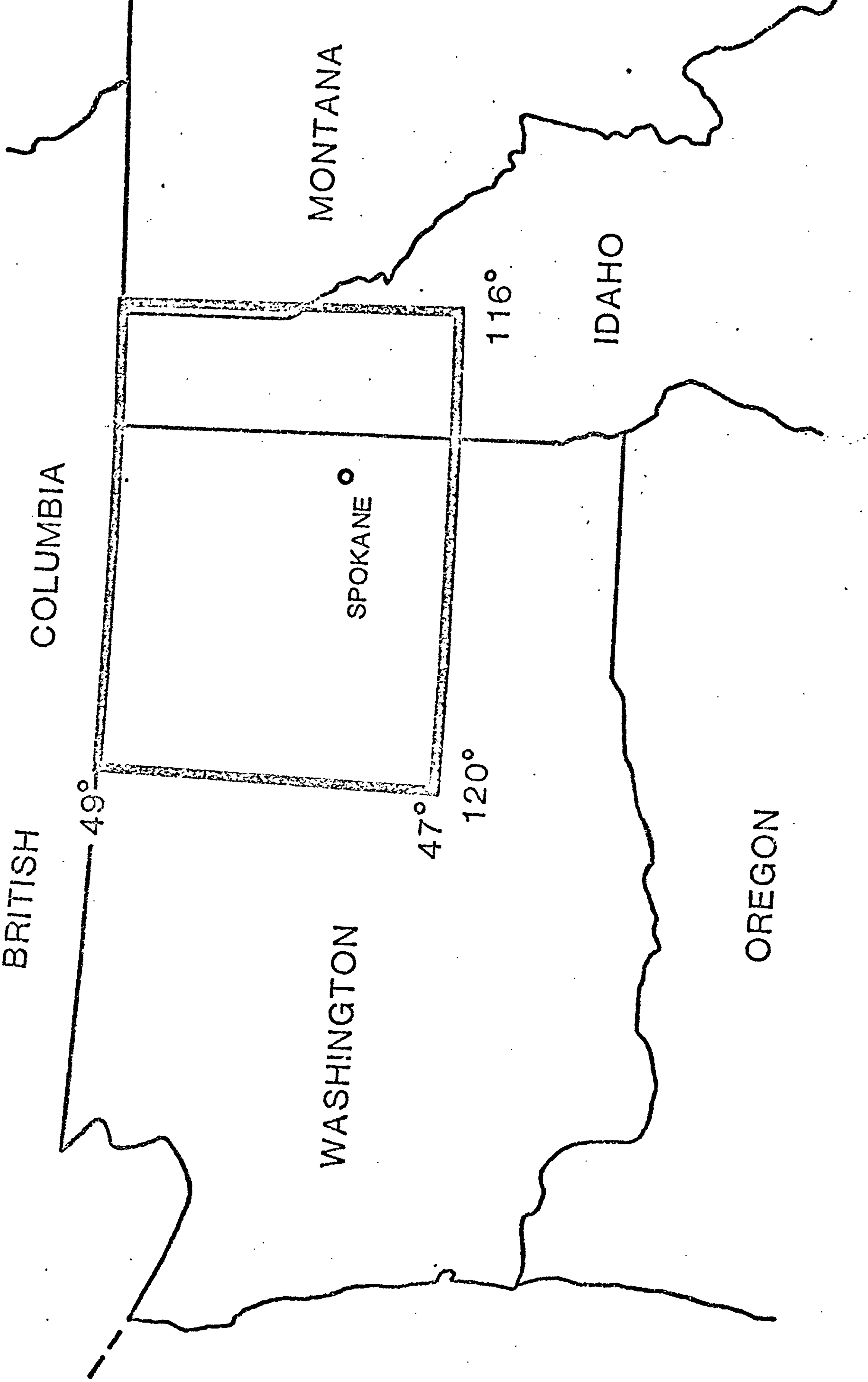
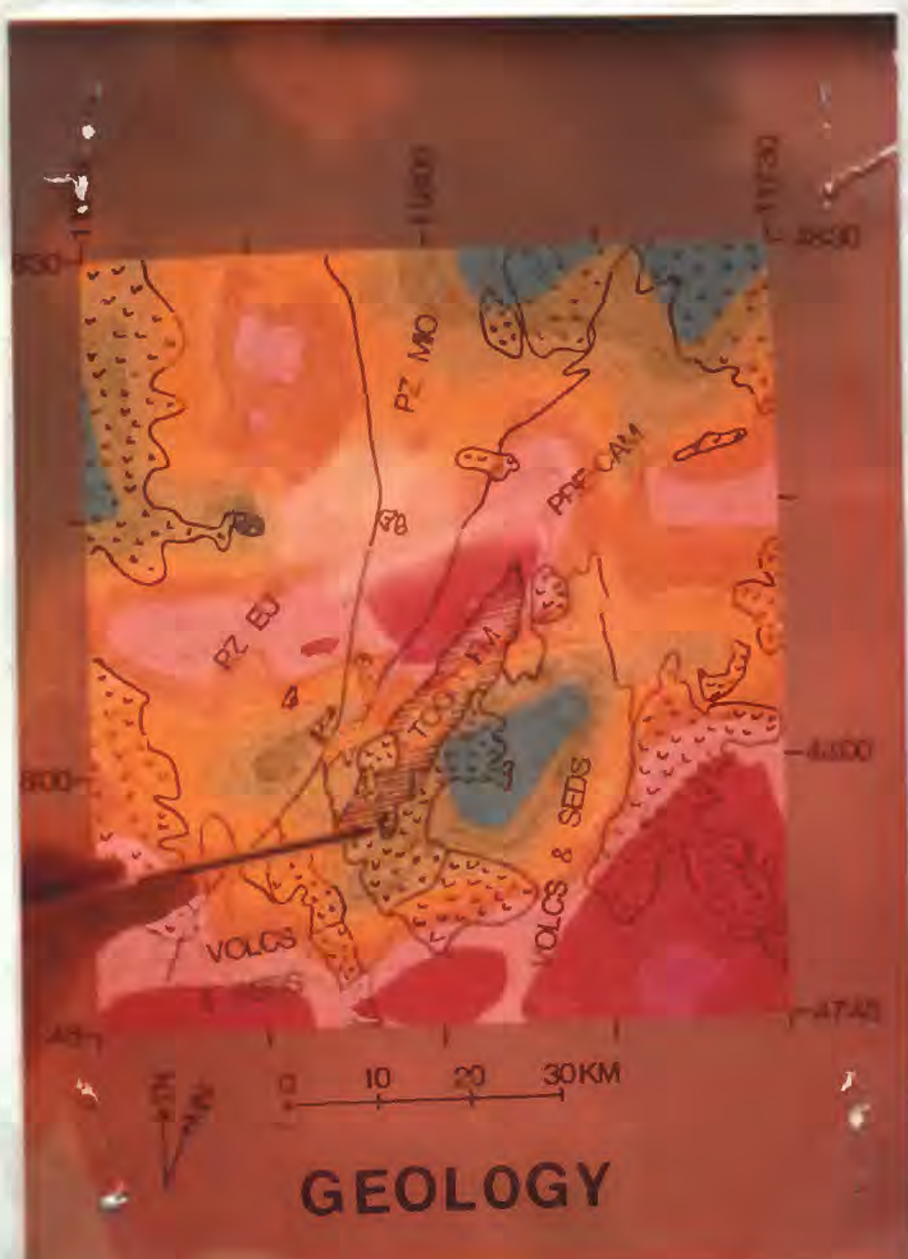


