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BALLISTIC WINDS STUDY

QUARTERLY REPORT

BY

FREDERICK P. OSTBY, JR.

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CONTRACT NO. DAAB07-67-C0296

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TECHNICAL REPORT ECOM-0296-1 October 1967

BALLISTIC WINDS STUDY

Report No. 5

1st Quarterly Report

1 March 1967 to 31 May 1967

Contract No. DAAB07-67-C0296

Prepared by

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For

U.S. ARMY ELECTRONICS COMMAND, FORT MONMOUTH, N. J.

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ABSTRACT

The overall objective of this study is to continue work begun under Contract DAAB07-67-C0296: To investigate the improvement of an integrated ballistic message from multiple stations and the effects of mountainous terrain on space and time variability of meteorological measurements.

One of the initial steps carried out during this reporting interval was the preparation of a detailed work plan for the contract year. The plan divides the technical work into five tasks: (1) CRAM modifications and tests; (2) ballistic winds evaluation; (3) withheld data experiments; (4) stability experiments; and (5) prediction techniques. The plan is contained in this report.

During the first year of study under this contract an objective analysis program, the Conditional Relaxation Analysis Method (CRAM), was developed and applied as a tool for investigation. Under the first task, modifications and improvements to CRAM are presently being carried out.

As a part of the second task (ballistic wind evaluation) residual errors (deflection) based on station observations along with those from Ft. Huachuca have been derived and are contained herein.

In general, one does not find residual errors increasing as distance increases. The minimum residual error occurred only 2 times in 24 test firings at the station closest to the firing—Ft. Huachuca. On the other hand, the minimum residual error occurred 8 times 50 km to the west southwest—Nogales.

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1.0 INTRODUCTION

This report describes technical progress during the initial quarter of the contract year March 1, 1967 through May 31, 1967, under Contract DAAB07-67-C0296, "Ballistic Winds Techniques Study." The overall objectives of this research program are stated in "Technical Guidelines No. 230103" found on page 2.

This contract includes logical follow-on work initiated under Contract DAAB07-67-C0296.*

One of the first steps of this research program was the production of a Work Plan describing in detail the technical work that would be performed during the year. This plan which subdivides the program into five tasks is presented in Section 2.0.

Progress on the five tasks is described in Section 3.0. The work is time-phased such that Tasks 3 and 5 will be initiated later on in the contract year.

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*Ostby, F. P., et. al., 1966: Ballistic Winds Study, Final Report, Tech. Report ECOM-01377-F, TRC.

TECHNICAL GUIDELINES FOR BALLISTIC WINDS TECHNIQUES STUDY

1. Present artillery procedure is to correct gun firings on the basis of meteorological information from a single metro station. In order to investigate the improvement of an integrated message from multiple stations and the effects of mountainous terrain on the variability of meteorological measurements, a temporary network of Rawin Sets was established in the vicinity of Ft. Huachuca, Arizona for the purpose of obtaining synoptic soundings in conjunction with actual firings.

2. The primary goal of this study, as set forth in the original technical guidelines was to answer the following questions:

(1) To what extent can artillery corrections be improved by using integrated map winds instead of a single sounding?

(2) How does mountainous terrain affect the variability of ballistic winds?

(3) What is the optimum placement and spacing of artillery metro sections in mountainous terrain?

(4) How often should soundings be made in mountainous terrain?

(5) How accurately, and for what duration can integrated map winds be predicted?

3. Using the above set of questions as the basis for the Ballistic Winds Study, an analysis of the field data will be continued under the technical guidelines given below:

(a) Analyze the data obtained at Ft. Huachuca, Arizona, using other stations rather than the Ft. Huachuca Station as a standard, beginning with the stations nearest the firing line.

(b) Compare CRAM results with stations upwind, downwind, and crosswind of the firing position.

(c) Perform more withheld data experiments in order to determine the optimum spacing of stations in mountainous terrain. Compare results with CRAM analysis for whole field.

(d) Classify the firing days on the basis of atmospheric stability in an attempt to link up the stability of the atmosphere with the accuracy of fire and develop stability criteria to select map wind analysis techniques.

(e) Perform sensitivity analysis on CRAM to determine the relationship of Grid size in CRAM to accuracy of wind field.

(f) Perform modifications of the CRAM program in order to improve the analysis; for example, determine whether repeated iteration improves the accuracy of

the technique, test, new weighting factors in the method of smoothing, etc.

(g) Continue work on improving the predictability of the integrated map winds.

4. Existing computer programs will be used to construct map winds.

2.0 WORK PLAN FOR BALLISTIC WINDS TECHNIQUES STUDY

2.1 Introduction

TRC Proposal P-706-23, December 1966, was prepared in response to RFQ No. DAAB07-67-Q-0029. In that proposal five tasks were proposed to achieve the research objectives stated in "Technical Guidelines No. 230103." This work plan has been prepared to supply additional detail to that proposal. In addition, percentage estimates of resources required for each task are included.

2.2 Ballistic Wind Tasks

2.2.1 Task 1—CRAM Modifications and Tests

There are three principal phases to this task. The first phase pertains to the three-dimensional CRAM program, the second has to do with the reduced grid-mesh analysis, and the third deals with various forms of machine output.

The effort in three-dimensional analysis will consist of adding data from artillery Zones 11 and 12 to the program in order to keep the upper boundary from contaminating the Zone 10 analysis. Zone 10 receives the greatest weight in making Line 10 calculations and for that reason the Zone 10 analysis is critical. To analyze these additional zones it will be necessary to perform some additional error checking of the basic data since previous error checking and editing did not extend beyond Zone 10. The modification of the CRAM program required to analyze these additional levels is straightforward and has already been accomplished. Experimentation is also planned to determine the best combination of program options in the initial guess-correct-relax-smooth cycle. The CRAM analysis produced by one application of this cycle will be used as a new "initial guess" of the next cycle. Tests will be performed to determine the optimum number of cycles and how the weighting factors in the smoothing procedure should be varied with successive cycles. Also, an error checking routine will be added to the program so that unrepresentative data can be discarded objectively.

The second phase of this task will consider the problem of reducing the basic analysis-grid interval. For the initial study, the basic horizontal grid interval was 10 km. We have been requested by the sponsor to conduct tests using a smaller grid interval. It is planned to perform analyses using a grid interval of 5 km and compare these with analyses from the 10 km experiments. Doing this however, will increase

the number of grid points analyzed by a factor of four. This increased computer storage requirement will exceed the storage capacity of the UNIVAC-1108 computer which is being used for this work. In order to perform these reduced-grid-interval tests it will be necessary to revert to the two-dimensional version of the CRAM program. Analyzing each zone separately will be a way to overcome this storage limitation problem.

The third phase of the task involves the form that the output should take. Interest has been expressed by the sponsor in having the station observations plotted on the analyzed map thereby providing a graphical presentation of how well the analyses fit the data. There are a variety of ways by which this may be accomplished. The most elaborate way would be through the use of a curve follower such as the Calcomp Incremental Plotter which is available at the computer installation being used. This equipment would draw isopleths for the analyses and would also be programmed to plot the actual observations in their approximate geographical locations. To output all the analyses for the 16 days of data using a curve follower would probably be beyond the scope of this contract, since an expenditure of several thousand dollars would be required. It might be possible, however, to provide one or two sets of analyses in this form from the 80 time periods which will be analyzed. The least elaborate form of output is to produce analyzed maps in the same fashion as the previous contract but to append a list of the stations used in the analysis with their geographical coordinates and observed data. These could then be plotted on the printout by hand. Another alternative is to produce printout as in the previous contract but with the station values printed out in their approximate geographical locations. This alternative is technically feasible and can be accomplished within the resources of the present contract. Some further exploratory work will be carried out while awaiting guidance from the sponsor as to the desired alternative. It is desirable to have this guidance as soon as possible.

2.2.2 Task 2--Ballistic Winds Evaluation

The principal objective of this task is to investigate space and time variability of ballistic winds as a means of determining optimum station spacing and observing frequency. Space and time variability will be studied using both station data and analyses.

Space variability based on station data will be derived from root-mean-square wind differences (RMSWD) between stations computed by zone (extending to Zone 12) over the entire 80 map series. Every combination of station pairs will be considered. From these differences, a variety of graphs and maps will be produced to study the spatial variability. For example, graphs will be produced showing the relationship of RMSWD with distance between stations and for each zone. Maps will be produced in which each station is used as a focal point with the RMSWD between it and each of the surrounding stations being plotted and analyzed for a given zone. (e.g., Map 1 will show the space variability with reference to Benson, Map 2 with reference to Bisbee, etc.).

In similar fashion, RMSWD will be computed for each station for time lags of 2, 4, 6, and 8 hrs to provide data for investigating time variability of ballistic winds. Results will be analyzed using both graphs and maps.

In addition to using station data, objectively analyzed wind fields will also be used to study space and time variability. Grid points which are close to significant topographical features will be used as focal points to determine the characteristics of space and time variability when referenced to ridges, valleys, etc.

Since previous time-and-space-variability studies of temperature and density indicate little variability on the scales being considered, primary emphasis in this study will be placed on wind variability.

Another phase of this task will be to work with residual errors computed from applying Line 10 ballistic information to the actual Ft. Huachuca artillery firings. Residual errors were computed in the previous study using CRAM analyses and also single station data from Ft. Huachuca. The next step will be to calculate residual errors based on other stations within the network. Maps of residual errors will be constructed and analyzed showing the horizontal variation in residual errors. Since the ballistic coefficients which were used in the original study introduced a bias in range error, only the deflection component of the residual error will be considered. If new coefficients are derived by BRL, the range errors can also be analyzed.

Another use of the firing data will be to classify residual errors derived from stations according to the prevailing flow (i.e., is the station upstream, downstream, from the firing position, etc.).

2.2.3 Task 3—Withheld Data Experiments

The primary objective of this task is to estimate the loss of accuracy in ballistic wind specification when rawinsonde observations are unavailable over a large geographical area, such as might be the case in a field combat situation in which the territory down-range from the artillery location is controlled by enemy forces. Ballistic winds based on the entire observational network will be compared with ballistic winds computed from a set of stations which are all "up-range" from the target location.

2.2.4 Task 4—Stability Experiments

This task was proposed to consider the effects of atmospheric stability on the circulation in the low levels. Soundings will be constructed from the rawinsonde data and the lapse rates will be used to classify situations as "stable" or "unstable." At the same time the trajectories of the balloons will be plotted on maps and their behavior in the vicinity of topographical features will be studied both for stable as well as unstable situations to determine whether the trajectories possess different characteristics which are related to stability. Also, time and space variability will be investigated by stratifying the data on the basis of stability.

2.2.5 Task 5—Prediction Techniques

Time variability studies conducted in the previous contract indicated that the variability in the low levels was much smaller than in the high levels. This suggests that the prediction technique of extrapolating the entire integrated ballistic wind may not be the best. One experiment is planned to predict the individual zones separately, with the predicted ballistic wind then computed from the predicted zone winds. Other prediction experiments will be designed from consideration of other time and space variability characteristics which are found from the other tasks to contribute useful information.

2.3 Allocation of Resources

The following percentage of resource allocation represents a best estimate of what is needed to satisfactorily perform the five tasks of the contract. Unforseen developments along the way, if they occur, could dictate some shifts in emphasis among the tasks. It should also be pointed out that the tasks are inter-related in many respects

and that the estimations of percentages were made within such an inter-related framework. The percentages are as follows:

Task		Percent
1	CRAM Modifications and Tests	20
2	Ballistic Winds Evaluation	30
3	Withheld Data Experiments	10
4	Stability Criteria Studies	20
5	Prediction Techniques	20

3.0 STATUS OF TASKS

3.1 Task 1—CRAM Modifications and Tests

The Conditional Relaxation Analysis Method (CRAM) computer program has been modified to accept input of Zone 11 and 12 data and use these additional zones in the two- and three- dimensional analysis routines.

After the initial CRAM program was written, a change in EDP equipment (from IBM-7094 to UNIVAC-1108) took place at the computer installation being used for this research. Since this change would provide greater efficiency for our computer requirements, it was decided to perform the necessary minor modifications, such as input/output revisions, tape conversions, etc., to be able to take advantage of this potential.

An additional program change being made to CRAM is one which will allow the observed station values to be printed on the analysis output in their approximate geographical locations. This will permit easier visual reference in evaluating the accuracy of the analyses.

Another phase of this task which is in progress is the formulation of a "fine mesh" version of the CRAM program. When completed, it will be possible to analyze a portion of the grid using a grid spacing of 5 km rather than 10 km.

3.2 Task 2—Ballistic Winds Evaluation

One phase of this task as mentioned in Section 2.2 is concerned with the computation of residual errors from other stations in the network in addition to Ft. Huachuca. Accordingly, Line 10 ballistic information has been employed to compute residual deflection errors for each station reporting (range errors are not shown because of the bias in the range data) for the 24 time periods for which 8-inch Howitzer firings were conducted. Maps of residual deflection errors are shown in Figs. 1 through 24. The minimum deflection error is generally not in the vicinity of the firing area (Ft. Huachuca) as can be seen from the figures. The minimum error is at Ft. Huachuca on only two occasions: 1000 MST 27 January and 1400 MST 6 February. On the other hand, the minimum error can be found at Nogales 8 times. The maximum deflection error is located at Ft. Huachuca on one map (1400 MST 16 January). The maximum error can be found at Douglas and Tombstone on five occasions each.

3.3 Task 3—Withheld Data Experiments

Inactive—later start.

3.4 Task 4—Stability Experiments

This task is still in the initial stages. Soundings have been plotted for all stations and will be used to compute low-level lapse rates which will be used to establish stability criteria. The plotting of radiosonde balloon trajectories will be initiated shortly.

