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

Gregg M. Petrie
Western Washington University

Follow this and additional works at: https://cedar.wwu.edu/wwuet

Recommended Citation
https://cedar.wwu.edu/wwuet/783

This Masters Thesis is brought to you for free and open access by the WWU Graduate and Undergraduate Scholarship at Western CEDAR. It has been accepted for inclusion in WWU Graduate School Collection by an authorized administrator of Western CEDAR. For more information, please contact westerncedar@wwu.edu.
MASTER'S THESIS

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Western Washington University, I agree that the Library shall make its copies freely available for inspection. I further agree that extensive copying of this thesis is allowable only for scholarly purposes. It is understood, however, that any copying or publication of this thesis for commercial purposes, or for financial gain, shall not be allowed without my written permission.

Signature

Date August 4, 1978

Gregg M. Petrie
MASTER'S THESIS

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Western Washington University, I grant to Western Washington University the non-exclusive royalty-free right to archive, reproduce, distribute, and display the thesis in any and all forms, including electronic format, via any digital library mechanisms maintained by WWU.

I represent and warrant this is my original work and does not infringe or violate any rights of others. I warrant that I have obtained written permissions from the owner of any third party copyrighted material included in these files.

I acknowledge that I retain ownership rights to the copyright of this work, including but not limited to the right to use all or part of this work in future works, such as articles or books.

Library users are granted permission for individual, research and non-commercial reproduction of this work for educational purposes only. Any further digital posting of this document requires specific permission from the author.

Any copying or publication of this thesis for commercial purposes, or for financial gain, is not allowed without my written permission.

Name: Gregory Pomerleau
Signature: ____________________________
Date: 5-22-18
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.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>v</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Previous Geologic Work</td>
<td>1</td>
</tr>
<tr>
<td>General</td>
<td>1</td>
</tr>
<tr>
<td>Chiwaukum Schist</td>
<td>1</td>
</tr>
<tr>
<td>Mt. Stuart Batholith</td>
<td>3</td>
</tr>
<tr>
<td>Ingalls Complex</td>
<td>6</td>
</tr>
<tr>
<td>Swauk and Related Rocks</td>
<td>7</td>
</tr>
<tr>
<td>Purpose and Scope of Investigation</td>
<td>7</td>
</tr>
<tr>
<td>FIELD WORK</td>
<td>9</td>
</tr>
<tr>
<td>REDUCTIONS</td>
<td>11</td>
</tr>
<tr>
<td>DENSITY VALUES FROM THE MOUNT STUART BLOCK</td>
<td>12</td>
</tr>
<tr>
<td>RESULTS</td>
<td>13</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>17</td>
</tr>
<tr>
<td>Feature A</td>
<td>17</td>
</tr>
<tr>
<td>Feature B</td>
<td>17</td>
</tr>
<tr>
<td>Feature C</td>
<td>18</td>
</tr>
<tr>
<td>Feature F</td>
<td>18</td>
</tr>
<tr>
<td>Feature G</td>
<td>20</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>23</td>
</tr>
<tr>
<td>REFERENCES CITED</td>
<td>25</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>29</td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>44</td>
</tr>
<tr>
<td>APPENDIX C</td>
<td>52</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------</td>
</tr>
<tr>
<td>1</td>
<td>Density values.</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Index map with simplified geologic map of the Mt. Stuart Block.</td>
</tr>
<tr>
<td>2</td>
<td>Geologic map of the Mt. Stuart Batholith.</td>
</tr>
<tr>
<td>3</td>
<td>Simplified structure-sections A-A' and B-B' through the Mt. Stuart Batholith.</td>
</tr>
<tr>
<td>4</td>
<td>Lower and middle Tertiary sedimentary and volcanic rock which surrounds the Mt. Stuart Block on the east, south and west.</td>
</tr>
<tr>
<td>5</td>
<td>Station locations.</td>
</tr>
<tr>
<td>6</td>
<td>3-dimension picture of gravity.</td>
</tr>
<tr>
<td>7</td>
<td>Fourier power spectrum.</td>
</tr>
<tr>
<td>8</td>
<td>Detailed geologic map of the area south of the Ingalls Complex with the percentage of Teanaway dikes proportional to the number of dots.</td>
</tr>
<tr>
<td>9</td>
<td>Diagrammatic cross section of the Mt. Stuart Batholith illustrating geometry for the formation of Feature F on Map 2.</td>
</tr>
<tr>
<td>10</td>
<td>System flow chart.</td>
</tr>
<tr>
<td>11</td>
<td>Data collection form with sample data.</td>
</tr>
<tr>
<td>12</td>
<td>Terrain correction distribution.</td>
</tr>
</tbody>
</table>
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°37.5'N and 120°53'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, Iherzolite 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 subdivision 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 Tertiary 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$^\circ$43.5'N and 120$^\circ$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

<table>
<thead>
<tr>
<th>NAME</th>
<th>DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt. Stuart Batholith</td>
<td></td>
</tr>
<tr>
<td>Two-pyroxene gabbro</td>
<td>2.95</td>
</tr>
<tr>
<td>Hypersthene-hornblende diorite</td>
<td>2.89</td>
</tr>
<tr>
<td>Hypersthene-hornblende-biotite quartz diorite</td>
<td>2.81</td>
</tr>
<tr>
<td>Main-phase quartz diorite</td>
<td>2.74</td>
</tr>
<tr>
<td>Leucoquartz diorite</td>
<td>2.70</td>
</tr>
<tr>
<td>Granodiorite</td>
<td>2.71</td>
</tr>
<tr>
<td>Aplite, granite, pegmatite</td>
<td>2.63</td>
</tr>
<tr>
<td>Biotite trondhjemite</td>
<td>2.60</td>
</tr>
<tr>
<td>Chiwaukum Schist</td>
<td>2.70</td>
</tr>
</tbody>
</table>
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 7. FOURIER POWER SPECTRUM.
line over the Ingalls Complex is perhaps illustrative. The con-
tour 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 parallel to 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.
REFERENCES CITED


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:

<table>
<thead>
<tr>
<th>Sta. no.</th>
<th>Station identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lat.</td>
<td>Latitude in degrees to hundredths</td>
</tr>
<tr>
<td>Long.</td>
<td>Longitude in degrees to hundredths</td>
</tr>
<tr>
<td>Elev.</td>
<td>Elevation in feet</td>
</tr>
<tr>
<td>S.B.A.</td>
<td>Simple Bouguer anomaly value in milligals (drift corrected)</td>
</tr>
<tr>
<td>T.C.</td>
<td>Terrain correction in milligals</td>
</tr>
<tr>
<td>F.B.A.</td>
<td>Final Bouguer anomaly value in milligals</td>
</tr>
<tr>
<td>STAT. NO.</td>
<td>LAT.</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>3011</td>
<td>47.10</td>
</tr>
<tr>
<td>3019</td>
<td>47.20</td>
</tr>
<tr>
<td>3023</td>
<td>47.25</td>
</tr>
<tr>
<td>3024</td>
<td>47.26</td>
</tr>
<tr>
<td>3025</td>
<td>47.27</td>
</tr>
<tr>
<td>3026</td>
<td>47.28</td>
</tr>
<tr>
<td>3037</td>
<td>47.30</td>
</tr>
<tr>
<td>3039</td>
<td>47.31</td>
</tr>
<tr>
<td>3029</td>
<td>47.32</td>
</tr>
<tr>
<td>3031</td>
<td>47.34</td>
</tr>
<tr>
<td>3041</td>
<td>47.10</td>
</tr>
<tr>
<td>3043</td>
<td>47.11</td>
</tr>
<tr>
<td>3045</td>
<td>47.15</td>
</tr>
<tr>
<td>3046</td>
<td>47.20</td>
</tr>
<tr>
<td>3047</td>
<td>47.22</td>
</tr>
<tr>
<td>3049</td>
<td>47.22</td>
</tr>
<tr>
<td>3054</td>
<td>47.27</td>
</tr>
<tr>
<td>3056</td>
<td>47.20</td>
</tr>
<tr>
<td>3058</td>
<td>47.30</td>
</tr>
<tr>
<td>3061</td>
<td>47.30</td>
</tr>
<tr>
<td>3062</td>
<td>47.26</td>
</tr>
<tr>
<td>3075</td>
<td>47.10</td>
</tr>
<tr>
<td>3076</td>
<td>47.12</td>
</tr>
<tr>
<td>3083</td>
<td>57.46</td>
</tr>
<tr>
<td>3086</td>
<td>47.42</td>
</tr>
<tr>
<td>STAT. NO.</td>
<td>LAT.</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>7057</td>
<td>47.66</td>
</tr>
<tr>
<td>7060</td>
<td>47.54</td>
</tr>
<tr>
<td>3066</td>
<td>47.22</td>
</tr>
<tr>
<td>3061</td>
<td>47.47</td>
</tr>
<tr>
<td>3133</td>
<td>47.47</td>
</tr>
<tr>
<td>3166</td>
<td>47.60</td>
</tr>
<tr>
<td>3145</td>
<td>47.45</td>
</tr>
<tr>
<td>3166</td>
<td>47.44</td>
</tr>
<tr>
<td>3157</td>
<td>47.40</td>
</tr>
<tr>
<td>3149</td>
<td>47.37</td>
</tr>
<tr>
<td>3140</td>
<td>47.31</td>
</tr>
<tr>
<td>3140</td>
<td>47.37</td>
</tr>
<tr>
<td>3156</td>
<td>47.37</td>
</tr>
<tr>
<td>3152</td>
<td>47.24</td>
</tr>
<tr>
<td>3112</td>
<td>47.34</td>
</tr>
<tr>
<td>3155</td>
<td>47.30</td>
</tr>
<tr>
<td>3161</td>
<td>47.33</td>
</tr>
<tr>
<td>3157</td>
<td>47.29</td>
</tr>
<tr>
<td>3156</td>
<td>47.32</td>
</tr>
<tr>
<td>3150</td>
<td>47.32</td>
</tr>
<tr>
<td>3151</td>
<td>47.31</td>
</tr>
<tr>
<td>3162</td>
<td>47.21</td>
</tr>
<tr>
<td>3182</td>
<td>47.33</td>
</tr>
<tr>
<td>3186</td>
<td>47.33</td>
</tr>
<tr>
<td>3168</td>
<td>47.32</td>
</tr>
<tr>
<td>3101</td>
<td>47.26</td>
</tr>
<tr>
<td>STATE</td>
<td>NUM</td>
</tr>
<tr>
<td>-------</td>
<td>-----</td>
</tr>
<tr>
<td>4094</td>
<td>47.2</td>
</tr>
<tr>
<td>4096</td>
<td>47.27</td>
</tr>
<tr>
<td>4098</td>
<td>47.17</td>
</tr>
<tr>
<td>4101</td>
<td>47.18</td>
</tr>
<tr>
<td>4102</td>
<td>47.16</td>
</tr>
<tr>
<td>4103</td>
<td>47.14</td>
</tr>
<tr>
<td>4106</td>
<td>47.22</td>
</tr>
<tr>
<td>4107</td>
<td>47.21</td>
</tr>
<tr>
<td>4109</td>
<td>47.20</td>
</tr>
<tr>
<td>4110</td>
<td>47.21</td>
</tr>
<tr>
<td>4111</td>
<td>47.25</td>
</tr>
<tr>
<td>4112</td>
<td>47.22</td>
</tr>
<tr>
<td>4114</td>
<td>47.22</td>
</tr>
<tr>
<td>4116</td>
<td>47.23</td>
</tr>
<tr>
<td>4118</td>
<td>47.24</td>
</tr>
<tr>
<td>4120</td>
<td>47.25</td>
</tr>
<tr>
<td>4122</td>
<td>47.44</td>
</tr>
<tr>
<td>4124</td>
<td>47.37</td>
</tr>
<tr>
<td>4126</td>
<td>47.26</td>
</tr>
<tr>
<td>4128</td>
<td>47.35</td>
</tr>
<tr>
<td>4130</td>
<td>47.37</td>
</tr>
<tr>
<td>4132</td>
<td>47.32</td>
</tr>
<tr>
<td>4134</td>
<td>47.29</td>
</tr>
<tr>
<td>4136</td>
<td>47.39</td>
</tr>
<tr>
<td>STAT, No.</td>
<td>LAT.</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
