Summer 1987

A Gravity Survey and Analysis of the Mount Stuart Block of Washington State

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MASTER'S THESIS

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MASTER'S THESIS

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A GRAVITY SURVEY AND ANALYSIS OF

THE MOUNT STUART BLOCK OF WASHINGTON STATE

by

Gregg M. Petrie

Accepted in Partial Completion

of the Requirements for the Degree

Master of Science

Dean of Graduate School

ADVISORY COMMITTEE

Chairperson

ABSTRACT

Gravity data were gathered in the vicinity of the Mt. Stuart Block, a horst of pre-Tertiary rocks which include the Chiwaukum Schist, the composite Mt. Stuart Batholith, and the Ingalls Complex with its related metasedimentary-volcanic sequence, located in the east central Cascade Mountains of Washington. The final complete Bouguer map suggests the following features: (1) displacement of the Chiwaukum Graben occurs mostly on the west side in a narrow, 4-5 km, block 5.5 to 7.5 km deep, expanding in width to the north; (2) the Ingalls Complex is a relatively shallow feature: certainly a model hypothesizing a deep plug of peridotite is incompatible with the gravity data; (3) there is gabbroic rock at depth, below the Mt. Stuart Batholith, which on the west side has been intruded in part by rock of the Snoqualmie Batholith; (4) there is a thickening of the Teanaway volcanic rocks south of the western part of the Mt. Stuart Block; and (5) rock of the Mt. Stuart Batholith extends to the south beyond the Ingalls Complex and forms basement for the Swauk Formation.

ACKNOWLEDGEMENTS

The writer is most grateful to his thesis committee consisting of Dr. M. E. Beck and Dr. D. R. Pevear, Western Washington University, and Dr. Z. F. Danes, University of Puget Sound, for their assistance throughout this study. Special thanks go to Dr. Danes for allowing me to use his gravity data and for the many hours of time he invested in this project.

Thanks are also due to Patricia Vreed, Mark and Steve Albright, Daria Kling, Susan Blanche, Carol Mitrani and V. Eileen Williams for their help and support. Special thanks must go to David Engebretson whose feet were offered up more than once in sacrifice for this project.

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INTRODUCTION

The Mt. Stuart Block is a feature in the central Cascade Mountains of Washington (Fig. 1). It occupies an area of roughly 1300 km^2 centered at $47^o37.5$'N and 120^o53'W. The principal geologic features of the block (Map 1) include the Chiwaukum Schist to the north, the composite Mt. Stuart Batholith dominating the center, and the Ingalls Complex (Frost, 1973) and its related rocks to the south. The block is surrounded on the west, south, and east by the Swauk Formation. The western and eastern boundaries of the block are faults (Deception Pass Fault on the west, Leavenworth Fault on the east). The southern boundary is depositional with only minor faulting. The northern boundary is not well defined; a convenient, but arbitrary, boundary is the Stevens Pass highway (U.S. 2).

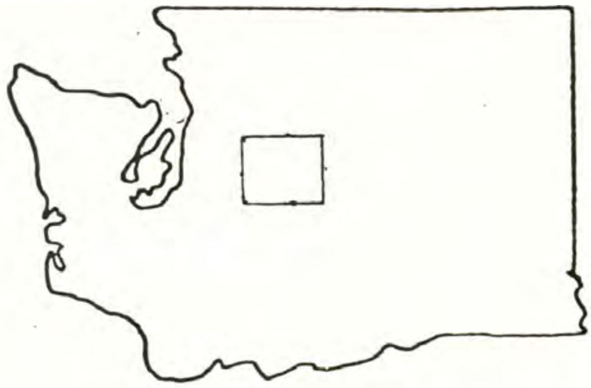
Previous Geologic Work

General

Numerous studies, mostly petrologic, have been made on the Mt. Stuart Block. Smith (1904) did the earliest specific work in the area with reconnaissance mapping of the Mt. Stuart 30 minute quadrangle. Page (1939) was the first to do a thesis on the area and was responsible for naming the Chiwaukum Schist. Page was followed by Pratt (1969) who did a broad reconnaissance of the area.

Chiwaukum Schist

Work in the study area by Page (1939), Oles (1956), Van Diver (1964), Plummer (1969), and Getsinger (1978) describes the mainly pelitic metasedimentary rock of the Chiwaukum Schist. They observed that the most common type of rock is a plagioclase-quartz-biotite schist. Other rock



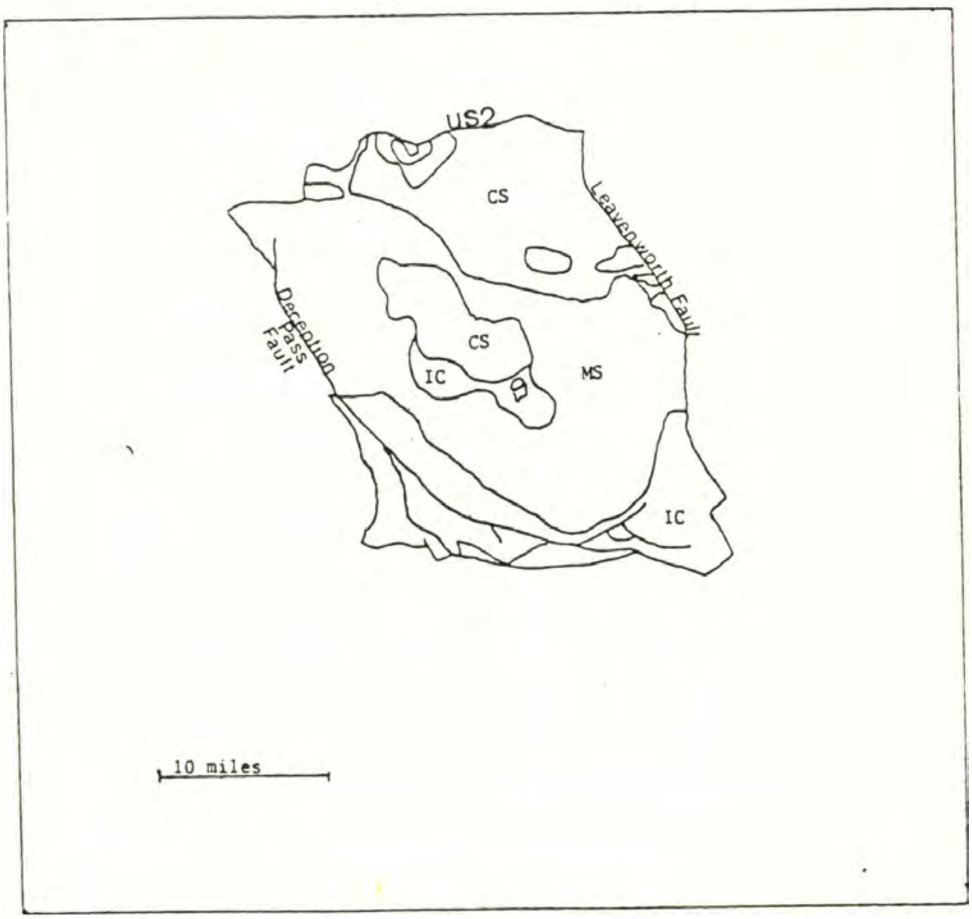


FIGURE 1. Index map with simplified geologic map of the Mt. Stuart Block, modified from Huntting et al. (1961). CS=Chiwaukum Schist, IC=Ingalls Complex and related rocks, MS=Mt. Stuart Batholith.

types include hornblende-bearing schist, amphibolites, marbles and meta-intrusive rocks. Getsinger (1978) gives a Late Paleozoic or earlier Mesozoic date to the original sediments that consisted mainly of thin-bedded sandstones and aluminous shales with subordinate greywackes, igneous rocks and minor calcareous material. These rocks were later intruded by small stocks of quartz diorite, diorite and more mafic rocks. Synkinematic regional Barrovian-type metamorphism (later Mesozoic?) and Late Cretaceous effects associated with the intrusion of the Mt. Stuart Batholith produced the rocks as seen today.

Mt. Stuart Batholith

Smith (1904), Pratt (1958), Plummer (1969), Pongsapich (1974) and Erickson (1977a, 1977b) all report on the Mt. Stuart Batholith. The picture presented is one of multiple emplacement, in the Late Cretaceous, of a series of intrusions that range systematically from gabbro to granite, although quartz diorite and granodiorite comprise more than 80 percent of the batholith (Figs. 2 and 3). Erickson (1977a) proposed a petrogenetic model for the development of the Mt. Stuart intrusive series found in the Mt. Stuart Batholith by invoking crystal fractionation in an ascending residual magma. According to Erickson the parent magma was a hypersthene gabbro now represented by the oldest rocks currently exposed in the batholith which are along the eastern edge. One consequence of this model is that an enormous amount of dense gabbroic cumulate must lie unexposed at depth. Erickson and Williams (1976) give a date of at least 55 ± 6 m.y. for uplift of the Mt. Stuart Block exposing granitic and ultramafic rock that provided source material for the Swauk Formation.

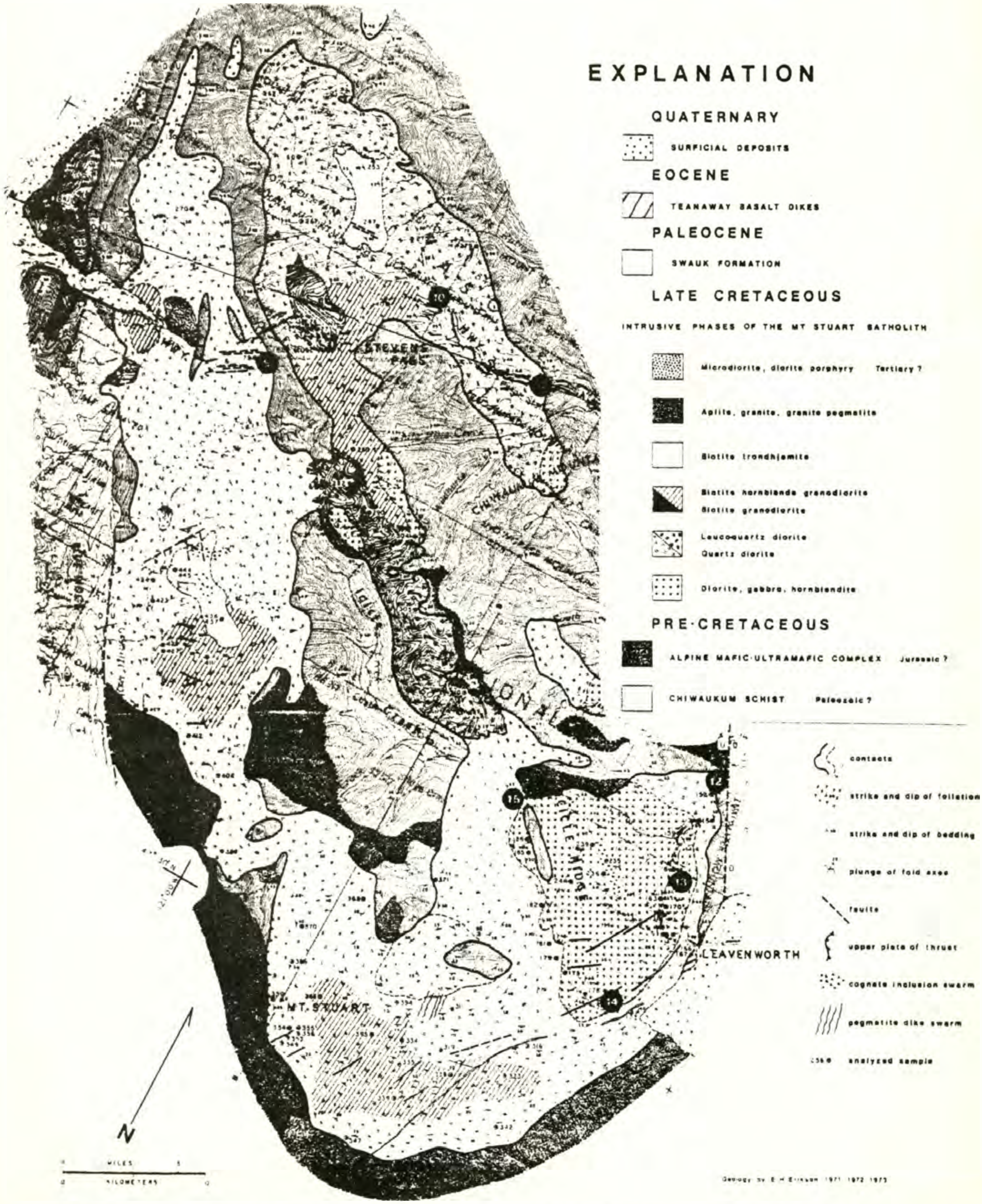


FIGURE 2. Geologic map of the Mt. Stuart Batholith after Erikson (1977b).

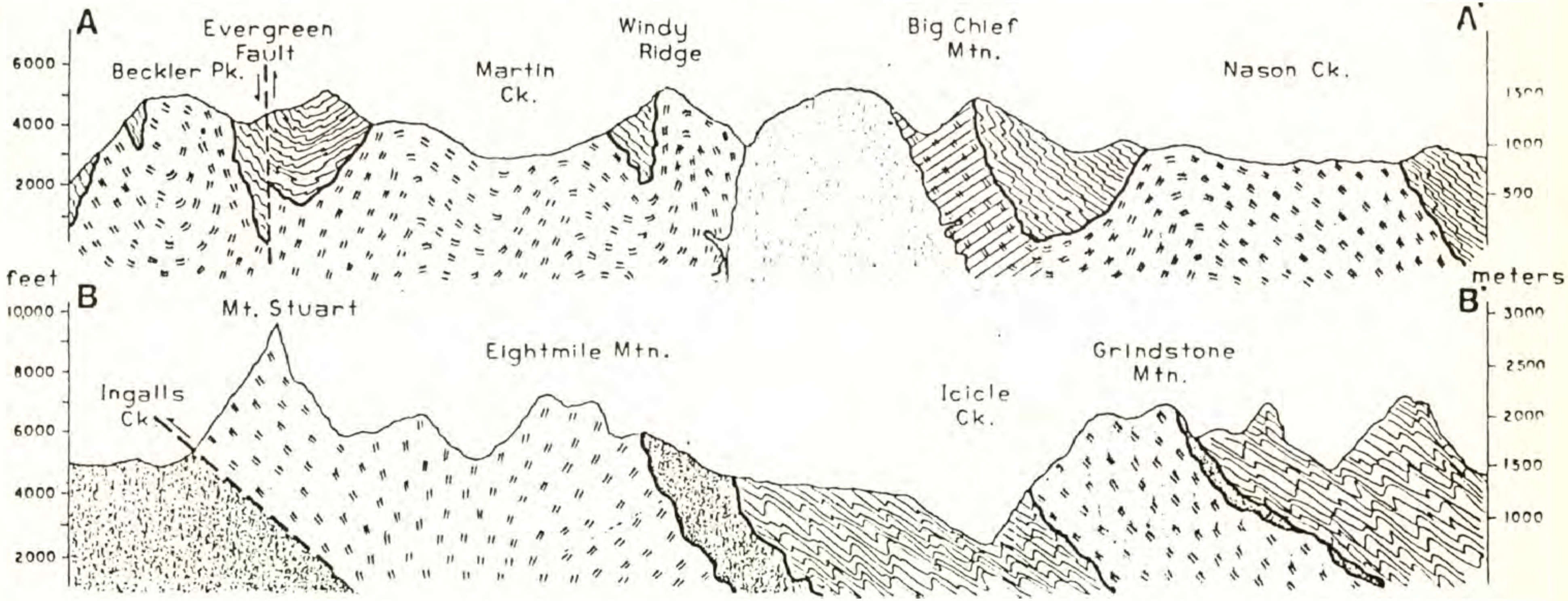


FIGURE 3. Simplified structure-sections A-A' and B-B' through the Mt. Stuart Batholith. Line of sections shown in Fig. 2. Symbols as in Fig. 2. Erikson (1977b).

Ingalls Complex

Work on the Ingalls Complex and its associated sedimentary-volcanic sequence by Smith (1904), Pratt (1958), Southwick (1972, 1974), Frost (1973), Miller (1975), Miller and Frost (1977), and Tabor et al. (1977) describe an assemblage of lithologies compatible with formation in a marginal basin, mid-ocean ridge or the submarine portion of an island arc. The most abundant rock type in the complex is the widely serpentinized Ingalls peridotite which occurs not only in the horseshoe-shaped southern boundary of the exposed Mt. Stuart Block but also as a roof pendent (Map 1) in the Mt. Stuart Batholith. Primary peridotites include harzburgite and, locally, lherzolite showing several periods of serpentinization, probably related to pre-Tertiary fault emplacement. Mafic intrusive rocks are generally massive gabbros and diabases, with minor trondhjemites and clinopyroxenites. Supracrustal rocks associated with the Ingalls Complex include the metasedimentary pelitic Peshastin Formation and the Hawkins Formation, mostly greenstone, which are probably interbedded on a large scale in the eastern portion of the Ingalls Complex. In the western half, the volcanic and sedimentary rocks are even more intimately interbedded (Miller, 1975). In two small fault slices southwest of the Mt. Stuart Batholith, Miller (1975) finds anomalous medium-grade foliated amphibolites which he tentatively correlates with Chiwaukum Schist. Mattinson (cited as written communication in Southwick, 1974) obtained a Late Jurassic U-Pb date on a gabbro. As corroborative paleontological evidence Tabor et al. (1977) reported radiolaria in a chert as Late Jurassic.

Swauk and Related Rocks

Gresens et al. (1977) present a convenient summary, and extensive bibliography, for the interbedded volcanics and fluviatile and lacustrine sedimentary rocks which bound the Mt. Stuart Block on the west, south, and east. They demonstrate that the rocks previously mapped as Swauk can be subdivided on the basis of lithology and/or age differences. This subdividion is shown in Figure 4 and will be adopted here. In total these rocks represent a complex record of erosion, deposition, and deformation.

Purpose and Scope of Investigation

The geologic analysis to date implies that the schematic model should look approximately as is shown in Figures 2 and 3 (Erickson, 1977b). A geologic model of this kind would produce strong gravity anomalies over the Ingalls Complex, the Leavenworth fault, the mafic component of the Mt. Stuart Batholith, and the Deception Pass Fault. It is the purpose of the present study to use gravity data to test and refine this and alternative geological models for the structure of the Mt. Stuart Block.

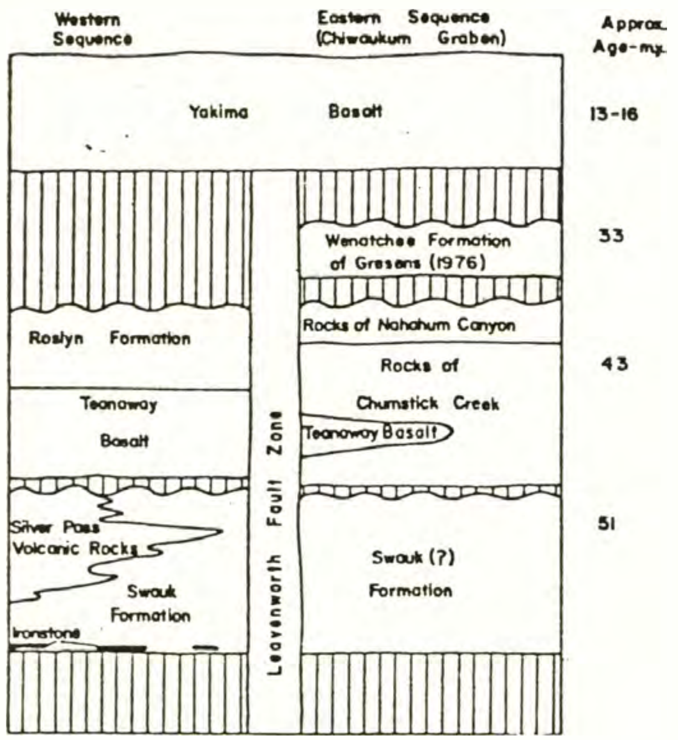


Figure 4. Lower and middle Teriary sedimentary and volcanic rock which surrounds the Mount Stuart Block on the east,south, and west(from Gresens et.al. 1977)

FIELD WORK

The field work was performed during the summer of 1977 and extends over an area of 7200 km^2. Altogether, 115 new gravity stations have been established. The survey has been tied into the Easton and Skykomish bases of the Army Map Service Gravity Base Network. For the sake of convenience, a new substation has been established at $47^{o}43.5'$N and 120^{o} 44.11'W (gravity station L4695). The instrument used was the Worden gravimeter (no. 857) owned by Western Washington University. Its sensitivity is 0.083 mgal/scale divisions.