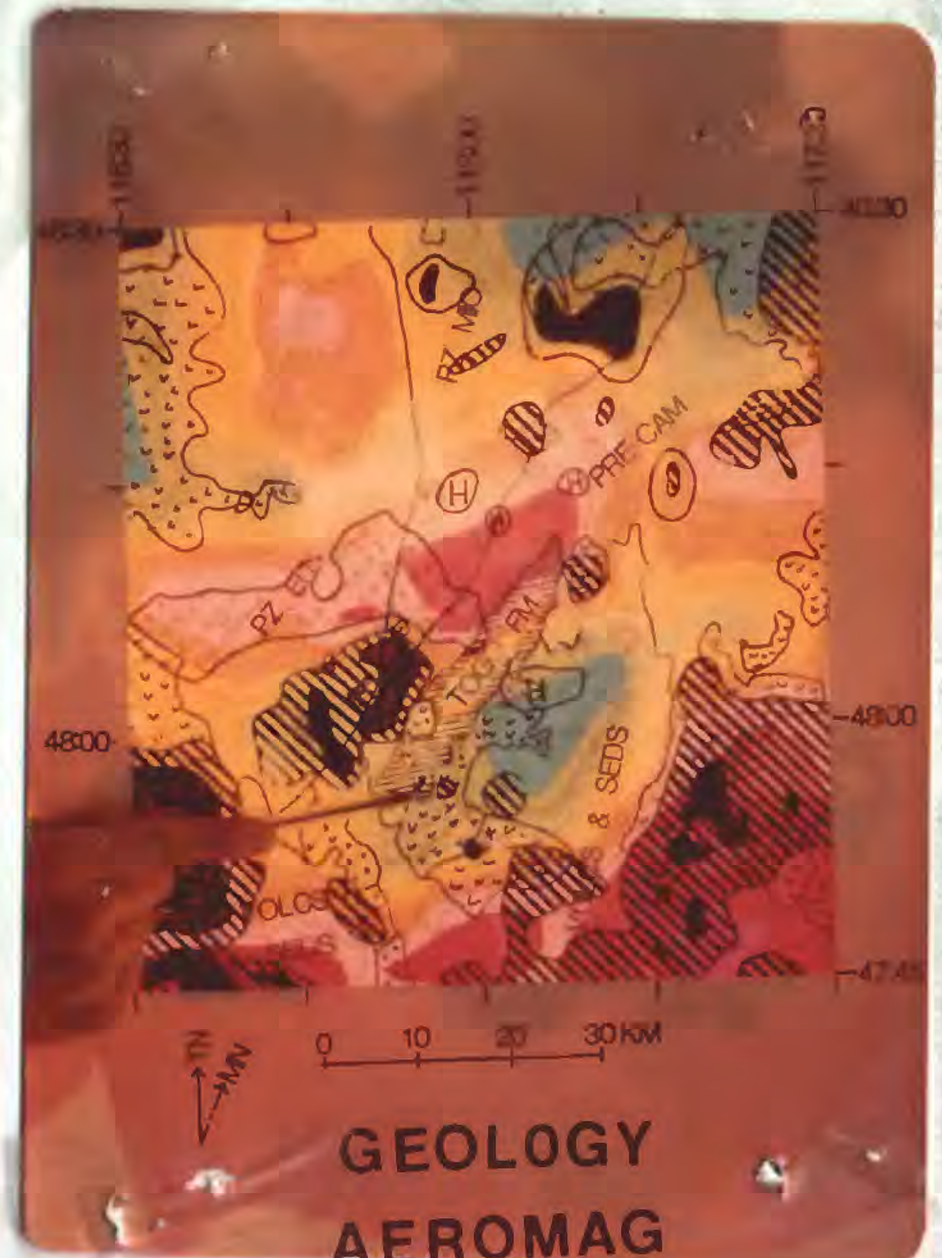
Figure 1. (Slide 1)