3.5 Task 5—Prediction Techniques

Inactive—later start.

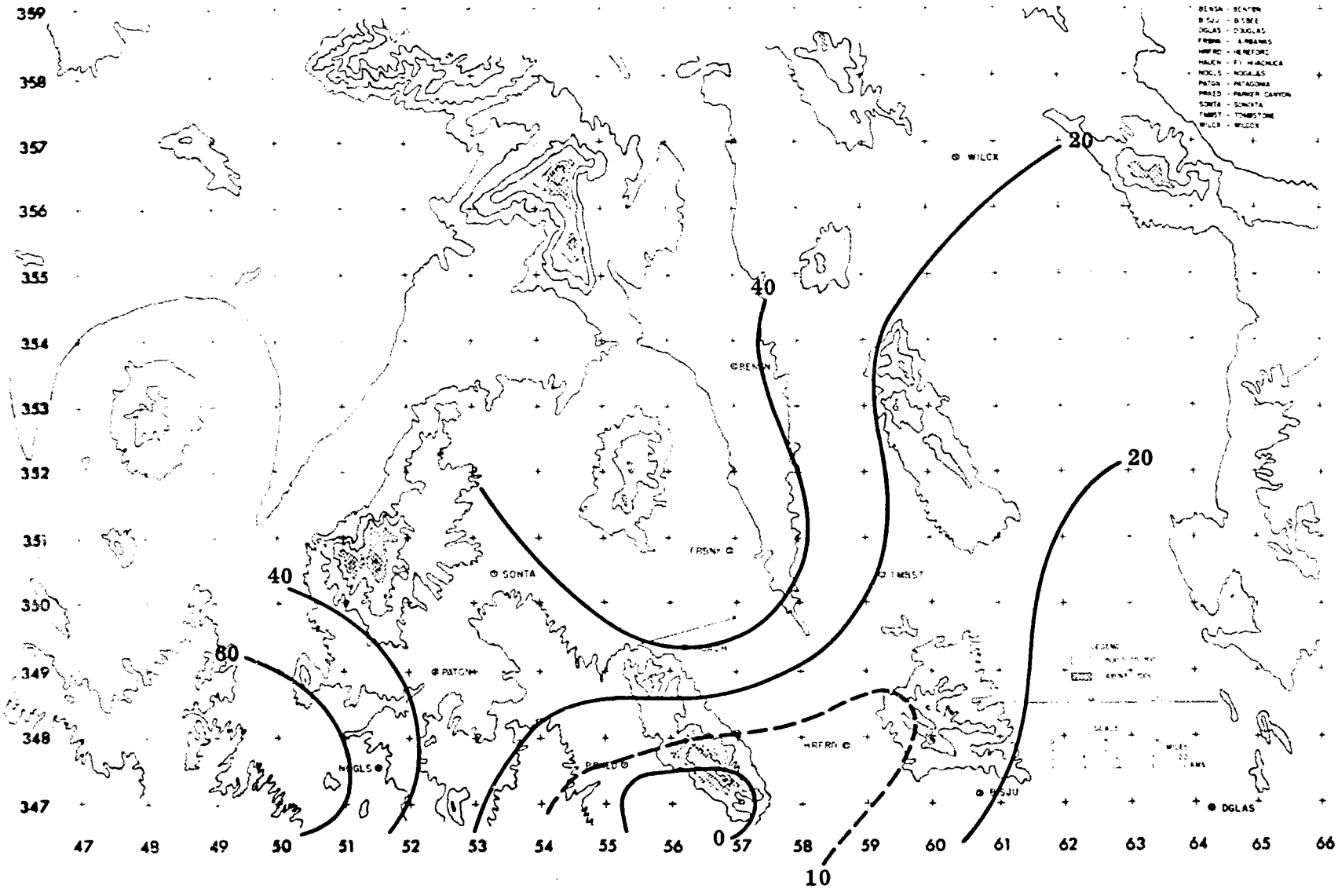

Fig. 1. Residual deflection errors; firing time is 1000 MST 16 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

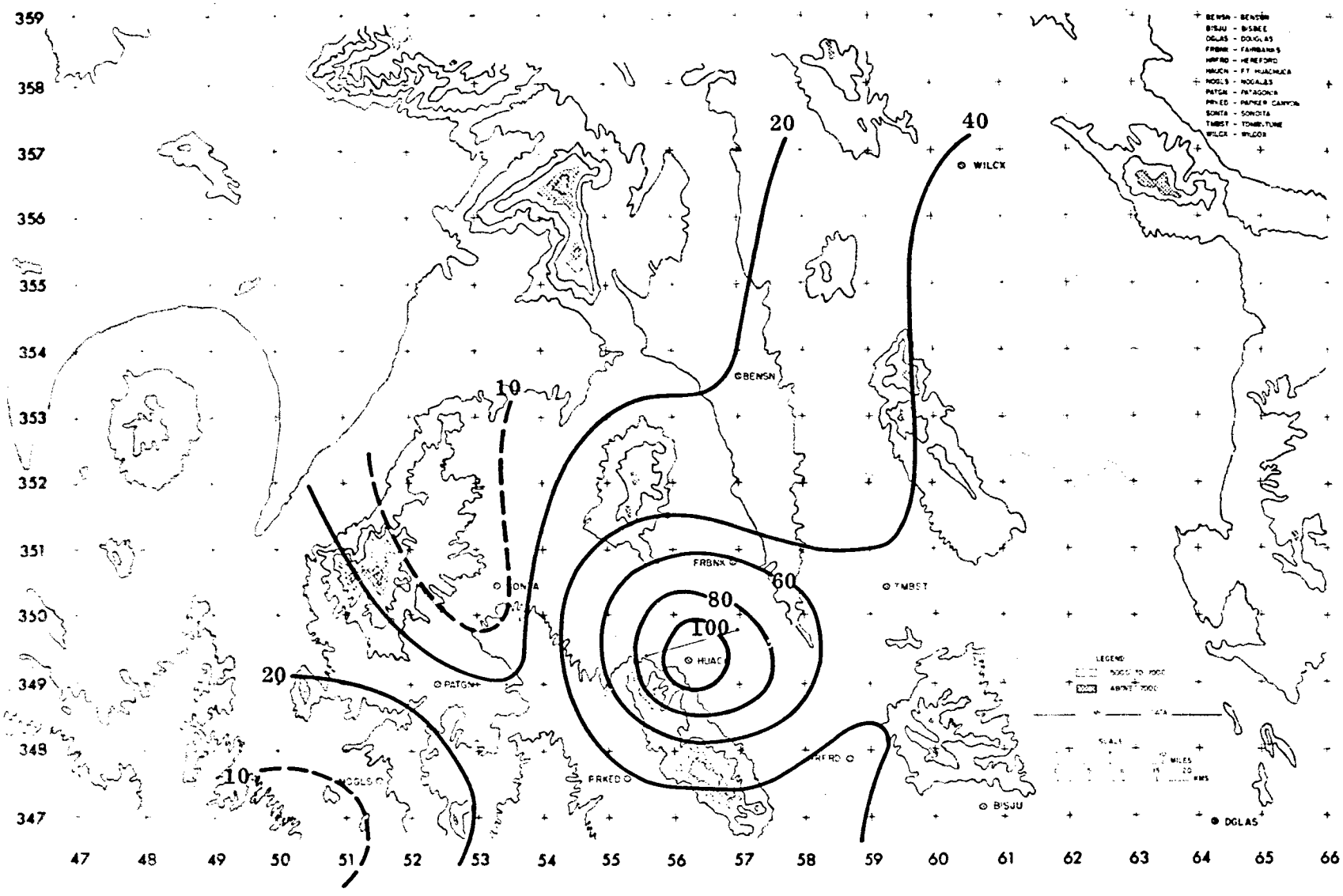

Fig. 2. Residual deflection errors; firing time is 1400 MST 16 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

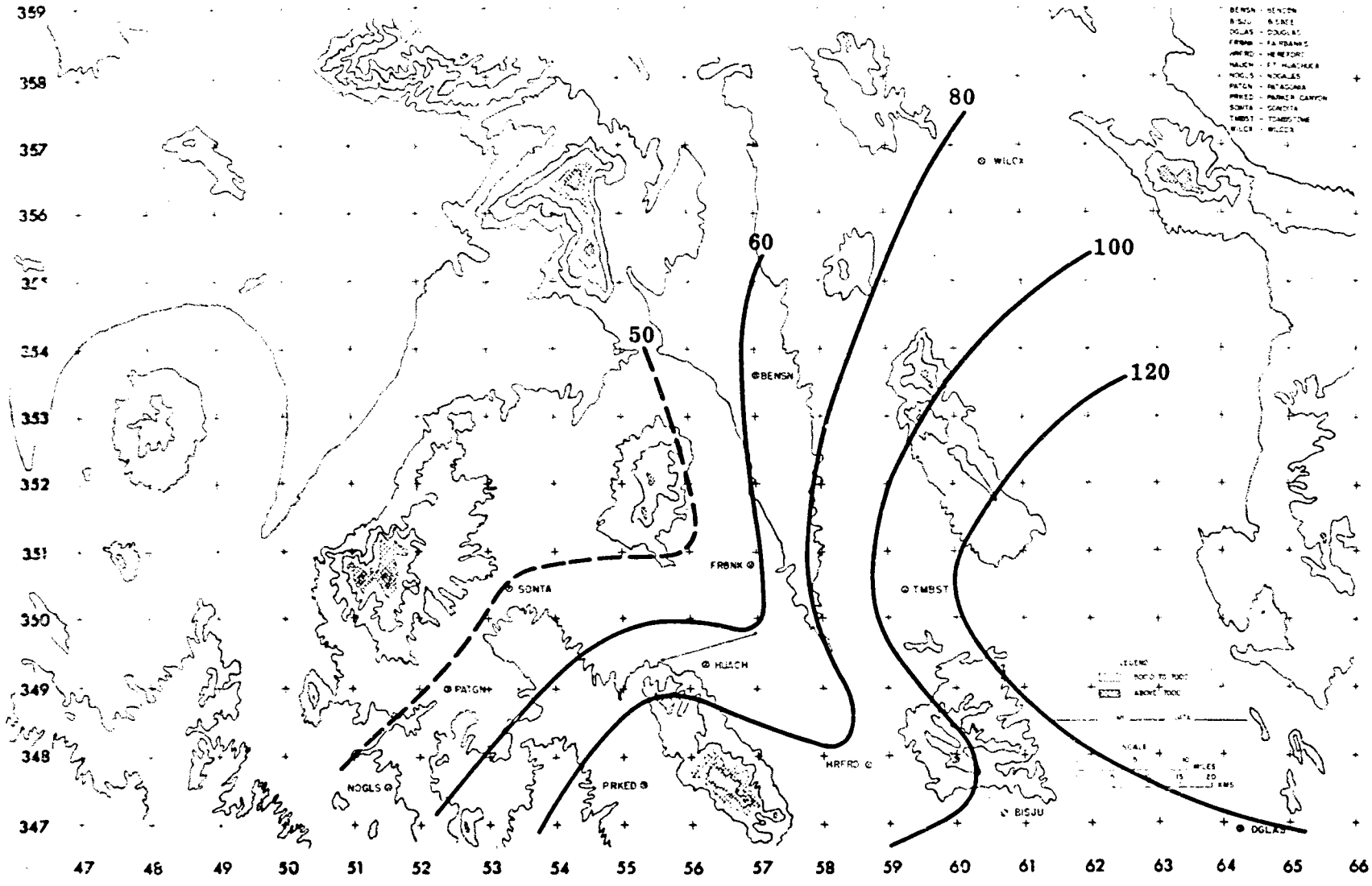

Fig. 3. Residual deflection errors; firing time is 1000 MST 18 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