The survey was carried out in loops starting and terminating at one of the bases of the substations. Most of the loops were shorter than 10 hours. However, in two cases, where more frequent reoccupation was impossible due to the inaccessibility of the terrain, the loops were longer; one lasting 52 hours and the other 81 hours. Fortunately, the drift during these extended periods proved to be small compared with the final accuracy of the data.

The survey was integrated with 6 previous gravity stations by Aiken (University of Washington, unpublished data) and 222 gravity stations by Danes (University of Puget Sound, unpublished data) (Fig. 5). Three of the Danes stations were reoccupied; the two estimates of gravity agreed to within 1 mgal.

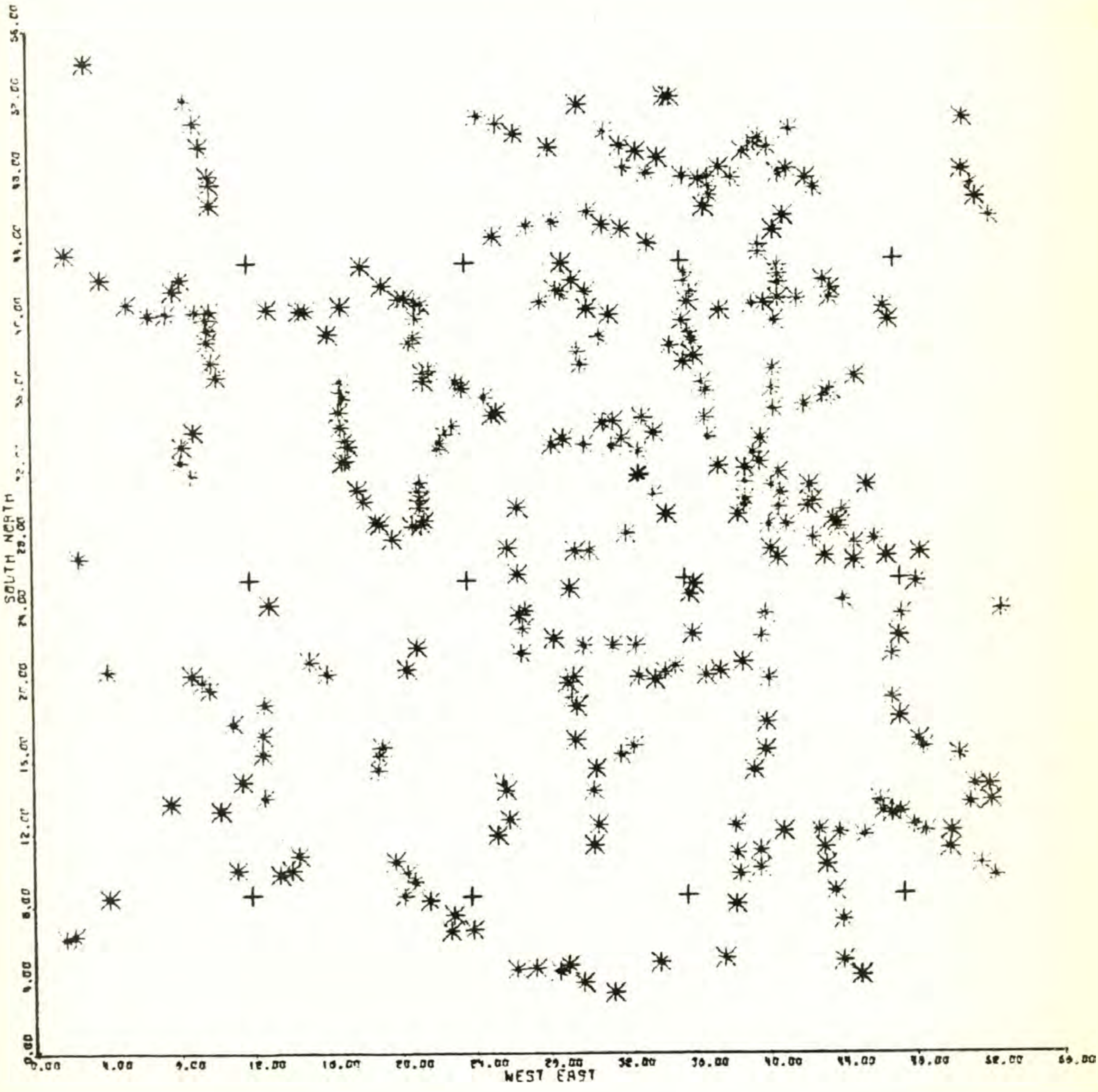


Figure 5. Station locations. Numbers on axis in miles, origin at 121 30' W and 47 7.5' N.

DENSITY VALUES FROM THE MOUNT STUART BLOCK

A total of 92 density measurements were made, 16 from the Chiwaukum Schist and 76 from the Mt. Stuart Batholith along Stevens Pass highway. Together with values given by Erikson (1977a), they are summarized in Table 1 below. Because the extreme tectonic mixing of the Ingalls Complex made it difficult to get representative surface samples and rendered doubtful any assumptions about how surface lithologies may continue at depth, no values were taken. This means that any analysis involving the Ingalls Complex will be mainly qualitative since only a rough guess for the density can be made using values from the literature.

TABLE 1. Density Values

NAME	DENSITY
Mt. Stuart Batholith	
Two-pyroxene gabbro	2.95
Hypersthene-hornblende diorite	2.89
Hypersthene-hornblende-biotite quartz diorite	2.81
Main-phase quartz diorite	2.74
Leucoquartz diorite	2.70
Granodiorite	2.71
Aplite, granite, pegmatite	2.63
Biotite trondhjemite	2.60
Chiwaukum Schist	2.70

RESULTS

The results of the gravity survey as presented on Map 2 and Figure 6 show:

A - A deep elongated trough trending roughly N20W through the town of Leavenworth. This feature agrees very well with the Chiwaukum Graben. The high value of the (1, 0) harmonic in the Fourier power spectrum (Fig. 7) suggests that this feature and feature B1-B4 are especially dominant components of the total gravity signal.

B1-B4 - A series of maxima paralleling feature A and representative of the eastern part of the Mt. Stuart Block.

C - A pronounced high in the southern part of the survey area.

D - A local minimum associated with an outcrop of Tertiary volcanics and Quaternary alluvium of doubtful tectonic significance.

E - A low without an obvious geological significance. It is possible that it is a part of a major minimum on the western flank of the block, and that it is separated from the main body by a small gravity maximum associated with the Eocene basalts. Additional data will be needed here.

F1-F2 - A major negative gravity anomaly striking perpendicular to the Deception Pass fault and its anticipated gravity signature.

G - This feature is of interest for its lack of strong definition over the Ingalls Complex. Other geologic elements in the study area have rather well defined gravity anomalies associated with them. For example, element B4 is over a known mafic component of the Mt. Stuart Batholith. The behavior of the -80 contour

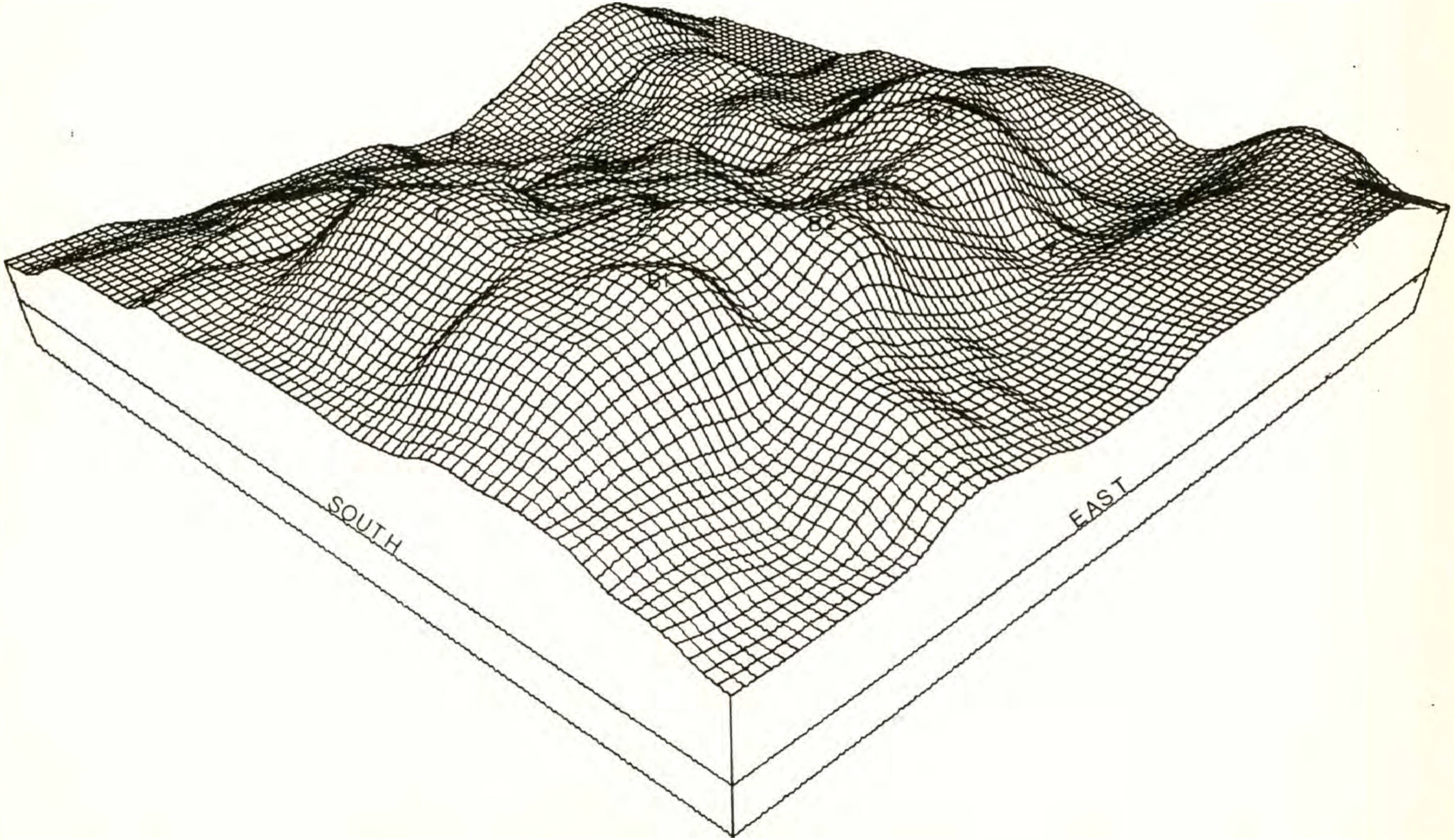


FIGURE 6. 3-dimension picture of gravity.

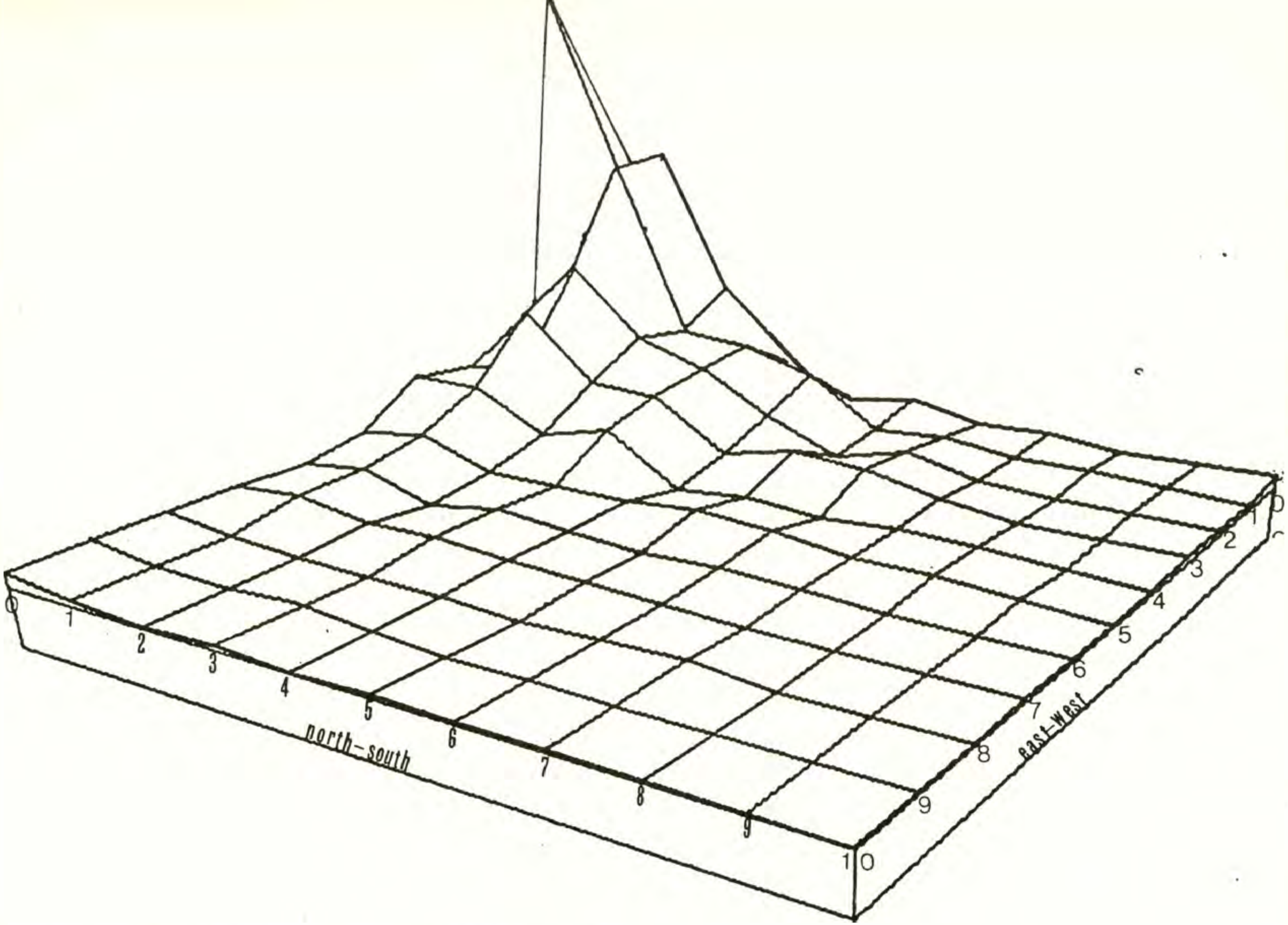


FIGURE 7. FOURIER POWER SPECTRUM.

line over the Ingalls Complex is perhaps illustrative. The contour line seems to be only slightly deflected upward by the high density mafic rock or deflected down by the relatively low density rock of the Complex. Elements labeled B2 and B3 appear to be more associated with a north-south ridge of gravity, defined above, than anything in the Ingalls Complex.

Discussion of the significant, interpretable features follows.

DISCUSSION

Feature A

Over the entire study area a series of simple shapes of varying density and form were adjusted until their combined effect accounted for the observed gravity. In the Chiwaukum Graben area, in all but the far northern part, the shape which best accounts for the observed gravity is a narrow, 4-5 km, block 5.5 to 7.5 km deep, limited to the west side of the graben. Thus the Chiwaukum Graben might be considered to be made up of two major downthrown blocks, a narrow, deep one on the west and a wide, shallow one on the east. In the north this distinction becomes less well-defined with the eastern block becoming thicker. Whetten (1977) makes the suggestion that the Chiwaukum Graben developed one or more subsidiary grabens during deposition of the Chunstick Creek and Nahahum Canyon units (Fig. 4).

Feature B

Feature B1-B4, a ridge of high gravity roughly paralleling the Leavenworth Fault, is somewhat ambiguous in the south since there is no obvious constraint imposed by the surface geologic patterns to account for the high. One local high, B1 on Map 2, is possibly associated with an anticline in the Swauk Formation, suggestions that the high may be due to dense rock at depth raised up at that point. There is certainly nothing in the Swauk to explain this high. The Teanaway dikes are for the most part relatively sparce so that, although it would be possible to account for the high B1 by invoking Teanaway basalt at depth, this explanation does not seem compelling. One part of the ridge which is relatively unambiguous is the local high labeled B4 on Map 2. Here the high is directly above the dense mafic rock of the Mt. Stuart Batholith. Thus, it seems more likely that the continuation of Feature B to the south is the result of basement of the Mt. Stuart Batholith rock underlying the Swauk at a relatively shallow depth. These highs are caused, like the B4 high in the north, by high density mafic rock of the Mt. Stuart Batholith located on the east side of the batholith and west of the Leavenworth Fault. This model implies that the Swauk sediments are relatively thin near Feature B3. Alternatively, the high may be caused by Teanaway basalt intruded, sill-like, at depth. In this case it could be argued that the lack of dikes exposed at the surface reflects the fact that the basalt was contained at depth and did not escape to the surface to be later eroded away.

Feature C

Given the occurrence of the gravity high directly over the Teanaway basalt with its contour lines at least roughly paralleling the surface exposure pattern, the simplest interpretation is that this represents a thickening of the basalt at this point, with a relatively thin cover of Roslyn Formation. Although the map of Tabor et al. (1977) does not cover this feature to its westernmost point, as far as it goes it shows a general increase in the number of Teanaway dikes in the Swauk, from east to west, reaching a maximum in about the same place as the gravity feature (Fig. 8). Thus the elongate high shown as Feature C on Map 2 probably represents high density basalt intruding (and underlying?) the Swauk.