Slide 2



Slide 3

Slide 4



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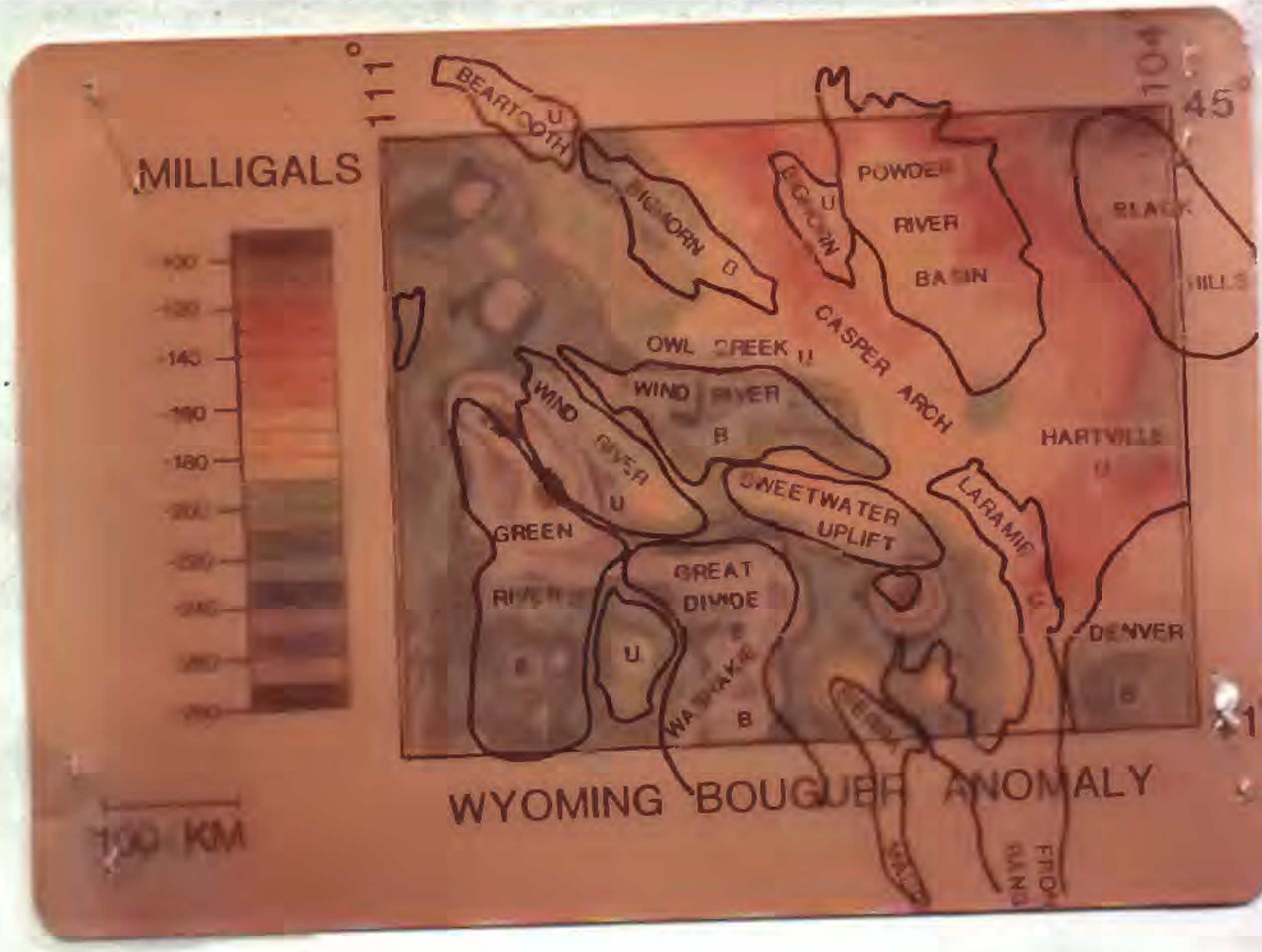

