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COMPUTER-BASED DISPLAYS AS AIDS IN THE PRODUCTION OF ARMY TACTICAL INTELLIGENCE

Russell J. Bowen, et al

Bolt Beranek and Newman, Incorporated

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Man-machine interactive computer-based display techniques are evaluated for their automatic data processing (ADP) applications in combat intelligence. Analysis of a tactical exercise helps conceptualize and formulate display formats and procedures for tactical intelligence production. Methods are suggested for transposing military exercises into data base structures which support computer-generated situation displays. Concepts of mass and movement analyses using interactive displays are developed. ADP problems of software, memory, and information organization are considered. Implementation of a

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20. prototype system will validate the analytic methods developed here and explore other techniques which also capitalize on the computer's ability to generate complex displays combined with the analyst's control of the specific displays to be generated.

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Russell J. Bowen, Carl E. Feehrer, Raymond S. Nickerson, and Thomas J. Triggs

Bolt Beranek and Newman, Inc.

Robert S. Andrews, Supervisory Project Director

SYSTEMS INTEGRA.ION & COMMAND/CONTROL TECHNICAL AREA
Cecil D. Johnson, Chief

Submitted by:
Joseph Zeidner, Director
ORGANIZATIONS & SYSTEMS
RESEARCH LABORATORY

Approved by:
J. E. Uhlaner
TECHNICAL DIRECTOR

U. S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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FOREWORD

The Intelligence Systems Work Unit Area within the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is concerned with problems of advancing and exploiting man/computer technology for improved tactical intelligence information processing. One major objective is to determine basic capabilities and limitations of man as an information processor and to devise complementary and compensatory processing aids and techniques. Some functions are best accomplished by man, some by computer, and some by an interactive relationship between man and computer. The present publication illustrates basic interactive graphic display concepts with a set of situation maps derived from a large tactical exercise scenario. Man-in-the-loop experimentation is in progress to extend these display concepts into a family of graphic aids.

The entire research effort, begun under RDTE Project 2Q662704A721 ("Surveillance Systems"), is responsive to requirements of RDTE Project 20062101A754, "Intelligence Systems," FY 1974 Work Program, and to special requirements of the U.S. Army Training and Doctrine Command. ARI research in this area is conducted as an in-house effort augmented by contracts with organizations chosen as having unique capabilities and facilities for research in human/machine aided information processing. The present effort was conducted jointly by personnel of Bolt, Beranek and Newman, Inc., and of the Army Research Institute.

J. E. UHLANER,
Technical Director

COMPUTER-BASED DISPLAYS AS AIDS IN THE PRODUCTION OF ARMY TACTICAL INTELLIGENCE

BRIEF

Requirement:

To develop dynamic computer-based aids for the intelligence analyst that will enable him to cope with increasing quantities of raw data; specifically, to develop concepts and procedures which use the display-generating capability of a computer in conjunction with aids for the analysis of tactical intelligence data.

Procedure:

Analyses of tactical exercise materials were used to conceptualize and formulate possible computer display procedures and formats for situation maps. Development of techniques is illustrated by a set of data displays and by suggested graphic analytic aids.

Findings:

Military exercises and, by inference, actual tactical engagements can be translated into data base structures for the generation of computer-based situation displays.

Computer display techniques appear to offer easier, more rapid integration of data concerning enemy activity, enemy posture, and estimates of enemy capability than other approaches offer.

Even a relatively primitive interactive computer display capability has potential for aiding the analysis and interpretation of tactical intelligence data.

Implementation of computer-based display techniques in tactical systems will impact on computer memory, software, and information structure requirements.

Cost-effective development, elaboration, and implementation of these techniques should be an evolutionary man-in-the-loop empirical process.

Utilization of Findings:

The analytically developed display techniques provide the basis for initial on-line man-in-the-loop experimentation. They are a forerunner for iterative experimentation for evolving a family of computer display techniques to aid in the analysis and interpretation of intelligence data.

The developed procedures for representing dynamic tactical exercises in a computerized data base will be used to provide a test bed for the evaluation of various additional computer-based display aids.

COMPUTER-BASED DISPLAYS AS AIDS IN THE PRODUCTION OF ARMY TACTICAL INTELLIGENCE

CONTENTS

FIGURES

COMPUTER-BASED DISPLAYS AS AIDS IN THE PRODUCTION OF ARMY TACTICAL INTELLIGENCE

Current combat intelligence systems often fail to meet the requirements of tactical commanders. Greatly improved collection capabilities without parallel improvement in processing capabilities have inundated the intelligence staff with data which frequently cannot be effectively analyzed, integrated, and interpreted in a timely manner. The Army's plan to develop and field computer-based tactical operations systems will provide needed automatic data processing (ADP) support for intelligence functions. The potential of such computer systems for alleviating processing problems can be fully exploited by developing methods of use--techniques and aids--which capitalize on the strength of man, the computer, and their interaction. These capabilities must be developed and reflected in system design hardware/software.

One way in which computers might be used most effectively in processing Army tactical intelligence is through the development of interactive situation display techniques. In an interactive system, men and computers can be coupled in real time in such a way that the strengths of each compensate for the weaknesses of the other. In contrast, an automated system is unrealistic in the foreseeable future and a semi-automated system would be a suboptimal utilization of the capabilities of both man and computer. The introduction of computers into the intelligence process should neither supplant the man nor simply relieve him of tedious, clerical chores, but should extend and augment his capabilities. Few possible applications of computers within the context of an interactive system hold more promise than does that of situation display generation. This report articulates the concept of computer-based display techniques for intelligence processing in terms of development methodology: Data base analysis and coding; static, dynamic, and other display parameters; and computer requirements.

INTERACTIVE DISPLAY GENERATION

The computer's ability to generate complex displays nearly instantaneously, coupled with man's ability to specify what displays should be generated, provides the basis for a truly synergetic collaboration. Moreover, tactical information lends itself naturally to visual display--much of it deals with events or objects at particular locations at specific times. It is well known that the situation map plays a key role in tactical analysis.

A natural way to conceptualize a tactical data base is in terms of a geometric model. In this conceptualization, each item is represented as a point in space and time. This means in terms of data representation within the computer that each item has a time tag and a pair of spatial coordinates. In addition, each item could be associated with a set of descriptors; for example, for armored vehicle sightings, such descriptors might include vehicle types, numbers, direction of movement, etc. Such organization of a data base should be particularly well suited to the interactive generation of situation displays. The man and the computer--in collaboration--essentially construct overlays in terms of space-time boundaries and any other descriptors with which the data are tagged. For example, to get a picture of trends of vehicle activity over a given time period and within a given geographical region, the computer could generate and display a sequence of overlays, each showing sightings of specified vehicle types during a short time period--say 24 hours. An example given in Appendix A illustrates this concept.

Scenarios and Practical Exercises as Data Bases

The data base for the present study was derived from a typical field situation. The situation developed over several days and involved sufficient numbers of messages to permit statistical representation of changes in enemy striking forces for display and decision analysis purposes. The data base scenario was originally written in 1965 for use in connection with System Design Test II (SDT-II) of Tactical Operations System (TOS).[1] The exercise, referred to as MAPEX SDT-II, represents a three-stage, six-day battle between U.S. and Aggressor forces covering a small area (Hof-Kronach-Sonneberg) of central Germany. It gives sufficient information about Aggressor forces, Friendly forces, and their general operational characteristics to enable the simulation of a tactical intelligence environment. The data consisted of approximately 15,000 messages generated at three different echelons: division, brigade, and battalion. For the most part, these messages represented activities of Friendly units and Friendly sightings of Aggressor activities in the field over six days. A relatively small number of messages was concerned with requests for (rather than reports of) information and with such factors as geographic definition of the forward edge battle area (FEBA), results of POW interrogation, refugee movement, etc. With few exceptions, the messages were transmitted from the observing unit to the intelligence section (G-2 or S-2, depending on echelon) at the same level. Few, if any, messages had forwarding addresses above or below the echelon within which the observations were made. All messages in the group had approximately the same format, consisting of an address block, a date/time receipt block, a statement block, a message-number block and a reliability/accuracy block. The statement block normally carried a description of the sighting (i.e., aerial/ground observer, radar, etc.), the number of units (e.g., tanks, trucks, troops) sighted, the direction of movement (if any), the position of the observed activity and the time of observation.