</tr>
<tr>
<td>4511</td>
<td>47.21</td>
</tr>
<tr>
<td>4512</td>
<td>47.27</td>
</tr>
<tr>
<td>4513</td>
<td>47.28</td>
</tr>
<tr>
<td>4514</td>
<td>47.44</td>
</tr>
<tr>
<td>4515</td>
<td>47.47</td>
</tr>
<tr>
<td>4516</td>
<td>47.37</td>
</tr>
<tr>
<td>4517</td>
<td>47.36</td>
</tr>
<tr>
<td>4518</td>
<td>47.35</td>
</tr>
<tr>
<td>4520</td>
<td>47.27</td>
</tr>
<tr>
<td>4521</td>
<td>47.28</td>
</tr>
<tr>
<td>4522</td>
<td>47.22</td>
</tr>
<tr>
<td>4523</td>
<td>47.42</td>
</tr>
<tr>
<td>4524</td>
<td>47.42</td>
</tr>
<tr>
<td>4526</td>
<td>47.42</td>
</tr>
<tr>
<td>4527</td>
<td>47.47</td>
</tr>
<tr>
<td>4528</td>
<td>47.12</td>
</tr>
<tr>
<td>4529</td>
<td>47.42</td>
</tr>
<tr>
<td>4530</td>
<td>47.43</td>
</tr>
<tr>
<td>4531</td>
<td>47.47</td>
</tr>
<tr>
<td>4532</td>
<td>47.42</td>
</tr>
<tr>
<td>4533</td>
<td>47.52</td>
</tr>
<tr>
<td>4534</td>
<td>47.42</td>
</tr>
<tr>
<td>4535</td>
<td>47.40</td>
</tr>
<tr>
<td>4536</td>
<td>47.47</td>
</tr>
<tr>
<td>4537</td>
<td>47.42</td>
</tr>
<tr>
<td>4538</td>
<td>47.48</td>
</tr>
<tr>
<td>STAT. NO.</td>
<td>LAT.</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>4566</td>
<td>47.88</td>
</tr>
<tr>
<td>4565</td>
<td>47.87</td>
</tr>
<tr>
<td>4599</td>
<td>47.69</td>
</tr>
<tr>
<td>4491</td>
<td>47.72</td>
</tr>
<tr>
<td>4602</td>
<td>47.71</td>
</tr>
<tr>
<td>4640</td>
<td>47.63</td>
</tr>
<tr>
<td>4612</td>
<td>47.61</td>
</tr>
<tr>
<td>4615</td>
<td>47.60</td>
</tr>
<tr>
<td>4616</td>
<td>47.60</td>
</tr>
<tr>
<td>4617</td>
<td>47.60</td>
</tr>
<tr>
<td>4618</td>
<td>47.61</td>
</tr>
<tr>
<td>4619</td>
<td>47.62</td>
</tr>
<tr>
<td>4620</td>
<td>47.62</td>
</tr>
<tr>
<td>4623</td>
<td>47.61</td>
</tr>
<tr>
<td>4624</td>
<td>47.62</td>
</tr>
<tr>
<td>4625</td>
<td>47.56</td>
</tr>
<tr>
<td>4626</td>
<td>47.51</td>
</tr>
<tr>
<td>4626</td>
<td>47.53</td>
</tr>
<tr>
<td>3547</td>
<td>47.52</td>
</tr>
<tr>
<td>3510</td>
<td>47.52</td>
</tr>
<tr>
<td>3522</td>
<td>47.49</td>
</tr>
<tr>
<td>3513</td>
<td>47.36</td>
</tr>
<tr>
<td>3514</td>
<td>47.28</td>
</tr>
<tr>
<td>3575</td>
<td>47.26</td>
</tr>
<tr>
<td>5052</td>
<td>47.82</td>
</tr>
<tr>
<td>6933</td>
<td>47.83</td>
</tr>
<tr>
<td>STAT. N0.</td>
<td>LAT.</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>35008</td>
<td>47.96</td>
</tr>
<tr>
<td>35009</td>
<td>47.86</td>
</tr>
<tr>
<td>35010</td>
<td>47.87</td>
</tr>
<tr>
<td>35011</td>
<td>47.88</td>
</tr>
<tr>
<td>35012</td>
<td>47.77</td>
</tr>
<tr>
<td>35013</td>
<td>47.77</td>
</tr>
<tr>
<td>35014</td>
<td>47.77</td>
</tr>
<tr>
<td>35022</td>
<td>47.78</td>
</tr>
<tr>
<td>35023</td>
<td>47.78</td>
</tr>
<tr>
<td>35034</td>
<td>47.77</td>
</tr>
<tr>
<td>35035</td>
<td>47.77</td>
</tr>
<tr>
<td>35036</td>
<td>47.77</td>
</tr>
<tr>
<td>35038</td>
<td>47.71</td>
</tr>
<tr>
<td>35039</td>
<td>47.70</td>
</tr>
<tr>
<td>35041</td>
<td>47.70</td>
</tr>
<tr>
<td>35042</td>
<td>47.71</td>
</tr>
<tr>
<td>35043</td>
<td>47.71</td>
</tr>
<tr>
<td>35044</td>
<td>47.72</td>
</tr>
<tr>
<td>35045</td>
<td>47.73</td>
</tr>
<tr>
<td>34570</td>
<td>47.51</td>
</tr>
<tr>
<td>34572</td>
<td>47.51</td>
</tr>
<tr>
<td>34576</td>
<td>47.58</td>
</tr>
<tr>
<td>34578</td>
<td>47.52</td>
</tr>
<tr>
<td>34580</td>
<td>47.52</td>
</tr>
<tr>
<td>34581</td>
<td>47.54</td>
</tr>
<tr>
<td>34592</td>
<td>47.51</td>
</tr>
<tr>
<td>STAT. NO.</td>
<td>LAT.</td>
</tr>
<tr>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>14584</td>
<td>47.53</td>
</tr>
<tr>
<td>14587</td>
<td>47.55</td>
</tr>
<tr>
<td>14583</td>
<td>47.57</td>
</tr>
<tr>
<td>14583</td>
<td>47.57</td>
</tr>
<tr>
<td>14584</td>
<td>47.55</td>
</tr>
<tr>
<td>14585</td>
<td>47.56</td>
</tr>
<tr>
<td>14582</td>
<td>47.56</td>
</tr>
<tr>
<td>14580</td>
<td>47.57</td>
</tr>
<tr>
<td>14561</td>
<td>47.57</td>
</tr>
<tr>
<td>14562</td>
<td>47.58</td>
</tr>
<tr>