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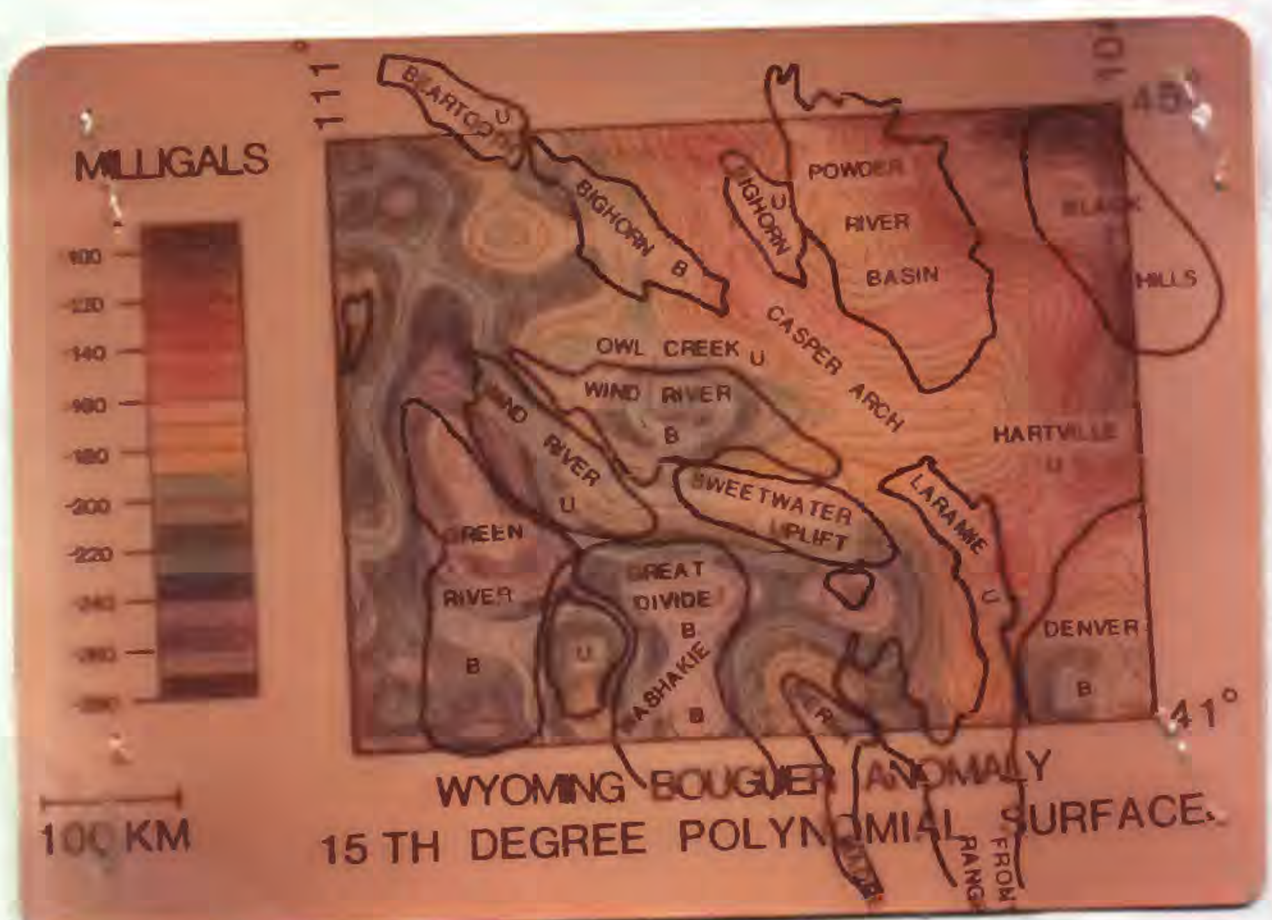