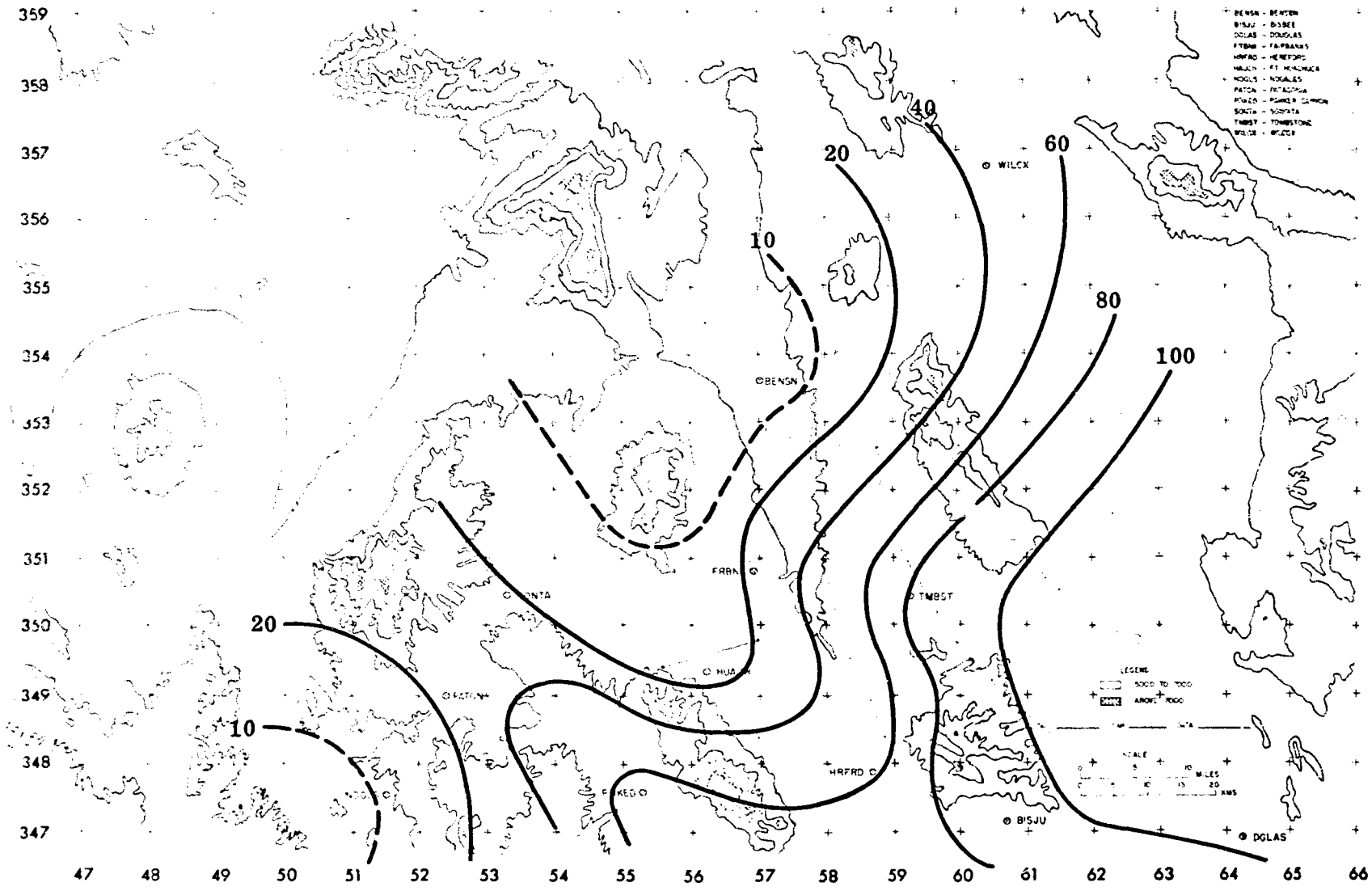

Fig. 4. Residual deflection errors; firing time is 1400 MST 18 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

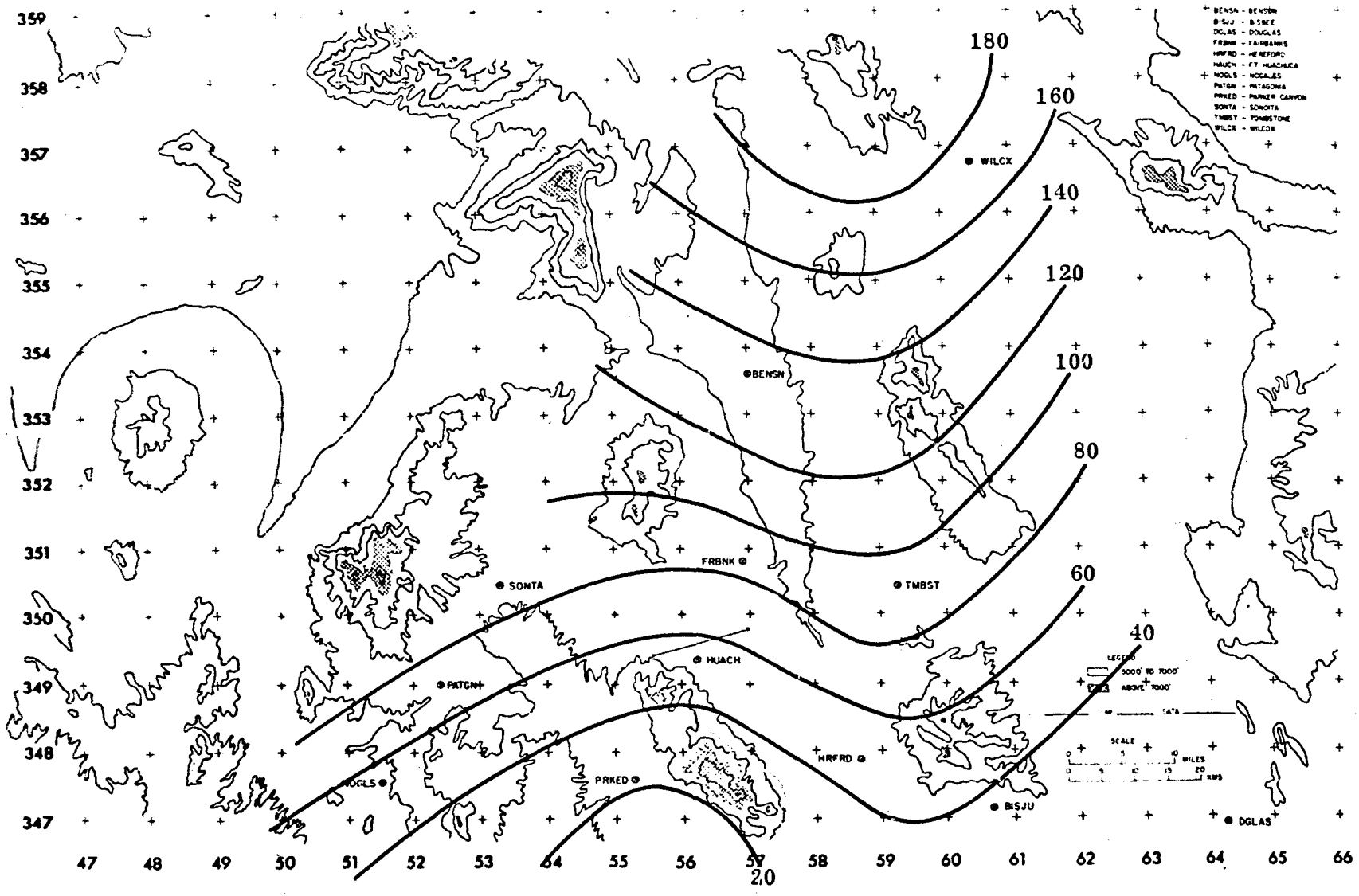

Fig. 5. Residual deflection errors; firing time is 1000 MST 20 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

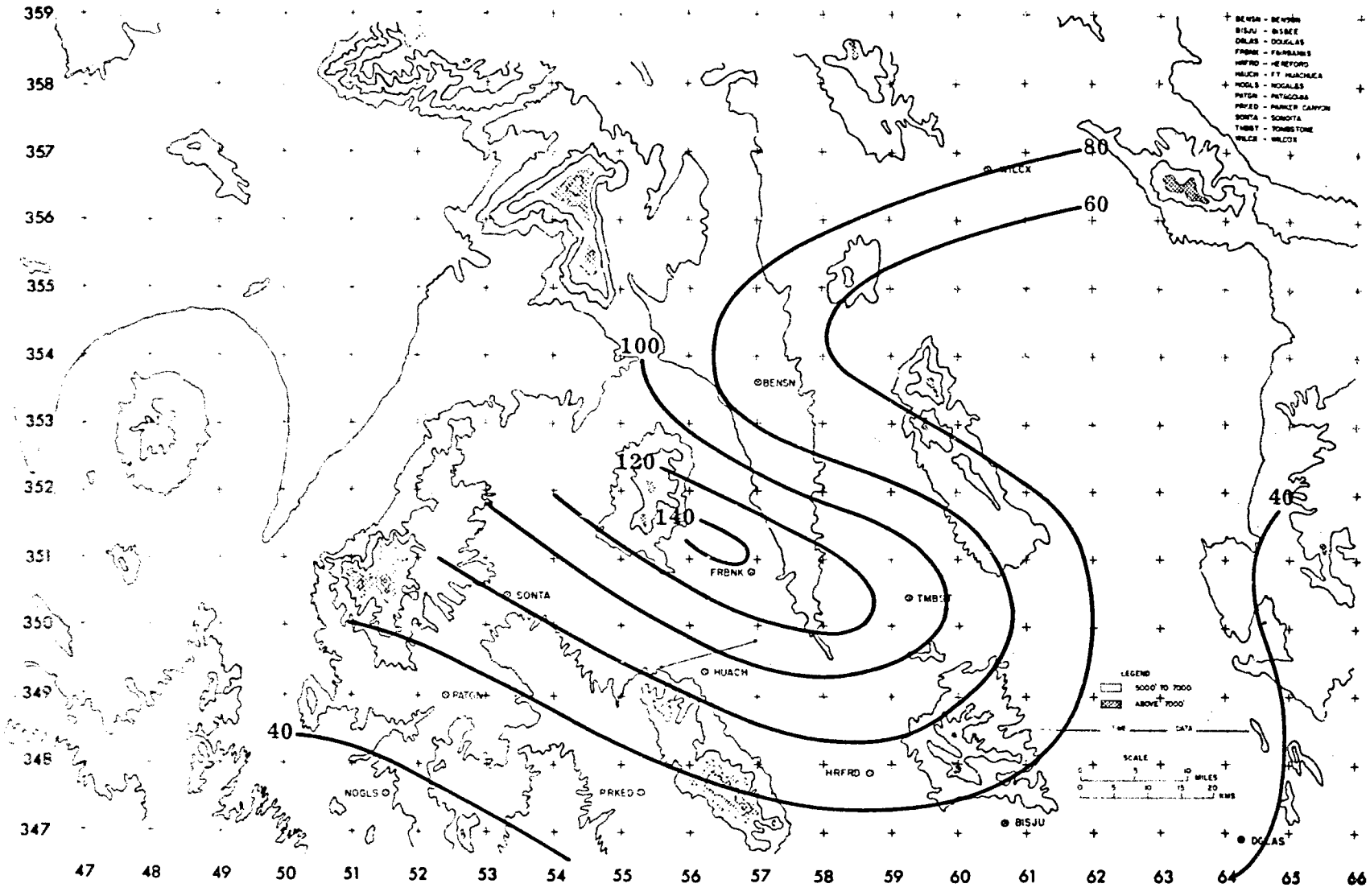

Fig. 6. Residual deflection errors; firing time is 1400 MST 20 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

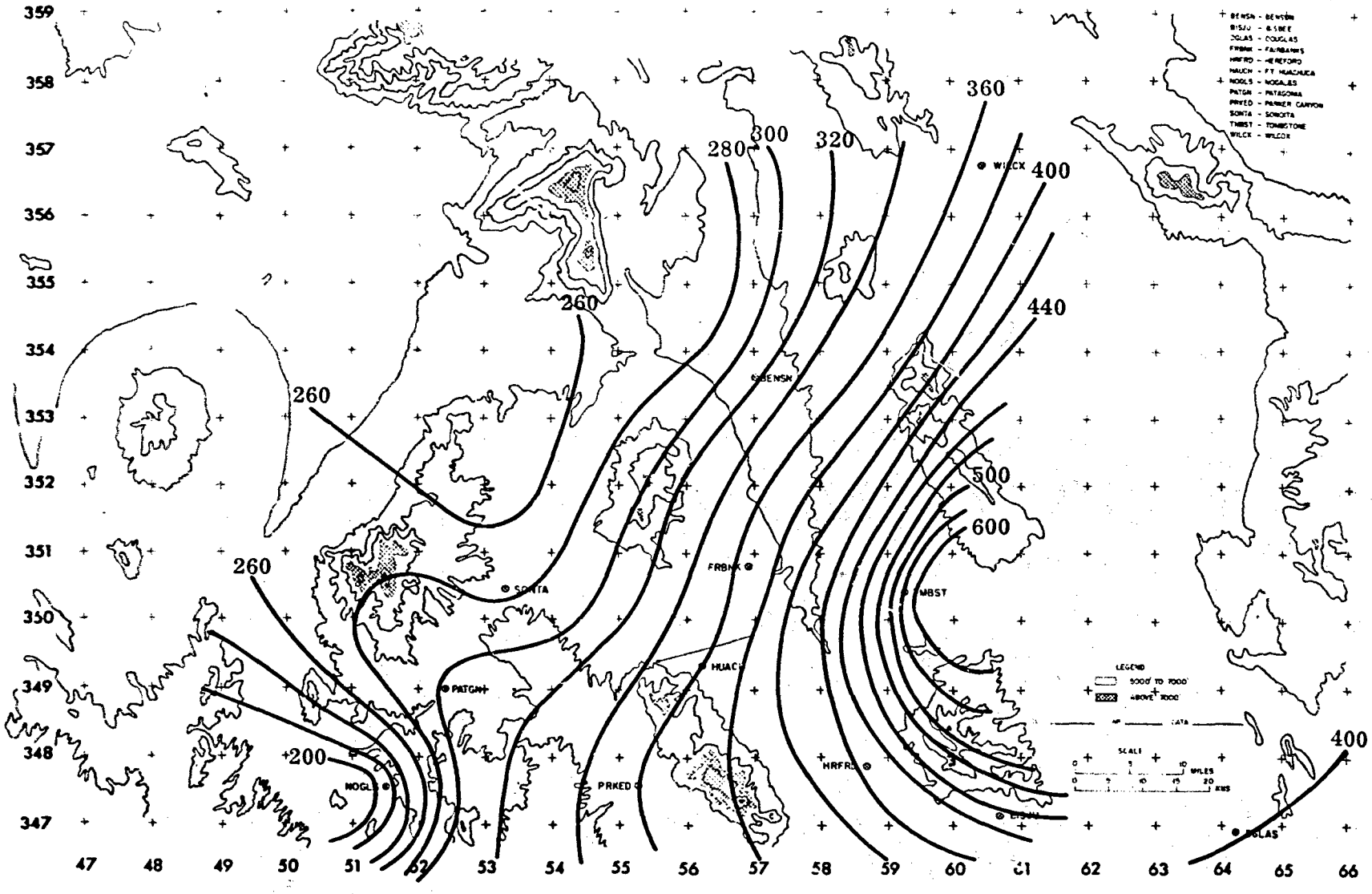

Fig. 7. Residual deflection errors; firing time is 1000 MST 22 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