<td>14563</td>
<td>47.58</td>
</tr>
<tr>
<td>14555</td>
<td>47.55</td>
</tr>
<tr>
<td>14555</td>
<td>47.55</td>
</tr>
<tr>
<td>14565</td>
<td>47.54</td>
</tr>
<tr>
<td>14567</td>
<td>47.55</td>
</tr>
<tr>
<td>14569</td>
<td>47.57</td>
</tr>
<tr>
<td>14569</td>
<td>47.56</td>
</tr>
<tr>
<td>14571</td>
<td>47.54</td>
</tr>
<tr>
<td>14571</td>
<td>47.57</td>
</tr>
<tr>
<td>14572</td>
<td>47.61</td>
</tr>
<tr>
<td>14574</td>
<td>47.60</td>
</tr>
<tr>
<td>14574</td>
<td>47.56</td>
</tr>
<tr>
<td>14575</td>
<td>47.57</td>
</tr>
<tr>
<td>14570</td>
<td>47.63</td>
</tr>
<tr>
<td>14581</td>
<td>47.64</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>14691</td>
<td>47.64</td>
</tr>
<tr>
<td>14692</td>
<td>47.65</td>
</tr>
<tr>
<td>14693</td>
<td>47.65</td>
</tr>
<tr>
<td>14694</td>
<td>47.71</td>
</tr>
<tr>
<td>14695</td>
<td>47.71</td>
</tr>
<tr>
<td>14692</td>
<td>47.67</td>
</tr>
<tr>
<td>14693</td>
<td>47.65</td>
</tr>
<tr>
<td>14694</td>
<td>47.64</td>
</tr>
<tr>
<td>14695</td>
<td>47.70</td>
</tr>
<tr>
<td>14696</td>
<td>47.71</td>
</tr>
<tr>
<td>14697</td>
<td>47.72</td>
</tr>
<tr>
<td>14698</td>
<td>47.72</td>
</tr>
<tr>
<td>14699</td>
<td>47.72</td>
</tr>
<tr>
<td>14700</td>
<td>47.72</td>
</tr>
<tr>
<td>14701</td>
<td>47.72</td>
</tr>
<tr>
<td>14702</td>
<td>47.72</td>
</tr>
<tr>
<td>14703</td>
<td>47.72</td>
</tr>
<tr>
<td>14704</td>
<td>47.73</td>
</tr>
<tr>
<td>14705</td>
<td>47.66</td>
</tr>
<tr>
<td>14706</td>
<td>47.61</td>
</tr>
<tr>
<td>14707</td>
<td>47.62</td>
</tr>
<tr>
<td>14708</td>
<td>47.64</td>
</tr>
<tr>
<td>14709</td>
<td>47.65</td>
</tr>
<tr>
<td>14710</td>
<td>47.67</td>
</tr>
<tr>
<td>14711</td>
<td>47.17</td>
</tr>
<tr>
<td>14712</td>
<td>47.71</td>
</tr>
<tr>
<td>STAT. NO.</td>
<td>LAT.</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td>14718</td>
<td>47.68</td>
</tr>
<tr>
<td>14719</td>
<td>47.66</td>
</tr>
<tr>
<td>14720</td>
<td>47.61</td>
</tr>
<tr>
<td>14721</td>
<td>47.70</td>
</tr>
<tr>
<td>14722</td>
<td>47.71</td>
</tr>
<tr>
<td>14723</td>
<td>47.72</td>
</tr>
<tr>
<td>14724</td>
<td>47.73</td>
</tr>
<tr>
<td>14725</td>
<td>47.74</td>
</tr>
<tr>
<td>14726</td>
<td>47.75</td>
</tr>
<tr>
<td>14727</td>
<td>47.76</td>
</tr>
<tr>
<td>14728</td>
<td>47.82</td>
</tr>
<tr>
<td>14729</td>
<td>47.86</td>
</tr>
<tr>
<td>14730</td>
<td>47.78</td>
</tr>
<tr>
<td>1660</td>
<td>47.71</td>
</tr>
<tr>
<td>1670</td>
<td>47.78</td>
</tr>
<tr>
<td>1690</td>
<td>47.65</td>
</tr>
<tr>
<td>1630</td>
<td>47.68</td>
</tr>
<tr>
<td>1690</td>
<td>47.66</td>
</tr>
<tr>
<td>1690</td>
<td>47.90</td>
</tr>
<tr>
<td>1692</td>
<td>47.17</td>
</tr>
<tr>
<td>1680</td>
<td>47.45</td>
</tr>
<tr>
<td>1670</td>
<td>47.45</td>
</tr>
<tr>
<td>1671</td>
<td>47.44</td>
</tr>
<tr>
<td>1672</td>
<td>47.45</td>
</tr>
<tr>
<td>1674</td>
<td>47.45</td>
</tr>
<tr>
<td>1675</td>
<td>47.74</td>
</tr>
<tr>
<td>STAT. NO.</td>
<td>LAT.</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>0020</td>
<td>47.73</td>
</tr>
<tr>
<td>0040</td>
<td>47.72</td>
</tr>
<tr>
<td>0050</td>
<td>47.72</td>
</tr>
<tr>
<td>0060</td>
<td>47.42</td>
</tr>
<tr>
<td>0501</td>
<td>47.30</td>
</tr>
<tr>
<td>0532</td>
<td>47.31</td>
</tr>
<tr>
<td>0564</td>
<td>47.33</td>
</tr>
<tr>
<td>0585</td>
<td>47.34</td>
</tr>
<tr>
<td>0601</td>
<td>47.40</td>
</tr>
<tr>
<td>0606</td>
<td>47.55</td>
</tr>
<tr>
<td>0667</td>
<td>47.57</td>
</tr>
<tr>
<td>0683</td>
<td>47.59</td>
</tr>
<tr>
<td>0681</td>
<td>47.47</td>
</tr>
<tr>
<td>0254</td>
<td>47.87</td>
</tr>
<tr>
<td>0266</td>
<td>47.94</td>
</tr>
<tr>
<td>0277</td>
<td>47.85</td>
</tr>
<tr>
<td>0259</td>
<td>47.85</td>
</tr>
<tr>
<td>0258</td>
<td>47.95</td>
</tr>
<tr>
<td>0411</td>
<td>47.72</td>
</tr>
<tr>
<td>0403</td>
<td>47.24</td>
</tr>
<tr>
<td>0405</td>
<td>47.39</td>
</tr>
<tr>
<td>0407</td>
<td>47.41</td>
</tr>
<tr>
<td>0609</td>
<td>47.52</td>
</tr>
<tr>