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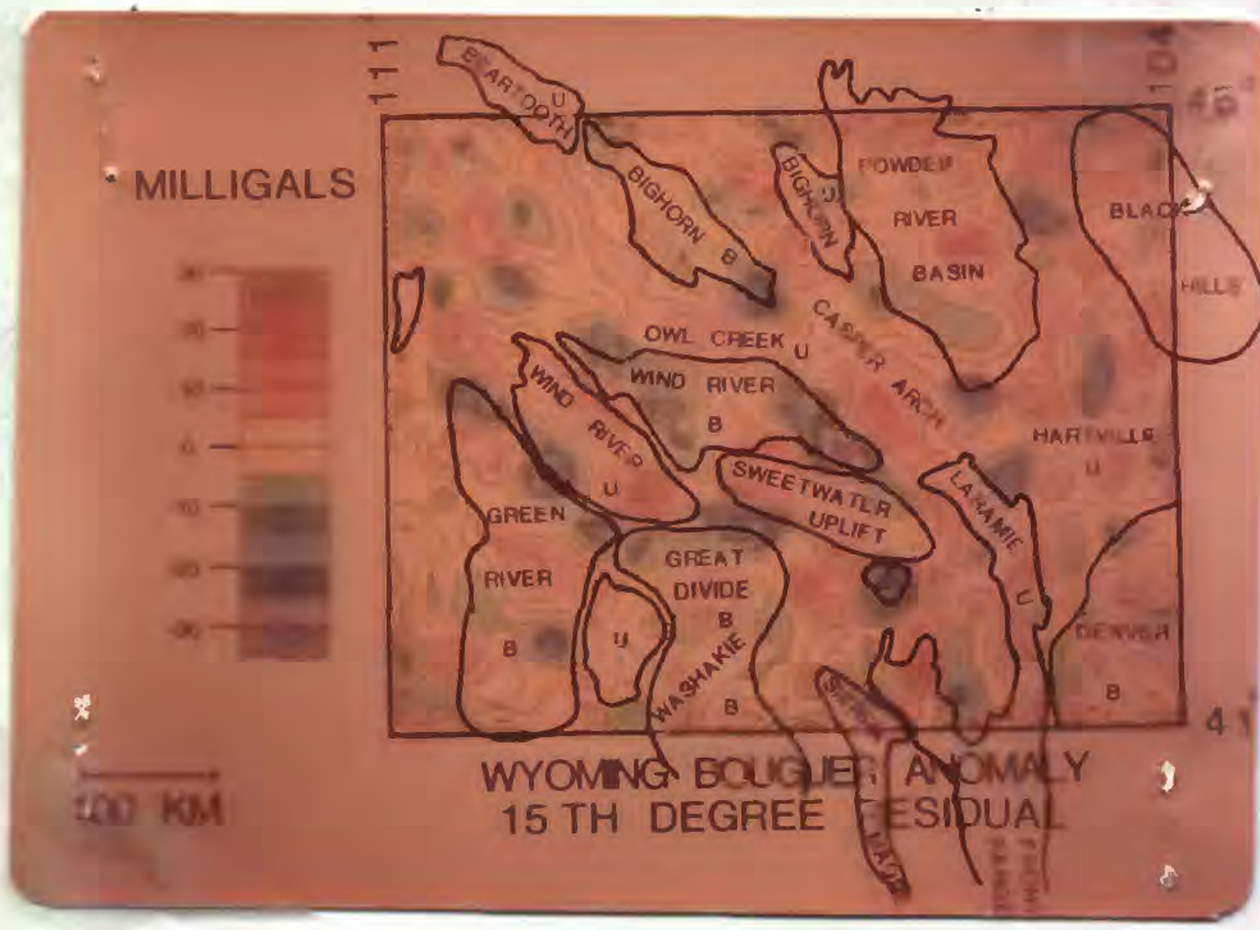