Feature F

Before considering Feature F, a low made up of Features F1-F2 on Map

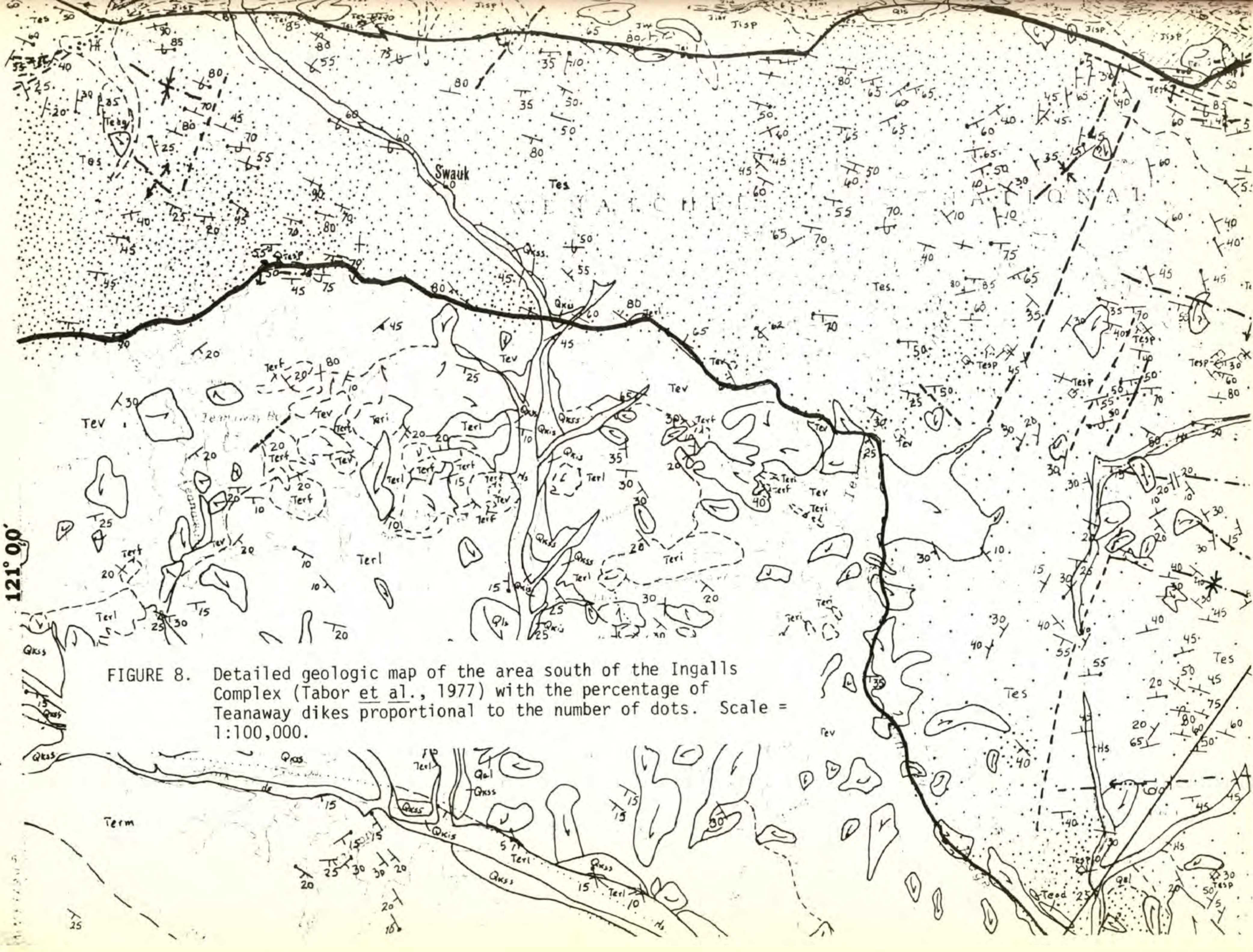


FIGURE 8. Detailed geologic map of the area south of the Ingalls Complex (Tabor et al., 1977) with the percentage of Teanaway dikes proportional to the number of dots. Scale = 1:100,000.

2, it is necessary to pause and consider Erikson's (1977a) preferred petrogenetic model for the Mt. Stuart Batholith, which postulated a large volume of dense gabbroic rock at depth. From Map 2, as well as the state regional map (Bonnini et al., 1974), it is seen that the Mt. Stuart Batholith has a generally higher gravity signal than the Snoqualmie Batholith. That this difference is due to deep seated effects does not seem likely since the gravity gradients between the two batholiths are sharp, implying a relatively shallow source. However, a surface source also seems unlikely, since the surface rocks exposed in the two batholiths, on the whole, are very similar. Thus, the source of the Mt. Stuart high may lie at some intermediate depth. The gravity map thus lends some support for Erikson's model.

Using Erikson's model, Feature F could be explained by younger, less dense rock of the Snoqualmie Batholith intruding Mt. Stuart gabbros at depth. This speculation is suggested by the surface outcrop pattern of the Snoqualmie Batholith which tapers to a point near where the gravity contours start to cut across the main gravity trend in the Mt. Stuart Batholith. This geometry is illustrated in Figure 9. In support of at least some contact between the two batholiths, it should be noted that they have at least interacted to the extent that age dates on the west side of the Mt. Stuart Batholith have been reset from reheating by the Snoqualmie Batholith (Erickson and Williams, 1976).

Feature G

Given that this feature is weakly defined by the gravity suggests that it is a relatively shallow unit. Alternatively, since the Ingalls Complex is such a tectonic mixture of rocks of different density, it is not incon-

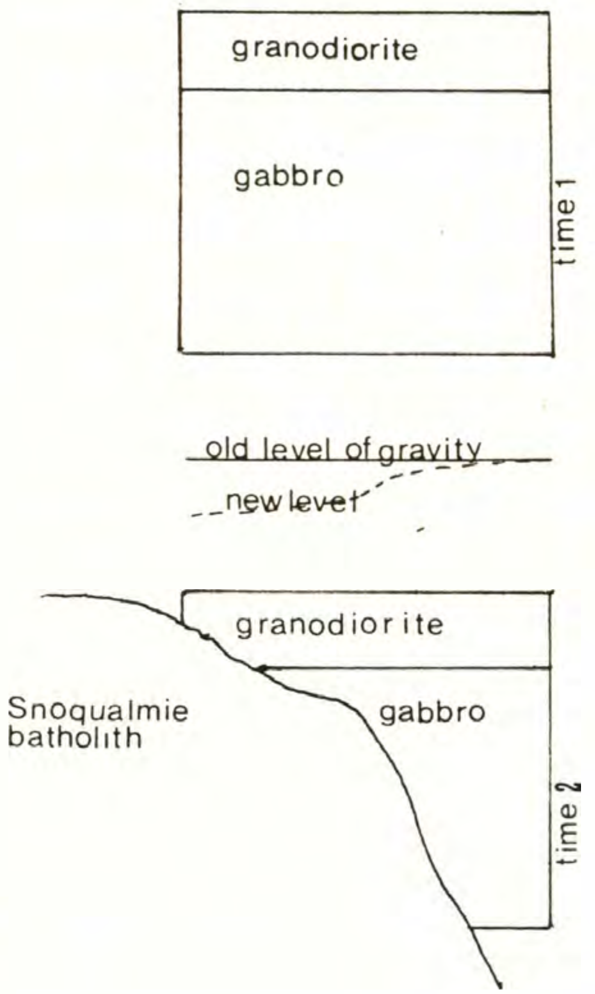


FIGURE 9. Diagrammatic cross section of the Stuart Batholith illustrating geometry for the formation of Feature F on Map 2.

ceivable that they just happen to cancel each other's effect. However, Miller (1975), to explain local metamorphic upgrading, suggested that the batholith may underly the Ingalls Complex at a shallow depth. Therefore, the information at hand is not inconsistent with a small thickness for the Ingalls Complex. Certainly it is unreasonable to postulate a large plug of peridotite extending to great depth.

CONCLUSIONS

Some features in the gravity data fit rather well with the current geologic models (Figs. 3 and 4). There is a general overall high over the Mt. Stuart Batholith in keeping with Erikson's (1977a) model for a gabbroic cumulate at depth. The supposed corresponding gabbroic rock which is exposed along the east side of the Mt. Stuart Batholith shows up well as a local high in a ridge of gravity apralleling the Leavenworth Fault. The Leavenworth Fault also shows up well in the gravity. Displacement in the Chiwaukum Graben occurs mostly on the west side in a narrow, 4-5 km, block 5.5 to 7.5 km deep, expanding in width to the north.

There are some discrepancies between the real gravity data and the anomalies expected from the current geologic model. The density contrasts across the Deception Pass Fault do not produce the expected roughly N20W trend of gravity contours paralleling the fault line. This may be due to a small relative vertical movement on this fault and/or because rocks of the Snoqualmie Batholith intruding the high density gabbroic rock under the Mt. Stuart Batholith, create a strong anomaly perpendicular to the fault which masks the effect of density contrasts across the fault. The gravity over the Ingalls Complex is not well defined probably because it does not extend to very great depth. Certainly a model hypothesizing a deep plug of peridotite is incompatible with the gravity data.

Several conclusions not implied by the geologic model of Figure 2 and 3 can be made. The series of maxima extending from the Mt. Stuart

Batholith to the south over the Swauk Formation, with no obvious explanation in the surface geology but with well-defined associations with the Mt. Stuart Batholith in the north, suggests that the Mt. Stuart Batholith may not stop at the Ingalls Complex but rather extends to the south, becoming basement to the Swauk. A high south of the western part of the Mt. Stuart Block may be due to thickening of the Teanaway basalt.

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APPENDIX A.

Principal Data for Gravity Stations

Station prefix codes:

P = stations measured for this thesis (Petrie)

UW = University of Washington stations (Aiken, unpublished)

All other = University of Puget Sound stations (Danes, unpublished)

Column headings:

Sta. no.	Station identification
Lat.	Latitude in degrees to hundredths
Long.	Longitude in degrees to hundredths
Elev.	Elevation in feet
S.B.A.	Simple Bouguer anomaly value in milligals (drift corrected)
T.C.	Terrain correction in milligals
F.B.A.	Final Bouguer anomaly value in milligals

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
3011	47.19	120.56	4890	-88.5	3.0	-85.5
3012	47.20	120.58	5434	-87.0	3.2	-83.8
3023	47.23	120.58	5251	-85.6	3.5	-82.1
3024	47.25	120.58	6233	-89.1	3.0	-86.1
3025	47.27	120.59	6136	-90.6	5.3	-85.3
3026	47.29	120.59	5796	-91.9	3.9	-88.0
3027	47.30	120.58	5615	-94.2	5.0	-89.2
3028	47.33	120.60	4953	-88.4	6.6	-81.8
3029	47.27	120.67	2835	-73.8	7.7	-66.1
3030	47.28	120.67	3140	-76.5	5.8	-70.7
3031	47.30	120.64	3811	-70.1	6.0	-64.1
3042	47.17	120.84	1321	-93.1	2.0	-91.2
3043	47.19	120.90	1873	-88.1	0.9	-87.2
3044	47.22	120.79	1949	-83.3	1.4	-81.9
3045	47.23	120.71	2208	-80.5	3.2	-77.3
3046	47.25	120.70	2412	-71.9	5.4	-66.6
3047	47.27	120.69	2545	-73.7	7.5	-66.2
3049	47.28	120.70	2671	-77.5	8.6	-69.0
3050	47.30	120.70	2799	-75.7	6.4	-69.3
3051	47.35	120.67	4066	-83.1	5.8	-77.3
3052	47.37	120.66	3529	-83.8	9.0	-74.7
3053	47.39	120.66	2646	-86.1	9.1	-76.9
3054	47.42	120.66	2324	-77.4	13.3	-64.1
3055	47.45	120.66	2262	-82.1	13.7	-68.4
3056	47.47	120.66	1722	-84.6	9.2	-75.4

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.A.A.
3057	47.55	120.60	1100	-98.2	1.5	-96.6
3059	47.54	120.57	977	-100.0	2.0	-98.0
3060	47.52	120.48	894	-98.4	1.8	-96.6
3061	47.47	120.39	658	-95.1	3.1	-92.0
3143	47.47	120.50	1124	-101.5	6.4	-95.0
3144	47.50	120.48	938	-100.8	4.9	-95.9
3145	47.45	120.50	1275	-101.3	8.0	-93.3
3146	47.44	120.51	1372	-100.4	7.7	-92.7
3147	47.40	120.51	1695	-98.0	10.0	-88.0
3148	47.37	120.48	2135	-95.8	9.1	-86.7
3149	47.35	120.51	1807	-96.6	10.1	-86.5
3150	47.37	120.48	2296	-95.3	10.1	-85.2
3151	47.36	120.44	2838	-92.6	6.2	-86.4
3152	47.34	120.42	3739	-92.3	8.7	-83.6
3153	47.34	120.40	4249	-95.3	4.4	-90.9
3155	47.30	120.45	5791	-96.8	7.6	-89.1
3156	47.30	120.48	5629	-92.8	8.5	-84.2
3157	47.30	120.55	5485	-93.1	3.2	-89.9
3159	47.32	120.53	5622	-91.7	5.8	-85.9
3160	47.32	120.53	5997	-92.8	7.4	-85.4
3161	47.31	120.52	5551	-90.4	6.8	-83.6
3162	47.31	120.51	5560	-92.1	6.4	-85.7
3163	47.30	120.49	5907	-95.0	7.4	-87.7
3165	47.32	120.43	4654	-94.3	4.9	-89.4
3166	47.32	120.40	3515	-91.2	7.9	-83.3
3201	47.20	120.45	6878	-110.6	18.9	-91.7

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
3284	47.26	120.40	6629	-110.1	13.0	-97.0
3286	47.27	120.42	6742	-112.0	16.1	-95.9
3290	47.19	120.87	1842	-88.8	0.9	-87.9
3291	47.19	120.89	1930	-87.8	1.3	-86.5
3292	47.19	120.93	1887	-89.1	0.7	-88.4
3293	47.19	120.95	2003	-89.8	1.3	-88.6
3296	47.32	121.34	2475	-104.6	2.2	-102.4
3297	47.40	121.41	3304	-112.9	3.3	-109.6
3446	47.26	121.22	2309	-91.8	2.2	-89.6
3447	47.27	121.27	2485	-102.5	5.6	-96.9
3909	47.21	121.46	1666	-115.2	5.1	-110.1
3910	47.22	121.46	1707	-114.4	5.8	-108.6
3912	47.25	121.41	2010	-115.4	10.6	-104.8
3940	47.22	121.00	2225	-85.1	1.6	-83.5
3941	47.22	121.02	2093	-86.1	2.2	-83.9
3942	47.23	121.02	2330	-84.6	1.9	-82.7
3943	47.24	121.05	2272	-83.9	1.5	-82.4
3944	47.25	121.08	2250	-86.8	1.1	-85.7
4502	47.44	120.94	4242	-99.5	17.7	-81.8
4504	47.37	120.88	2105	-83.6	7.9	-75.8
4505	47.35	120.86	2728	-81.0	6.0	-75.0
4506	47.36	120.83	2875	-82.3	7.6	-74.7
4507	47.37	120.81	3087	-82.0	9.0	-73.0
4508	47.32	120.86	2611	-80.9	2.3	-78.6
4509	47.30	120.86	2553	-73.5	2.0	-71.6
4510	47.28	120.86	2380	-76.9	2.5	-74.3

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
4511	47.26	121.06	2285	-85.5	3.3	-82.1
4512	47.27	121.07	2344	-82.9	2.8	-80.1
4513	47.28	121.09	2265	-82.2	2.5	-79.7
4514	47.44	121.06	2836	-100.1	12.8	-87.2
4515	47.42	121.07	2830	-105.4	16.3	-89.1
4516	47.37	121.10	2302	-99.4	7.3	-92.1
4517	47.36	121.10	2261	-97.3	6.8	-90.5
4518	47.35	121.10	2247	-95.5	8.3	-87.2
4520	47.27	121.20	2269	-93.6	2.0	-91.6
4521	47.28	121.20	2261	-103.0	7.6	-95.4
4522	47.32	121.23	2261	-95.9	8.7	-87.3
4532	47.42	120.71	2976	-87.9	14.5	-73.4
4534	47.42	120.79	5764	-87.2	8.4	-78.8
4535	47.42	120.80	7223	-109.3	27.3	-82.0
4536	47.42	120.77	7297	-109.6	35.6	-74.0
4537	47.43	120.76	7169	-112.8	32.8	-80.0
4538	47.42	120.73	3576	-87.8	14.8	-72.9
4541	47.43	120.68	2462	-83.7	13.7	-70.0
4546	47.42	120.98	3947	-86.3	10.6	-75.7
4547	47.42	120.89	5250	-83.7	5.9	-77.8
4548	47.42	120.38	5587	-84.9	6.7	-78.2
4549	47.42	120.98	4321	-87.9	12.4	-75.5
4554	47.46	120.94	6495	-93.8	11.0	-82.7
4557	47.43	121.16	2798	-112.9	10.6	-102.3
4558	47.42	121.18	2791	-108.4	8.4	-99.9
4560	47.48	121.22	2084	-106.1	9.9	-96.1

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
4566	47.58	120.69	1175	-89.9	6.6	-83.3
4598	47.57	120.54	2648	-98.8	8.6	-90.3
4599	47.68	120.76	2032	-105.4	16.0	-89.4
4601	47.72	120.89	5211	-90.1	8.7	-81.4
4602	47.71	120.91	6079	-94.1	5.4	-88.7
4610	47.63	120.97	2958	-114.0	13.4	-100.7
4612	47.61	120.89	2663	-102.7	17.6	-85.1
4615	47.60	120.86	2516	-106.7	22.2	-84.6
4616	47.60	120.83	2469	-101.9	18.0	-83.9
4617	47.60	120.80	3272	-95.2	20.5	-74.7
4618	47.61	120.82	2691	-101.3	20.4	-80.9
4619	47.62	120.84	3956	-92.7	17.9	-74.7
4620	47.62	120.83	4117	-89.4	16.8	-72.6
4623	47.61	120.78	6879	-104.2	26.6	-77.6
4624	47.62	120.80	6302	-93.6	21.9	-71.6
4628	47.58	120.80	2257	-110.1	26.4	-83.8
4629	47.56	120.78	2119	-108.8	24.9	-83.9
4636	47.53	120.82	3250	-112.1	23.0	-89.1
4637	47.52	120.86	4405	-107.2	17.0	-90.2
4638	47.52	120.88	4641	-105.3	17.1	-88.2
4639	47.49	120.38	5066	-94.7	13.4	-81.3
4873	47.36	121.24	2259	-105.5	6.6	-98.9
4874	47.28	121.24	2256	-112.9	12.0	-100.9
4875	47.40	121.23	2257	-117.1	12.8	-104.3
5092	47.82	120.77	1804	-100.3	5.0	-95.3
5093	47.83	120.80	1991	-102.1	9.9	-92.2

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
5095	47.84	120.81	1872	-100.3	8.9	-91.4
5096	47.85	120.83	1912	-107.9	13.4	-94.5
5097	47.82	120.81	1869	-102.9	9.5	-93.4
5098	47.81	120.78	1969	-100.3	8.1	-92.2
5099	47.77	120.82	2165	-105.4	10.3	-95.1
5100	47.77	120.84	2180	-106.6	15.1	-91.5
5101	47.76	120.78	2167	-101.9	3.9	-98.0
5102	47.78	120.85	2254	-107.9	14.3	-93.6
5103	47.79	120.90	2652	-100.8	12.9	-87.9
5104	47.77	120.92	2503	-106.5	12.9	-93.6
5105	47.77	120.96	2758	-106.5	12.8	-93.8
5107	47.71	121.14	2247	-113.0	15.5	-97.5
5108	47.71	121.18	2030	-121.4	15.3	-106.1
5109	47.72	121.36	931	-111.0	6.4	-104.6
5111	47.70	121.34	997	-112.1	5.7	-106.4
5112	47.71	121.29	1188	-112.1	10.1	-102.0
5115	47.71	121.39	901	-110.4	7.4	-103.0
5116	47.73	121.42	849	-108.0	9.6	-98.4
5117	47.75	121.46	793	-105.0	12.4	-92.6
14570	47.51	120.52	1030	-101.5	2.7	-98.8
14573	47.51	120.55	1897	-103.9	5.3	-98.6
14576	47.49	120.57	3028	-94.8	3.5	-91.3
14579	47.52	120.53	870	-101.1	3.0	-98.1
14580	47.52	120.55	1030	-99.8	2.1	-97.7
14581	47.54	120.57	977	-99.7	2.0	-97.7
14582	47.51	120.59	2700	-100.6	8.8	-91.8