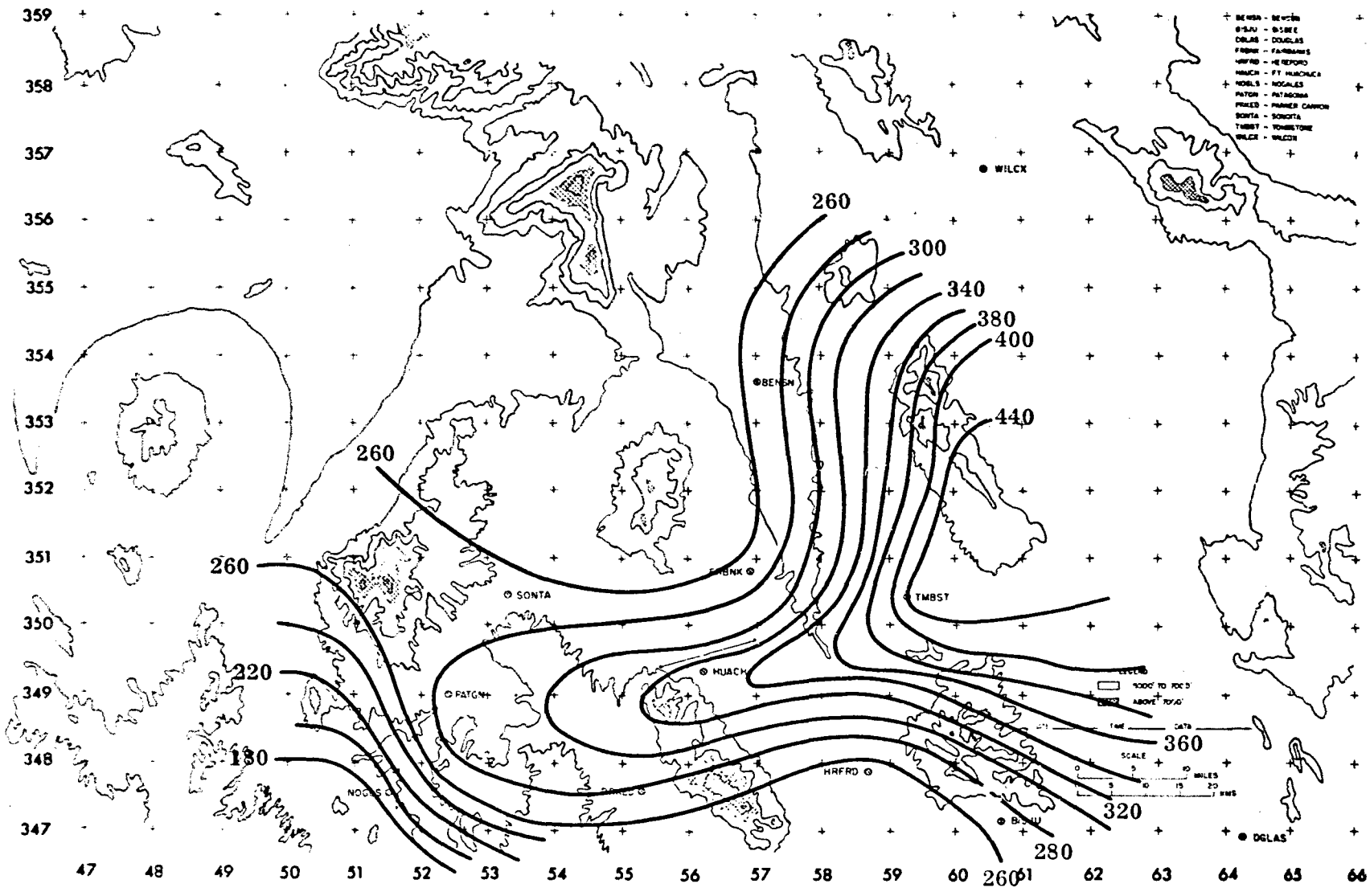

Fig. 8. Residual deflection errors; firing time is 1400 MST 22 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

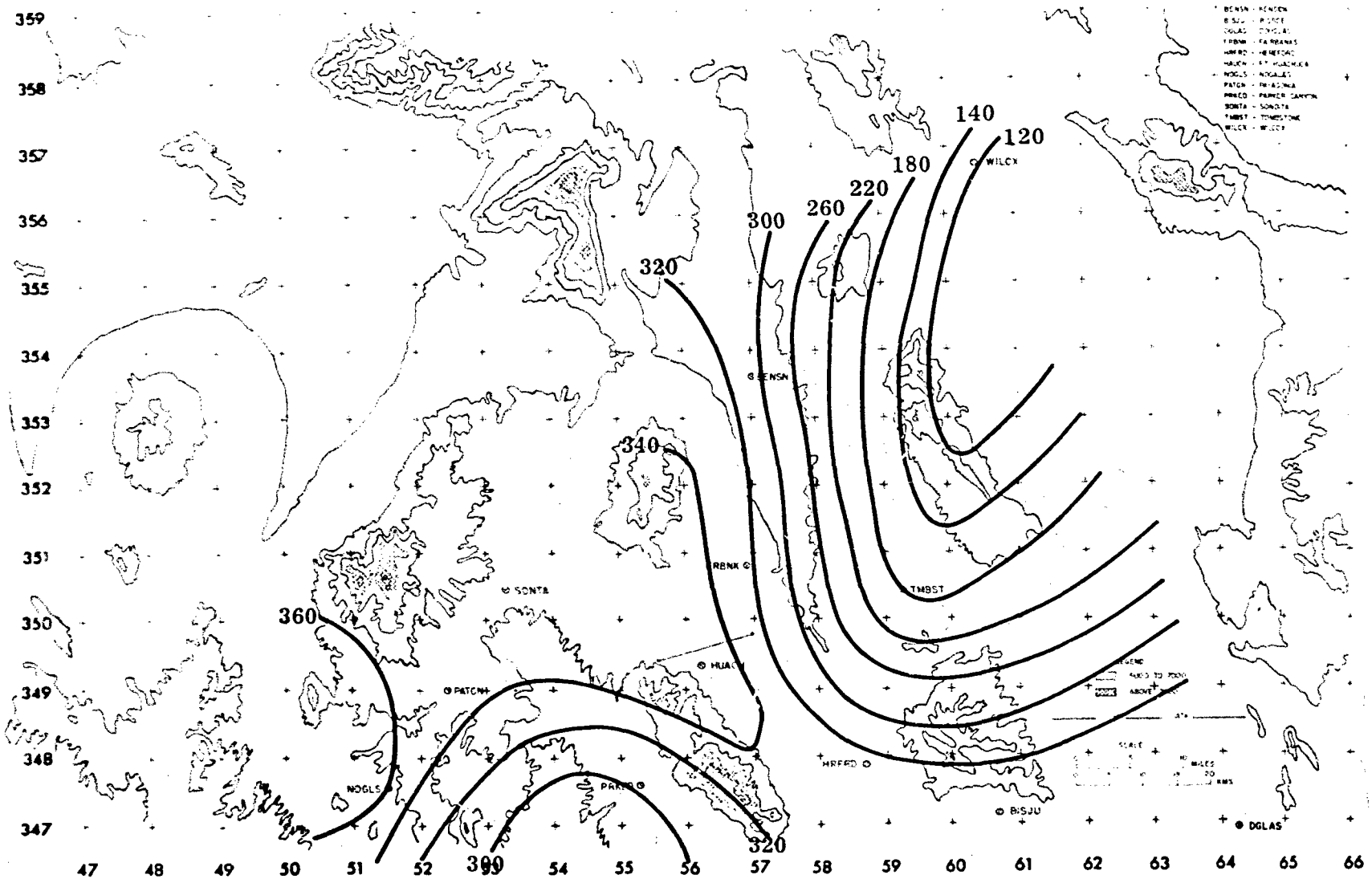

Fig. 9. Residual deflection errors; firing time is 1000 MST 25 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

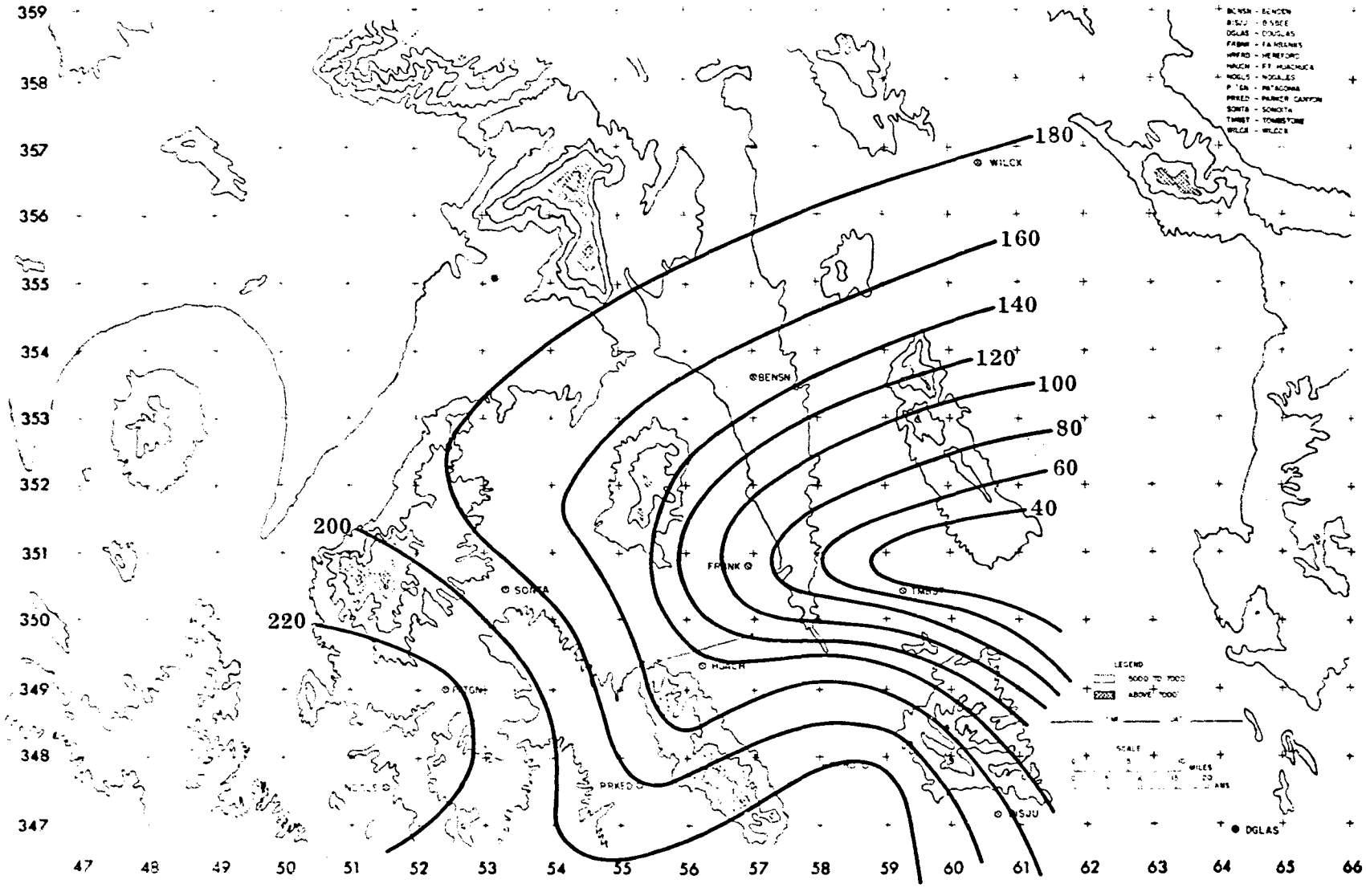

Fig. 10. Residual deflection errors; firing time is 1400 MST 25 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