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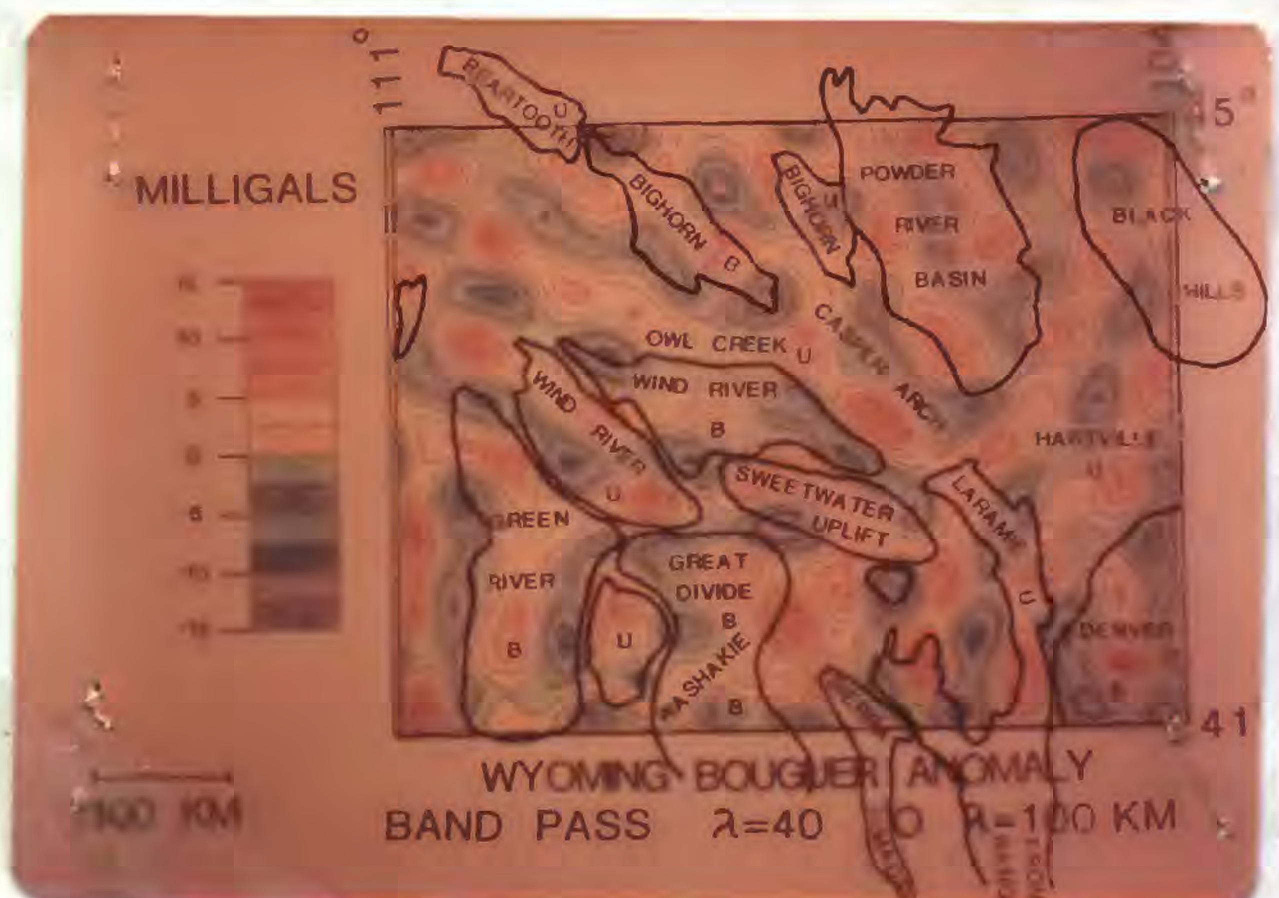