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
14584	47.53	120.60	2738	-98.4	6.7	-91.7
14597	47.55	120.57	1184	-99.7	1.9	-97.8
14648	47.87	120.75	2628	-106.6	6.6	-99.9
14649	47.87	120.76	2603	-106.4	6.9	-99.5
14654	47.55	120.77	1885	-109.6	26.6	-83.0
14655	47.55	120.69	1220	-96.7	15.9	-80.8
14658	47.56	120.68	1172	-95.1	12.8	-82.2
14659	47.56	120.68	1150	-93.9	11.4	-82.6
14660	47.57	120.68	1170	-93.4	11.4	-82.0
14661	47.57	120.65	1116	-92.3	3.1	-89.2
14662	47.58	120.64	1123	-98.7	4.0	-94.8
14663	47.51	120.64	2635	-89.3	5.5	-83.7
14664	47.52	120.65	2725	-88.5	6.2	-82.3
14665	47.54	120.63	3166	-100.7	18.4	-82.2
14666	47.54	120.65	2410	-89.5	6.9	-82.6
14667	47.55	120.64	2030	-90.5	5.4	-85.1
14668	47.57	120.64	1926	-93.3	5.5	-87.8
14669	47.56	120.60	1100	-98.4	1.5	-96.9
14670	47.54	120.58	970	-98.4	1.8	-96.6
14671	47.57	120.60	1043	-100.6	1.6	-99.0
14672	47.61	120.66	1384	-95.3	5.2	-90.1
14673	47.60	120.67	1230	-91.9	4.3	-87.6
14674	47.59	120.66	1166	-95.0	2.4	-92.6
14676	47.67	120.75	2365	-94.0	13.4	-80.5
14679	47.63	120.61	1389	-101.3	5.9	-95.4
14680	47.64	120.59	1604	-101.9	6.4	-95.4

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
14681	47.64	120.58	1639	-101.0	6.5	-94.5
14682	47.65	120.58	1708	-100.1	7.0	-93.1
14683	47.65	120.55	2000	-99.9	7.7	-92.3
14684	47.71	120.51	3820	-97.1	8.8	-88.3
14685	47.70	120.51	3284	-96.7	8.7	-88.0
14692	47.62	120.64	1264	-100.0	6.7	-93.3
14693	47.65	120.64	1321	-100.6	6.3	-94.3
14694	47.66	120.64	1415	-102.0	4.4	-97.6
14695	47.70	120.64	1626	-103.9	5.7	-98.2
14696	47.71	120.65	1769	-104.6	5.9	-98.7
14697	47.72	120.63	1707	-103.2	3.8	-99.4
14698	47.73	120.63	1852	-104.5	4.5	-100.0
14699	47.74	120.63	1982	-105.2	4.7	-100.5
14700	47.74	120.63	2090	-106.1	5.4	-100.7
14701	47.72	120.61	1817	-103.0	4.7	-98.3
14702	47.72	120.58	2188	-103.1	6.5	-96.6
14703	47.72	120.57	2438	-102.1	7.3	-94.8
14704	47.73	120.58	3058	-103.4	6.7	-96.7
14705	47.59	120.71	1367	-102.2	28.5	-73.7
14706	47.61	120.72	1479	-99.2	25.8	-73.4
14707	47.62	120.72	1526	-100.0	25.1	-75.0
14708	47.64	120.72	1626	-98.3	23.4	-74.9
14709	47.65	120.73	1643	-97.7	20.4	-77.3
14710	47.67	120.73	1687	-96.0	11.1	-84.8
14711	47.71	120.70	1909	-104.9	4.6	-100.3
14712	47.71	120.66	1788	-103.7	8.5	-95.2

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
L4713	47.68	120.73	1775	-97.3	9.9	-87.4
L4714	47.69	120.74	1794	-97.6	9.6	-88.0
L4715	47.69	120.74	1825	-98.3	8.9	-89.3
L4716	47.70	120.75	1871	-101.0	8.0	-93.0
L4717	47.71	120.74	1968	-105.8	6.5	-99.3
L4718	47.72	120.74	2046	-104.4	5.7	-98.7
L4719	47.73	120.74	2076	-104.9	4.8	-100.1
L4720	47.74	120.74	2045	-105.9	4.0	-101.3
L4731	47.79	120.40	1582	-94.6	7.8	-86.8
L4732	47.82	120.42	1588	-101.9	11.1	-90.8
L4733	47.86	120.42	1662	-117.3	15.4	-101.9
L4749	47.81	120.41	1574	-99.6	8.7	-90.9
L4750	47.78	120.39	1495	-92.5	6.1	-86.5
P360	47.71	120.86	3355	-104.4	16.7	-87.7
P870	47.70	120.83	3360	-101.4	16.7	-84.7
P880	47.69	120.84	3680	-104.7	21.9	-82.7
P890	47.68	120.87	4160	-105.9	17.4	-88.5
P900	47.66	120.87	4330	-108.7	18.6	-90.1
P203	47.80	120.71	1872	-108.3	1.8	-106.4
P692	47.47	120.94	6464	-92.3	6.5	-85.8
P69	47.45	120.90	4810	-93.6	12.5	-81.1
P70	47.45	120.87	4320	-93.0	14.3	-78.6
P71	47.44	120.83	3920	-101.4	20.4	-81.0
P72	47.45	120.81	3680	-105.6	25.5	-80.1
P74	47.45	120.74	3000	-101.8	23.4	-78.4
P820	47.74	120.88	5500	-94.7	7.8	-86.9

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
P820	47.73	120.87	5190	-92.7	6.4	-86.3
P840	47.72	120.86	5573	-92.4	6.5	-85.9
P850	47.72	120.89	5210	-90.1	8.1	-82.0
P409	47.42	121.32	4640	-110.3	6.6	-103.7
P501	47.30	120.97	2720	-73.3	5.3	-68.0
P502	47.31	120.96	2800	-78.9	9.7	-69.2
P504	47.33	120.96	2962	-82.9	12.0	-70.9
P505	47.34	120.96	3020	-87.2	10.0	-77.3
P60	47.60	120.90	3118	-98.6	16.2	-82.4
P66	47.55	120.94	3675	-111.1	14.9	-96.2
P67	47.52	120.95	4080	-98.8	16.7	-82.0
P68	47.50	120.94	4560	-96.5	15.8	-80.7
P691	47.47	120.93	6405	-93.7	9.2	-84.5
P254	47.87	120.86	1920	-106.8	8.9	-97.8
P256	47.84	120.90	2000	-106.7	13.1	-93.6
P257	47.85	120.94	2146	-108.3	11.3	-96.9
P258	47.85	120.96	2348	-108.3	10.5	-97.8
P259	47.86	120.98	2328	-113.6	9.6	-104.0
P401	47.32	121.28	2472	-102.8	4.0	-98.8
P403	47.34	121.26	2312	-103.8	8.0	-95.8
P405	47.38	121.27	2638	-104.0	8.9	-95.1
P407	47.41	121.30	3140	-108.0	12.7	-95.3
P409	47.42	121.30	3200	-114.5	12.8	-101.7
P233	47.77	120.64	2051	-107.2	3.3	-104.0
P234	47.78	120.63	1984	-107.3	3.6	-103.8
P236	47.84	120.64	2216	-110.6	3.6	-107.0

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
P237	47.84	120.65	2200	-110.8	3.4	-107.3
P2371	47.84	120.66	2173	-110.5	3.3	-107.3
P238	47.84	120.66	2137	-109.7	3.0	-106.7
P239	47.83	120.67	2068	-110.9	2.5	-108.4
P240	47.82	120.70	1971	-108.9	2.9	-106.0
P250	47.81	120.72	1940	-106.6	0.8	-105.8
P251	47.81	120.74	1868	-104.9	2.8	-102.1
P204	47.80	120.71	1874	-107.6	1.3	-106.3
P205	47.81	120.71	1922	-107.4	0.7	-106.7
P206	47.81	120.68	1938	-107.9	2.0	-106.0
P211	47.82	120.63	2238	-108.9	3.8	-105.1
P212	47.82	120.62	2273	-109.2	5.0	-104.3
P213	47.81	120.60	2908	-105.8	9.3	-96.5
P2131	47.80	120.59	3060	-106.2	8.8	-97.4
P2141	47.85	120.62	3520	-106.4	12.0	-94.4
P231	47.76	120.65	1879	-105.0	1.7	-103.4
P232	47.76	120.66	1859	-105.7	1.5	-104.1
P0170	47.63	120.96	2880	-115.4	13.6	-101.8
P130	47.72	121.33	981	-112.2	6.0	-106.2
P131	47.73	121.32	1012	-113.9	8.1	-105.8
P132	47.79	121.29	1295	-118.1	10.8	-107.3
P133	47.81	121.29	1387	-119.4	12.2	-107.2
P134	47.91	121.29	1444	-120.6	13.8	-106.9
P135	47.94	121.30	1904	-117.4	10.0	-107.4
P136	47.86	121.31	2154	-116.8	10.0	-106.8
P137	47.87	121.32	2589	-117.0	6.7	-110.3

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
P201	47.79	120.72	1949	-109.3	3.1	-106.2
P0520	47.69	121.15	2760	-120.1	17.4	-102.7
P104	47.61	121.31	2035	-134.6	23.1	-111.5
P106	47.60	121.32	3961	-119.8	6.1	-113.6
P107	47.59	121.32	4204	-120.2	6.0	-114.2
P108	47.58	121.31	4545	-121.5	6.5	-115.0
P120	47.70	121.29	1060	-116.4	9.2	-107.3
P121	47.69	121.29	1174	-117.8	11.6	-106.2
P122	47.68	121.29	1250	-120.7	12.8	-107.8
P123	47.67	121.29	1502	-124.0	13.7	-110.3
P124	47.66	121.28	1604	-119.2	11.3	-107.9
P0370	47.57	121.12	3448	-124.0	18.7	-105.3
P0390	47.59	121.14	4475	-112.2	5.3	-106.9
P0400	47.59	121.14	4445	-114.1	10.8	-103.3
P0410	47.60	121.13	4402	-117.4	12.6	-104.8
P0420	47.61	121.14	4460	-117.8	9.1	-108.7
P0430	47.62	121.14	4760	-124.7	10.9	-113.8
P0450	47.63	121.14	5053	-112.6	6.0	-106.6
P0460	47.64	121.14	5765	-117.2	9.7	-107.5
P0470	47.64	121.14	5133	-115.2	8.9	-106.3
P0480	47.65	121.14	4806	-112.5	9.5	-102.9
P0240	47.56	121.05	4260	-111.0	15.1	-95.9
P0250	47.56	121.05	4373	-111.9	15.7	-96.2
P0260	47.55	121.05	4450	-106.6	16.4	-90.1
P0290	47.54	121.05	5450	-98.9	9.4	-89.5
P0300	47.54	121.06	6105	-101.9	14.0	-87.9

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
P0320	47.53	121.08	3373	-112.2	12.8	-99.3
P0330	47.54	121.10	3380	-113.1	14.9	-98.1
P0340	47.54	121.10	3480	-113.8	10.3	-103.5
P0360	47.56	121.12	3448	-120.5	14.6	-105.9
P0130	47.65	121.04	3413	-113.2	10.7	-102.5
P0140	47.65	121.01	3195	-113.3	11.1	-102.3
P0150	47.65	121.00	3104	-118.5	13.2	-105.3
P0160	47.64	120.98	3040	-112.6	13.1	-99.5
P0171	47.62	121.01	3260	-120.2	16.7	-103.5
P0180	47.61	121.02	3330	-121.9	16.0	-105.9
P0181	47.60	121.03	3330	-120.8	15.8	-105.0
P0190	47.60	121.03	3348	-121.0	17.2	-103.9
P0220	47.57	121.05	3837	-118.4	15.5	-102.9
P0230	47.57	121.05	3900	-118.3	15.9	-102.4
P010A	47.73	121.09	4520	-116.2	8.0	-108.2
P030A	47.72	121.07	4600	-111.9	9.3	-102.7
P040A	47.72	121.07	4597	-108.5	5.4	-103.1
P050A	47.71	121.05	4682	-107.1	4.8	-102.4
P060A	47.71	121.05	4382	-107.1	4.4	-102.7
P080A	47.70	121.05	4122	-114.5	7.4	-107.1
P090A	47.69	121.06	3777	-113.1	9.0	-104.1
P092	47.68	121.06	3600	-113.0	10.2	-102.8
P0110	47.66	121.04	3240	-112.1	11.8	-100.3
P0120	47.66	121.04	3265	-110.6	11.2	-99.4
UW15	47.71	121.19	2030	-120.4	15.0	-105.4
UW18	47.71	121.22	1787	-121.1	13.3	-107.8

STAT. NO.	LAT.	LONG	ELEV	S.B.A.	T.C.	F.B.A.
UW20	47.74	121.11	3143	-119.2	9.8	-109.3
UW45	47.71	121.31	1008	-106.6	5.9	-100.7
UW58	47.51	121.45	1428	-142.5	24.1	-118.4
UW75	47.90	121.43	1301	-119.8	13.5	-106.3
W4641	47.49	120.74	4950	-93.6	17.2	-76.4
W4642	47.49	120.74	5416	-90.1	12.4	-77.7

APPENDIX B.

Data Processing

In order to help in the interpretation of the data, a series of inter-related programs were developed (Fig. 10). The first program labeled BASIC (Fig. 10) reads in cards punched from data collection sheets (Fig. 11) containing all the field information. Program BASIC then does all preliminary calculations, described in the reduction section, except for the terrain corrections, and punches cards containing the following information:

(1) Station identification.

(2) X (west to east) and Y (south to north) coordinates in inches, taken off the Wenatchee 1:250,000 map, for each station. The point $121^{0}30'$W and $47^{0}7.5'$N was used as the origin.

(3) Elevation in feet.

(4) Absolute gravity.

(5) Simple Bouguer anomaly.

Data supplied by Danes was punched on cards in the same format. Before further processing, station locations were plotted on the Calcomp drum plotter in the same scale as the Wenatchee map. These locations were checked against the Wenatchee base map, where the stations were also plotted and any discrepancies in station locations between the two were corrected to the nearest one hundredth of an inch. Terrain corrections, calculated using a Hanner Chart to zone J, were next incorporated into the data. All of the above information was stored on a disc file for future use. Also stored on disc was a geologic map of the area in digitized form.

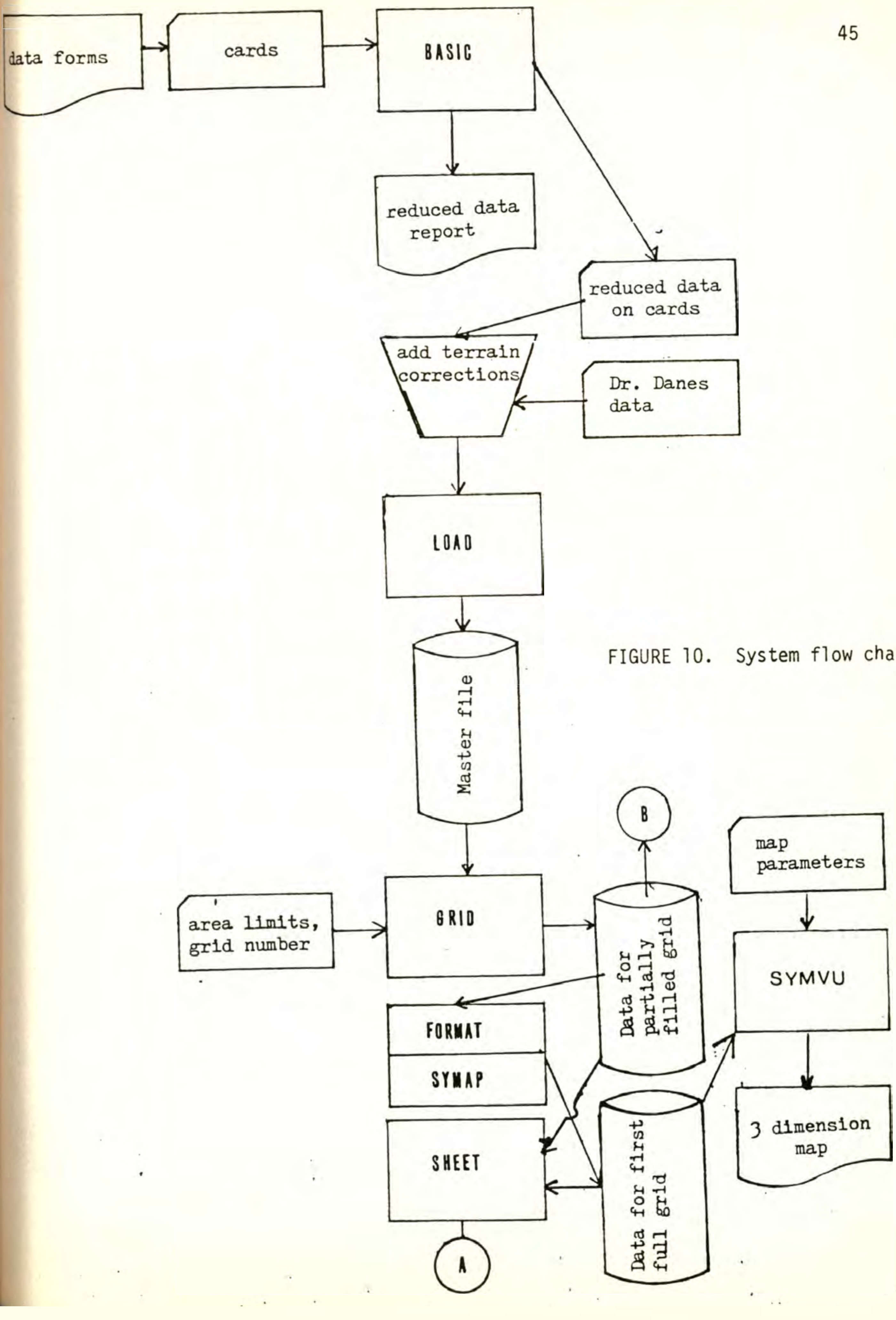
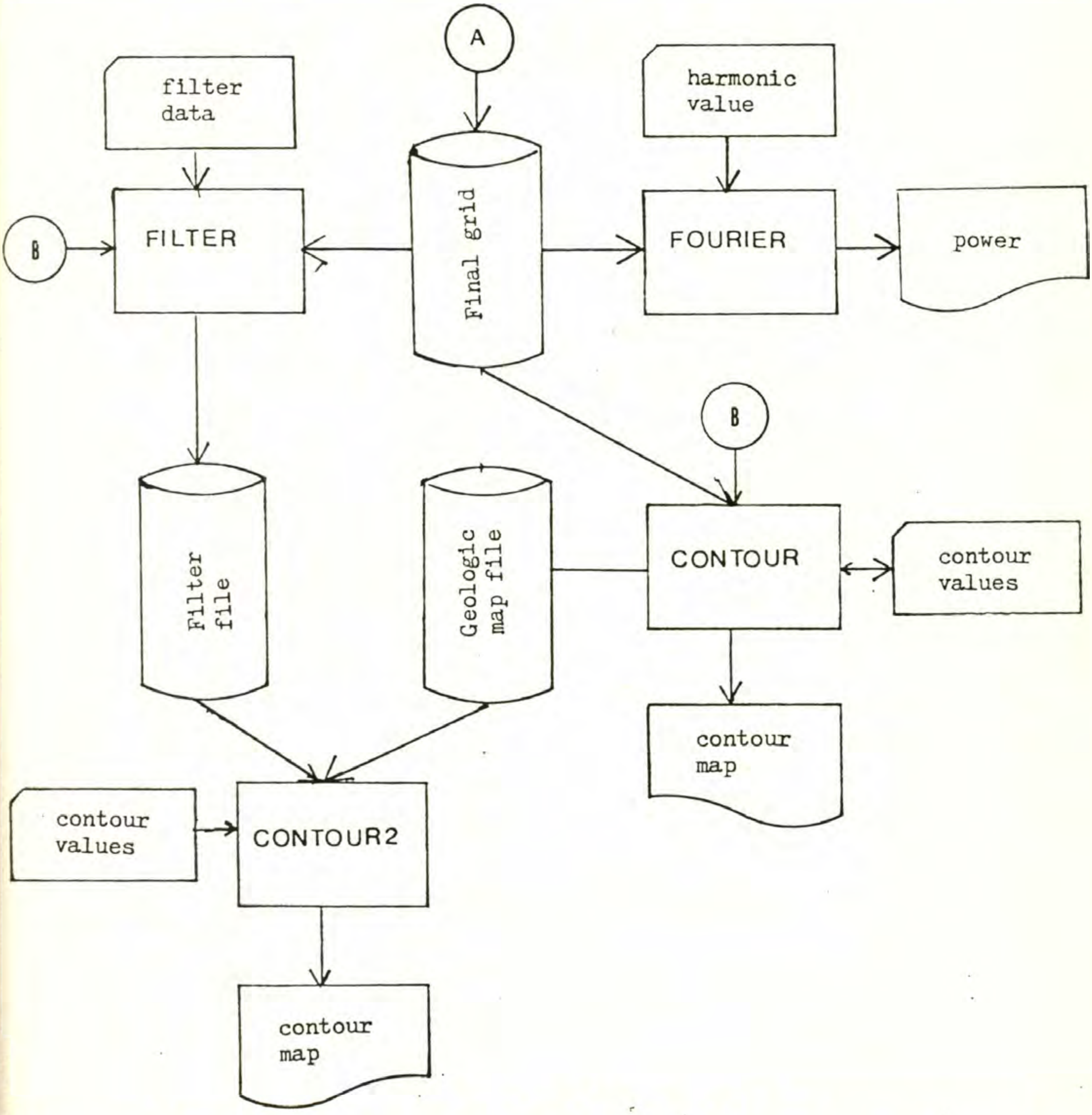


FIGURE 10. System flow chart.