[1] The purpose of describing a particular scenario in detail is merely to show how any available scenario which the planners consider appropriate may be used in developing graphic materials for an interactive man-computer system. Other scenarios may serve the purpose as well.

Analysis of the data base was broken down into four phases. The objective in the first phase was to understand some of the superficial statistical aspects of the data base, to become familiar with the region over which the action took place, and to gain a preliminary orientation. During the second phase, selected messages were coded in a fixed format to provide a convenient means for generating displays. The objective of the third phase was to produce displays and formalize the symbology, etc. required for the tactical decision-making exercise. Additional display types are considered in the fourth phase.

Phase I: Preliminary Analysis

An overview of the scenario was read and loci of significant sightings were plotted.[2] The content of messages was sampled in order to determine what categories of messages existed and the frequency with which each category was used. In addition, several other factors--such as the flow of information (as judged from the address block) and time lag between observation and formal report--were considered. Thus, messages covering the first day (15 September) of the scenario were examined. Five categories--armor, artillery, vehicles (e.g., Armored Personnel Carriers (APC), trucks), patrols, and troop movements--were defined; the number of messages falling into each category was tabulated.

The results of this analysis are shown in Table 1. Perhaps the only surprising aspect of these data is the relatively low level of activity related to patrols. This could be due to several factors, such as the phase of the battle examined or to an inability to identify movements of small groups of soldiers on patrol.[3] At any rate, a sufficient number of messages was distributed among the remaining categories to permit development of the overlay materials.

Of some concern during this preliminary phase was the average time lag between the observation of an activity and its formal report. To obtain a sample, all time lags related to messages generated at 20th Division level and approximately half at both 1st and 2d Brigade level were examined. The results showed that although a few time lags were quite long (more than 20 minutes), the vast majority were in a 3-15 minute range.

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[2]For this purpose, a map of Erfurt (1:250,000 scale) was utilized.

[3]Subsequent sampling on other days yielded consistently low frequencies of patrol activity, though not as low as on the initial day.

Table 1

APPROXIMATE NUMBER OF SIGHTINGS IN EACH OF FIVE CATEGORIES ON ONE SAMPLED DAY (15 SEPTEMBER) OF MAPEX SDT-II

Reporting Unit (friendly)	Report Category				
	Armor	Artillery	Vehicles	Patrols	Troops
20th Division	37	20	16	0	36
1st Brigade	37	27	17	0	29
2d Brigade	24	41	28	1	27
66th INF Bn.	36	47	15	0	125
67th INF Bn.	51	56	9	0	105
68th INF Bn.	49	76	29	1	88
69th INF Bn.	44	80	16	2	54
70th INF Bn.	54	51	17	3	81
1st Arm. Bn.	34	40	28	4	33
TOTAL	366	438	175	11	578

Phase 2: Coding Messages of the Data Base

Armor and Artillery. The task during this phase was to format and code the messages in a manner that would make them readily available for overlay production. Armor and artillery data from tactical intelligence activity were initially formatted and coded; armor data, because it represented a highly mobile and effective striking force in a tactical exercise; artillery data, because it represented a relatively static element present in great numbers and variety. Accordingly, the data relevant to these messages were transcribed onto the format shown in Figure 1.

20th Division Unit Reporting				16 Sept. Date				Armor Sighting Category	
Message No.	Sequence No.	Day and Time of Sighting	Sighting Type	Number Elements Sighted	Location	Direc-tion of Movem.	Condition? On Road? Firing?	Time Message Sent	Reliab. Accuracy
A 404	1	160715	MDM TKS	3	PA 51507990	W	-	160717	B-3
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
A 460	11	161218	TK	1	PA 465765	NW	On Road	161220	B-2
.	.	.	.	.	.	.	.	.	.
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Figure 1. Format used for transcription of messages

Troops and Armored Personnel Carriers (APC). In the course of coding data, few differences were found in message content among the three echelon levels. Predictable differences in geographical coverage could be observed, however, to be progressively narrowing as one proceeded from division down to battalion. Coding troop and APC reports below the level of brigade was eliminated.

Additional analyses of the messages, particularly at division and brigade levels, suggested that at least three different degrees (or types) of massings or geographical scatterings of sightings could be identified across the six days. These corresponded roughly to the three tactical stages portrayed in the scenario. The first of these scatterings, occurring on 16 September at the conclusion of scenario Stage I (retrograde), exhibited a high concentration of sightings in a relatively small area with a predominant Aggressor movement toward the west. The second type of scatterings, occurring on 18 September at the conclusion of scenario Stage II (defense), was considerably more diffuse and appeared to have a nominal north-south orientation. The third type was a concentration with an apparent easterly orientation; this corresponded to a period (20 September) near the end of scenario Stage III (offense). It was decided to pursue these observed distinctions further, primarily for heuristic purposes.

Phase 3: Generation of Lower Level Displays

Armor and Artillery Displays. Activity category and time-slice information were used to produce simulated computer displays. For example, separate raw-data plots of armor and artillery activity were made daily for every reporting unit. This initial set of plots provided a data base for time-slice displays. No attempt was made to filter out occasional duplicate reports which may have arisen because independent units sighted the same enemy activity.

The displays were produced by hanging a sheet of vellum either directly over the map of interest or over an overlay on which observations of interest were then plotted. Large-scale maps (1:50,000) were used and the comparison of displays was simplified by using sets of standard reference coordinates.

Separate preliminary plots were made of armor and artillery observations falling within daily time intervals. There were six 24-hour reporting periods. Time-slices were made by breaking up each day into four three-hour intervals and one twelve-hour interval: 0601-0900 hours; 0901-1200 hours; 1201-1500 hours; 1501-1800 hours; 1801-0600 hours. These time-slice plots showed that the vast majority of daily reports were made between the hours of 0900 and 1800.

New plots were made using only the three time intervals: 0901-1200 hours; 1201-1500 hours; 1501-1800 hours. These new plots combined information from sightings at the division and the brigade levels. The symbols used for plotting contained a message sequence number that permitted cross-referencing to descriptive information on a coding sheet (Figure 1). A circle containing a number identified division sightings; a square with a number labeled 1st Brigade sightings, while a triangle with a number identified information from the 2d Brigade. Selected display examples are illustrated in Figures 2-5.

Troop Movement and APC Displays. Plotting of troop movement and APC activity was done similarly to that for armor and artillery. Since most daily reports in all activity categories occurred during 0900-1800 hours, plots were made only for the three time-slices within this interval. Reports made by the division and the brigades concerning troop movement and APC activity were combined on the same plot, as was eventually done for armor and artillery sightings. Most of the messages concerning troop movement and APC as well as armor and artillery were from Sonneberg (on 16 and 18 September) and Teuschnitz (on 20 September). Table 2 shows the distribution by activity category, time, and reporting unit of messages used in the display plots.

Summary. With the coding activity and lower-level plotting of raw and time-sliced data completed, a net data base with dimensions as shown in Figure 6 was available. Two points should be made here. First, this data base represents a subset of the data contained in the 15,000 messages in the MAPEX SDT-II exercise. Given that all data manipulation in this example was done without a computer, it was necessary to reduce the original data base to manageable proportions. In an interactive computer system such as that envisioned, this reduction would not be necessary. Second, the structure that is imposed on the data base is relatively inflexible. For example, as Figure 6 shows, the time dimension is separated into three fixed intervals. The answer to a question concerning sightings during time slices other than those represented explicitly could be obtained only with difficulty. If these data were stored within a computer memory, however, the structure could be made much more malleable. Each datum could have its own time tag, and displays could be generated using any time slicing desired.