<td>0233</td>
<td>47.72</td>
</tr>
<tr>
<td>0234</td>
<td>47.79</td>
</tr>
<tr>
<td>0238</td>
<td>47.84</td>
</tr>
<tr>
<td>STAT.</td>
<td>LAT.</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>0217</td>
<td>47.66</td>
</tr>
<tr>
<td>0217</td>
<td>47.64</td>
</tr>
<tr>
<td>0218</td>
<td>47.64</td>
</tr>
<tr>
<td>0220</td>
<td>47.62</td>
</tr>
<tr>
<td>0220</td>
<td>47.62</td>
</tr>
<tr>
<td>0230</td>
<td>47.61</td>
</tr>
<tr>
<td>0241</td>
<td>47.61</td>
</tr>
<tr>
<td>0241</td>
<td>47.60</td>
</tr>
<tr>
<td>0256</td>
<td>47.61</td>
</tr>
<tr>
<td>0260</td>
<td>47.61</td>
</tr>
<tr>
<td>0271</td>
<td>47.62</td>
</tr>
<tr>
<td>0283</td>
<td>47.61</td>
</tr>
<tr>
<td>0283</td>
<td>47.60</td>
</tr>
<tr>
<td>0311</td>
<td>47.65</td>
</tr>
<tr>
<td>0311</td>
<td>47.76</td>
</tr>
<tr>
<td>0322</td>
<td>47.76</td>
</tr>
<tr>
<td>0331</td>
<td>47.62</td>
</tr>
<tr>
<td>0340</td>
<td>47.72</td>
</tr>
<tr>
<td>0357</td>
<td>47.72</td>
</tr>
<tr>
<td>0367</td>
<td>47.76</td>
</tr>
<tr>
<td>0373</td>
<td>47.81</td>
</tr>
<tr>
<td>0374</td>
<td>47.61</td>
</tr>
<tr>
<td>0385</td>
<td>47.94</td>
</tr>
<tr>
<td>0386</td>
<td>47.86</td>
</tr>
<tr>
<td>0397</td>
<td>47.87</td>
</tr>
<tr>
<td>STAT.</td>
<td>LAT.</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>P201</td>
<td>47.76</td>
</tr>
<tr>
<td>P0520</td>
<td>47.69</td>
</tr>
<tr>
<td>P105</td>
<td>47.61</td>
</tr>
<tr>
<td>P106</td>
<td>47.61</td>
</tr>
<tr>
<td>P107</td>
<td>47.58</td>
</tr>
<tr>
<td>P108</td>
<td>47.59</td>
</tr>
<tr>
<td>P120</td>
<td>47.70</td>
</tr>
<tr>
<td>P121</td>
<td>47.65</td>
</tr>
<tr>
<td>P122</td>
<td>47.68</td>
</tr>
<tr>
<td>P123</td>
<td>47.67</td>
</tr>
<tr>
<td>P124</td>
<td>47.66</td>
</tr>
<tr>
<td>P0770</td>
<td>47.57</td>
</tr>
<tr>
<td>P0390</td>
<td>47.59</td>
</tr>
<tr>
<td>P0400</td>
<td>47.59</td>
</tr>
<tr>
<td>P0410</td>
<td>47.60</td>
</tr>
<tr>
<td>P0420</td>
<td>47.61</td>
</tr>
<tr>
<td>P0430</td>
<td>47.62</td>
</tr>
<tr>
<td>P0450</td>
<td>47.63</td>
</tr>
<tr>
<td>P0460</td>
<td>47.64</td>
</tr>
<tr>
<td>P0470</td>
<td>47.64</td>
</tr>
<tr>
<td>P0480</td>
<td>47.65</td>
</tr>
<tr>
<td>P0490</td>
<td>47.56</td>
</tr>
<tr>
<td>P0500</td>
<td>47.56</td>
</tr>
<tr>
<td>P0550</td>
<td>47.55</td>
</tr>
<tr>
<td>P0600</td>
<td>47.54</td>
</tr>
<tr>
<td>P0610</td>
<td>47.54</td>
</tr>
<tr>
<td>STAT. NO.</td>
<td>LAT.</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td>P0320</td>
<td>47.53</td>
</tr>
<tr>
<td>P0330</td>
<td>47.54</td>
</tr>
<tr>
<td>P0340</td>
<td>47.54</td>
</tr>
<tr>
<td>P0350</td>
<td>47.56</td>
</tr>
<tr>
<td>P0130</td>
<td>47.65</td>
</tr>
<tr>
<td>P0140</td>
<td>47.65</td>
</tr>
<tr>
<td>P0150</td>
<td>47.65</td>
</tr>
<tr>
<td>P0160</td>
<td>47.64</td>
</tr>
<tr>
<td>P0170</td>
<td>47.62</td>
</tr>
<tr>
<td>P0180</td>
<td>47.61</td>
</tr>
<tr>
<td>P0181</td>
<td>47.60</td>
</tr>
<tr>
<td>P0190</td>
<td>47.60</td>
</tr>
<tr>
<td>P0220</td>
<td>47.57</td>
</tr>
<tr>
<td>P0230</td>
<td>47.57</td>
</tr>
<tr>
<td>P0101</td>
<td>47.72</td>
</tr>
<tr>
<td>P0301</td>
<td>47.72</td>
</tr>
<tr>
<td>P0401</td>
<td>47.72</td>
</tr>
<tr>
<td>P0501</td>
<td>47.71</td>
</tr>
<tr>
<td>P0601</td>
<td>47.71</td>
</tr>
<tr>
<td>P0801</td>
<td>47.70</td>
</tr>
<tr>
<td>P0901</td>
<td>47.69</td>
</tr>
<tr>
<td>P1001</td>
<td>47.68</td>
</tr>
<tr>
<td>P1101</td>
<td>47.66</td>
</tr>
<tr>
<td>P1201</td>
<td>47.67</td>
</tr>
<tr>
<td>UW15</td>
<td>47.71</td>
</tr>
<tr>
<td>UW16</td>
<td>47.71</td>
</tr>
<tr>
<td>STAT. NO.</td>
<td>LAT.</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td>U8720</td>
<td>47.74</td>
</tr>
<tr>
<td>U8725</td>
<td>47.71</td>
</tr>
<tr>
<td>U8729</td>
<td>47.51</td>
</tr>
<tr>
<td>U8775</td>
<td>47.99</td>
</tr>
<tr>
<td>U4641</td>
<td>47.46</td>
</tr>
<tr>
<td>U4642</td>
<td>47.46</td>
</tr>
</tbody>
</table>
APPENDIX B.
Data Processing