A
filter
data
harmonic
value
B
FILTER
Final grid
FOURIER
power
B
Filter
file
Geologic
map file
CONTOUR
contour
values
contour
map
contour
values
CONTOUR2
contour
map

PAGE __ OF __

Figure 11. Data collection form with sample data

I.D.	LONG		LAT		day	TIME	TEMP.	READING	CHANGE	ELEV	EST ERROR	CONTROL CODE	TRUE GRAVITY/ COMMENT	DENSITY/ MAP NAME
BASE1					0	03.30	69	1518.5					980647.87	2.67
P990	120	42.58	47	47.24	0	03.45	69	1601.7		1949		B	B.M. ON RIVER	PLAIN
P991	(	42.73	(	48.22	0	03.55	69	1686.6		1872		G	ROAD TO 2635	PLAIN
P992	)	44.63	)	49.10	0	04.35	69	1746.4		1868		L	FISH LAKE	PLAIN
BASE2					0	07.20	69	1513.8						

The next step was to take the irregularly located data points and interpolate them onto an equally spaced grid. This was probably the most critical step in the whole system. Grant (1972) points out that the quality of the contour map is largely dependent on the correct choice of gridding methods. Filtering also requires accurate gridding. While Fourier analysis does not strictly require gridded data, computations are greatly extended and simplified if gridded data are available. There are several possible methods for gridding data (Grant, 1972; Walters, 1969; Crain, 1969; Corbyn, 1971). The method selected (Briggs, 1974) is based upon solving a fourth order differential equation which describes the displacement of a thin sheet in two dimensions under the influence of point forces. This method has the property of inducing minimum curvature in extrapolating values and thus gives the smoothest possible contour map. Although this method appears to give excellent results (Grant, 1972), it is costly in computer time.

There are several steps to implementing the Briggs method. The first step involves superimposing a grid over the area of interest. Then, each station's data is moved, by some method of interpolation, to the grid point nearest to it. This interpolation introduces some error and a number of interpolation methods were tried to minimize this error. Emperically it was found that by taking the 9 nearest points and forming a simple weighted, by distance, average gave the least error. This may not be true for other data sets. This step is implemented by program GRID in Figure 10. Data into GRID includes the upper and lower bounds for both the x and y values and the number of grid points in the x direction. It is worth a slight digression here to note that by changing the upper and lower bounds of the x and y values it is possible to "window" any part of the study for more detailed analysis. For example, by supplying limits of 4.0 to 6.0 map inches in the x direction and 4.0 to 6.0 in the y direction with the number of grid intersections set to 80, it is possible to set up a grid of data to be used in a detailed contouring of just the central part of the study area. When program GRID is done it has filled some grid intersections with data. This information, along with the area boundaries and number of grid points, is stored for the next step.

The next step begins with program FORMAT (Fig. 10) reading the data stored by GRID and formating it for use by the SYMAP program. SYMAP takes this data and fills out the rest of the grid with gravity values. SYMAP does a relatively crude job of filling up the empty grid points with values, so that these values are merely used as a first approximation by program SHEET (Fig. 10).

In the last step of the gridding process, program SHEET, based on the method developed by Briggs (1974) mentioned above, reads in the data created by SYMAP and data stored by GRID. Using the data from SYMAP as starting values, and data from GRID as fixed boundary conditions, SHEET solves the differential equation numerically to create the first grid of data. It is the final grid of points from program SHEET which is used in contouring, filtering, and Fourier analysis.

Contouring

The program labeled CONTOUR in Figure 10 reads in the grid of data, the number of grid points, the area limits, the digitized geologic map and the values to be contoured. It produces a map of the geology for the area and then, using the gridded data, produces a gravity contour map for the values given.

Filtering

The program labeled FILTER in Figure 10 reads in the gridded data, number of grid points, area limits, size of filter, and filter coefficients (Zurflueh, 1967). The program sets no limits on the type of filtering done. It then filters the data (Robinson, 1966; Darby and Davies, 1967; Dean, 1958) and produces a disc file containing the new area limits, new grid size, and filtered data. This information is read by program CONTOUR 2 (Fig. 10) to produce a map in the same manner as program CONTOUR.

Fourier Analysis

The program labeled FOURIER in Figure 10 read in the gridded data, the number of grid points, and the number of harmonics needed. The program calculates and prints the power for each harmonic (Davies, 1973).

3-Dimensional Maps

The standard SYMVU program reads in the SYMAP disc file to produce a 3-dimensional picture of the data.

Uses and Limitations

A particularly useful application of this system other than those mentioned above, would be to decide on a particular sampling system. The investigator would gather all previous data and use the system to create a series of maps. Using these preliminary maps he would next decide where to gather his next samples, since he would now have a better idea of where the most interesting features may be. After getting his data he would then add to the master file and create a new series of maps and could use these new improved maps to again decide where to sample. This process would continue until he is satisfied that all the important features are covered. During this process, obvious errors should show up in time for correction. Using this system also has the advantage of allowing the investigator to form models at an early stage. At the last step the computer generated maps would help him draw his final map. Unless the data is fairly dense, a worker would probably do well to consider creating the final gravity map by hand, since, while the computer seems to be able to pick the gross features correctly, the human still does a better job.

APPENDIX C.

Error Analysis

Possible sources of error include drift, location errors, lack of elevation control, and errors in making the terrain correction. Location error was minimized by locating stations at clearly defined map locations. It was thought that location accuracy was 250 feet or better on the 15 minute maps resulting in a maximum error of about 0.05 mgal, much less than other sources of error discussed below.

Tidal and instrument drift are not linear but were accounted for on that assumption. However, the average drift for this survey was .6 mgal and thus the average error is probably not greater than ± .3. Even the loop with the worst drift probably falls near this value since comparison with one of the Danes stations on this loop was made and found to be in good agreement.

Elevation was a problem since gravity varies with elevation by about 0.06 mgal/ft. and some stations had to be interpolated from topographic maps with 80 foot contour intervals. This means possible errors due to elevation of as much as ± 2.4 mgal. Fortunately, a large majority of stations have better control than this.

Terrain corrections have the potential for the largest source of error because of the qualitative judgment used to define average elevations in areas of large relief. The values for terrain corrections ranged over 2 orders of magnitude in this study (Fig. 12); the average correction was 9.45 mgal. If terrain corrections are accurate to about 10 percent, then the average error induced by terrain corrections is about ± 1 mgal.

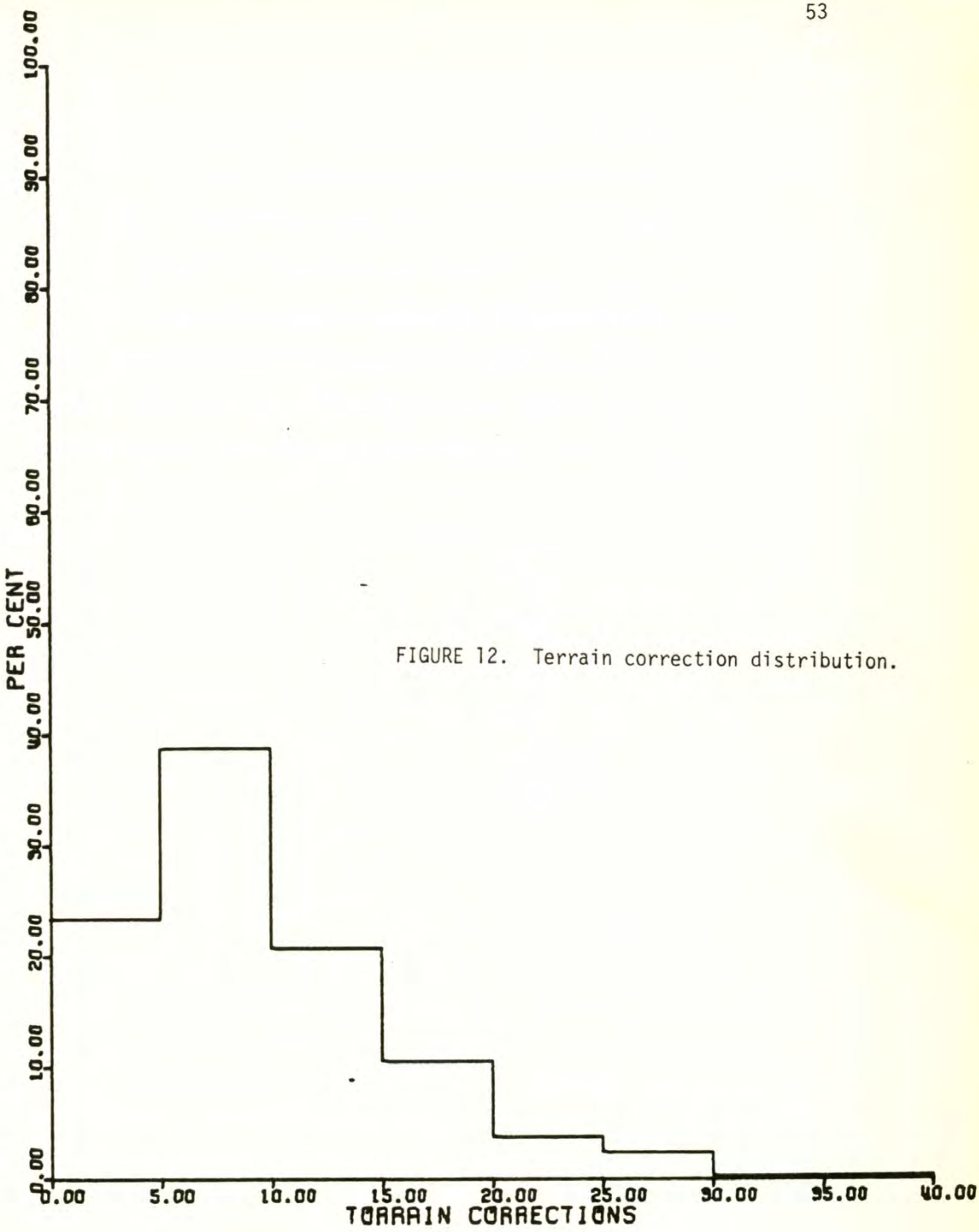


FIGURE 12. Terrain correction distribution.

However, in this study stations with the largest terrain corrections were done twice and the results averaged since the potential for error was large. In all cases, the difference between the two measurements was less than 10 percent indicating that a value of ± 1 mgal error from terrain corrections is perhaps too large.

As a result of several sources of error the amount of possible error varies from less than 1.0 to almost 3.0 mgal. However, the questions posed in this study are all of a broad regional nature, not requiring extremely precise values, and errors of this magnitude probably are acceptable.

```
1      BASIC OF FIGURE 10
//FIRST JOB (R0022,539509925),PETRIE
// EXEC PL1LFCLG,PARM.PL1L='SM=(2,80,1)'
//PL1L.SYSIN DD *
  FIRST: PROC OPTIONS (MAIN);
      DCL PUNC OUTPUT;
      DCL (THEORETICAL,FLAT) FLOAT DEC (16);
      OPEN FILE (SYSPRINT) LINESIZE (132) PAGESIZE (60) PRINT;
      NMAX = 100;
```

```
1
 BEGIN;
      ON ENDFILE (SYSIN) GO TO EOJ ;
      DCL (ID(NMAX)      ) CHAR (10);
      DCL (LONG(NMAX),LAT(NMAX),TIMES(NMAX),ELEV(NMAX),READING(NMAX ) )
      FLOAT DEC;
      DCL TEMP (NMAX)  FLOAT DEC;
      DCL (HOUR,MIN TE) FLOAT DEC;
      DCL  ( COMMENT,MAP_NAME)  CHAR (15);
      DCL TEMP_ID   CHAR (10);
      DCL CODE CHAR (8) INIT (' TSPLBGR');
      DCL CONTROL_CODE ( 0:8) CHAR (26) INIT (
      'INVALID CONTROL CODE', 'NO INFRO','TRAIL INTERSECTION',
      'TRAIL STREAM INTERSECTION','PASS','LAKE','BENCH MARK',
      'GIVEN ON MAP','ROAD INTR');
      DCL C_CODE  CHAR (1);
```