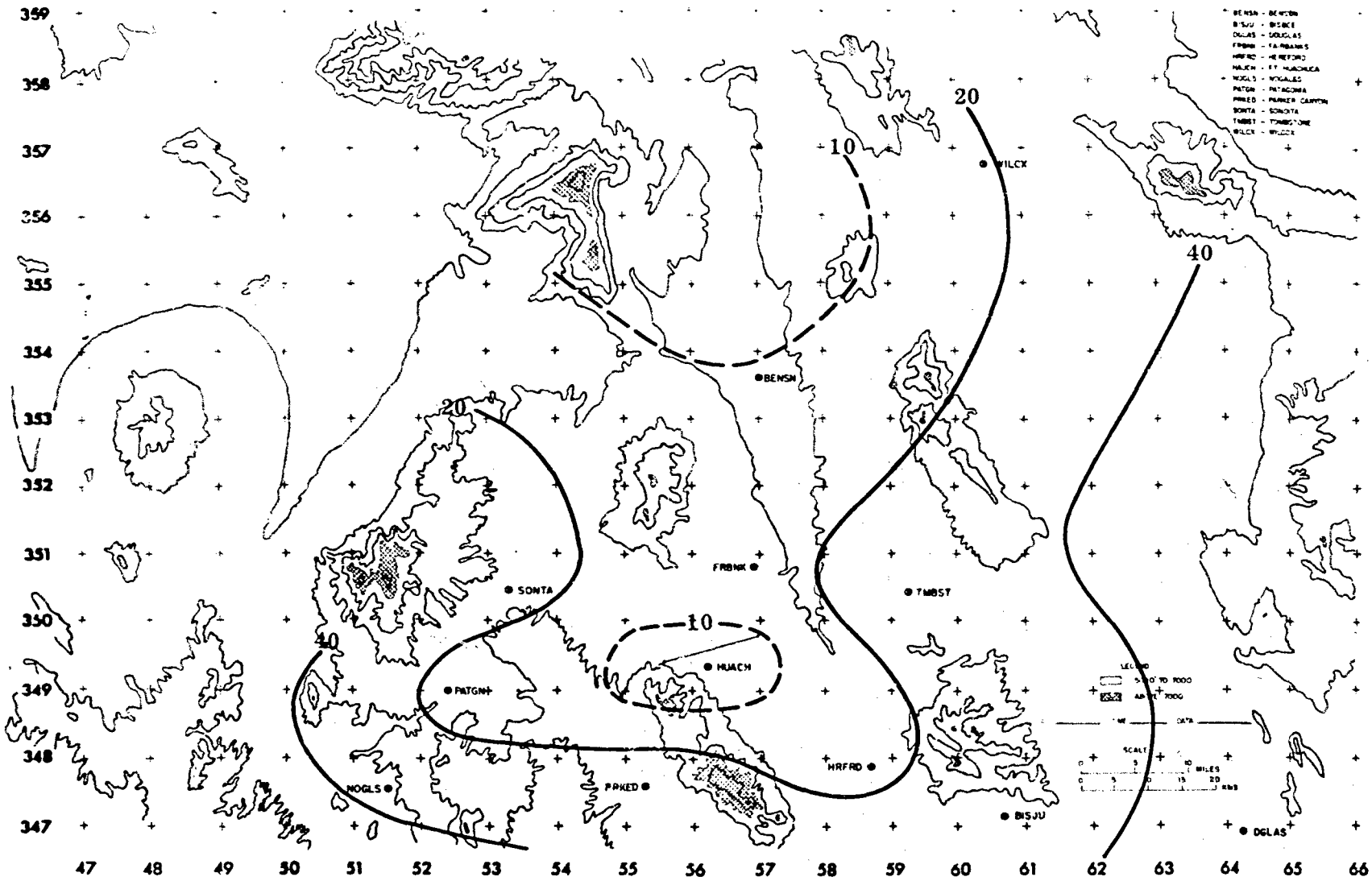

Fig. 11. Residual deflection errors; firing time is 1000 MST 27 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

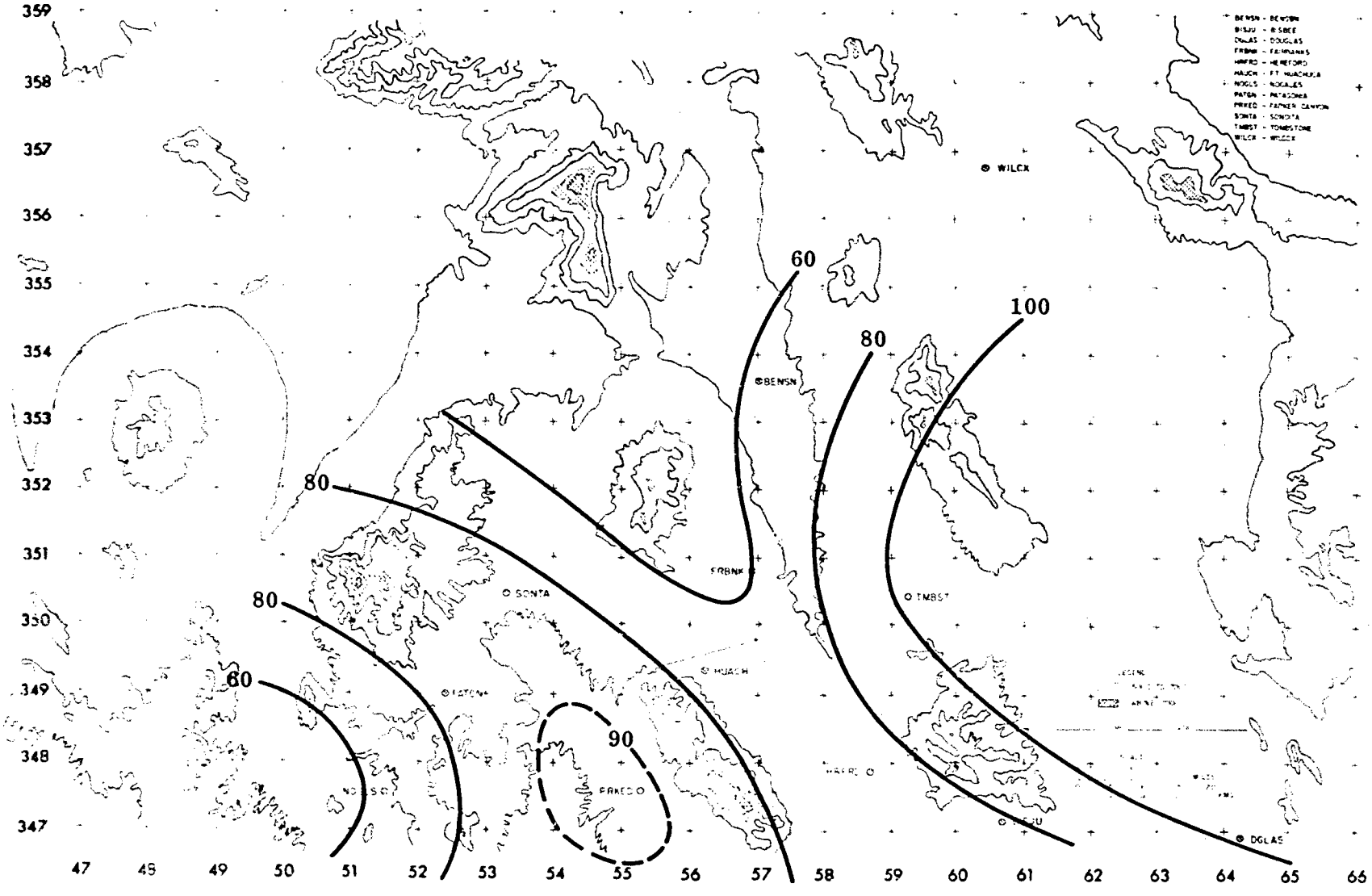

Fig. 12. Residual deflection errors; firing time is 1400 MST 27 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

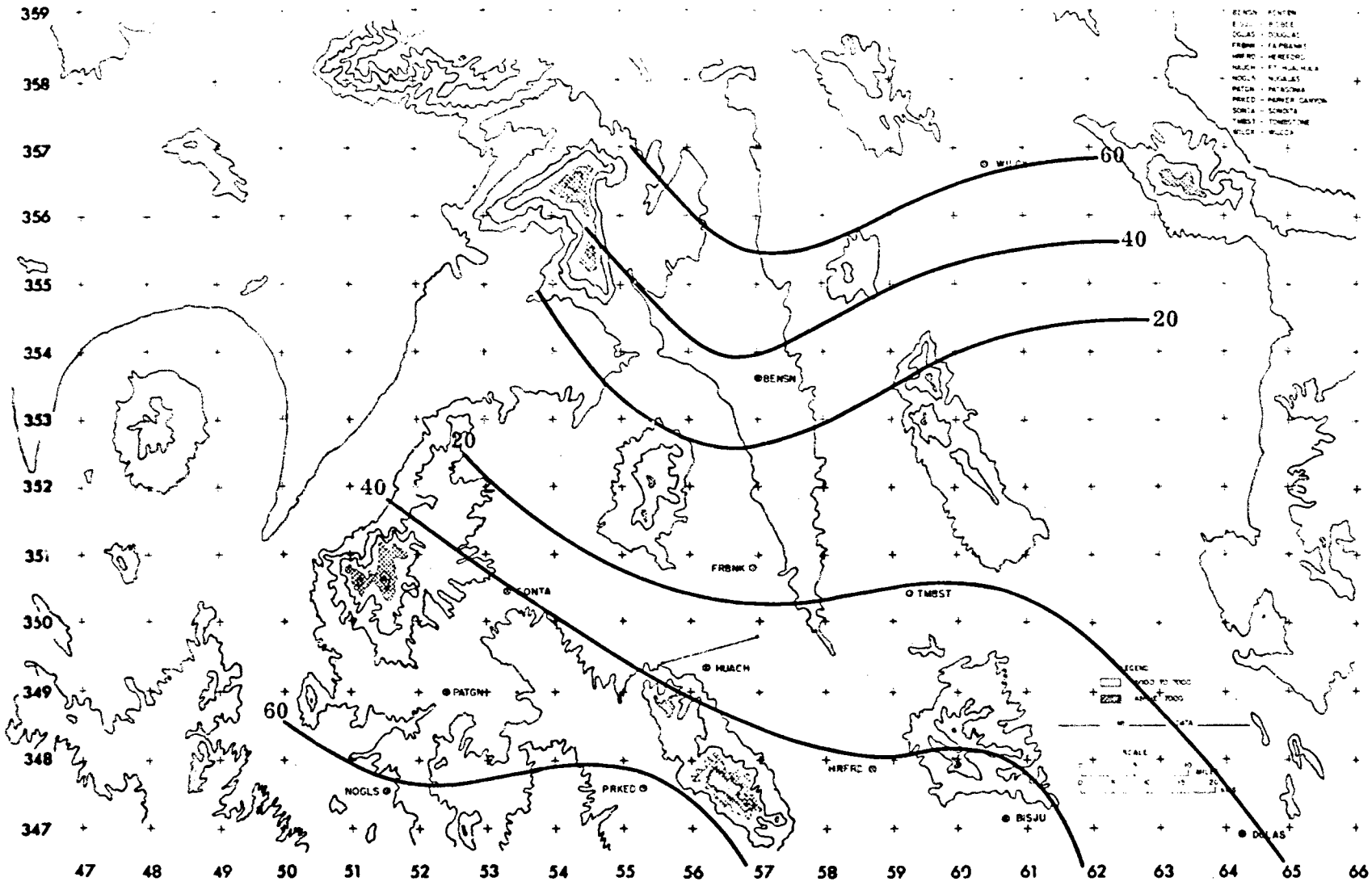

Fig. 13. Residual deflection errors; firing time is 1000 MST 29 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

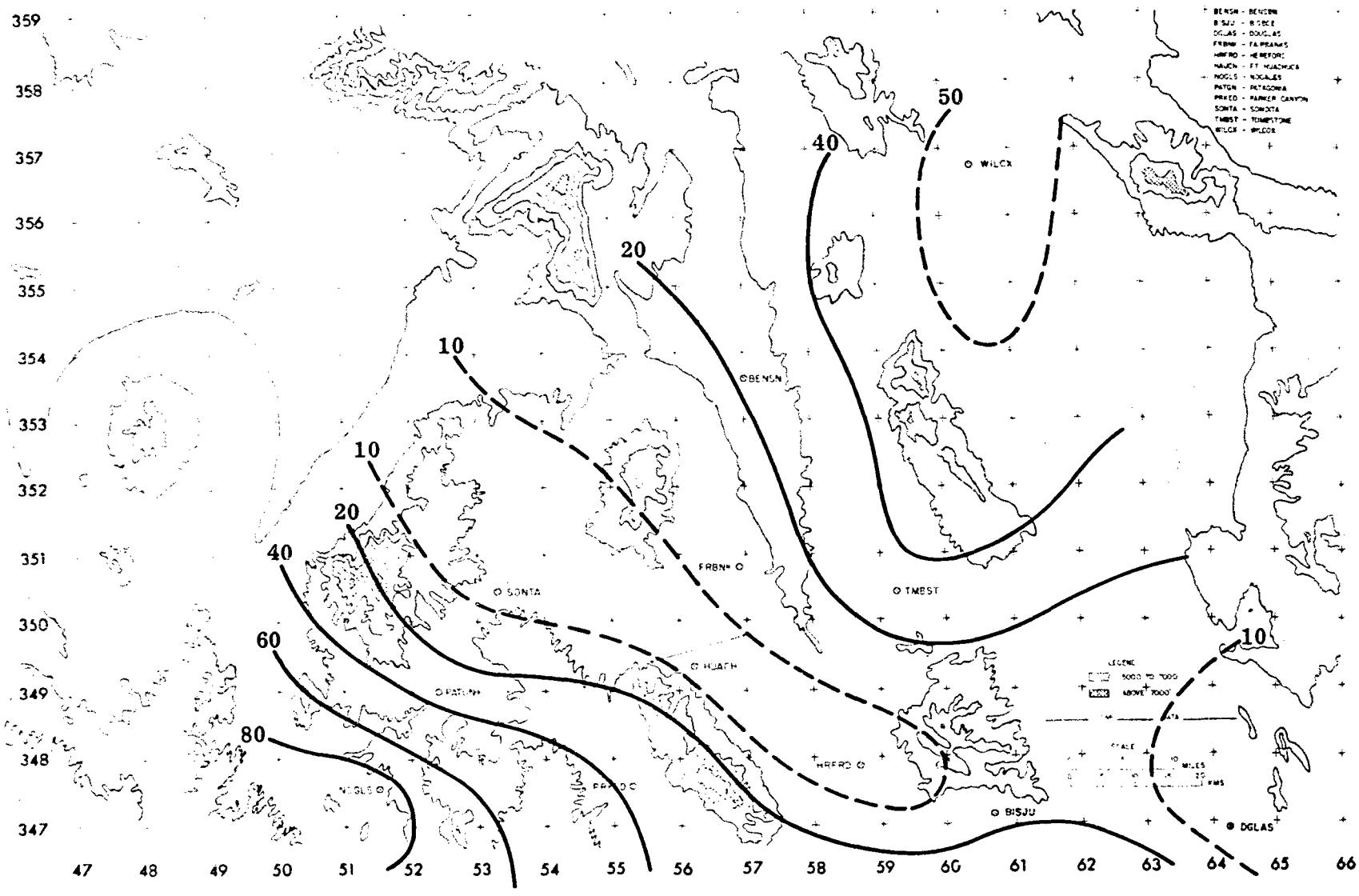

Fig. 14. Residual deflection errors; firing time is 1400 MST 29 January 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