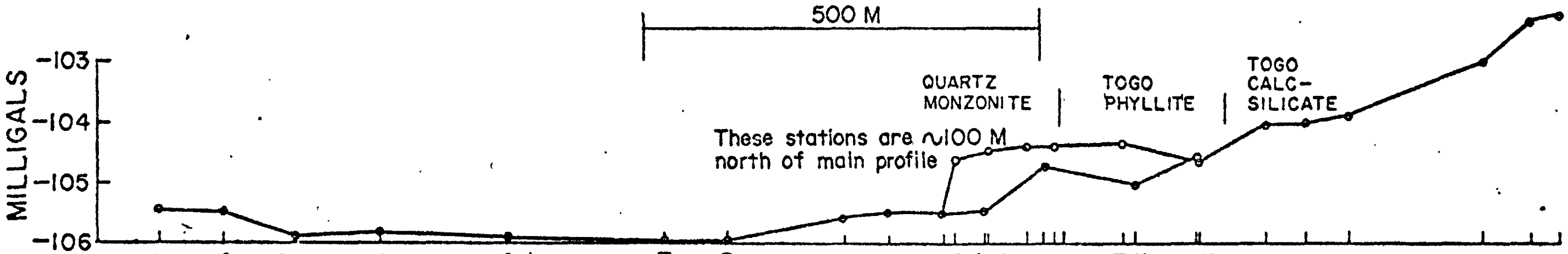
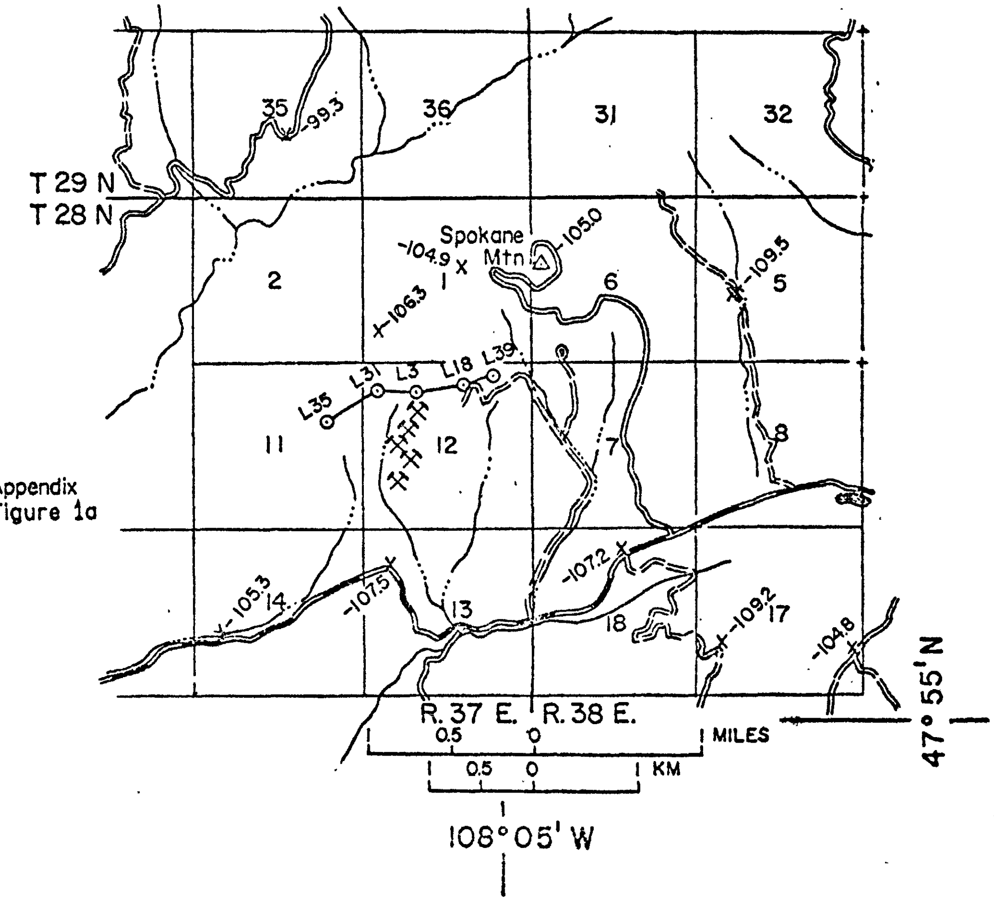