In order to help in the interpretation of the data, a series of interrelated 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°30'W and 47°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.
filter data → FILTER

Final grid → FOURIER

harmonic value → power

Filter file → CONTOUR

Geologic map file → CONTOUR2

contour values → contour map

contour values → contour values
Figure 11. Data collection form with sample data

<table>
<thead>
<tr>
<th>I.D.</th>
<th>LONG</th>
<th>LAT</th>
<th>TIME</th>
<th>TEMPERATURE</th>
<th>READING</th>
<th>CHANGE</th>
<th>ELEV</th>
<th>EST ERROR</th>
<th>TRUE GRAVITY/ COMMENT</th>
<th>DENSITY/ MAP NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>1.23</td>
<td>6.78</td>
<td>10</td>
<td>4567890</td>
<td>123456</td>
<td>67890</td>
<td>12345</td>
<td>67890</td>
<td>5160</td>
<td>6170</td>
</tr>
<tr>
<td>210</td>
<td>42.58</td>
<td>47.24</td>
<td>0</td>
<td>034567</td>
<td>6910</td>
<td>4724</td>
<td>691</td>
<td>15185</td>
<td>1949</td>
<td>B. R. ON RIVER</td>
</tr>
<tr>
<td>310</td>
<td>42.73</td>
<td>48.22</td>
<td>0</td>
<td>035569</td>
<td>6824</td>
<td>16826</td>
<td>1672</td>
<td>1868</td>
<td>FISH LAKE</td>
<td>PLAIN</td>
</tr>
<tr>
<td>410</td>
<td>44.53</td>
<td>49.10</td>
<td>0</td>
<td>063569</td>
<td>1746</td>
<td>1868</td>
<td>1868</td>
<td>15138</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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. Empirically 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 formatting 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.
BASIC OF FIGURE 10
//FIRST JOB {R0022, 539509925}, PETRIE
// EXEC PLILFCLG, PARM.PLIL='SM=(2,80,1)'
//PLIL 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;
BEGIN:
ON ENDFILE (SYSIN) GO TO ECJ;
DCL (ID(NMAX) ) CHAR (10);
DCL (LONG(NMAX),LAT(NMAX),TIMES(NMAX),ELEV(NMAX),READING(NMAX )) FLOA T 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 INFO','TRAIL INTERSECTION', 'TRAIL STREAM INTERSECTION','PASS','LAKE','BENCH MARK', 'GIVEN ON MAP','ROAD INT');
DCL C_CODE CHAR (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 INSTEAD ',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);
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;
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 */
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),I-1) = 'C' THEN GO TO SKIPLIST;
PUT SKIP (2) EDIT (ID(I), LAT(I), LONG(I));
(COL(I), A(10), R(8,3), R(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 NETTLETON (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)( 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(I), 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 ('IC', '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
LOAD OF FIGURE 10
//LOAD JOB (G0242,103425037),PETRICE
//EXEC PL1LFCGLG,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;
NEX T_C ARD:

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))
-0.000059*(SIN(2.0*LAT)*SIN(2.0*LAT)));
FREE_AIR=FREE_AIR-TH EORY;
LAT=LAT/R;
XEXTRA=(Y/15.28)*0.2;
LONG=121.5-(X/(11.92-XEXTRA));
PUT SKIP EDIT (IC,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_C ARD;
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
GRID OF FIGURE 10

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 (IOS(NMAX) ) CHAR (5);
   DCL (X1(9),Y1(9),Z1(9) ) FLOAT DEC (16);
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:
CALL READ_IN_DATA;

CALL WRITE_GRIDDED_DATA;

/* THAT'S IT   ALL DONE */
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;
WRITE_GRIDDED_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 BOUNDARY 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_OUT*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 = 99999999;
DO II=1 TO TOTAL_POINTS;
IF DISTANCE(II) < DIST_MIN THEN DO;
DIST_MIN = DISTANCE(II);
X(K) = X(II);
Y(K) = Y(II);
Z(K) = Z(II);
I_POINT = II;
END;
END;
DISTANCE(I_POINT) = 9999999999;
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
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 UNREASONABLE');
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 PLILFCG, PARM. PLIL='SM=(2,80,1)'
// PLIL.SYSIN DD *
TRANS: PROC OPTIONS (MAIN);
  DCL IJZ INPUT;
  ON ENDFILE (IJZ) STOP;
  DCL CARD CHAR (80);
NEXTCNE:
  GET FILE (IJZ) EDIT (CARD) (A(80));
  PUT SKIP LIST (CARD);
  GO TO NEXTCNE;
END TRANS;
//GO.IJZ DD DSN=F0229.IJZ,DISP=SHR
// EXEC PLILFCGLG, PARM. PLIL='SM=(2,80,1)'
// PLIL.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));
I = 1;
NEXT:
GET FILE (IJZ) LIST (X(I), Y(J), Z(I));
I = I + 1;
GO TO NEXT;
CONTINUE:
ITOTAL = I - 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);
/* 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')(CCL(1),A);
/* 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;
XLLOW=0.0;
YLOW=0.0;
PUT SKIP EDIT ('2',XLLOW,YLOW,R#X,R#Y)(COL(5),A,COL(11),4(F(10,1)));
PUT SKIP FILE (SYMAP)
EDIT ('2',XLLOW,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')(COL(4),A);
PUT EDIT ('99999')(COL(1),A);
PUT FILE (SYMAP)
EDIT ('99999')(COL(1),A);
PUT EDIT ('99999')(COL(1),A);
PUT FILE (SYMAP)
EDIT ('99999')(COL(1),A);
END TRANS;
//GO.IJZ DD DSN=F0229.IJZ,DISP=SHR
//GO.SYMAP DD DSN=&GCARDS,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=GO180.RAW,DISP=OLD,VOL=SER=HU003,
// SPACE=(CYL,(1,1)),UNIT=2314,
// DCB=(BLKSIZE=804,LRECL=80,RECFM=VB)
//GO.FT08F001 DD DSN=&GCARDS,DISP=(OLD, PASS)
//FORT.SYSD D &
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 (110,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 (13OF7.1)
103 FORMAT (1X,18F7.1)
101 FORMAT (13OF7.1)
16 CONTINUE
C
END
//GO.FT08F001 DD DSN=GO180.RAW,DISP=SHR
//GO.FT08F001 DD DSN=GO180.FORT,DISP=OLD,
// SPACE=(CYL,(1,1)),VOL=SER=HU003,
// UNIT=2314,DCB=(BLKSIZE=6370,LRECL=910,DSORG=PS,RECFM=FB)
SHEET OF FIGURE 10