Phase 4: Higher-Level Displays

Attention was next focused on the derivation of higher-level displays showing activity clusters, centers of mass, and common activity areas. Preparation of the lower-level display materials showed that the density of activities reported over a region was not uniform; clusters of points were separated by areas in which either few observations had been made and/or little activity existed. This is a predictable phenomenon for at least two reasons: (1) The overall distribution of Aggressor movements

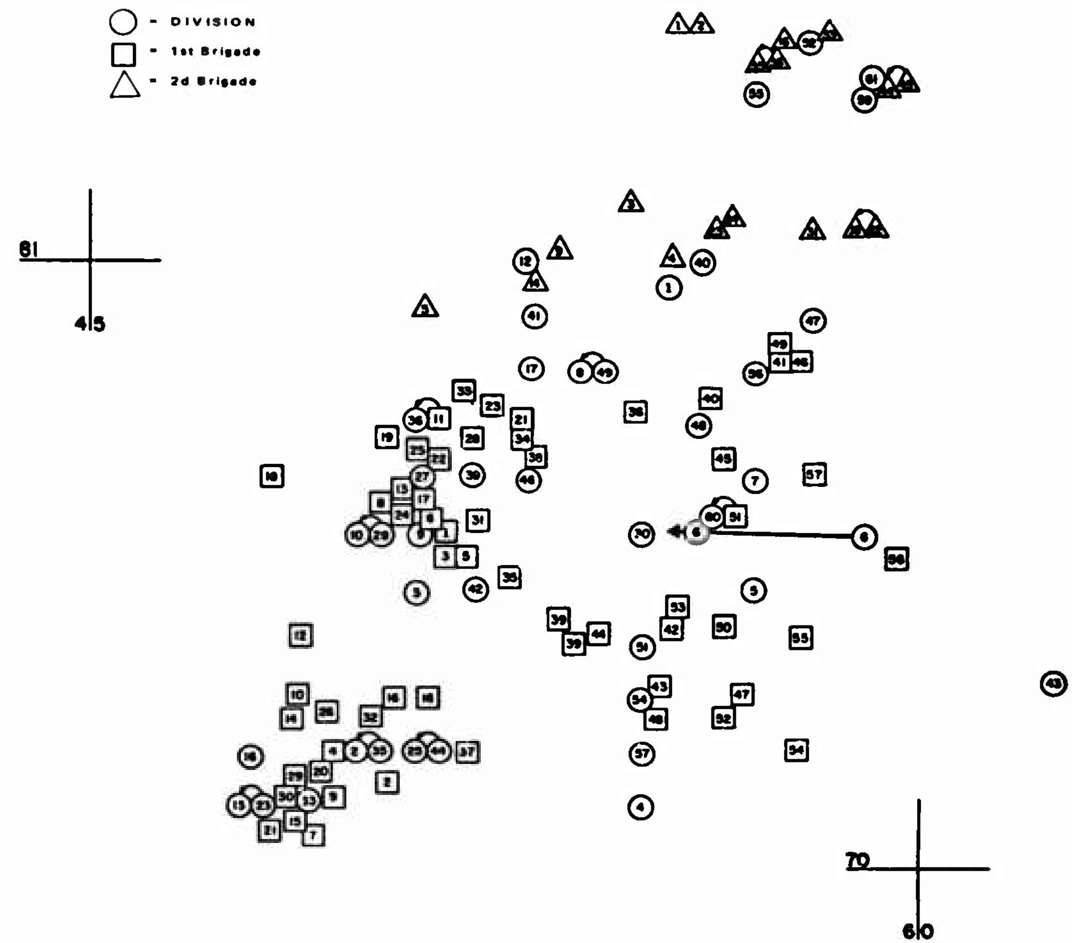

Figure 2. Lower-level data display: Sonneberg region, 18 Sept. **All armor sightings for 20th Div., Ist Bde., 2d Bde.**

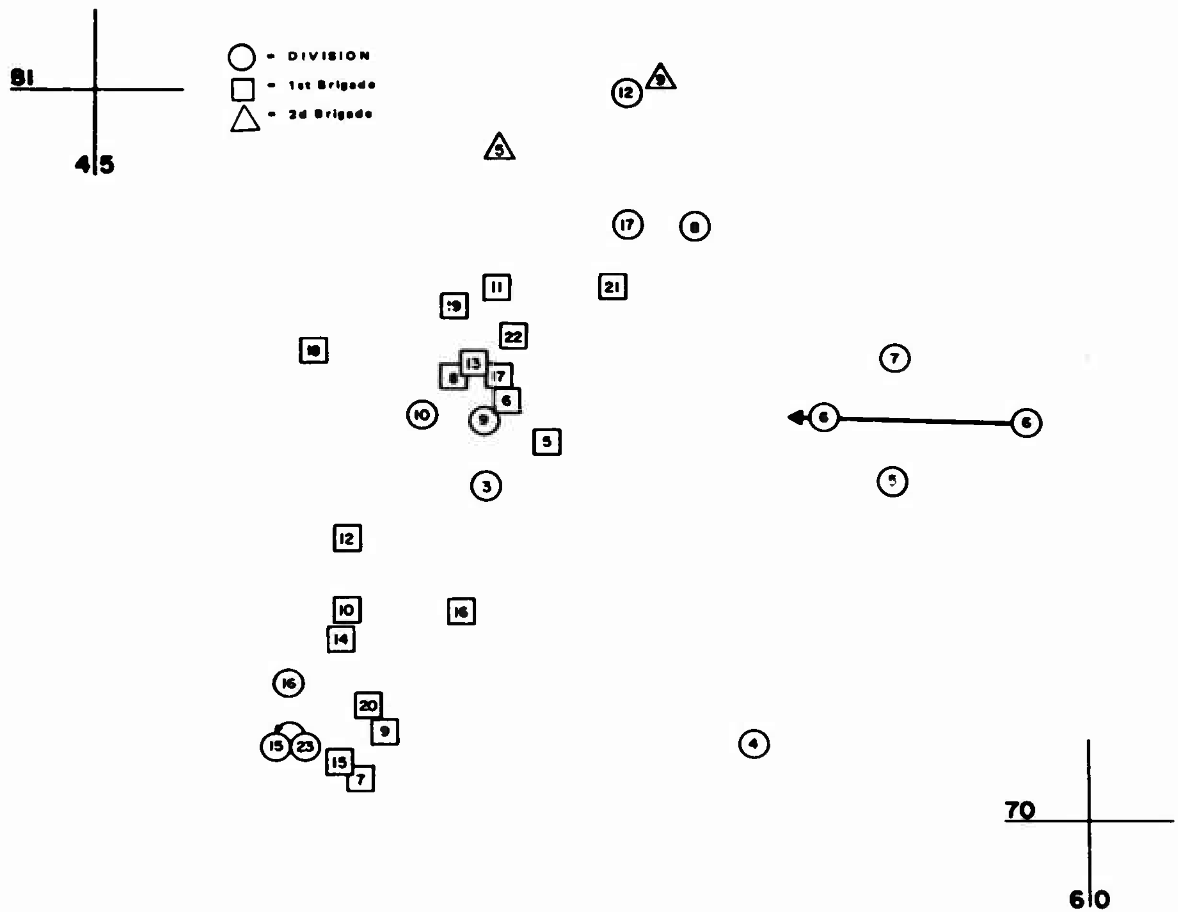

Figure 3. Lower-level data display: Sonneberg region, 18 Sept., armor sightings between 0901-1200 hrs for 20th Div., Ist Bde., 2d Bde.