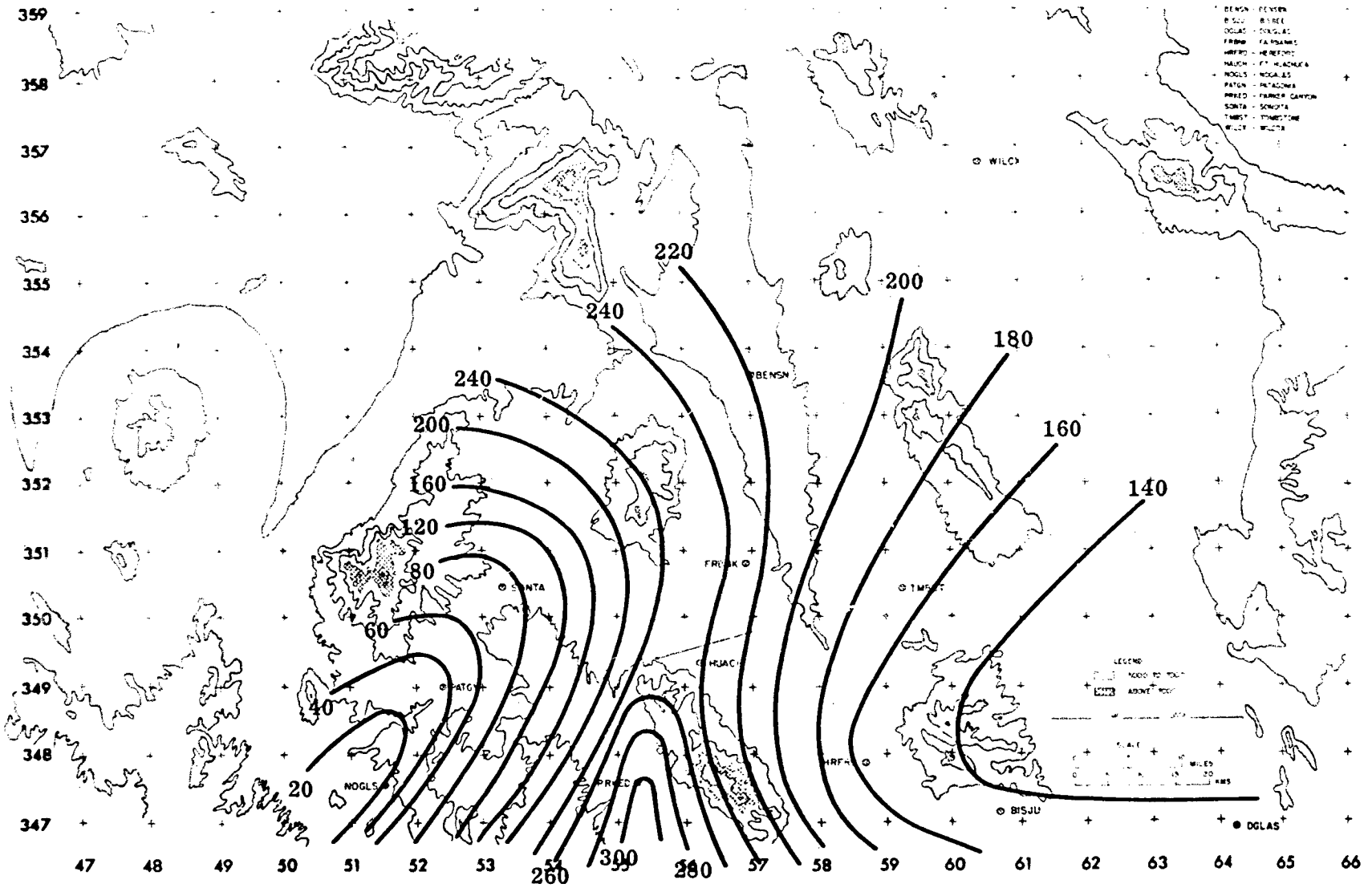

Fig. 15. Residual deflection errors; firing time is 1000 MST 2 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

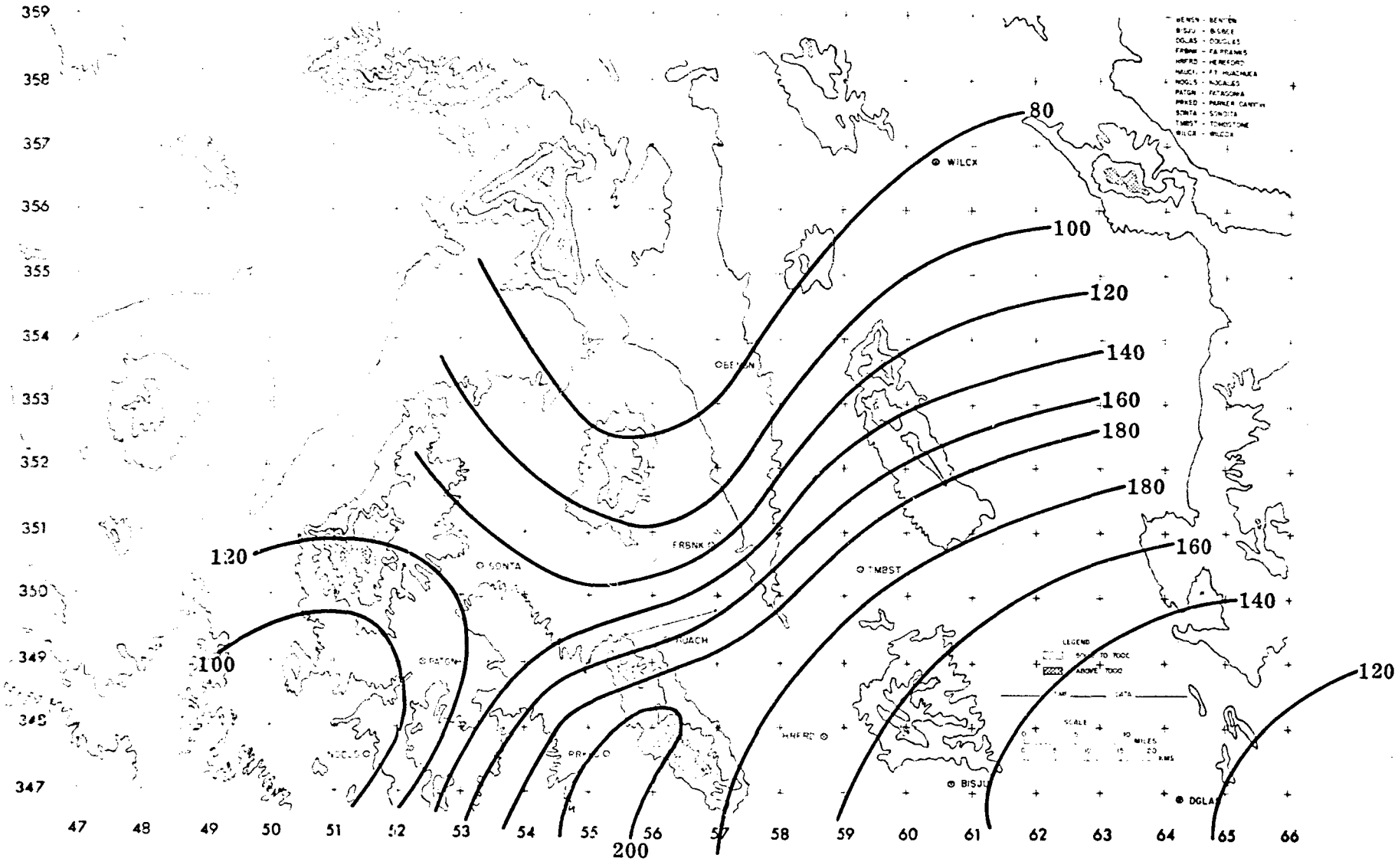

Fig. 16. Residual deflection errors; firing time is 1400 MST 2 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

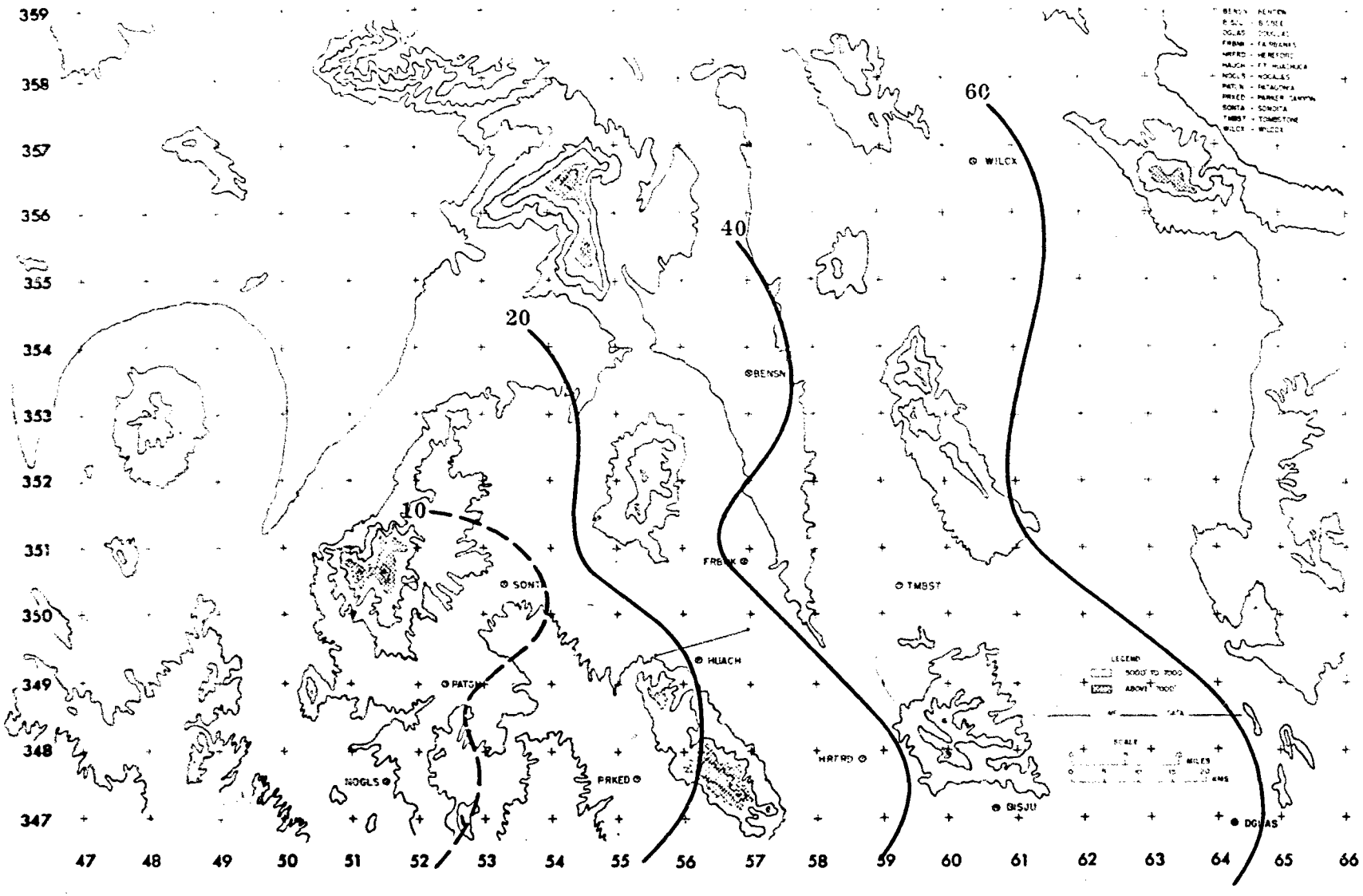

Fig. 17. Residual deflection errors; firing time is 1000 MST 4 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