1


```
GET_BASE_READING_1:
     I = 1;
     CURRENT_SCALE_CHANGE = 0.0;
     GET EDIT (TEMP_ID)(  COL(1),A(10)   );
     IF SUBSTR(TEMP_ID,1,5) ¬= 'BASE1' THEN DO;
        PUT SKIP LIST ('NO BASE STATION READING FOUND');
        PUT SKIP (3) LIST ('BUT INSTED ',TEMP_ID);
        PUT SKIP LIST (' WILL SET BASE VALUES TO 0 ');
        TIME1 = 0.0;
        READING = 0.0;
        TRUE_GRAV = 0.0;
        GO TO NORMAL_DATA;
        END;


      GET EDIT (DAY,HOUR,MINITE,READING1)
     (COL(24),F(1),F(2),F(2),COL(31),F(5,1))              ;
     GET LIST (TRUE_GRAV,DENSITY);
     TIME1 = HOUR+MINITE/60.0+DAY*24.0;
     PUT PAGE EDIT ('STARTING TIME =',TIME1,' BASE READING =',
     READING1,' GRAVITY =',TRUE_GRAV,' DENSITY = ',DENSITY)
     (A,F(8,2),A,F(8,1),A,F(14,2),A,F(5,2)  );
     PUT SKIP (3);
```

```
1
NORMAL_DATA:
BEGIN;
     CALL HEADER1;
NEXT_NORMAL_DATA:
     ON ENDPAGE BEGIN;
        PUT PAGE;
        CALL HEADER1;
        END;
     IF I > NMAX THEN DO;
        PUT EDIT ('TOO MANY SITES FOR THIS  SET')(A);
        I = NMAX;
        END;


     GET EDIT (TEMP_ID)(  COL(1),A(10)   );
     IF SUBSTR(TEMP_ID,1,5)  = 'BASE2' THEN DO;
        GET EDIT (DAY,HOUR,MINITE,READING2)
     (COL(24),F(1),F(2),F(2),COL(31),F(5,1))          ;
        READING2 = READING2 + CURRENT_SCALE_CHANGE;
        TIME2 = HOUR+MINITE/60.0+DAY*24.0;
        GO TO REDUCE_DATA;
        END;

     ID (I) = TEMP_ID;
     GET EDIT (RLONG1,RLONG2,RLAT1,RLAT2,DAY,HOUR,MINITE,TEMP(I),
     READING(I),
     CHANGE,ELEV(I),C_CODE,COMMENT,MAP_NAME)
     (COL(11),F(3) ,F(4,2),F(2),F(4,2),F(1),F(2),F(2),
     COL(29),F(2),
     COL(31),F(5,1),F(5,1),F(5),COL(50) ,A(1),A(15),A(15));
     PUT SKIP EDIT (ID(I),READING(I))(A(10),F(10,2)  );
     TIMES(I) = HOUR+MINITE/60.0+DAY*24;
     LONG   (I) = RLONG1 + RLONG2/60.0;
     LAT  (I) = RLAT1 + RLAT2/60.0;
     IF CHANGE > 0.0 THEN DO;
        DIFF = READING(I) -CHANGE;
        READING(I) = CHANGE;
        CURRENT_SCALE_CHANGE = CURRENT_SCALE_CHANGE + DIFF;
        END;

     READING (I) = READING (I) + CURRENT_SCALE_CHANGE;
     PUT EDIT (READING(I))(F(10,2));
     READING(I) = READING(I) - READING1;
      PUT EDIT (ELEV(I))(F(10,2));
     PUT EDIT ( READING(I),TIMES(I),COMMENT,MAP_NAME)
     (F(10,2),F(10,2),X(2),A(15),X(2),A(15)   );
     N = INDEX(CODE,C_CODE);
     PUT EDIT (CONTROL_CODE (N),TEMP(I) )(X(2),A(26),F(4));
     PUT SKIP (2);
     I = I+1;
     GO TO NEXT_NORMAL_DATA;
```

```
1
 HEADER1: PROC;
      PUT SKIP EDIT ('RAW','AFTER SCALE','ALTITUDE')
      (COL(16),A,COL(22),A,COL(97 ),A);
      PUT SKIP EDIT ('ID','READING','CHANGE','ELEVATION','DIFFERENCE',
      'TIME','COMMENT','MAP','CONTROL','TEMP')
      (A,COL(14),A,COL(25),A,COL(33),A,COL(43),A,COL(56),A,COL(63),A,
      COL(80),A,COL(97),A,COL(124),A);
      PUT SKIP (3);
      END HEADER1;


 END;  /* OF BLOCK */
```

```
1
REDUCE_DATA:
BEGIN;
     ON ENDPAGE BEGIN;
        PUT PAGE;
        CALL HEADER2;
        END;
     DIFF_GRAV = READING2-READING1;
     DIFF_TIME = (TIME2-TIME1);
     IF ABS (DIFF_TIME) < 0.00001 THEN DO;
        PUT SKIP EDIT ('NO TIME CHANGE ,SET TO 1',TIME1,TIME2)
        (A,F(10,2),F(10,2)    );
        DIFF_TIME = 1;
        END;
     DRIFT = DIFF_GRAV/DIFF_TIME;
     PUT PAGE EDIT ('FOR THE FOLLOWING SET THE  DRIFT WAS ',
     DIFF_GRAV ,' OVER',DIFF_TIME,' HOURS ')(A,F(10,2),A,F(8,2),A)  ;
     PUT SKIP (3);
     CALL HEADER2;

     ITOTAL = I-1;


     DO I=1 TO ITOTAL;
        IF SUBSTR(ID(I),1,1) = 'C' THEN GO TO SKIPLIST;
        PUT SKIP (2) EDIT (ID(I),LAT(I),LONG(I)    )
        (COL(1),A(10) ,F(8,3),F(8,3));
        READING (I) = READING(I)+DRIFT*(TIMES(I)-TIME1)   ;
        PUT EDIT (READING(I))(F(10,2));
        CONVERSION=0.00071*(TEMP(I)/120.0) +0.08253;
      GRAVITY = READING(I)*CONVERSION+TRUE_GRAV;
        PUT EDIT (GRAVITY)(F(14,3)    );
        /* SEE NETTLETION (TN,271,P4,N47) PAGE 279-280 */
        FREE_AIR= GRAVITY + 0.09406*ELEV(I);
        BOUGUER = FREE_AIR          -0.01278*DENSITY    *ELEV(I);
        FLAT = LAT (I)*3.14159265/180.0;
        THEORETICAL = 978049.0*(1.0+0.0052884*(SIN(FLAT   )*SIN(FLAT))
     -0.0000059*(SIN(2.0*FLAT    )*SIN(2.0*FLAT)    ));
        FREE_AIR_ANOMALY = FREE_AIR -THEORETICAL;
        BOUGUER_ANOMALY = BOUGUER -THEORETICAL;
        PUT EDIT (FREE_AIR,BOUGUER,THEORETICAL,FREE_AIR_ANOMALY,
        BOUGUER_ANOMALY)( (3)F(14,2)   ,(2)(F(11,2) )     ) ;
        /* PUT OTHER CALCULATIONS HERE */
        /* PUNCH DATA HERE */
        GRAV_T = GRAVITY-980000.0;
        YY=((LAT(I)-47.125)/0.875)*15.28;
        XEXTRA=(YY/15.28)*0.2;
        XX=(121.5-LONG(I))*(11.92-XEXTRA);
        PUT FILE (PUNC)
        EDIT (ID(I),XX,YY,ELEV(I),GRAV_T,BOUGUER_ANOMALY)
        (COL(1),A(10),5(F(12,2)));
     SKIPLIST:
        END;
```

```
HEADER2: PROC;
      PUT SKIP EDIT ('READING AFTER'       ,'ABSOLUTE','ANOMALY')
      (COL(26),A,COL(44),A,COL(103),A);
      PUT SKIP EDIT ('ID','LAT','LONG','DRIFT','GRAVITY','FREE AIR',
      'BOUGEUR','THEORETICAL','FREE AIR','BOUGEUR')
      (A,COL(14),A,COL(21),A,COL(31),A,COL(44),A,COL(56),A,COL(72),A,
      COL(83),A,COL(97),A,COL(109),A);
      PUT SKIP (3);
      END HEADER2;
 END; /* OF BLOCK */


      GO TO GET_BASE_READING_1;
```

```
1
 EOJ:
       END; /* OF MAIN BLOCK */
       END FIRST ;
//GO.SYSIN DD *
//GO.PUNC DD DUMMY,DCB=BLKSIZE=80
//
```

```
1       LOAD OF FIGURE 10
//LOAD    JOB (G0242,103425037),PETRIE
// EXEC PL1LFCLG,PARM.PL1L='SM=(2,80,1)'
//PL1L.SYSIN DD *
 LOADS: PROC OPTIONS (MAIN);
      ON ENDFILE (SYSIN)  GO TO EOJ;
      DCL (OUTS) RECORD;

      DCL
      1 REC_OUT,
         2 X                     FLOAT DEC,
         2 Y                     FLOAT DEC,
         2 LAT                   FLOAT DEC,
         2 LONG                  FLOAT DEC,
         2 GRAV                  FLOAT DEC,
         2 B_AN                  FLOAT DEC,
         2 ELEVATION             FLOAT DEC,
         2 FREE_AIR              FLOAT DEC,
      2 TORRAIN_CORRECTION       FLOAT DEC,
         2 ID                    CHAR (5);



      R=0.01745329;
      N=0;
      XMIN = 10000.0;
      YMIN = 10000.0;
      YMAX = -1;
      XMAX = -1;
```

```
1
NEXT_CARD:
      GET EDIT (ID) (COL(1),A(5));
      GET LIST (X,Y,ELEVATION,GRAV,B_AN)      ;
      IF XMAX  < X THEN XMAX = X;
      IF XMIN > X THEN XMIN = X;
      IF YMIN > Y THEN  YMIN = Y;
      IF YMAX  < Y THEN YMAX = Y;
      GET LIST (TORRAIN_CORRECTION);
      N=N+1;
      B_AN=-ABS(B_AN);
      LAT = ((Y/15.28)*0.875+47.125)*R;
      FREE_AIR=(GRAV+980000.0)+0.09406*ELEVATION;
      THEORY=978049.0*(1.0+0.0052884*(SIN(LAT)*SIN(LAT))
      -0.0000059*(SIN(2.0*LAT)*SIN(2.0*LAT)));
      FREE_AIR= FREE_AIR-THEORY;
      LAT=LAT/R;
      XEXTRA=(Y/15.28)*0.2;
      LONG =121.5-(X/(11.92-XEXTRA));
      PUT SKIP  EDIT (ID,X,Y,LAT,LONG,GRAV,B_AN,ELEVATION,FREE_AIR,
      TORRAIN_CORRECTION)
      (A(5),9(F(10,2)) );
      WRITE FILE (OUTS) FROM (REC_OUT);
      GO TO NEXT_CARD;
```

1


```
 EOJ:
      PUT PAGE LIST (N);
      PUT SKIP EDIT ('YMIN= ',YMIN)(A,F(8,2));
      PUT SKIP EDIT ('YMAX= ',YMAX)(A,F(8,2));
      PUT SKIP (2);
      PUT SKIP EDIT ('XMIN= ',XMIN)(A,F(8,2));
      PUT SKIP EDIT ('XMAX= ',XMAX)(A,F(8,2));
      END LOADS;
//GO.SYSIN DD *
//GO.OUTS DD DSN=F0018.GRAV,DISP=OLD
```

```
1      GRID OF FIGURE 10
//IZJ     JOB (G0242,103425037),PETRIE
//  EXEC  PL1LFCG,PARM.PL1L='SM=(2,80,1)',TIME.GO=8
//PL1L.SYSIN DD *
 MOVEIT: PROC OPTIONS (MAIN);
      DCL (IJFILE) FILE OUTPUT;
      DCL (TOTAL_POINTS) FIXED BIN;
      OPEN FILE (SYSPRINT) LINESIZE(132) PAGESIZE (63) PRINT;
      DCL
      1 MASTER_REC,
        2 X_IN_INCHES          FLOAT DEC,
        2 Y_IN_INCHES          FLOAT DEC,
        2 LAT                  FLOAT DEC,
        2 LONG                 FLOAT DEC,
        2 GRAV_RAW             FLOAT DEC,
        2 BOUGUER              FLOAT DEC,
        2 ELEVATION            FIXED BIN,
        2 FREE_AIR             FLOAT DEC,
        2 CORRECTION           FLOAT DEC,
        2 ID                   CHAR (5);







      NMAX = 400;
 BEGIN;
      DCL (X(NMAX),Y(NMAX),Z(NMAX)    ) FLOAT DEC;
      DCL (DISTANCE( NMAX) ) FLOAT DEC;
      DCL (J_OUT,I_OUT) FLOAT DEC;
      DCL (   IDS(NMAX)    ) CHAR (5);
      DCL (X1(9),Y1(9),Z1(9) ) FLOAT DEC (16);
```

1


```
GET LIST (XMIN,XMAX,YMIN,YMAX,INTERVALS_IN_X);
DX = (XMAX-XMIN)/INTERVALS_IN_X;
DY = DX;
INTERVALS_IN_Y =TRUNC(  (YMAX-YMIN)/DX +0.5);
YMAX = DY*INTERVALS_IN_Y+YMIN +0.00000001;
RADIUS = SQRT ( (DY/2.0)**2+(DX/2.0)**2   );


PUT SKIP EDIT ('RANGE IN X  = ',XMIN,' TO ',XMAX)
(A,F(10,3),A,F(10,3));
PUT SKIP EDIT ('RANGE IN Y  = ',YMIN,' TO ',YMAX)
(A,F(10,3),A,F(10,3));
PUT EDIT ('   Y MAX MAY BE CHANGED  TO INSURE THAT DX=DY')(A);
PUT SKIP EDIT ('INTERVAL STEP = ',DX)(A,F(10,5));
PUT SKIP EDIT ('INTERVALS FOR X =',INTERVALS_IN_X)
(A,F(4)    );
PUT SKIP EDIT ('INTERVALS FOR Y =',INTERVALS_IN_Y)
(A,F(4)    );
PUT SKIP EDIT ('MAX MOVEMENT = ',RADIUS)(A,F(10,3));
PUT FILE (IJFILE) EDIT (XMIN,XMAX,YMIN,YMAX,DX,INTERVALS_IN_X,
INTERVALS_IN_Y)
(7(  F(10,5)  ),2(  F(7)  )       );
PUT FILE (IJFILE) EDIT (' ')(COL(80),A);
/* DO THE ABOVE TO ALLOW FOR FORTRAN  4 READ */
PUT PAGE;
```

1

```
CALL READ_IN_DATA;


CALL WRITE_GRIDED_DATA;


/* THATS IT   ALL DONE */
```

```
1
 READ_IN_DATA: PROC;
      ON ENDFILE (MASTER) GO TO CONTINUE;
      I=0;
 NEXT_RECORD:
      READ FILE (MASTER) INTO (MASTER_REC);
      I=I+1;
      X(I)= X_IN_INCHES - XMIN;
      Y(I)= Y_IN_INCHES -YMIN;
      Z(I)= BOUGUER+CORRECTION;
      IDS (I)= ID;
      GO TO NEXT_RECORD;
 CONTINUE:
      TOTAL_POINTS=I;

      END READ_IN_DATA;
```

```
1
WRITE_GRIDED_DATA: PROC;
     YMAX=YMAX-YMIN;
     XMAX=XMAX-XMIN;
     XMIN=0.0;
     YMIN=0.0;
     /* REMOVE ALL POINTS OUTSIDE BOUNDARIES */
     I=1;
     DO WHILE ( I<= TOTAL_POINTS) ;
        /* FIRST MOVE POINTS JUST OUT SIDE THE BOUNARY IN */
        DX2=DX/2.0;
        DY2=DY/2.0;
        IF X(I) < XMIN /* BUT ALSO */ & X(I) >XMIN-DX2 THEN X(I)=XMIN;
        IF Y(I) < YMIN /* BUT ALSO */ & Y(I) >YMIN-DY2 THEN Y(I)=YMIN;
        IF X(I) > XMAX & X(I) <  XMAX+DX2 THEN X(I)=XMAX;
        IF Y(I) > YMAX & Y(I)<  YMAX+DX2 THEN Y(I)=YMAX;

        IF X(I) < XMIN |X(I) > XMAX|Y(I) < YMIN|Y(I) > YMAX THEN DO;
        PUT SKIP LIST ('OUT SIDE DATA =',X(I), Y(I),Z(I),IDS(I)    );
          X(I) = X(TOTAL_POINTS);
          Y(I) = Y(TOTAL_POINTS);
        Z(I)= Z(TOTAL_POINTS);
        IDS(I)= IDS(TOTAL_POINTS);
          TOTAL_POINTS = TOTAL_POINTS -1;
          END;
        ELSE I= I+1;
     END;   /* OF WHILE LOOP */


     /* MOVE POINTS TO NEAREST GRID POINT */
     I=1;
     DO WHILE(I<= TOTAL_POINTS );
        /* FIND NEAREST GRID POINT */
        I_OUT =TRUNC(X(I)/DX);
        J_OUT =TRUNC(Y(I)/DY);
        IF ABS(I_OUT*DX-X(I))>ABS((I_OUT+1)*DX-X(I)) THEN
          I_OUT = I_OUT+1;
        IF ABS(J_O T*DY-Y(I))>ABS((J_OUT+1)*DY-Y(I)) THEN
          J_OUT = J_OUT+1;

        XC = I_OUT*DX;
        YC= J_OUT*DY;
     /* FIND ALL POSSIBLE DISTANCES TO GRID POINT */
        DO II=1 TO TOTAL_POINTS;
               DISTANCE (II) = SQRT((X(II)-XC   )**2+(Y(II)-YC   )**2);
               END;

        /* NOW THAT YOU HAVE FOUND ALL POSSIBLE DISTANCES FIND THE CLOSE ONES*/
        DO K=1 TO 9;
          DIST_MIN = 9999999;
          DO II=1 TO TOTAL_POINTS;
            IF DISTANCE(II) < DIST_MIN THEN DO;
              DIST_MIN = DISTANCE(II);
              X1(K) = X(II);
              Y1(K) = Y(II);
              Z1(K) = Z(II);
              I_POINT     = II;
              END;
            END;
```

```
      DISTANCE(I_POINT      )=999999999;
      END;  /* OF K LOOP */

    Z_OUT = AVE  (XC,YC,X1,Y1,Z1);

   /* ADD 1 FOR FORTRAN 4 MATRIX NOTATION */
   J_OUT=J_OUT +1;
   I_OUT=I_OUT+1;
      /* WRITE RECORD  HERE */
   PUT FILE (IJFILE) EDIT (I_OUT,J_OUT,Z_OUT)(F(4),F(4),F(8,1));

   PUT  EDIT (I_OUT,J_OUT,X(I),Y(I) )(F(12,2));
   PUT EDIT (IDS(I))(A(5));
     I = I+1;
   END; /* OF WHILE LOOP*/


   PUT FILE (IJFILE) EDIT (' ')(COL(01),A);
   END WRITE_GRIDED_DATA;
   END MOVEIT;
*PROCESS
```

```
1
 AVE: PROC (XC,YC,X,Y,Z);
      DCL (X(*),Y(*),Z(*)  ) FLOAT DEC (16);
      X=X-XC; Y=Y-YC;
      DCL D /* DISTANCE */ (9) FLOAT DEC (16);

      DO I=1 TO 9;
      D(I) = (X(I)*X(I) + Y(I)*Y(I)    );
         IF D(I) < 0.00001 THEN RETURN (Z(I)  );
         END;
      AVERAGE= SUM(Z/D)/SUM(1.0/D)    ;
      DIFF = Z(1)-AVERAGE;
      IF ABS(DIFF) > 2.5 THEN DO;
         PUT SKIP EDIT (X)(F(10,4));
         PUT SKIP EDIT (Y)(F(10,4));
         PUT SKIP EDIT (D)(F(10,4));
         PUT SKIP EDIT (Z)(F(10,4));
         PUT SKIP LIST ('THE ABOVE UNREASONALBLE');
         END;
      PUT SKIP EDIT (Z(1),AVERAGE,DIFF)(F(10,2));
      RETURN (AVERAGE);
      END AVE;
//GO.SYSIN DD *
0.4 13.2 0.8 13.6 60
0 15 0 15 200
//GO.MASTER DD DSN=F0018.GRAV,DISP=OLD
//GO.IJFILE DD DSN=F0229.IJZ,DISP=OLD
```

```
1       FORMAT / SYMAP OF FIGURE 10
//   EXEC   PL1LFCG,PARM.PL1L='SM=(2,80,1)'
//PL1L.SYSIN DD *
 TRANS: PROC OPTIONS (MAIN);
       DCL IJZ INPUT;
       ON ENDFILE (IJZ)  STOP;
       DCL CARD CHAR (80);
 NEXTONE:
       GET FILE (IJZ) EDIT (CARD)(A(80));
       PUT SKIP LIST (CARD);
       GO TO NEXTONE;
       END TRANS;
//GO.IJZ DD DSN=F0229.IJZ,DISP=SHR
// EXEC PL1LFCLG,PARM.PL1L='SM=(2,80,1)'
//PL1L.SYSIN DD *
 TRANS: PROC OPTIONS (MAIN);
       /* READ I J Z FILE  TO FORM INPUT TO  SYMAP */
       DCL IJZ INPUT;
       ON ENDFILE (IJZ)   GO TO CONTINUE;
       DCL SYMAP OUTPUT;
       DCL(XI(1000),YJ(1000),Z(1000)) FLOAT DEC;
       GET FILE (IJZ) LIST (XMIN,XMAX,YMIN,YMAX,CELL_SIZE,INX,INY);
       PUT SKIP EDIT (INX,INY)(F(5));
```

1


```
      I=1;
 NEXT:
      GET FILE (IJZ)         LIST (XI(I),YJ(I),Z(I));
      I=I+1;
      GO TO NEXT;
 CONTINUE:
      ITOTAL = I-1;
```

```
1
      /* DO B DATA POINTS  */
      PUT
      EDIT ('B-DATA POINTS')(COL(1),A);
      PUT FILE (SYMAP)
      EDIT ('B-DATA POINTS')(COL(1),A);
      DO I=1 TO ITOTAL;
         PUT
         EDIT (XI(I),YJ(I))(COL(11),F(10,1),F(10,1)    );
      PUT FILE (SYMAP)
         EDIT (XI(I),YJ(I))(COL(11),F(10,1),F(10,1)    );
         END;


      PUT
      EDIT ('99999')(COL(1),A);
      PUT FILE (SYMAP)
      EDIT ('99999')(COL(1),A);
```

1


```
/* NOW DO E VALUES */
PUT
EDIT ('E-VALUES                    ')(COL(1),A);
PUT FILE (SYMAP)
EDIT ('E-VALUES                    ')(COL(1),A);
DO I=1 TO ITOTAL;
   PUT
   EDIT (Z(I))(COL(11),F(10,1)     );
PUT FILE (SYMAP)
   EDIT (Z(I))(COL(11),F(10,1)     );
   END;

PUT
EDIT ('99999')(COL(1),A);
PUT FILE (SYMAP)
EDIT ('99999')(COL(1),A);
```