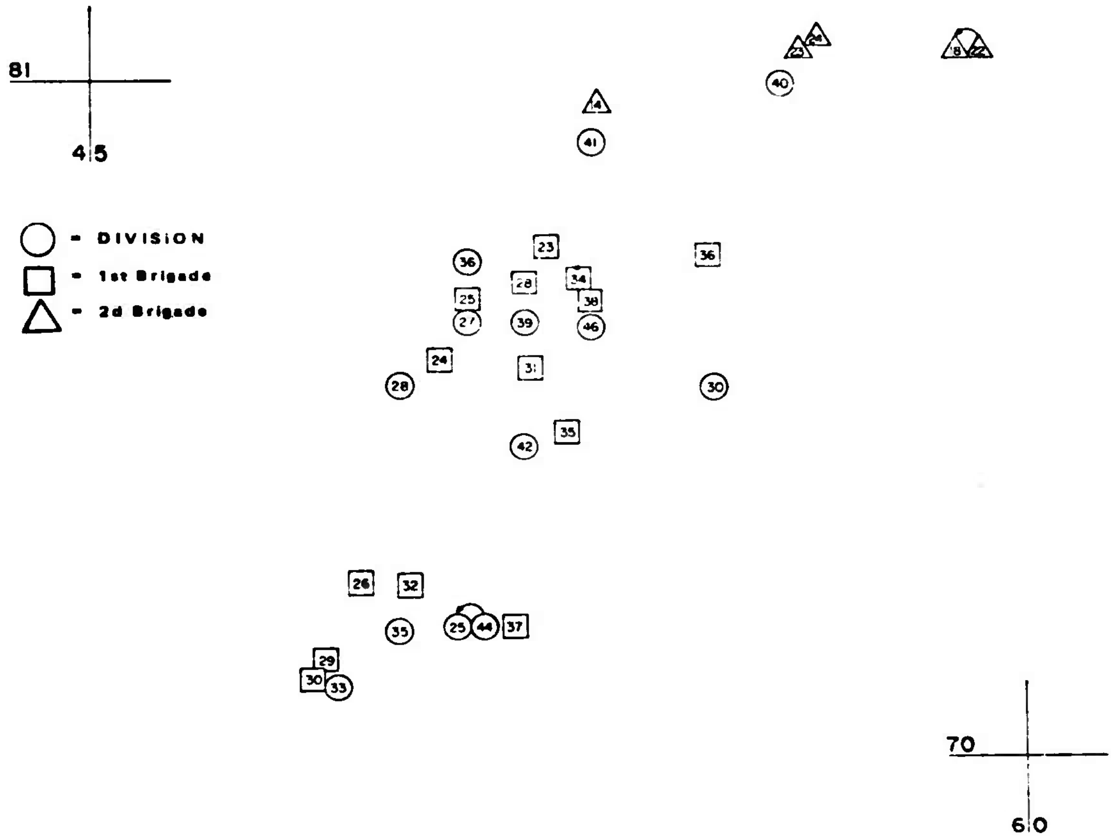

Figure 4. Lower-level data display: Sonneberg region, 18 Sept., armor sightings between 1201-1500 hrs, for 20th Div., Ist Bde., 2d Bde.

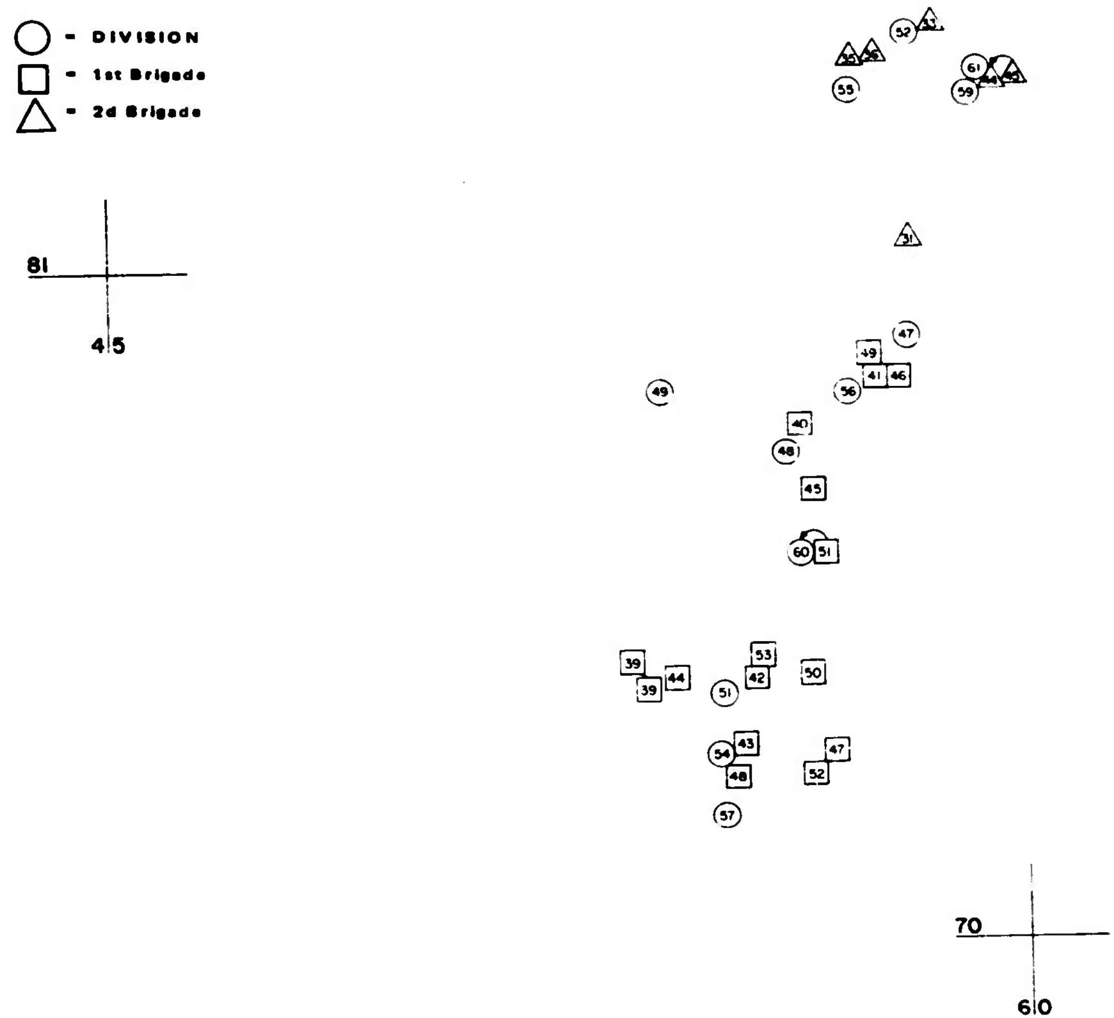

Figure 5. Lower-level data display: Sonneberg region, 18 Sept., armor sightings between 1501-1800 hrs, for 20th Div., Ist Bde., 2d Bde.

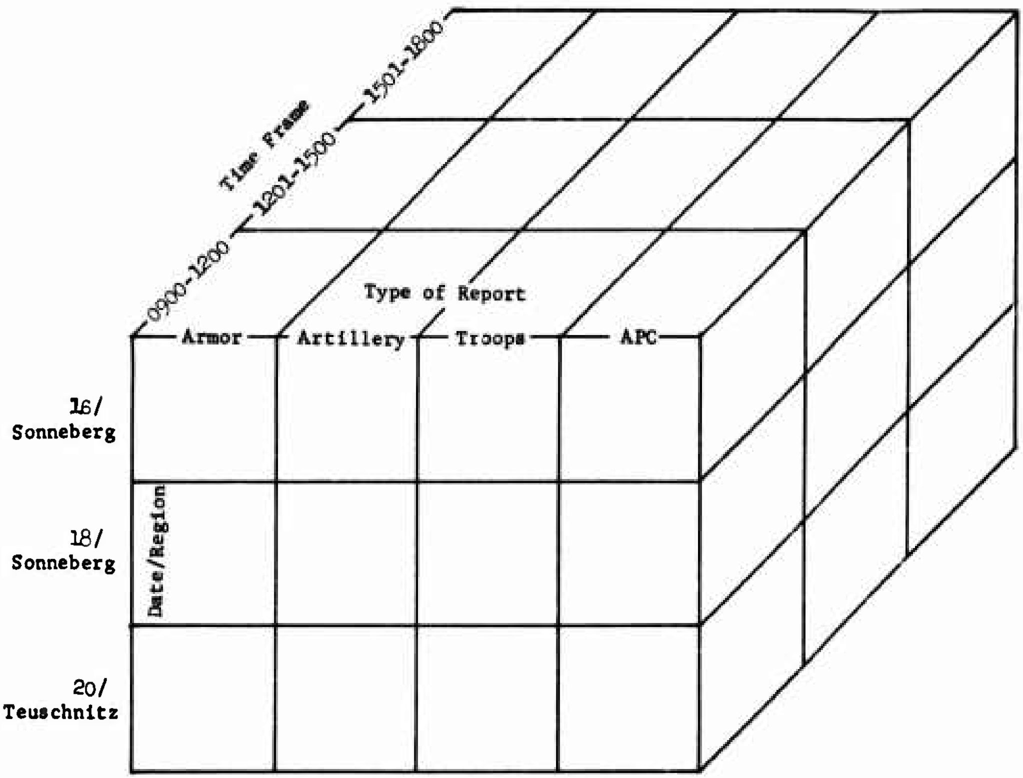

Figure 6. Net data base at conclusion of lower-level display activity. Cells contain all relevant reports by division, 1st Brigade and 2d Brigade