// INT JOB (G0180,539509925),PETRIE,CLASS=B
// EXEC FORTCCG
// EXEC PLILFCG,PARM,PLIL='SM=(2,80,1)',TIME.GO=25
// PLIL,SYSIN DD *

INTER: PROC OPTIONS (MAIN):
  /* INTERPOLATION USING A FOURTH 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 */
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 ENDOFILE (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;
INTERPOLATION:
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;
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;
      /* I E 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;
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+1, 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;
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;
/* 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;
/* NEXT TC CORNER NORTH OR SOUTH */
IF I = 1 & J = 2 THEN DO; /* NEXT S W COR NORTH */
  UNEW = -1
  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;
/* 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)+U(I+1,J1) +
+ 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)+U(I+1,J) + U(I,J-1)
-4.0*U(I,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;
/* 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+1, 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+2, J) + 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 ('LCLOSE IT HERE', I, J);


```
1

```

```

```
SET_FLAG: PROC (II, JJ);
ISET = (II-1) * INTY + JJ;
SUBSTR(DATA_FLAG, ISET, 1) = '1'B;
END SET_FLAG;
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;
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=GO180.FORT,DISP=SHR
//GO.IJZFILE DD DSN=F0229.IJZ,DISP=SHR
//
CONTOUR OF FIGURE 10

//PLCON JOB (R0022,539509925),PETRIE,CLASS=B
// EXEC WFPLT,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 PLOTS
CALL FACTOR (0.7)

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)

NOW DRAW IN MAP
103 CONTINUE
NP = MAPCOR (X,Y)
IF (NP .EQ. 0) GO TO 600
OUTSID = TRUE.
AT END OF MAP DATA READ IN GRAVITY DATA

DO 200 I=1,NP
XX = X(I)
YY = Y(I)
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
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

GET NEXT LINE OF MAP COORDINATES
GOTO 103

READ IN GRAVITY VALUES
600 CONTINUE
READ (8,1313) NX,NY
1313 FORMAT (I10,I10)
WRITE (6,500) NX,NY
500 FORMAT (1H, 13, 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
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
NOW READ IN AND THEN COUNTOUR VALUES
C
C
700 CONTINUE
READ(5, 800, END=999) CN
WRITE (6, 801) CN
800 FORMAT (1H, 13, F10.2)
801 FORMAT (1H, 13, F10.2)
CALL CNTOUR(XP, NX, YP, NY, ZP, 130, CN, 3.0, CN)
GO TO 700
C
C
C
999 CONTINUE
CALL PLOT (0.0, 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
NTOTAL = 0
NT=1
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 ,13)
    MAPCOR = NTOTAL
RETURN
END
//GD.FT02F001 DD DSN=F0229.IJZ,DISP=SHR
//GD.FT11F001 DD DSN=F0229.MAPS,DISP=SHR
//GD.FT08F001 DD DSN=G0180.FORT,DISP=SHR
//GD.SYSIN DD *
65.0
70.0
75.0
80.0
85.0
90.0
95.0
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)

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 +13,13)

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
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
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
GET NEXT LINE OF MAP COORDINATES
GOTO 103
C
C
READ IN GRAVITY VALUES
600 CONTINUE
DO 601 J=1,NX
   READ(3) ( ZP(J,I), I=1,NY )
   CONTINUE

DO 699 J=1,NX
   DO 699 I=1,NY
      ZP(J,I)=ABS(ZP(J,I))
   CONTINUE

SET X AND Y VALUES FOR PLOT
DO 602 I=1,NX
   XP(I)=(I-1)*CELL
   CONTINUE

DO 604 I=1,NY
   YP(I)=(I-1)*CELL
   CONTINUE

NOW READ IN AND THEN COUNTOUR VALUES

700 CONTINUE
   READ(5,800,END=999) CN
   WRITE (6,801) CN
   CONTINUE

800 FORMAT (F10.2)
   801 FORMAT (1H,F10.2)
   CALL CNTOUR(XP,NX,YP,NY,ZP,130,CN,3.0,CN)
   GO TO 700

999 CONTINUE
   CALL PLOTX(ZP,NX,NY,130,130)
   CALL PLOT(0.0,0.0,0.0,999)
   END

FUNCTION MAPCOR (X,Y)
   DIMENSION X(300),Y(300)
   READ MAP FILE AND STORE CORROINATES IN X AND Y ARRAY

NTOTAL = 0
NT=1

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) GC TO 200
      NTOTAL=NTOTAL+1
   CONTINUE
   NT=NT+5
CONTINUE

WRITE (6,300) N TOTAL

FORMAT (1H,13)

M A P C O R = N T O T A L

RETURN

END

SUBROUTINE P L O T X(Y,N R ,M C ,N R 1 ,M C 1 )

P L O T C O N T O U R M A P F O R M A RECTANGULAR M A T R I X O F G R I D V A L U E S

D M E N S I O N Y(NR1,MC1),IOU T (100),IC H A R (9)

D A T A I C H A R ,1 H 3 ,I H ,1 H 9 /

F I N D L A R G E S T A N D S M A L L E S T V A L U E S I N M A P

Y M I N = Y(1,1)

Y MAX = Y M I N

D O 100 I = 1,N R

D O 100 J = 1,M C

Y T = Y ( I , J )