1


```
/* NOW DO F PACKAGE */
PUT
EDIT ('F-MAP')(COL(1),A);
PUT FILE (SYMAP)
EDIT ('F-MAP')(COL(1),A);
DO IKJ=1 TO 3;
PUT
EDIT ('C')(COL(1),A);
PUT FILE (SYMAP)
EDIT ('C')(COL(1),A);
END;
XV=(INX+2)/10.0;
YH=(INY+2)/10.0;
PUT SKIP
EDIT ('1',XV,YH)(COL(5),A,COL(11),F(10,1),F(10,1));
PUT SKIP FILE (SYMAP)
EDIT ('1',XV,YH)(COL(5),A,COL(11),F(10,1),F(10,1));
R#X=INX+2.0;
R#Y=INY+2.0;
XLOW= 0.0;
YLOW= 0.0;
PUT SKIP
EDIT ('2',XLOW,YLOW,R#X,R#Y)(COL(5),A,COL(11),4(    F(10,1)  )    );
PUT SKIP FILE (SYMAP)
EDIT ('2',XLOW,YLOW,R#X,R#Y)(COL(5),A,COL(11),4(    F(10,1)  )    );
TEN=10.0;
PUT SKIP
EDIT ('15',TEN,TEN)(COL(4),A,COL(11),F(10,1),F(10,1)  );
PUT SKIP FILE (SYMAP)
EDIT ('15',TEN,TEN)(COL(4),A,COL(11),F(10,1),F(10,1)  );
PUT SKIP
EDIT ('21')(COL(4),A);
PUT SKIP FILE (SYMAP)
EDIT ('21')(CCL(4),A);
PUT
EDIT ('99999' )(CCL(1),A);
PUT FILE (SYMAP)
EDIT ('99999' )(COL(1),A);
PUT
EDIT ('999999')(COL(1),A);
PUT FILE (SYMAP)
EDIT ('999999')(COL(1),A);
```

```
      END TRANS;
//GO.IJZ DD DSN=F0229.IJZ,DISP=SHR
//GO.SYMAP   DD DSN=&&CARDS,UNIT=2314,DISP=(NEW,PASS),SPACE=(TRK,30),
//    DCB=(BLKSIZE=7200,LRECL=80,DSORG=PS,RECFM=FB)
// EXEC SYMAP,TIME.GO=20
//GO.FT08F001 DD DSN=G0180.RAW,DISP=OLD,VOL=SER=HUX003,
//    SPACE=(CYL,(1,1)),UNIT=2314,
//     DCB=(BLKSIZE=804,LRECL=80,RECFM=VBS)
//GO.FT05F001  DD DSN=&&CARDS,DISP=(OLD,PASS)
//FORT.SYSIN DD *
C     TRANSLATE UNFORMATED CORE IMAGE I/O TO FORMATED I/O
C     TO GIVE EASY PL/1 INPUT;
      DIMENSION A (130)
C
      READ (8) NROW,NCOL
      WRITE (9,100) NROW,NCOL
      WRITE (6,100) NROW,NCOL
 100  FORMAT (I10,I10)
      DO 16 J=1 ,  NROW
      READ (8) (A(I),I=1,NCOL)
      WRITE (6,103) (A(I),I=1,18)
      WRITE (9,102) (A(I),I=1,NCOL)
 102  FORMAT (130F7.1)
 103  FORMAT (1X   ,18F7.1    )
 101  FORMAT (130F7.1)
 16   CONTINUE
      END
//GO.FT08F001  DD DSN=G0180.RAW,DISP=SHR
//GO.FT09F001  DD      DSN=G0180.FORT,DISP=OLD,
//    SPACE=(CYL,(1,1)),VOL=SER=HUX003,
//    UNIT=2314,DCB=(BLKSIZE=6370,LRECL=910,DSORG=PS,RECFM=FB)
```

```
1       SHEET OF FIGURE 10
//INT      JOB (G0180,539509925),PETRIE,CLASS=B
// EXEC FORTGCG
//   EXEC  PL1LFCG,PARM.PL1L='SM=(2,80,1)',TIME.GO=25
//PL1L.SYSIN DD *
 INTER: PROC OPTIONS (MAIN);
      /* INTERPOLATION USING A FOUTH ORDER DIFFERENTIAL */
      /* EQUATION IN FINITE DIFFERENCE FORM GIVEN BY */
      /* I.C. BRIGGS (GEOPHYSICS,1974, PAGE 39) */
      /* ALSO SEE I.K. CRAIN, GEO EXPLORATION 8(1970). 71 - 86 */
```

1


```
DCL (IJZFILE) INPUT;
DCL (GUESS) FILE;



GET FILE (GUESS) LIST (INTX,INTY);
PUT SKIP LIST (INTX,INTY);
COUNTUR_VALUES = 5.0;
COUNTUR_VALUE = COUNTUR_VALUE/100.0;
I_TOTAL = 0;
```

```
BEGIN;
     ON ENDFILE (IJZFILE) GO TO INTERPOLATION;




     DCL U(INTX,INTY) FLOAT DEC (16);
     DCL DATA_FLAG BIT (INTX*INTY);
     DCL DATA_POINT  BIT (1);


     DO I=1 TO INTX*INTY;
        SUBSTR( DATA_FLAG,I,1) = '0'B;  END;
     CALL LIST_FLAGS;






     DO I=1 TO INTX;
        GET        FILE (GUESS) EDIT ( (U(I,J) DO J=1 TO INTY)  )
        ( COL(1),(INTY)(F(7,1)    )     );
        END;
```

```
1/*   READ IN RAW DATA AND FIND THE NEAREST GRID POINT */
      GET FILE (IJZFILE) LIST (XMIN,XMAX,YMIN,YMAX,CELL_SIZE,IJXN,IJYM);
      PUT SKIP           LIST (XMIN,XMAX,YMIN,YMAX,CELL_SIZE,IJXN,IJYM);

 NEXT_CARD:
      GET FILE (IJZFILE) LIST (I_IN,J_IN,Z_IN);
      PUT SKIP EDIT (I_IN,J_IN,Z_IN)(F(10,3));
      U(I_IN,J_IN) = Z_IN ;
      CALL SET_FLAG (I_IN,J_IN);

      GO TO NEXT_CARD;
```

```
1
 INTERPOLATICN:
      CALL LIST_FLAGS;

      PUT PAGE;
      DO I=1 TO INTX;
      PUT SKIP;
      DO J=1 TO INTY;
         PUT EDIT ( U(I,J))(F(10,3));             END;END;
      PUT PAGE;
```

```
1
NEXT_INTERPOLATION:
     DIFF_MAX = -1000000.0;


   DO I=1 TO INTX ;
     DO J=1 TO INTY;
     UNEW = 9999999999.99999;
     ISET = (I-1)*INTY + J;
     DATA_POINT = SUBSTR( DATA_FLAG,ISET,1) ;
     IF DATA_POINT THEN DO;
        GO TO SKIP_CHANGE;
        END;




     IF I > 2 & I < INTX-1 & J > 2 & J < INTY -1 THEN DO;
     /* IE INSIDE THE BOUNDARY */
        UNEW   = -(U(I+2,J)+U(I,J+2)+U(I-2,J)+U(I,J-2)+
        2.0*(U(I+1,J+1)+U(I-1,J+1)+U(I+1,J-1)+U(I-1,J-1)   )-
        8.0*(U(I+1,J)+U(I-1,J)+U(I,J+1)+U(I,J-1)   )   )/20.0;
        GO TO SKIP_TESTING; END;
```

```
1       /* CORNER ONLY */
        IF J=1 & I=1 THEN DO; /* S W COR */
           UNEW = -(
           U(I,J+2)+U(I+2,J)
           -2.0*(U(I,J+1)+U(I+1,J)  )             )/2.0;
           GO TO SKIP_TESTING; END;

        IF I = 1     & J = INTY THEN DO; /* N W COR */
           UNEW = -(
           U(I,J-2) + U(I+2,J)
           - 2.0*(  U(I,J-1)+U(I+1,J)  )          )/2.0;
           GO TO SKIP_TESTING; END;

        IF I = INTX & J = INTY THEN DO; /* N E COR */
           UNEW = -(
           U(I,J-2)+ U(I-2,J)
           -2.0 *(U(I,J-1) +U(I-1,J)   )          )/2.0;
           GO TO SKIP_TESTING; END;

        IF I = INTX & J =1 THEN DO; /* S E COR */
           UNEW = -(
           U(I,J+2)+U(I-2,J)
           -2.0*( U(I,J+1)+U(I-1,J)   )            )/2.0;
           GO TO SKIP_TESTING; END;
```

```
1       /* DIAGONAL ONLY */
        IF I=2 & J=2 THEN DO; /* S W DIA */
           UNEW = -(
           U(I,J+2)+U(I+2,J)+U(I-1,J+1)+U(I+1,J-1) + 2.0*U(I+1,J+1)
           -8.0*(U(I,J+1)+U(I+1,J)   )
           -4.0*(U(I,J-1)+U(I-1,J)    )         )/18.0;
           GO TO SKIP_TESTING; END;


        IF I=2 & J = INTY -1 THEN DO; /* N W DIA */
           UNEW = -(
           U(I,J-2)+U(I+2,J)+U(I-1,J-1)+U(I+1,J+1)+2.0*U(I+1,J-1)
           -8.0*(    U(I,J-1) + U(I+1,J)    )
           -4.0*(  U(I,J+1)+U(I-1,J)    )              )/18.0000;
           GO TO SKIP_TESTING; END;


        IF I= INTX-1 & J = INTY -1 THEN DO; /* N E DIA */
           UNEW = -(
           + U(I-2,J)+U(I+1,J-1)+U(I-1,J+1)+2.0*U(I-1,J-1) + U(I,J-2)
           -8.0* (U(I,J-1)+U(I-1,J)    )
           - 4.0*(  U( I,J+1)+U(I+1,J)    )             )/18.0;
           GO TO SKIP_TESTING; END;

        IF I= INTX-1 & J=2 THEN DO; /* S E DIA */
           UNEW = -(
           U(I,J+2)+U(I-2,J)+U(I+1,J+1)+U(I-1,J-1) +2.0*U(I-1,J+1)
           -8.0*(  U(I,J+1)   +U(I-1,J)     )
           -4.0*(  U(I,J-1)+U(I+1,J)     )              )/18.0000;
           GO TO SKIP_TESTING; END;
```

```
1       /* NEXT TO CORNER EAST OR WEST */
        IF J=1 & I=2 THEN DO; /* NEXT S W COR EAST */
           UNEW = -(
           U(I,J+2) +U(I+1,J+1)+U(I-1,J+1)+U(I+2,J) -2.0*U(I-1,J)
           -4.0*(U(I+1,J) + U(I,J+1)     )              )/6.0;
           GO TO SKIP_TESTING; END;

        IF J=1 & I = INTX-1 THEN DO; /* NEXT S E COR WEST */
           UNEW = -(
           U(I,J+2)+U(I-1,J+1) +U(I+1,J+1) +U(I-2,J) -2.0*U(I+1,J)
           -4.0*(U(I-1,J)+U(I,J+1)   )            )/6.0;
           GO TO SKIP_TESTING; END;

        IF J=INTY & I=INTX-1 THEN DO; /* NEXT N E COR WEST */
           UNEW = -(
           U(I,J-2)+U(I-1,J-1)+U(I+1,J-1)+U(I-2,J)-2.0*U(I+1,J)
           -4.0*( U(I-1,J)+U(I,J-1)   )            )/6.0;
           GO TO SKIP_TESTING; END;

        IF J = INTY & I= 2 THEN DO; /* NEXT  N W COR EAST */
           UNEW = -(
           U(I,J-2)+U(I+1,J-1) +U(I-1,J-1)+U(I+2,J) -2.0*U(I-1,J)
           -4.0*(  U(I+1,J)+U(I,J-1)    )                  )/6.0;
           GO TO SKIP_TESTING; END;
```

```
1       /* NEXT TO CORNER NORTH OR SOUTH */
        IF I=1 & J=2 THEN DO; /* NEXT S W COR NORTH */
          UNEW = -(
           U(I+2,J)+U(I+1,J+1)+U(I+1,J-1) +U(I,J+2)-2.0*U(I,J-1)
           -4.0*(  U(I,J+1)+U(I+1,J)     )                  )/6.0;
           GO TO SKIP_TESTING; END;

        IF J=2 & I = INTX THEN DO; /* NEXT S E COR NORTH */
           UNEW = -(
           U(I-2,J)+U(I-1,J+1)+U(I-1,J-1) +U(I,J+2)-2.0*U(I,J-1)
           -4.0*( U(I,J+1)+U(I-1,J)    )                  )/6.0;
           GO TO SKIP_TESTING; END;

        IF I= INTX & J= INTY-1 THEN DO; /* NEXT N E COR SOUTH */
           UNEW = -(
           U(I-2,J)+U(I-1,J-1)+U(I-1,J+1)+U(I,J-2)-2.0*U(I,J+1)
           -4.0*( U(I,J-1)+U(I-1,J)  )                     )/6.0;
           GO TO SKIP_TESTING; END;

        IF I=1 & J = INTY-1 THEN DO; /* NEXT N W COR SOUTH */
           UNEW = -(
           U(I+2,J)+U(I+1,J-1)+U(I+1,J+1)+U(I,J-2)-2.0*U(I,J+1)
           -4.0*(  U(I,J-1)+U(I+1,J)   )                  )/6.0;
           GO TO SKIP_TESTING; END;
```

```
1     /* EDGES + 1 */
      IF J =2 & I> 2 & I < INTX-1 THEN DO;
      /* I.E. SOUTH +1 */
         UNEW = -(
         U(I-2,J) + U(I+2,J) + U(I,J+2)
         + 2.0*(  U(I-1,J+1)+U(I+1,J+1)       ) +
         U(I-1,J-1)+U(I+1,J-1)
         -8.0*( U(I-1,J)+U(I,J+1)+U(I+1,J)    )
         -4.0*U(I,J-1)                       )/19.0;
         GO TO SKIP_TESTING; END;

      IF J = INTY -1 & I>2 & I< INTX-1 THEN DO;
      /* NORTH -1 */
         UNEW  = -(
         U(I-2,J)+U(I+2,J) + U(I,J-2)   +
         + 2.0*(  U(I-1,J-1)+U(I+1,J-1)       )
         + U(I-1,J+1) + U(I+1,J+1)
       -8.0*(  U(I-1,J)+U(I,J-1) +U(I+1,J)    )
         - 4.0* U(I,J+1)                       )/19.000;
         GO TO SKIP_TESTING; END;

      IF I=2 & J> 2 & J < INTY-1 THEN DO;
      /* WEST + 1 */
         UNEW = -(
         U(I,J+2) +U(I,J-2)+U(I+2,J)
         + 2.0*(U(I+1,J+1) +U(I+1,J-1)     )
         + U(I-1,J+1) + U(I-1,J-1)
         -8.0 *(  U(I,J+1)+U(I+1,J) + U(I,J-1)      )
         - 4.0*U(I-1,J)       )/19.00;
         GO TO SKIP_TESTING; END;

      IF I = INTX-1 & J  > 2 & J < INTY -1 THEN DO;
      /* EAST -1 */
         UNEW = -(
         U(I,J-2)+U(I,J+2)+U(I-2,J)
         + 2.0*(  U(I-1,J-1)+U(I-1,J+1))
         + U(I+1,J-1)+U(I+1,J+1)
         - 8.0*(  U(I,J-1)+U(I-1,J) +U(I,J+1)   )
         -4.0* U(I+1,J)       )/19.0000;
         GO TO SKIP_TESTING; END;
```

```
1    /* EDGES ONLY */
     IF J =1 & I> 2 & I < INTX-1 THEN DO;
     /* SOUTH */
        UNEW = -(
        U(I-2,J)+U(I+2,J)+U(I,J+2)+U(I-1,J+1)+U(I+1,J+1)
        -4.0*( U(I-1,J)+U(I,J+1)+U(I+1,J) )
        )/7.0;
        GO TO SKIP_TESTING; END;

     IF J = INTY     & I>2 & I< INTX-1 THEN DO;
     /* NORTH */
        UNEW = -(
        U(I-2,J)+U(I+2,J)+U(I,J-2)+U(I-1,J-1)+U(I+1,J-1)
        -4.0*( U(I-1,J)+U(I,J-1)+U(I+1,J) )  )/7.0;
        GO TO SKIP_TESTING; END;

     IF I=1 & J> 2 & J < INTY-1 THEN DO;
     /* WEST */
        UNEW = -(
        U(I,J-2)+U(I,J+2) +U(I+2,J)+U(I+1,J+1)+U(I+1,J-1)
        -4.0*(  U(I,J+1)+U(I+1,J)+ U(I,J-1)   )      )/7.0;
        GO TO SKIP_TESTING; END;

     IF I = INTX   & J  > 2 & J < INTY -1 THEN DO;
     /* EAST */
        UNEW = -(
        U(I,J-2) + U(I,J+2)+U(I-2,J) +U(I-1,J-1)+U(I-1,J+1)
        -4.0* ( U(I,J-1)+U(I-1,J) + U(I,J+1)  )  )/7.0;
        GO TO SKIP_TESTING; END;

     PUT SKIP LIST  ('LCLOST IT HERE',I,J);
```

```
1
    SKIP_TESTING:
      IF ABS (U(I,J)-UNEW) > DIFF_MAX THEN  DO;
         DIFF_MAX = ABS (U(I,J)-UNEW)    ;
         IMAX = I;
         JMAX = J;  END;
      U(I,J) = UNEW;
 SKIP_CHANGE:
    END; /* OF I LOOP */
    END; /* OF J LOOP */

      ITOTAL = ITOTAL +1;
      IF MOD(ITOTAL,10 )= 0 THEN PUT LIST (ITOTAL,DIFF_MAX ,IMAX,JMAX);
      IF MOD(ITOTAL,80 )= 0 THEN DO;
         PUT PAGE LIST ('DUPING TO DISK FILE FOR NEXT TIME');
         GO TO DUMPIT;  END;
      IF DIFF_MAX <  COUNTUR_VALUE & ITOTAL > 10 THEN GO TO DUMPIT;
      GO TO NEXT_INTERPOLATION;
```