Table 2

NUMBER OF MESSAGES EXAMINED IN LOWER-LEVEL DISPLAY PHASE

	16 Sept. Activity					18 Sept. Activity					20 Sept. Activity					
Reporting Unit	Armor	Artillery	APC	Troops	Subtotal	Armor	Artillery	APC	Troops	Subtotal	Armor	Artillery	APC	Troops	Subtotal	Total
Time	0901-1200					0901-1200					0901-1200					
20th Div.	4	3	1	2	10	13	13	2	1	29	7	6	9	19	41	80
1st Bde.	4	4	-	1	9	18	13	2	4	37	-	-	-	-	-	46
2d Bde.	2	3	1	4	10	2	7	2	1	12	4	6	-	15	25	47
Subtotal	10	10	2	7	29	33	33	6	6	78	11	12	9	34	66	173
Time	1201-1500					1201-1500					1201-1500					
20th Div.	41	8	1	27	77	14	9	9	9	41	14	6	7	14	31	149
1st Bde.	29	9	1	11	50	16	12	2	7	37	5	11	2	18	36	123
2d Bde.	16	10	2	31	59	6	7	7	3	23	10	7	4	6	27	109
Subtotal	86	27	4	69	186	36	28	18	19	101	29	24	13	38	94	381
Time	1501-1800					1501-1800					1501-1800					
20th Div.	10	2	-	4	16	11	9	5	5	30	5	9	5	9	28	74
1st Bde.	9	6	2	4	21	15	14	6	9	44	8	18	7	5	38	103
2d Bde.	1	5	-	6	12	6	4	1	1	12	2	5	-	13	20	44
Subtotal	20	13	2	14	49	32	27	12	15	86	15	32	12	27	86	221
Total					264					265					246	775

is not likely to be random, although movements within small circumscribed areas may occasionally appear that way; and (2) the topography and geography of a given area significantly determine what is possible and reasonable in the way of resource distribution. The process of resolving potential action should be greatly facilitated, then, if the clusters could be identified, defined, and monitored.

Activity Clusters. Many techniques might be used to identify and subsequently define clusters of observations. One could, for example, treat a set of plotted points mathematically, computing the total distance between all pairs of points, between all triads, between all quadruples, etc., and by supplying some distance criterion arrive at a formal definition. Alternatively, one could treat the matter statistically by defining the location of a cluster as that area in which X percent of the activity is located.

Perhaps the simplest procedure is to take advantage of human perceptual capacity to identify and delimit neighborhoods of points. Given a light-pen, one could draw a contour around an apparent cluster and then monitor changes in visual density within the contour over time. Under these conditions, the definition of the cluster could be as constrained or unconstrained by topographical and geographical factors as the analyst desired it to be.

The procedure utilized on the current set of displays was similar to a visual organization of data points. However, it was completely unconstrained by known terrain features and by post hoc knowledge of Aggressor actions. As such, this was the simplest possible treatment of the data. Starting with the earliest time-slice overlay (0901-1200) of a given activity type on a given day, a contour was drawn around the outermost set of data points, creating a convex polygon whose total inscribed area gave a rough indication of the distribution and density of reports. This procedure was then carried through with the remaining time-slices and activities. With the contours completed, it was possible to generate composites made up of the individual time-slice/activity-type displays (Figures 7-9). These composites yielded a fairly dynamic picture of the major shifts in reported activity overtime. The next step was to develop a finer grain method for assessing changes in mass.

Centers of Mass. Although the contour procedure provided a relatively simple and quick look at the dimensional shifts of reported activity, it was, of course, insensitive to the quantitative aspects (e.g., number of tanks sighted in a given region, strength of troop units) of individual activities. Thus, a report of one tank at a fairly remote location (relative to the bulk of armor sightings) could, when assimilated into the contour, give a distorted impression of the "reasonable" area of concern. For example, given such a display, the apparent shift in

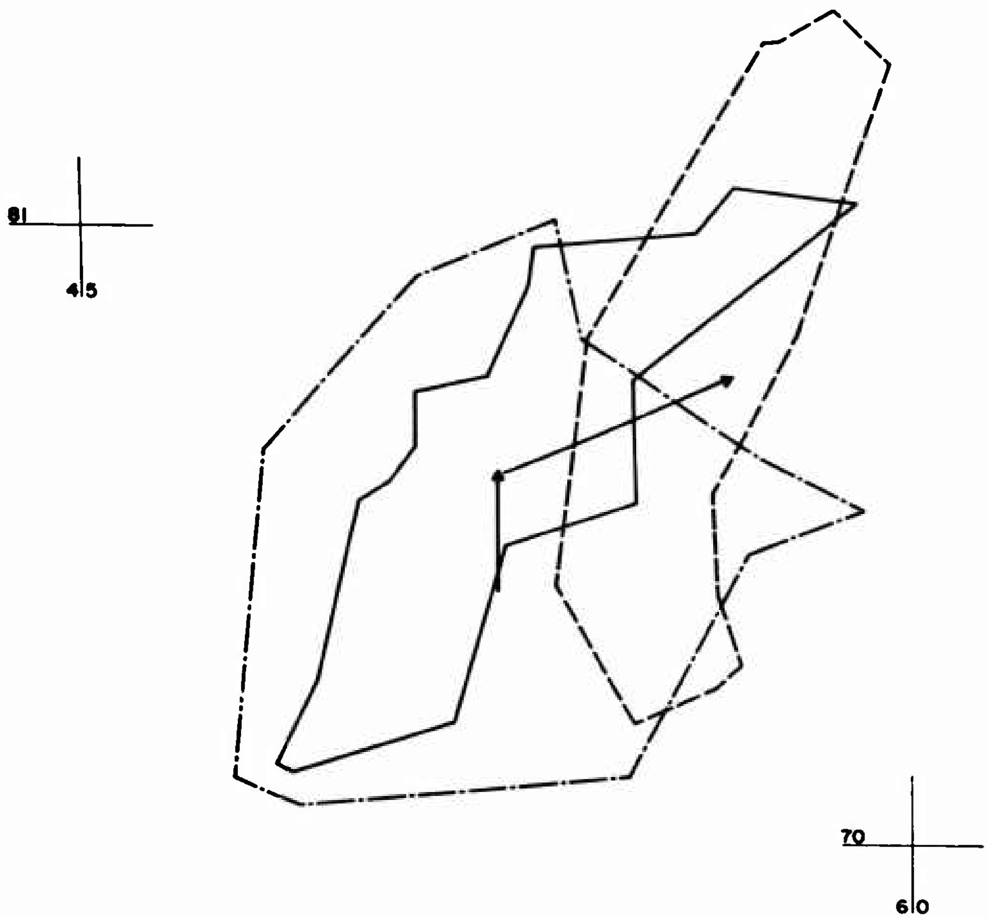

Figure 7. Composite higher-level display showing area contours of reports for armor in the Sonneberg regior on 18 Sept. for periods 0901-1200 hrs (dot-dash line), 1201-1500 hrs (solid line), 1500-1800 hrs (dash line). Centers of mass positions are indicated by movement vectors.