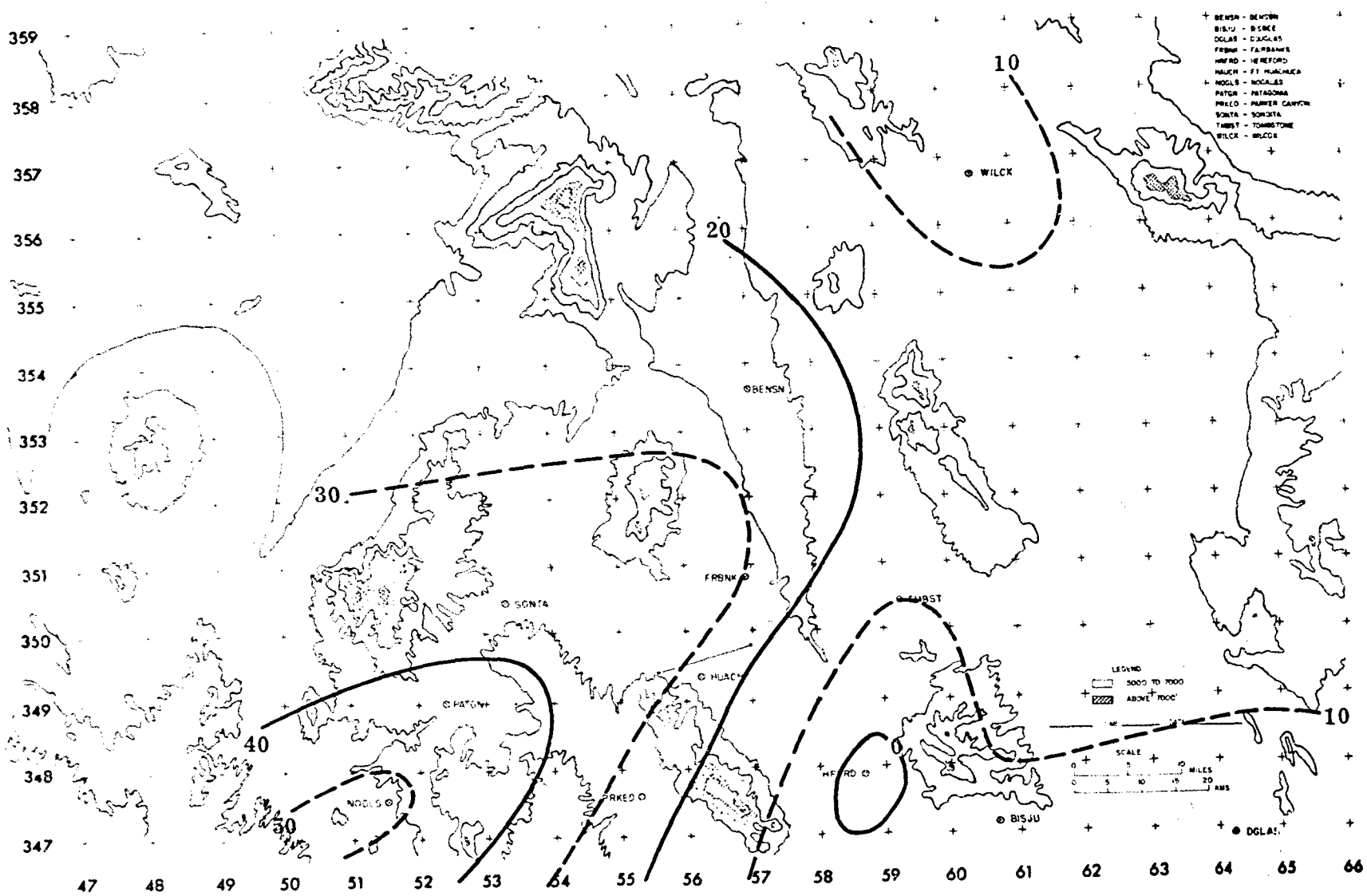

Fig. 18. Residual deflection errors; firing time is 1400 MST 4 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

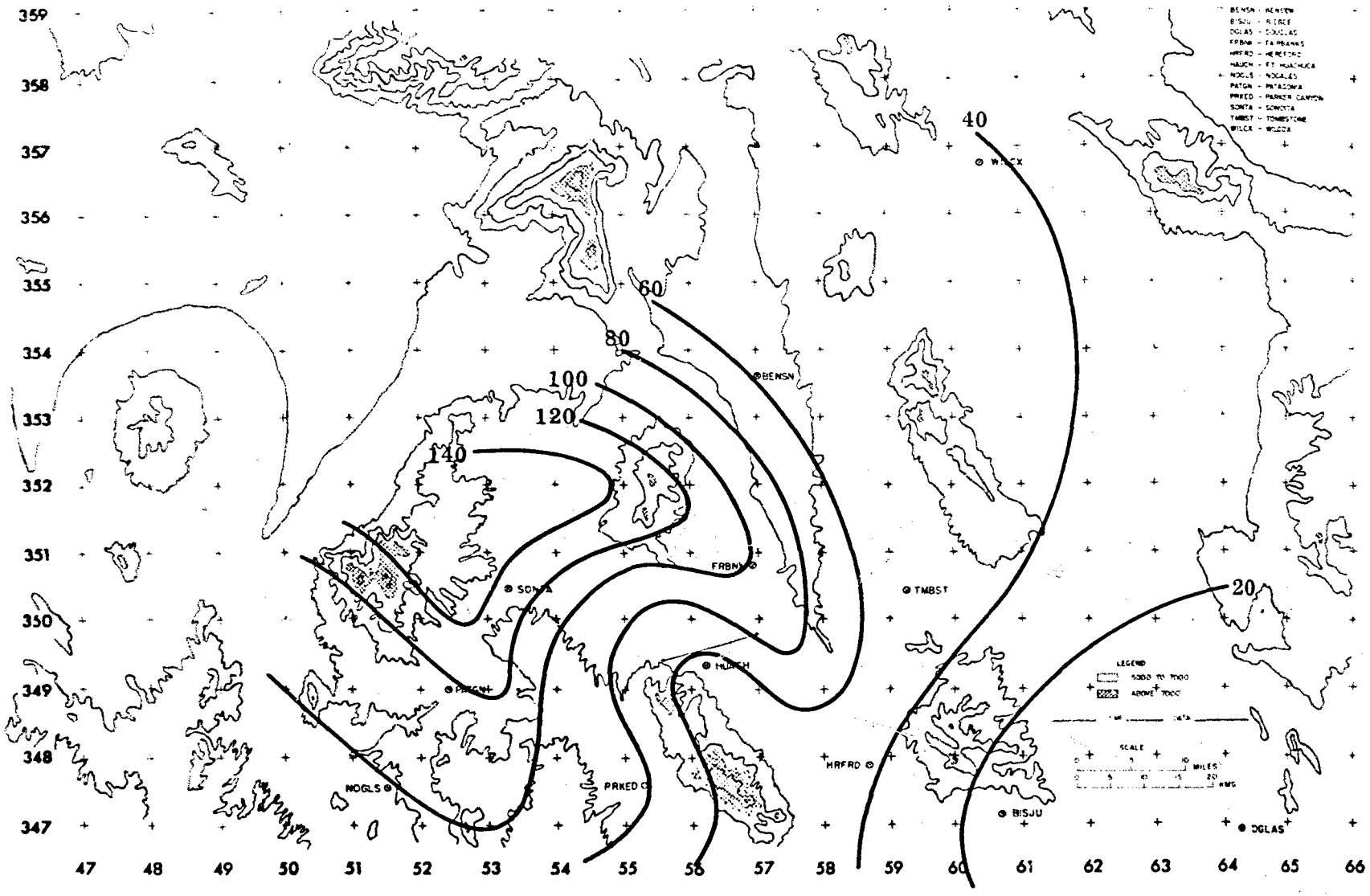

Fig. 19. Residual deflection errors; firing time is 1000 MST 6 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

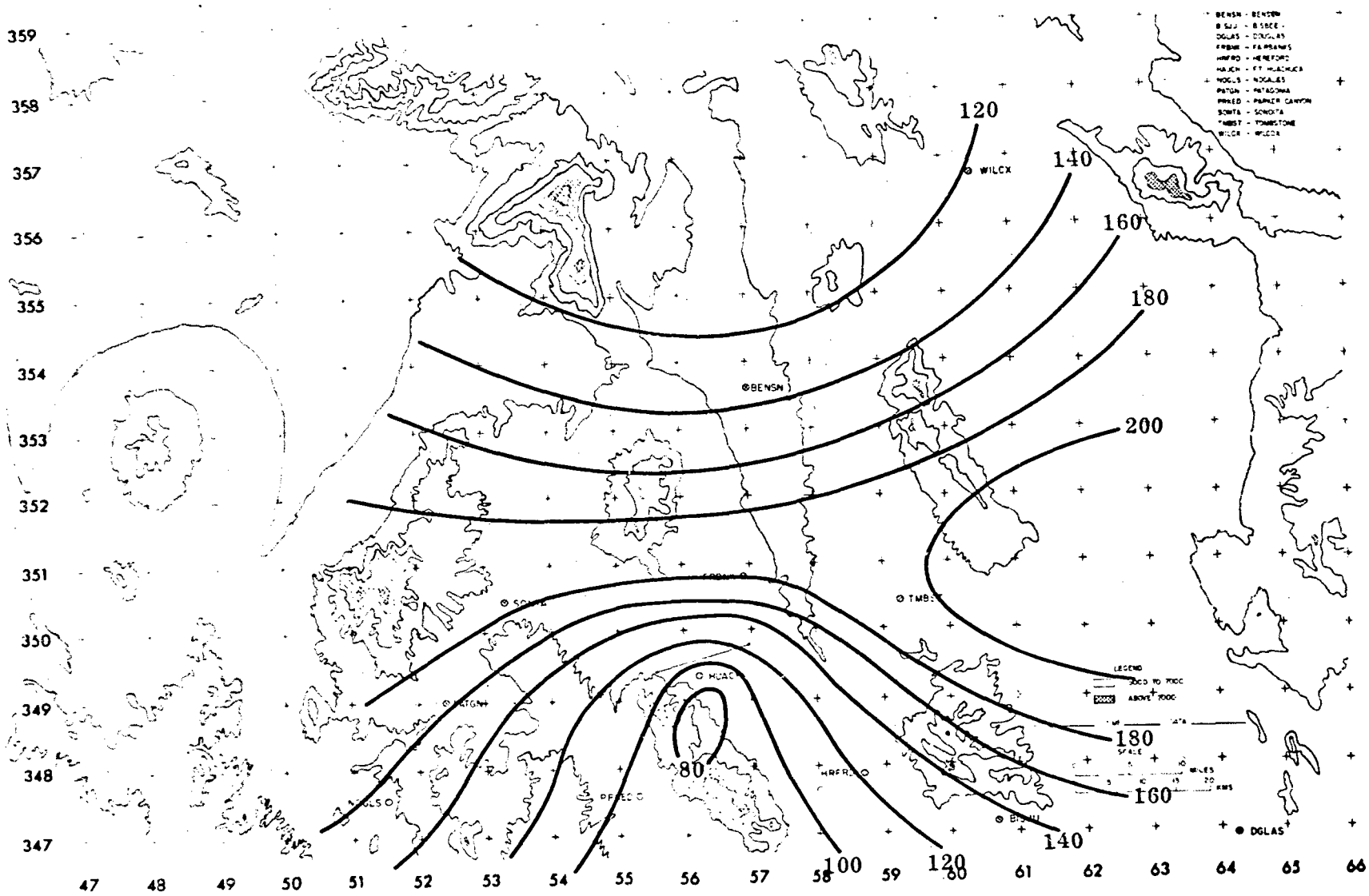

Fig. 20. Residual deflection errors; firing time is 1400 MST 6 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

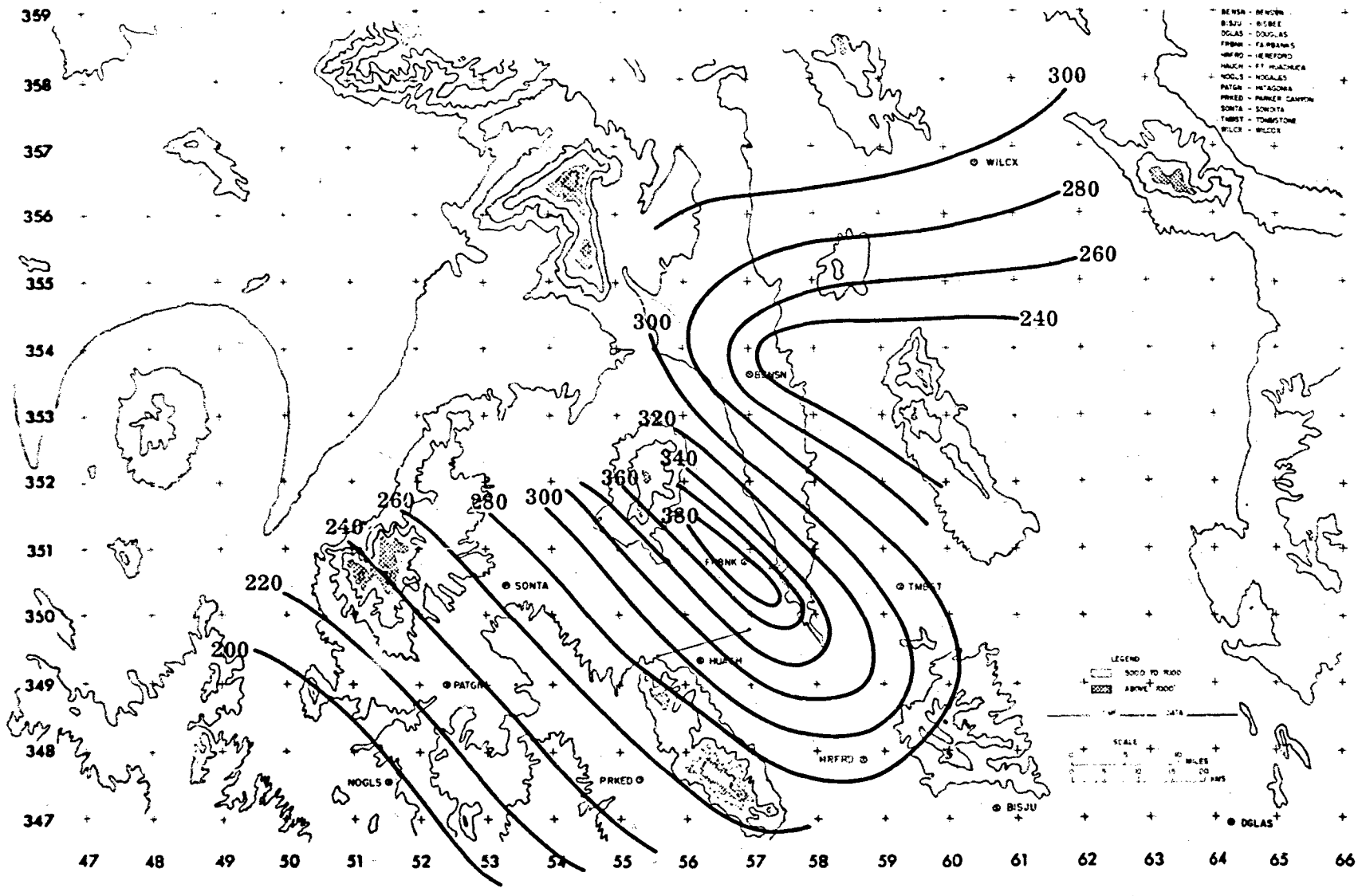

Fig. 21. Residual deflection errors; firing time is 1000 MST 10 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