I F ( Y T . L T . Y M I N ) Y M I N = Y T

I F ( Y T . G T . Y M A X ) Y M A X = Y T

CONTINUE

P R I N T M A P O N E L I N E A T A T I M E

WRITE (6,2001)

F O R M A T (1H1)

D O 101 I = 1,N R

D O 102 J = 1,M C

I F ( A B S ( Y M A X - Y M I N ) . G T . 00001 ) G O T O 600

W R I T E (6,500)

500 F O R M A T (4X,10HLO S T I T )

IY = 1

G O T O 606

600 C O N T I N U E

I Y = ((Y(I,J)-Y M I N )/(Y M A X - Y M I N ))*9.0 +1.0

606 C O N T I N U E

I F ( IY . G T . 9 ) I Y = 9

I O U T ( J ) = I C H A R ( I Y )

1 0 2 C O N T I N U E

W R I T E (6,2002) (I O U T ( J ) ,J = 1,M C)

2002 F O R M A T (1H,100A1)

101 C O N T I N U E

C I N T = ( Y M A X - Y M I N ) / 9 . 0

R E F C = Y M I N + 5.0*C I N T

W R I T E (6,2003) R E F C , C I N T

2003 F O R M A T (1H0,4X*22HREFERENCE COUNTOUR ++F10.4,3X

1 2 2 H C O U N T O U R I N T E R V A L = , +F10.4,///)

R E T U R N

E N D

//G0 F T O R F 0 0 1 D D D S A = F 0 2 2 9 . F I L , D I S P = S H R
//G0 F T 1 1 F 0 0 1 D D D S M = F 0 2 2 9 . M A P S , D I S P = S H R
//G0 S Y S I N D D *

-4.0

-3.5

-1.0
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 READ IN GRAVITY
C STARTING WITH THE SIZE OF THE ARRAY
READ (8) NX,NY
C READ (8,1313) NX,NY
1313 FORMAT (1I0,1I0)
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 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 (12,F10.1)
C
C GET FILTER 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
   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 NECESSARY 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),J=NLAST1,NFIL)

CONTINUE

SCALE FILTER ARRAY

DO 705 I=1,NFIL
    DO 706 I=1,NFIL
        FILTER(I,J)=FILTER(I,J)*SCALE
    CONTINUE

CONTINUE

NLESS=(NFIL-1)/2

ALLOW 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

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 (IX,5I3,5F10.3)

AMIN=9999999.9
AMAX=-AMIN

DO 900 I=ISTART,NX
    L=1
    DO 901 J=JSTART,NY
        AROW(L)=FILTER(GRID,I,J,FILTER,NFIL,NLESS)
        L=L+1
    CONTINUE

NZ=26

IF (NY.LT.NZ)NZ=NY

WRITE OUT THE FIRST 26 OR SO

WRITE (6,918) (AROW(K),K=1,NZ)

918 FORMAT (IX,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

WRITE (6,555) AMIN,AMAX

555 FORMAT (IX,2F10.2)

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
//GO FT08F001 DD DSN=G0180.FORT, DISP=SHR
//GO FT08F001 DD DSN=G0180.RAW, DISP=SHR
//GO FT09F001 DD DSN=F0229.FIL, DISP=CLD
//
FOURIER OF FIGURE 10
//FORT JOB (G0180,539509925),PETRIE
// EXEC FORTGCG,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 MEASUREMENTS MADE AT THE NODES OF AN NR BY MC GRID
C
C C PROGRAM MODIFIED FROM STATISTICS AND DATA ANALYSIS IN GEOLOGY
C
C DIMENSION X(100,100), P(66,66), Tcx(130), Tsx(130)
C
C READ INPUT DATA MATRIX
C READ (8) NR, MC
C READ (8,1313) NR, MC
C 1313 FORMAT (11C,11C)
C WRITE (6,90) NR, MC
C 90 FORMAT (1X,13,13,////////)
C DO 91 I=1, NR
C READ (8,1314) (X(I,J), J=1, MC)
C 1314 FORMAT (13OF7.1)
C 91 CONTINUE
C
C CALCULATE SOME CONSTANTS TO BE USED BY THE PROGRAM
C
C PIY=6.2831854/FLOAT(NR)
C PI X = 6.2831854/FLOAT (MC)
C R=4.0/FLOAT (NR*MC)
C READ (5,1613) NT, MT
C 1618 FORMAT (12,12)
C FIND AVERAGE
C SUMX = 0.0
C DO 13 I=1, NR
C DO 13 J=1, MC
C SUMX = SUMX+X(I,J)
C 13 CONTINUE
C
C REMOVE AVERAGE FORM ARRAY
C AVE = SUMX/FLOAT (MC*NR)
C DO 14 I=1, NR
C DO 14 J=1, MC
C X(I,J) = X(I,J) - AVE
C 14 CONTINUE
C WRITE (6,1414) AVE
C 1414 FORMAT (1H1, 'AVERAGE = ',F10.2)
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
C DO 100 J=1, MT
DO 101 JJ=1,MC
   ARG=FLOAT((J-1)*(JJ-1))*PI
   TCX(JJ)=CCS(ARG)
   TSX(JJ)=SIN(ARG)
CONTINUE
101
DO 102 II=1,NR
   ARG=FLOAT((I-1)*(II-1))*PI
   CY=COS(ARG)
   SY=SIN(ARG)
DO 102 JJ=1,MC
   CX=TCX(JJ)
   SX=TSX(JJ)
   XX=XC(II,JJ)
   AA=AA+XX*CY*CX
   BB=BB+XX*CY*SX
   CC=CC+XX*SY*CX
   DD-DD+XX*SY*SX
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=SQR(PSQR)
WRITE (6,990) I,J,PSQR,SQRTP
990 FORMAT (1X,I4,I4,F12.2,F12.2)
CONTINUE
C
C
END
MAP KEY: Rock Units

METAMORPHIC ROCKS
Meta-igneous rock associated with the Ingalls Complex
Chiwaukum Schist
Easton Schist

SEDIMENTARY ROCKS
Alluvium
Roslyn
Swauk
Guye

IGNEOUS ROCKS
Yakima Basalt
Tertiary granitic rock, mostly Snoqualmie Bath.
Diabase and gabbro
Teanaway Basalt
Tertiary volcanic rock, undivided
Mt. Stuart Batholith
Ingalls Complex