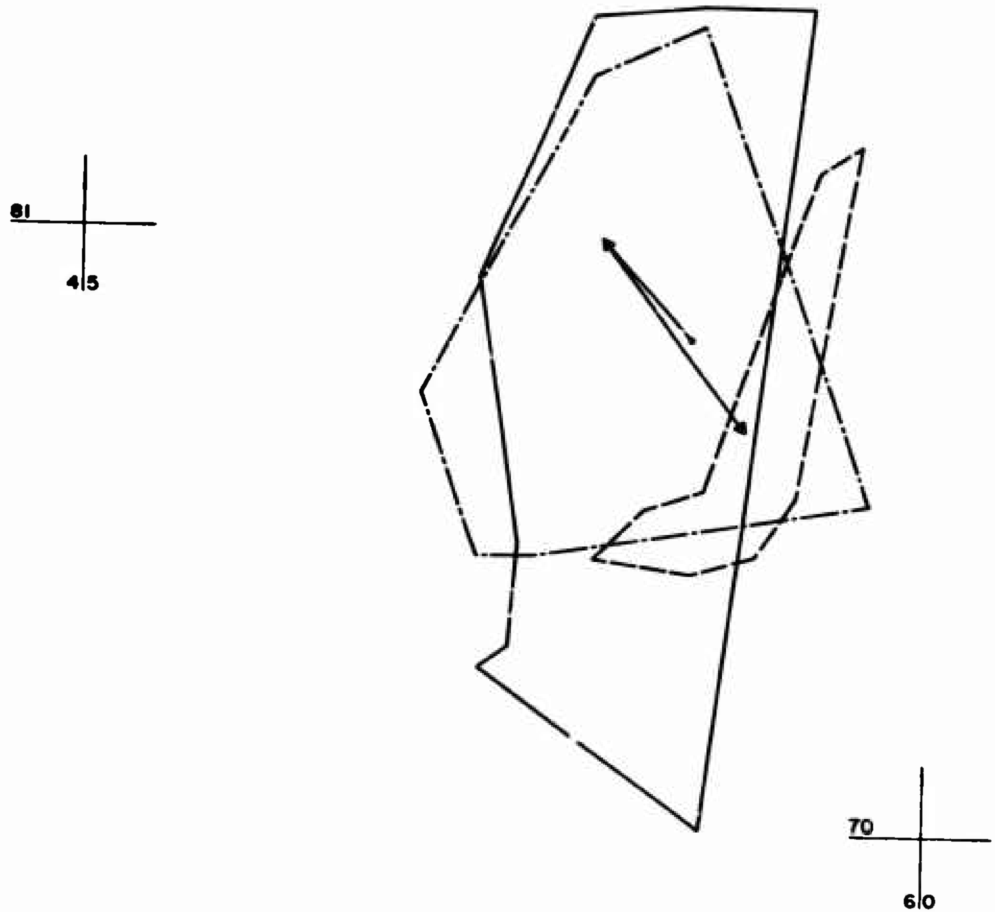

Figure 8. Composite higher-level display showing area contours of reports for APC in the Sonneberg region on 18 Sept. for periods 0901-1200 hrs (dot-dash line), 1201-1500 hrs (solid line), 1501-1800 hrs (dash line). Centers of mass positions are indicated by movement vectors.

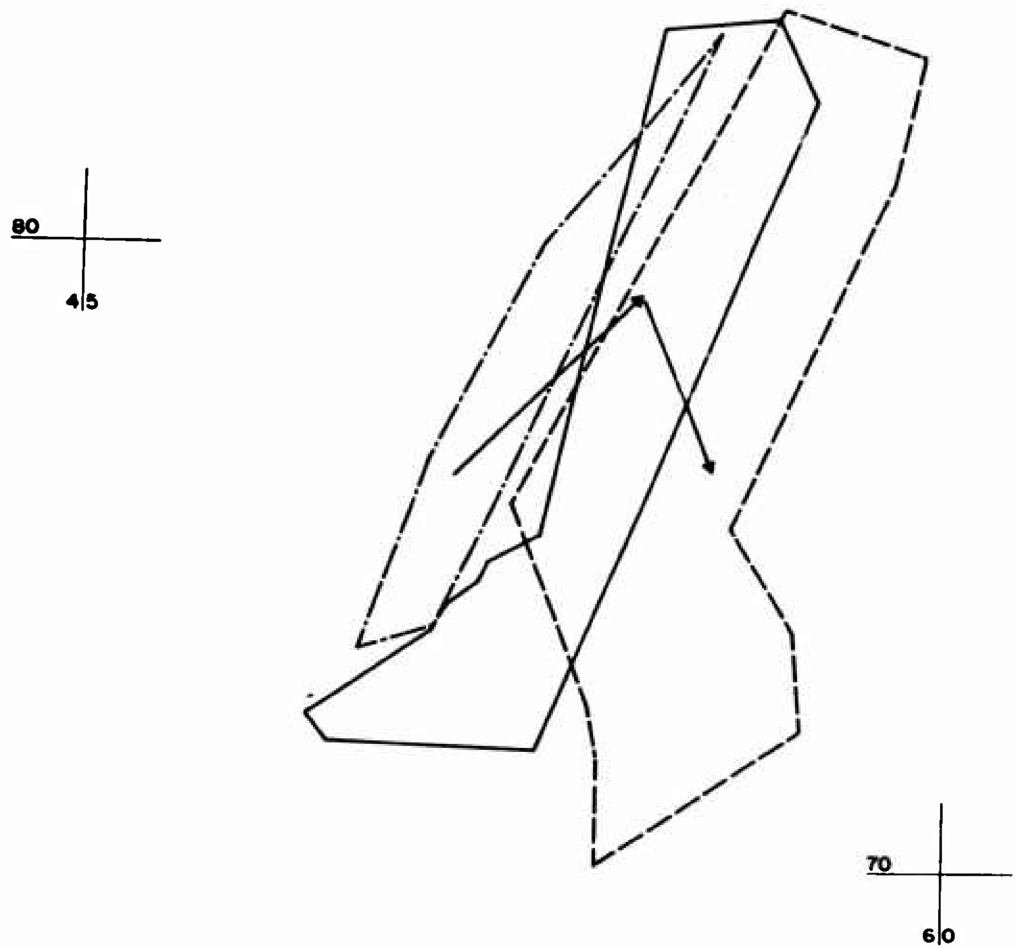

Figure 9. Composite higher-level display showing area contours of reports for troops in the Sonneberg region on 18 Sept. for periods 0901-1200 hrs (dot-dash line), 1201-1500 hrs (solid line), 1501-1800 hrs (dash line). Centers of mass positions are indicated by movement vectors.

contours could suggest movement toward the east, even though the center of mass activity were static or conceivably shifting west. An obvious solution was to compute the center of mass of sighted activity for each activity type within each time frame, and develop a composite display, connecting the centers by vectors. The computed centers of mass for all activities, days, regions, and time periods of concern are presented in Tables 3-6.

Displays were prepared which consisted of the set of three contours describing dimensions of activity for a given activity type and day (without individual data points) and the computed centers of mass connected by vectors (Figures 7-9). This combination provided an effective visual presentation of six major aspects of reported activity: (1) Total area subsumed within a given time frame by the set of reports; (2) geographical center of mass of sightings; (3) total area subsumed over total time; (4) direction of change of mass over time; (5) velocity of change of mass over time, as indicated by the length of a given vector; and (6) acceleration (or deceleration) of change of mass, as indicated by ratios of the lengths of vectors.

Common Areas of Activity. A final display combining contours and centers of mass was constructed for armor, APC, and troop activity on 18 September for Sonneberg (Figure 10). In this display, the contours were drawn around only those areas in which all three types of activity had been reported. Centers of mass and connecting vectors for each of the three types were superimposed as before. Thus, the completed display had three contours (one for each time period) and nine centers of mass (one for each of three activity types within a time period x three time periods).

The properties of this display were quite interesting. First, whereas previous contours had overlapped considerably, no overlap was evident here. Areas common to all three types of sightings were well isolated between time periods, giving a clear impression of eastward movement of men and equipment. Second, centers of mass for a given time period and equipment type occasionally fell inside the corresponding time-frame contour, occasionally outside, although their prevailing direction across the three periods was also easterly. Third, the total distance between centers of mass for the three activity types within the same period decreased significantly from the first to the third time frame.

Discussion. Three different but related varieties of displays have been presented above. The first (Figures 2-5) contains outlines of the areas over which activity of a given type had been reported in each of several time slices; the second (Figures 7-9) combines these outlines with centers of mass connected by vectors from which direction, velocity, and acceleration can be derived; the third (Figure 10) is similar to the second except that (1) outlined areas are those in which several

Table 3

CENTERS OF MASS: ARMOR

Date/Region	Coord.	Periods 0901-1200	1201-1500	1501-1800
16/ Sonneberg	X	46.7	47.4	45.6
	Y	75.7	75.2	73.8
18/ Sonneberg	X	51.2	52.8	56.5
	Y	75.2	77.0	78.0
20/ Teuschnitz	X	79.1	79.9	81.6
	Y	79.9	78.4	78.3

Table 4

CENTERS OF MASS: ARTILLERY

Date/Region	Coord.	Periods 0901-1200	1201-1500	1501-1800
16/ Sonneberg	X	47.8	48.2	49.4
	Y	78.2	77.1	76.9
18/ Sonneberg	X	52.9	53.7	56.7
	Y	75.9	77.2	77.6
20/ Teuschnitz	X	78.8	80.8	81.6
	Y	77.9	78.8	77.3

Table 5

CENTERS OF MASS: APC

Date/Region	Coord.	Periods 0901-1200	1201-1500	1501-1800
16/ Sonneberg	X	51.6	47.5	46.0
	Y	80.5	71.1	72.1
18/ Sonneberg	X	55.8	54.3	56.8
	Y	79.0	80.8	77.3
20/ Teuschnitz	X	78.8	79.8	81.6
	Y	75.3	81.2	79.4