1


```
SET_FLAG: PROC (II,JJ);
      ISET = (II-1)*INTY + JJ;
      SUBSTR(DATA_FLAG ,ISET,1) = '1'B;
      END SET_FLAG;
```

```
1
 DUMPIT:
      PUT PAGE;
      CALL PUT_DATA;
      CLOSE FILE (GUESS);
      OPEN FILE (GUESS) OUTPUT;

      PUT FILE (GUESS) EDIT (INTX,INTY)(2(F(10)));

      DO I=1 TO INTX;
         PUT        FILE (GUESS) EDIT ( (U(I,J) DO J=1 TO INTY)   )
         ( COL(1),(INTY)(F(7,1)    )      );
         END;

      CLOSE FILE (GUESS);




 PUT_DATA: PROC;
      PUT SKIP (5);
      DO I=1 TO INTX;
      PUT SKIP;
      DO J=1 TO INTY;
         PUT EDIT ( U(I,J))(F(10,3));
         END;
         END;
       PUT SKIP (5);
      END PUT_DATA;
```

```
1
 LIST_FLAGS: PROC;

      PUT PAGE LIST (' FLAGES=');
      DO J=1 TO INTY;
    PUT SKIP (2);
    NCOL = 1;
      DO I=1 TO INTX;
      ISET = (I-1)*INTY +J;
      DATA_POINT = SUBSTR(DATA_FLAG,ISET,1);
      IF DATA_POINT THEN PUT EDIT ('D')(COL(NCOL),A);
      ELSE PUT EDIT ('N')(COL(NCOL),A);
      NCOL = NCOL +1;
      END; END;
    END LIST_FLAGS;
      END; /* OF  MAIN BEGIN BLOCK */
      END INTER;
//GO.GUESS DD DSN=G0180.FORT,DISP=SHR
//GO.IJZFILE DD DSN=F0229.IJZ,DISP=SHR
//
```

```
1      CONTOUR OF FIGURE 10
//PLCCON JOB (R0022,539509925),PETRIE,CLASS=B
//  EXEC WFPLOT,TIME.GO=8
//FORT.SYSIN DD *
      LOGICAL OUTSID
      DIMENSION XP(130),YP(130),ZP(130,130),X(300),Y(300)
      CALL LIMITS (30.0,30.0)
      CALL PLCTS
      CALL FACTOR (0.7)
C
C
C
      READ (2,100) XMIN,XMAX,YMIN,YMAX,CELL
 100  FORMAT (5F10.5)
      WRITE (6,101) XMIN,XMAX,YMIN,YMAX,CELL
 101  FORMAT (1X,5F10.5)
C
C
C
C

C
C     NOW DRAW IN MAP
 103  CONTINUE
      NP = MAPCOR  (X,Y)
      IF (NP .EQ. 0) GO TO 600
      OUTSID  = .TRUE.
C     AT END OF MAP CATA  READ IN  GRAVITY DATA
C
C
      DO 200 I=1,NP
         XX=X(I)
         YY= Y(I)
C        IF INSIDE  OF BOUNDS THEN PLOT POINT STARTING AT 201
         IF(XX.GT.XMIN.AND.XX.LT.XMAX.AND.YY.GT.YMIN.AND.YY.LT.YMAX)
     1   GO TO  201
C        ELSE MARK  CUT OF BOUNDS AND TRY A NEW POINT
         OUTSID  =  .TRUE.
         GO TO 200
 201     CONTINUE
         XX=XX-XMIN
         YY=YY-YMIN
         IF (OUTSID ) CALL PLOT (XX,YY,3)
         IF(.NOT.OUTSID ) CALL PLOT (XX,YY,2)
         OUTSID = .FALSE.
 200     CONTINUE
C
C     GET NEXT LINE OF MAP COORDINATES
      GOTO 103
C
C
C
C
C
C     READ IN GRAVITY VALUES
 600  CONTINUE
      READ (8,1313) NX,NY
 1313 FORMAT (I10,I10)
      WRITE (6,500) NX,NY
```

```
 500   FORMAT (1H  ,I3,I3)
C
       DO 601 J=1,NX
       READ (8,1314) (ZP  (J,I),I=1,NY)
 1314  FORMAT (130F7.1)
 601      CONTINUE
       DO 699 J=1,NX
       DO 699 I=1,NY
          ZP(J,I)= ABS(ZP(J,I))
 699      CONTINUE
C
C
C      SET X AND Y VALUES FOR PLOT
       DO 602 I=1 ,NX
          XP(I)=(I-1)*CELL
 602      CONTINUE
C
       DO 604 I=1,NY
          YP(I)=(I-1)*CELL
 604      CONTINUE
C
C
C
C      NOW  READ IN AND THEN COUNTOUR VALUES
C
C
C
 700   CONTINUE
       READ(5,800,END=999) CN
       WRITE (6,801)CN
 800   FORMAT (F10.2)
 801   FORMAT (1H    ,F10.2)
       CALL CNTOUR(XP,NX,YP,NY,ZP,130,CN,3.0,CN)
       GO TO 700
C
C
C
C
 999   CONTINUE
       CALL PLOT (0.0,0.0,999)
       END
       FUNCTION MAPCOR (X,Y)
       DIMENSION X(300),Y(300)
C      READ MAP FILE AND STORE CORRDINATES IN X AND Y ARRAY
C
C
C
C
       NTOTAL = 0
       NT=1
C
C
       DO 100 I=1,60
          NEND=NT+4
          READ (11,101,END=200)(X(J),Y(J),J=NT,NEND)
 101      FORMAT (5(F8.2,F8.2))
          DO 102 II=NT,NEND
             IF (X(II) .LT. 0.0) GO TO 200
             NTOTAL=NTOTAL+1
 102         CONTINUE
```

```
        NT=NT+5
 100    CONTINUE
C
C
C
 200  CONTINUE
      WRITE (6,300) NTOTAL
 300  FORMAT (1H    ,I3)
      MAPCOR = NTOTAL
      RETURN
      END
//GO.FT02F001 DD DSN=F0229.IJZ,DISP=SHR
//GO.FT11F001 DD DSN=F0229.MAPS,DISP=SHR
//GO.FT08F001 DD DSN=G0180.FORT,DISP=SHR
//GO.SYSIN DD *
65.0
70.0
75.0
80.0
85.0
90.0
95.0
```

```
1      CONTOUR2 OF FIGURE 10
//CONFIL JOB (G0180,539509925),PETRIE,CLASS=B
//  EXEC WFPLOT,TIME.GO=8
//FORT.SYSIN DD *
      LOGICAL OUTSID
C     CONTOUR VALUES FORM    FILTERING
      DIMENSION XP(130),YP(130),ZP(130,130),X(300),Y(300)
      CALL LIMITS (30.0,30.0)
      CALL PLOTS
      CALL FACTOR (0.7)
C
C
C
      READ (8) NX,NY, XMIN,XMAX,YMIN,YMAX,CELL
 100  FORMAT (5F10.5)
      WRITE (6,101) XMIN,XMAX,YMIN,YMAX,CELL
 101  FORMAT (1X,5F10.5)
      WRITE (6,500) NX,NY
 500  FORMAT (1H  ,I3,I3)
C
C
C
C

C
C     NOW DRAW IN MAP
 103  CONTINUE
      NP = MAPCOR  (X,Y)
      IF (NP .EQ. 0) GO TO 600
      OUTSID  = .TRUE.
C     AT END OF MAP DATA  READ IN  GRAVITY DATA
C
C
      DO 200 I=1,NP
         XX=X(I)
         YY= Y(I)
C        IF INSIDE  OF BOUNDS THEN PLOT POINT STARTING AT 201
         IF(XX.GT.XMIN.AND.XX.LT.XMAX.AND.YY.GT.YMIN.AND.YY.LT.YMAX)
     1   GO TO  201
C        ELSE MARK  OUT OF BOUNDS AND TRY A NEW POINT
         OUTSID  = .TRUE.
         GO TO 200
 201     CONTINUE
         XX=XX-XMIN
         YY=YY-YMIN
         IF (OUTSID ) CALL PLOT (XX,YY,3)
         IF(.NOT.OUTSID ) CALL PLOT (XX,YY,2)
         OUTSID = .FALSE.
 200     CONTINUE
C
C     GET NEXT LINE OF MAP COORDINATES
      GOTO 103
C
C
C
C
C
C     READ IN GRAVITY VALUES
 600  CONTINUE
```

```
C
      DO 601 J=1,NX
         READ(8)( ZP(J,I),I=1,NY)
 601     CONTINUE
      DO 699 J=1,NX
      DO 699 I=1,NY
         ZP(J,I)= ABS(ZP(J,I))
 699     CONTINUE
C
C
C     SET X AND Y VALUES FOR PLOT
      DO 602 I=1 ,NX
         XP(I)=(I-1)*CELL
 602     CONTINUE
C
      DO 604 I=1,NY
         YP(I)=(I-1)*CELL
 604     CONTINUE
C
C
C
C     NOW  READ IN AND THEN COUNTOUR VALUES
C
C
C
 700  CONTINUE
      READ(5,800,END=999) CN
      WRITE (6,801)CN
 800  FORMAT (F10.2)
 801  FORMAT (1H     ,F10.2)
      CALL CNTOUR(XP,NX,YP,NY,ZP,130,CN,3.0,CN)
      GO TO 700
C
C
C
C
 999  CONTINUE
      CALL PLOTX (ZP,NX,NY, 130,130)
      CALL PLOT (0.0,0.0,999)
      END
      FUNCTION MAPCOR (X,Y)
      DIMENSION X(300),Y(300)
C     READ MAP FILE AND STORE CORRDINATES IN X AND Y ARRAY
C
C
C
C
      NTOTAL = 0
      NT=1
C
C
      DO 100 I=1,60
         NEND=NT+4
         READ (11,101,END=200)(X(J),Y(J),J=NT,NEND)
 101     FORMAT (5(F8.2,F8.2))
         DO 102 II=NT,NEND
           IF (X(II) .LT. 0.0) GO TO 200
           NTOTAL=NTOTAL+1
 102       CONTINUE
         NT=NT+5
```

```
 100      CONTINUE
C
C
C
 200   CONTINUE
       WRITE (6,300) NTOTAL
 300   FORMAT (1H    ,I3)
       MAPCOR = NTOTAL
       RETURN
       END
       SUBROUTINE PLOTX(Y,NR,MC,NR1,MC1)
C      PLOT CONTOUR MAP FORM A RECTANGULAR MATRIX OF GRID VALUES
       REAL LCINT
       DIMENSION  Y(NR1,MC1),IOUT(100),ICHAR(9)
       DATA ICHAR /1H1,1H  ,1H3, 1H  ,1H$,1H  ,1H7,1H   , 1H9/
C
C      FIND LARGEST AND SMALLEST VALUES IN MAP
C
       YMIN = Y(1,1)
       YMAX = YMIN
       DO 100 I=1,NR
       DO 100 J=1,MC
       YT = Y(I,J)
       IF (YT .LT. YMIN) YMIN = YT
       IF ( YT .GT. YMAX) YMAX = YT
 100   CONTINUE
C
C.....PRINT MAP ONE LINE AT A TIME
C
       WRITE (6,2001)
 2001 FORMAT (1H1)
       DO 101 I=1,NR
       DO 102 J=1,MC
       IF (  ABS(YMAX - YMIN) .GT. .00001) GO TO 600
       WRITE (6,500)
 500   FORMAT (4X,10HLOST IT            )
       IY = 1
       GO TO 606
 600   CONTINUE
       IY = ((Y(I,J) -YMIN)/(YMAX-YMIN))*9.0 +1.0
 606   CONTINUE
       IF (IY .GT. 9) IY =9
       IOUT (J) = ICHAR (IY)
 102   CONTINUE
       WRITE (6,2002) (IOUT(J),J=1,MC)
 2002 FORMAT(1H ,100A1)
 101   CONTINUE
       CINT = (YMAX -YMIN)/9.0
       REFC = YMIN +5.0*CINT
       WRITE (6,2003) REFC,CINT
 2003 FORMAT(1H0,4X" 22HREFERENCE COUNTOUR      ,F10.4,3X
     1 22HCOUNTOUR INTERVAL =              ,F10.4,///)
       RETURN
       END
//GO.FT08F001 DD DSN=F0229.FIL,DISP=SHR
//GO.FT11F001 DD DSN=F0229.MAPS,DISP=SHR
//GO.SYSIN DD *
-4.0
-3.5
-1.0
```

```
1     FILTER OF FIGURE 10
//PLCFIL JOB (G0180,539509925),PETRIE
// EXEC FORTGCLG,TIME.GO=7
//FORT.SYSIN DD *
      DIMENSION GRID (100,100),FILTER (20,20),AROW (130)
C
C     READ IN AREA PARAMETERS
      READ (2,100)  XMIN,XMAX,YMIN,YMAX,CELL
 100  FORMAT (5F10.5)
      WRITE (6,101) XMIN,XMAX,YMIN,YMAX,CELL
 101  FORMAT (1X,5F10.5)
C
C
C     READ IN GRAVITY
C     STARTING WITH THE SIZE OF THE ARRAY
      READ (8) NX,NY
C     READ (8,1313) NX,NY
 1313 FORMAT (I10,I10)
      WRITE (6,500) NX,NY
 500  FORMAT (2X,I4,I4)
      DO 601 J=1,NX
      READ (8) (GRID (J,I),I=1,NY)
C     READ (8,1314) (GRID(J,I),I=1,NY)
      WRITE(6,1344) (GRID(J,I),I=1,18)
 1344 FORMAT (1X,18F7.1)
 1314 FORMAT (130F7.1)
 601     CONTINUE
C
C
C
C
C
C   READ IN FILTER
C     FIRST SIZE THEN SCALE TERM
      READ (5,700) NFIL,SCALE
      WRITE (6,690) NFIL,SCALE
 690  FORMAT (1X,I3,F12.2)
 700  FORMAT (I2,F10.1)
C
C     GET FILER FORM 'BOTTOM'  TO 'TOP'
      NLOCAL = NFIL/8
      NLAST = NLOCAL*8
      NLAST1 = NLAST +1
      DO 701 I=1,NFIL
         IF (NLOCAL .EQ. 0)  GO TO 703
C        IF LESS THAN 8 ELEMENTS IN ARRAY SKIP DO LOOP
         JSTART = 1
         DO 702 K=1,NLOCAL
           JEND = JSTART +7
           READ (5,800)(FILTER(I,J),J=JSTART,JEND)
           WRITE(6,678)(FILTER(I,J),J=JSTART,JEND)
 678       FORMAT (1X, 8F10.2)
           JSTART = JSTART+8
 702       CONTINUE
 800       FORMAT (8F10.2)
 703     CONTINUE
C        IF NECCESARY READ THE REST OF THIS ROW
         IF (MOD (NFIL,8) .NE. 0) READ (5,800)(FILTER(I,J),
     1   J=NLAST1,NFIL)
```

```
         IF (MOD (NFIL,8) .NE. 0) WRITE(6,678)(FILTER(I,J),
     1   J=NLAST1,NFIL)
 701     CONTINUE
C
C
C     SCALE FILLTER ARRAY
      DO 705 I=1,NFIL
         DO 706  I=1,NFIL
           FILTER (I,J)= FILTER(I,J)*SCALE
 706       CONTINUE
 705     CONTINUE
C
C
C
      NLESS =(NFIL-1)/2
C
C     ALOW FOR EDGE EFFECTS
      XMIN = XMIN+FLOAT(NLESS)*CELL
      XMAX = XMAX-FLOAT (NLESS)*CELL
      YMAX = YMAX -FLOAT (NLESS)*CELL
      YMIN = YMIN+FLOAT(NLESS)*CELL
      NX= NX-NLESS
      NY=NY-NLESS
      ISTART=1+NLESS
      JSTART= 1+NLESS
      NXNEW= NX-NLESS
      NYNEW= NY-NLESS
C     WRITE OUT NEW PARAMETERS HERE
      WRITE (9) NXNEW,NYNEW,XMIN,XMAX,YMIN,YMAX,CELL
      WRITE (6,916) NX,NY,NLESS,NXNEW,NYNEW,XMIN,XMAX,YMIN,YMAX,CELL
 916  FORMAT (1X,5I3,5F10.3)
C
C
C
      AMIN = 9999999.9
      AMAX = -AMIN
      DO 900 I=ISTART,NX
         L=1
         DO 901 J=JSTART , NY
           AROW (L)=FILER  (GRID   ,I,J,FILTER,NFIL,NLESS)
           L=L+1
 901       CONTINUE
         NZ=26
         IF (NY .LT. NZ)NZ = NY
C        WRITE OUT THE FIRST 26 OR SO
         WRITE (6,918) (AROW(K),K=1,NZ)
 918     FORMAT (1X,26F5.0)
         WRITE (9) (AROW(K),K=1,NY)
         DO 411 K=1,NYNEW
           IF (AROW(K) .GT. AMAX)  AMAX = AROW(K)
           IF ( AROW (K) .LT. AMIN)   AMIN = AROW (K)
 411       CONTINUE
 900  CONTINUE
      WRITE (6,555) AMIN ,AMAX
 555  FORMAT (1X,2F10.2)
C
C
      STOP
      DEBUG SUBCHK
      END
```

```
      FUNCTION FILER  (GRID,I,J,FILTER,NFIL,NLESS)
      DIMENSION GRID (100,100),FILTER (20,20)
      TOTAL = 0.0
      IGRID =I-NLESS
      DO 100 II=1,NFIL
         JGRID = J-NLESS
         DO 101 JJ=1,NFIL
            TOTAL = TOTAL+GRID(IGRID,JGRID)*FILTER(II,JJ)
            JGRID = JGRID +1
 101        CONTINUE
         IGRID = IGRID +1
 100  CONTINUE
C
C
      FILER = TOTAL
      RETURN
      DEBUG SUBCHK
      END
//GO.SYSIN DD *
//GO.FT02F001 DD DSN=F0229.IJZ,DISP=SHR
//*O.FT08F001 DD DSN=G0180.FORT,DISP=SHR
//GO.FT08F001 DD DSN=G0180.RAW,DISP=SHR
//GO.FT09F001 DD DSN=F0229.FIL,DISP=OLD
//
```

```
1     FOURIER OF FIGURE 10
//FORT JOB (G0180,539509925),PETRIE
//  EXEC FORTGCLG,TIME.GO=18
//FORT.SYSIN DD *
C
C     PROGRAM TO CALCULATE THE DOUBLE FOURIER SERIES POWER SPECTRUM
C     OF DATA IN MATRIX X,WHICH HAS NR ROWS AND MC COLUMNS REPRESENTING
C     MEASURMENTS MADE AT THE NODES OF AN NR BY MC GRID
C
C
C     PROGRAM MODIFIED FROM STATISTICS AND DATA ANALYSIS IN GEOLOGY
C     ================================================================
      DIMENSION X(100,100),P(66,66),TCX(130),TSX(130)
C
C
C
C     READ  INPUT DATA MATRIX
C     READ (8) NR,MC
      READ (8,1313) NR,MC
 1313 FORMAT (I10,I10)
      WRITE (6,90) NR,MC
 90   FORMAT (1X,I3,I3,///////)
      DO 91 I=1,NR
         READ (8,1314)  (X(I,J),J=1,MC)
 1314 FORMAT (130F7.1)
 91      CONTINUE
C
C
C.....CALCULATE SOME CONSTANTS TO BE USED BY THE PROGRAM
C
      PIY=6.2831854/FLOAT(NR)
      PIX = 6.2831854/FLOAT (MC)
      R=4.0/FLOAT (NR*MC)
      READ (5,1618) NT,MT
 1618 FORMAT (I2,I2)
C     FIND AVERAGE
      SUMX = 0.0
      DO 13 I=1,NR
         DO 13 J=1,MC
            SUMX = SUMX+X(I,J)
 13      CONTINUE
C
C
C     REMOVE AVERAGE FORM ARRAY
      AVE= SUMX/FLOAT(MC*NR)
      DO 14 I=1,NR
         DO 14 J=1,MC
            X(I,J)=X(I,J)-AVE
 14      CONTINUE
      WRITE(6,1414) AVE
 1414 FORMAT (1H    ,'AVERAGE =',F10.2 )
C
C
C     FOR EACH TIME THROUGH DO LOOP 100 CALCULATE THE
C     COEFFICIENTS FOR HARMONIC (I-1),(J-1)
C
C
      DO 100 I=1,NT
      DO 100 J=1,MT
```

```
      AA=0.0
      BB=0.0
      CC=0.0
      DD=0.0
      DO 101 JJ=1,MC
         ARG=FLOAT((J-1)*(JJ-1))*PIX
         TCX(JJ)=COS(ARG)
         TSX(JJ)= SIN(ARG)
 101     CONTINUE
      DO 102 II=1,NR
         ARG=FLOAT((I-1)*(II-1))*PIY
         CY=COS(ARG)
         SY= SIN(ARG)
         DO 102 JJ=1,MC
           CX=TCX(JJ)
           SX=TSX(JJ)
           XX=X(II,JJ)
           AA=AA+XX*CY*CX
           BB=BB+XX*CY*SX
           CC=CC+XX*SY*CX
           DD=DD+XX*SY*SX
 102     CONTINUE
      RR=R
      IF (I.EQ. 1) RR=RR/2.0
      IF (J.EQ. 1) RR=RR/2.0
      PSQR  =RR*RR*(AA*AA+BB*BB+CC*CC+DD*DD)
      SQRTP=SQRT(PSQR  )
      WRITE (6,990) I,J ,PSQR,SQRTP
 990  FORMAT (1X,I4,I4,F12.2,F12.2)
 100  CONTINUE
C
C
      END
//*-.FT08F001 DD DSN=G0180.RAW,DISP=SHR
//GO.FT08F001 DD DSN=G0180.FORT,DISP=SHR
//GO.SYSIN DD *
0202
//
```

MAP KEY: Rock Units

IGNEOUS ROCKS

Tm	Yakima Basalt
Tg	Tertiary granitic rock, mostly Snoqualmie Bath.
Teoc	Diabase and gabbro
Tev	Teanaway Basalt
Tv	Tertiary volcanic rock, undivided
Ks	Mt. Stuart Batholith
Ji	Ingalls Complex

SEDIMENTARY ROCKS

Qa	Alluvium
Teru	Roslyn
Tes	Swauk
Tpog	Guye

METAMORPHIC ROCKS

Jmi	Meta-igneous rock associated with the Ingalls Complex
Jms	Meta-sedimentary rocks associated with Ingalls Complex
pJsc	Chiwaukum Schist
pJph	Easton Schist