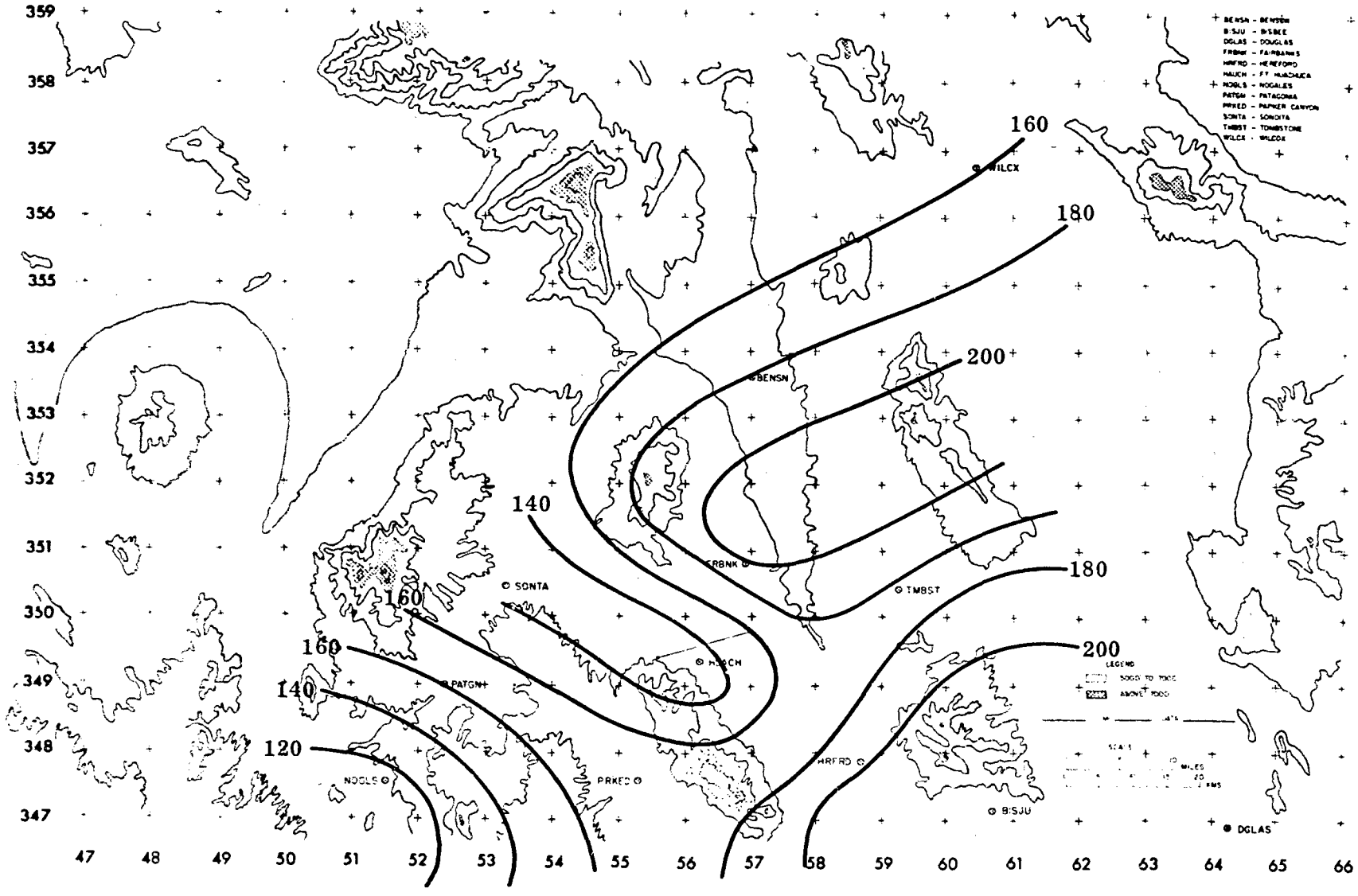

Fig. 22. Residual deflection errors; firing time is 1400 MST 10 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

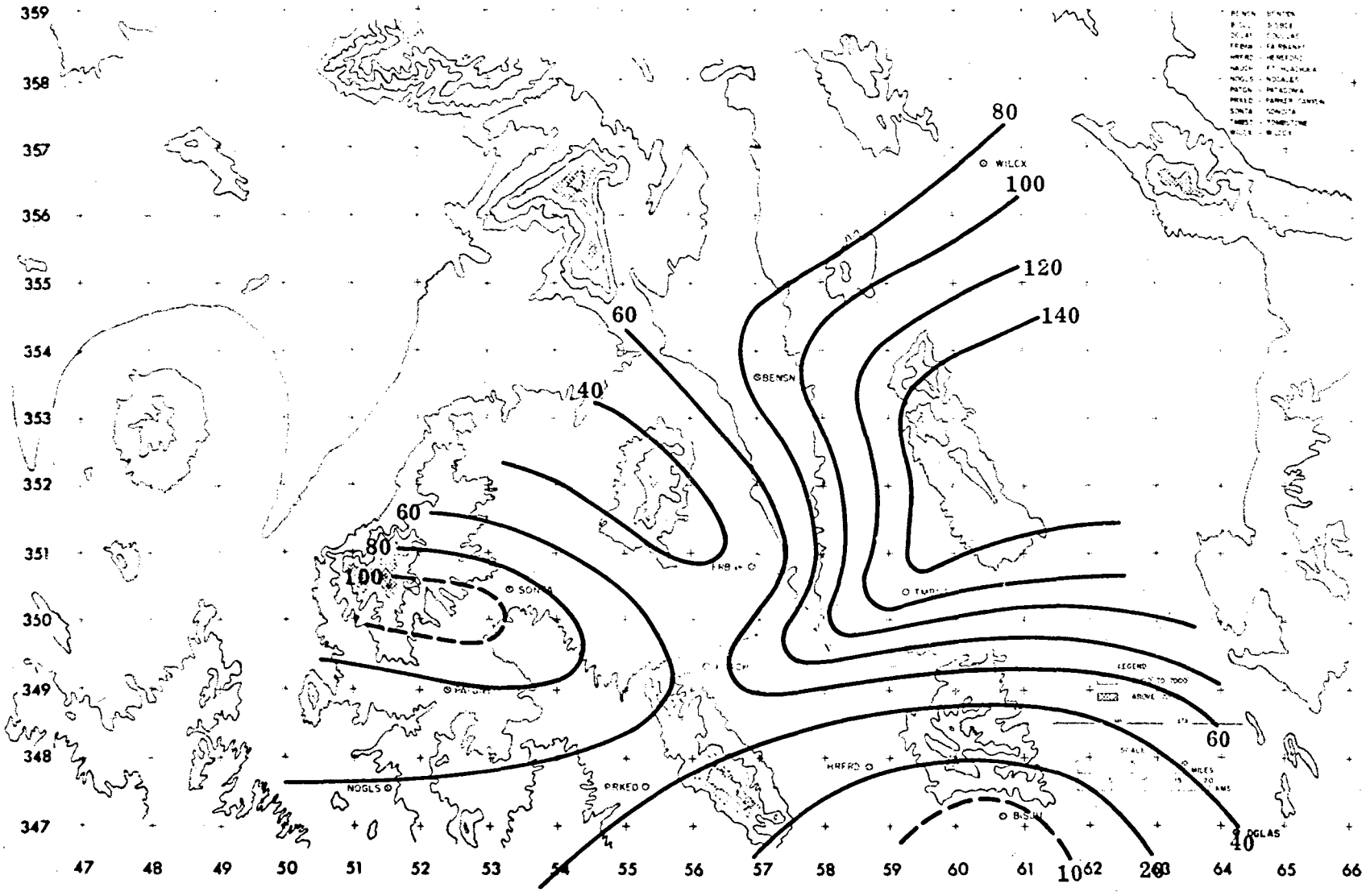

Fig. 23. Residual deflection errors; firing time is 1000 MST 12 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

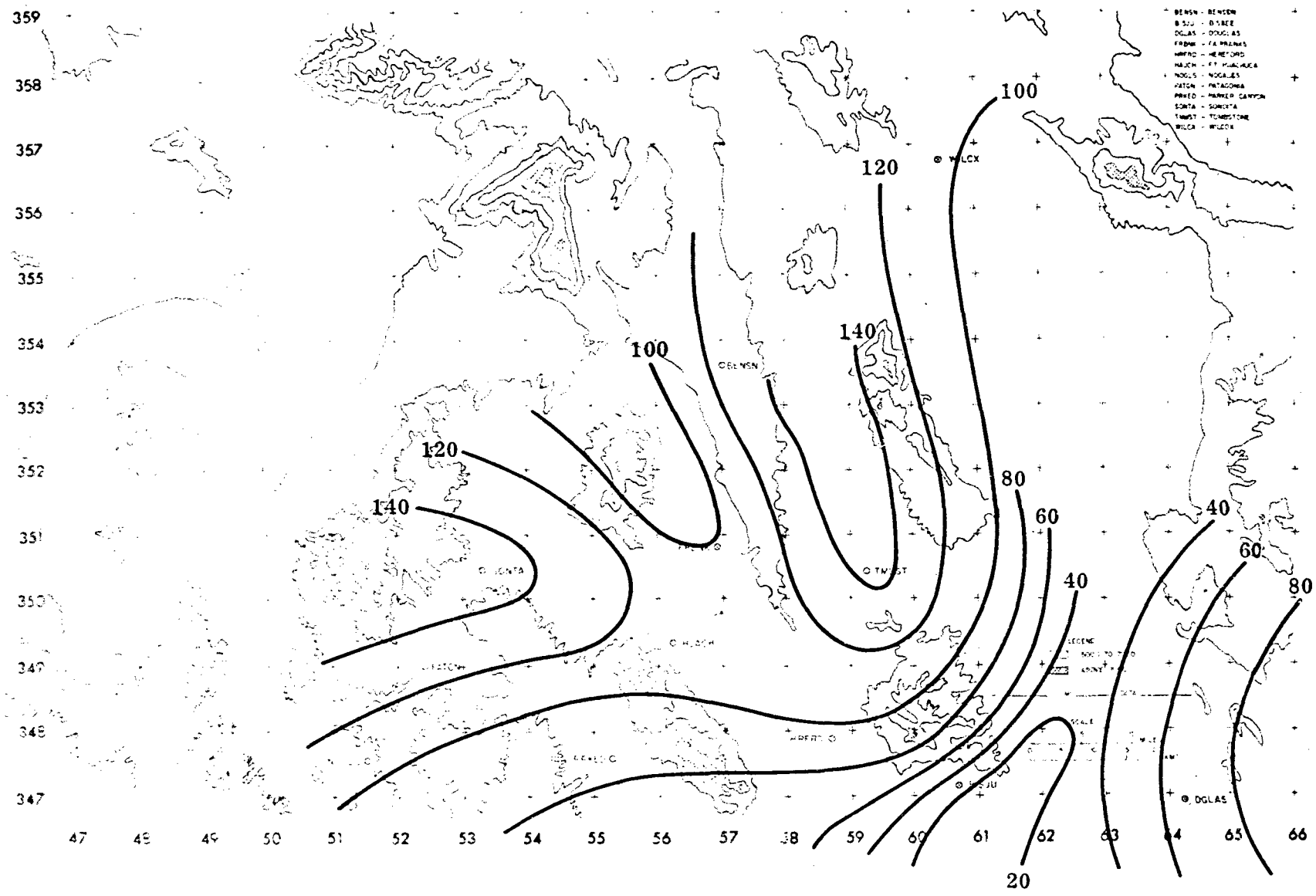

Fig. 24. Residual deflection errors; firing time is 1400 MST 12 February 1965. Errors are plotted in meters. Isopleths are for the magnitude of the errors.

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13. ABSTRACT

The overall objective of this study is to continue work begun ~~under Contract DAAB07-67-C0296-1~~. To investigate the improvement of an integrated ballistic message from multiple stations and the effects of mountainous terrain on space and time variability of meteorological measurements.

One of the initial steps carried out during this reporting interval was the preparation of a detailed work plan for the contract year. The plan divides the technical work into five tasks: (1) CRAM modifications and tests; (2) ballistic winds evaluation; (3) withheld data experiments; (4) stability experiments; and (5) prediction techniques. The plan is contained in this report.

During the first year of study ~~under this contract~~ an objective analysis program, the Conditional Relaxation Analysis Method (CRAM), was developed and applied as a tool for investigation. Under the first task, modifications and improvements to CRAM are presently being carried out.

As a part of the second task (ballistic wind evaluation) residual errors (deflection) based on station observations along with those from Ft. Huachuca have been derived and are contained herein.

In general, one does not find residual errors increasing as distance increases. The minimum residual error occurred only 2 times in 24 test firings at the station closest to the firing—Ft. Huachuca. On the other hand, the minimum residual error occurred 8 times 50 km to the west southwest, at Nogales.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Temperature						
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