Table 6

CENTERS OF MASS: TROOP MOVEMENTS

Date/Region	Coord.	Periods 0901-1200	1201-1500	1501-1800
16/ Sonneberg	X	52.7	52.2	49.2
	Y	79.8	80.8	74.8
18/ Sonneberg	X	51.8	52.3	56.2
	Y	77.4	76.8	78.1
20/ Teuschnitz	X	79.6	79.8	82.3
	Y	81.6	78.9	81.1

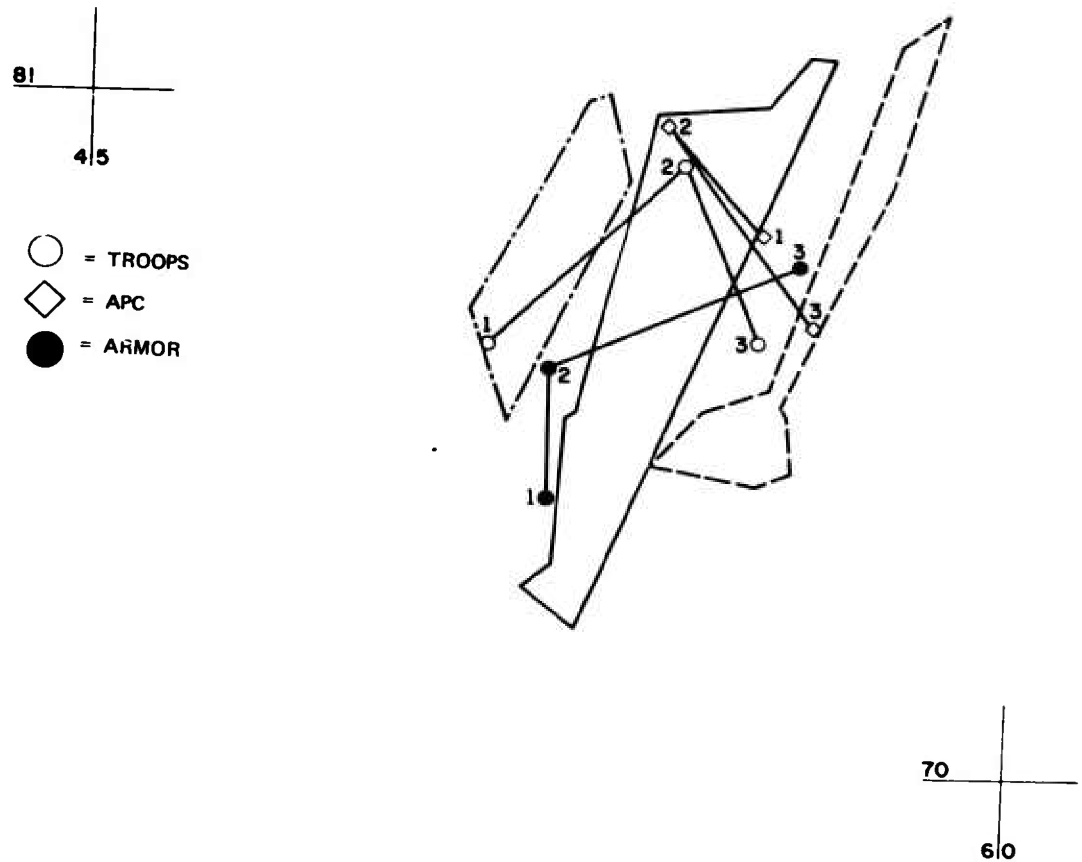

Figure 10. Higher-level display showing areas common to armor, APC, and troop sightings on 18 Sept. in the Sonneberg region for the three periods 0901-1200 hrs (dot-dash line), 1201-1500 hrs (solid line, 1501-1800 hrs (dash line). Sequences of centers of mass for the three types of sightings are also shown.

activity types were reported; and (2) centers of mass for the different types and time frames are simultaneously represented. All displays were prepared without regard to geographical and topographical factors.

How might displays help analyze potential Aggressor actions? They provide an initial and very general context within which specific questions can be asked of the data base. The major aspects of Aggressor resources--distribution, direction of movement, velocity and acceleration/deceleration of movement--are conveniently assembled to provide a quick orientation to the historical course of activity. Their further usefulness depends largely on the degrees of freedom in the data management procedures and the extent to which critical geographical and topographical details can be incorporated into the system. For example, with the outline describing Aggressor activity in the time frame 0901-1200, hours, one might want to ask: "How does the activity during the final hour compare in terms of geographical distribution and numbers of units with that in the preceding two hours?" In other words, one might want to slice an existing time frame finer and add to the display some index of activity. Following this, the data shown in the time frame could be qualified by displaying only those observations which, because of proximity, terrain, etc., could be associated with the hypothesized activity. Given such a display, the next step might be to compute a center of mass which could be monitored over corresponding time/location frames in subsequent intervals. Two points are to be made here: (1) Displays of this sort will be used iteratively in the course of formulating and verifying hypotheses about possible Aggressor action; and (2) the limitations on the nature of the questions these displays will help to answer are largely a function of the flexibility of the computer system and the programs that drive it.

Other Display Parameters

Boolean Combination of Data-Base Flements. The utility of displays such as we have discussed lies in their ability to convey information quickly and efficiently about gross aspects of Aggressor activity. As with any summary presentation, however, details of potential significance to the original observations may be lost. In these examples, these details had to do mainly with the instantaneous directions of armor, vehicles, and troops. The following example develops a set of displays in which direction was the parameter of interest in a hypothetical data base query protocol. The data used for this exercise were sightings of the 20th Division on 18 September in the Sonneberg area. The progression consisted of the following set of inquiries:

Q(uery)1: Display all armor sightings which have occurred within the period 1201-1800 hours. (Rule: (1201-1800 hrs))

Q2: Display all sightings within that time frame which relate to undamaged armor or in which no information relative to condition is given (Rule: (Q1) $\wedge$ ((all undamaged) $\vee$ (no information)))

Q3: From that set, display the subset of armor which was reported as moving. (Rule: (Q2) $\wedge$ (moving))

Q4: Display all armor within that time frame which was reported to be moving west. (Rule: (Q3) $\wedge$ (west))

Q5: From that set, display the subset of all armor observations associated with five or more units (tanks). (Rule: (Q4) $\wedge$($\underline{x} \geq 5$))

Note that this example started with a large number of sightings of individual tanks and successively reduced it by adding arguments. In response to a different question, the protocol could have started with the smallest subset and proceeded to the largest by subtracting arguments. Under actual conditions, changes in the resolution of the display content would very likely be bidirectional, moving from large to small to medium to combinations with new arguments not yet called out.[4]

Discussion on Representation of Armor. The most appropriate representation of armor movement presents an interesting problem. Tanks normally have great freedom of direction in off-road travel compared to most wheeled vehicles. Thus, a plot of observations containing the instantaneous directions of large numbers of tanks may present a confusing picture. This confusion can be reduced by substituting average direction of mass over time for instantaneous direction in the mass-vector displays. Both representations have merit since each may answer different questions. When the characteristics of a given concentration are needed, as for targeting purposes, there is no real substitute for a parametric plot. When, on the other hand, the concern is with trends, the averaging technique is of great value. There is also no apparent reason why the instantaneous directions and center of mass vectors cannot be portrayed simultaneously; the only problems might be the increased clutter in the display, and the fact that instantaneous-direction information probably loses its value rapidly.

[4]The adjectives large, small, medium are intended here to mean the nominal size of the set of interest; i.e., number of data points contained.

Radius of Action Displays. When a given entity (e.g., tank concentration or cluster of troops) has been identified, either (1) the time required to travel a given distance, or (2) the possible distance traveled in a given time can be readily computed. For example, the analyst might want to determine where a particular troop cluster could be at the end of the next three-hour interval.[5] One could construct similar radii for other components of a force (e.g., tanks, truck-towed artillery, or self-propelled guns) and look for regions of possible new concentrations to explore hypotheses of Aggressor action.