Slide 9

MIDNITE MINE GRAVITY



Appendix Figure 1b



Appendix Figure 1a

BOUGUER GRAVITY DATA

APPENDIX TABLE 1. PRINCIPAL FACTS FOR DETAILED GRAVITY LINE,
MIDNITE URANIUM MINE, STEVENS COUNTY, WASHINGTON.
DENSITY: 2,67

STATION IDENTIFICATION			LATITUDE	LOCATION LONGITUDE		ELEV.	ST.	OBSERVED GRAVITY	STD. GRV.	CORRECTIONS TERRAIN	FREE-AIR	BOUGUER	SPECIAL	BOUGUER ANOMALY
U-TH	.	L01	47 56,69	-118	5,71	922,96	WA	980596,52	-980885,18	2,68	284,70	-104,33		-105,61
U-TH	.	L02	47 56,69	-118	5,70	920,92	WA	980597,06	-980885,18	2,62	284,07	-104,10		-105,53
U-TH	.	L03	47 56,69	-118	5,69	922,42	WA	980597,13	-980885,18	2,52	284,53	-104,27		-105,27
U-TH	.	L06	47 56,68	-118	5,68	921,96	WA	980597,90	-980885,16	2,53	284,39	-104,22		-104,50
U-TH	.	L08	47 56,68	-118	5,67	915,10	WA	980599,39	-980885,16	2,58	282,27	-103,44		-104,36
U-TH	.	L10	47 56,68	-118	5,66	909,22	WA	980600,59	-980885,16	2,47	280,46	-102,78		-104,42
U-TH	.	L11	47 56,69	-118	5,65	906,87	WA	980601,03	-980885,18	2,55	279,74	-102,52		-104,38
U-TH	.	L12	47 56,68	-118	5,63	904,69	WA	980601,09	-980885,16	2,58	279,12	-102,29		-104,66
U-TH	.	L14	47 56,69	-118	5,62	900,23	WA	980602,06	-980885,18	2,58	277,69	-101,77		-104,62
U-TH	.	L16	47 56,69	-118	5,60	899,40	WA	980602,91	-980885,18	2,62	277,45	-101,68		-103,68
U-TH	.	L17	47 56,69	-118	5,58	901,60	WA	980603,44	-980885,18	2,62	278,11	-101,92		-102,93
U-TH	.	L18	47 56,69	-118	5,61	904,16	WA	980601,84	-980885,18	2,64	278,90	-102,21		-104,01
U-TH	.	L21	47 56,70	-118	5,64	914,55	WA	980599,26	-980885,19	2,63	282,10	-103,38		-104,58
U-TH	.	L22	47 56,69	-118	5,65	914,70	WA	980598,79	-980885,18	2,62	282,15	-103,40		-105,02
U-TH	.	L25	47 56,69	-118	5,67	918,85	WA	980598,42	-980885,18	2,67	283,43	-103,87		-104,53
U-TH	.	L26	47 56,69	-118	5,67	919,73	WA	980598,16	-980885,18	2,56	283,70	-103,97		-104,73
U-TH	.	L27	47 56,69	-118	5,68	920,19	WA	980597,65	-980885,18	2,54	283,84	-104,02		-104,97
U-TH	.	L29	47 56,69	-118	5,69	920,62	WA	980598,10	-980885,18	2,50	283,98	-104,07		-104,67
U-TH	.	L30	47 56,66	-118	5,73	925,31	WA	980595,35	-980885,16	3,00	285,42	-104,59		-105,98
U-TH	.	L31	47 56,66	-118	5,75	926,07	WA	980595,06	-980885,16	3,13	285,66	-104,68		-105,99
U-TH	.	L33	47 56,67	-118	5,76	926,93	WA	980594,70	-980885,15	3,39	285,92	-104,78		-105,92
U-TH	.	L34	47 56,66	-118	5,79	925,59	WA	980594,65	-980885,13	3,55	285,51	-104,63		-105,85
U-TH	.	L35	47 56,65	-118	5,81	925,28	WA	980594,77	-980885,12	3,63	285,41	-104,59		-105,90
U-TH	.	L36	47 56,66	-118	5,83	928,57	WA	980594,49	-980885,13	3,67	286,43	-104,96		-105,50
U-TH	.	L37	47 56,66	-118	5,84	929,43	WA	980594,29	-980885,13	3,74	286,69	-105,06		-105,47
U-TH	.	L38	47 56,70	-118	5,57	905,29	WA	980602,42	-980885,19	2,63	279,25	-102,34		-103,23
U-TH	.	L39	47 56,70	-118	5,57	900,29	WA	980603,53	-980885,19	2,57	277,71	-101,77		-103,15
U-TH	.	SP162	47 57,39	-118	4,68	1179,58	WA	980537,05	-980880,23	13,57	363,83	-133,23		-105,01