Terrain and Road Displays. Any inferences concerning Aggressor intent which can be drawn by examining the displays presented must be qualified by topographical and geographical details of the area involved. The majority of these details also can be handled with special displays on the same scale as the primary plots. For example, a display containing important aspects of terrain, such as wooded areas and elevation information, was developed for the Sonneberg area in 1:50,000 scale (Figure 11). A second display on the same scale showed the major roadways and towns (Figure 12). By simultaneously overlaying or superimposing these two displays on the raw data plot of armor sightings, one can begin to make inferences about what Aggressor activities can reasonably be associated with each other. Such a technique enables one to generate critical contours surrounding significant Aggressor activities and to define accurately the areas and activities for center of mass computations.

Supplementary Display Possibilities. The computer-based displays discussed thus far constitute some of the more promising computer techniques and aids for analysis and interpretation of intelligence information. Situation and map display content need not be limited to these, however. For example, situation displays for artillery operations might require no-fire lines, graphic illustration of range fans, etc. Similarly, an OB display may differ from a situation map because the former emphasizes location of enemy units and headquarters elements, and the boundaries between them; whereas, the latter highlights the disposition of enemy strength based on individual reports. These, in turn, could differ from the situation displays developed in the counter-intelligence section.

The primary situation displays might also be supplemented by information presented in tabulations, bar graphs, time-line charts, pie charts, or text. The best form for presenting this supplemental information would depend on the context and the amount of display space available. Such formats could be used for presenting quantitative information, for making qualitative distinctions, for indicating relationships between variables, and for presenting temporal sequences of activity.

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[5] It is suggested that computation be based on movement data presented in Army Field Manual 30-102.

Figure 11. Terrain detail in Sonneberg area (wooded areas and elevation information). Scale 1:50,000

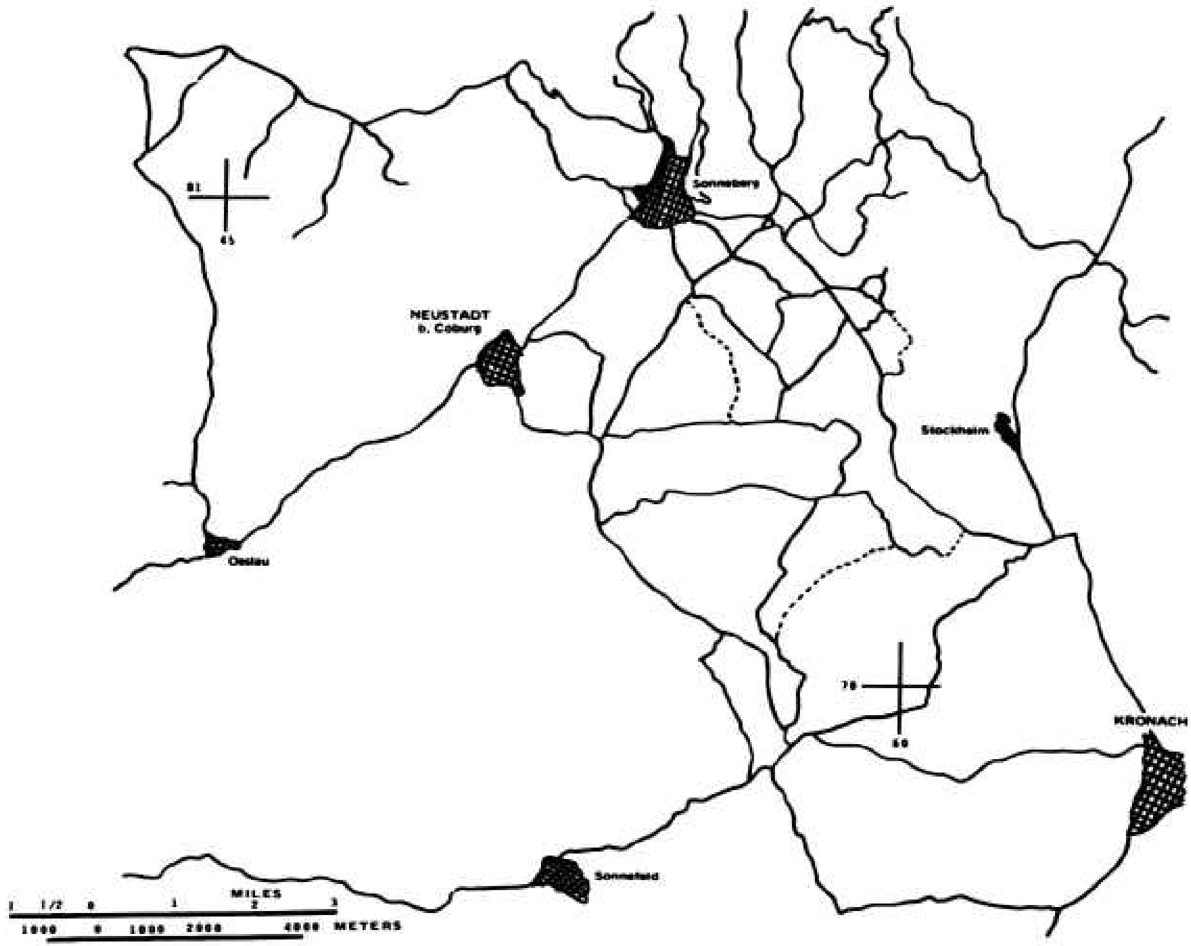

Figure 12. Major roadways and towns in the Sonneberg area. Scale 1:50,000

Composite displays could combine basic situation displays with supplemental information presented in one of various formats. Such composites could provide improved or alternative means of presenting the desired information. For instance, one way to indicate changes with time in battlefield activity in different areas would be to put contours around these areas on the situation display and to use bar graphs within each area to indicate changes over time.

In summary, how helpful a different format or a composite display would be is best determined by trying examples using actual computer displays. The data from analysts who work with a prototype system capable of displaying field exercise data could be used to evaluate alternate formats, components, and coding methods. In addition, analysts' comments due to interaction with a basic display capability could be a source for further ideas to be developed and tested.

DATA ORGANIZATION AND COMPUTER REQUIREMENTS

Several types of displays that an intelligence analyst might want to generate, given an adequate interactive facility, have been considered. However, one's ability to anticipate what displays will prove to be most useful, before the fact, is very limited. The most critical insights concerning the particular features and capabilities a system should have are most likely to come from analysts who interact with the system under controlled conditions, even if that system is relatively primitive in design.

In keeping with this assumption, an evolutionary approach would seem to be the best way to develop the requirements and functional specifications for an interactive display capability. More specifically, the technique with maximum probability of success in developing a system that in fact works, and does something that the users will consider useful, is to build a rudimentary system as a test bed with some of the desired features of the eventual system. One can then use such a functioning system as a basis for experimentation with qualified users to evolve an increasingly useful intelligence producing capability.

This philosophy of how an interactive display capability should be developed influences the design and implementation of software since computer program development cannot be divorced from the development of procedures for performing substantive tasks. In order to write a program to generate a display, one obviously must know in detail the nature of the display that is desired. But, what is desired is apt to change considerably as the user's appreciation of what is possible increases. Thus a close coupling of programmer talent and user/experimenter expertise is needed throughout the development process.

One of the first problems the programmer faces before writing display programs is the question of how the data for display generation should be organized within the machine. Our study suggests that he should be aware, from the beginning, that the initial data organization may have to be changed as the system evolves. Indeed, one can be fairly confident that information structures appropriate in a system that depends on present processing techniques will not be appropriate if radically different processing procedures replace those currently used. Thus, any organizational scheme used initially must be viewed as an expedient which permits one to get started but which may be transformed several times as the system develops.

The data organization to be used in the experimental or test-bed system must accommodate (1) the particular data base that is to be stored, and (2) the specific displays to be developed first. The MAPEX SDT-II exercise data constitutes one of many possible bases on which to begin an experimental system. Morever, the organization (Figure 1) is well suited for computer storage and for the generation of the sorts of displays described in this report.

The first problem when considering how data might best be represented in the computer is the amount of storage capacity required. In order to estimate this quantity, it is useful to distinguish between operational data (data like that contained in a message) and organizational data (data that are used to manage the operational data; e.g., pointers, dictionaries, indexes,). As arranged in Figure 1, the operational data in a single message could require as much as 200 bits of computer memory to be encoded. Thus, in order to store the entire MAPEX-II SDT exercise (15,000 messages), one would need on the order of 3,000,000 bits of storage capacity for the operational data alone. How much organizational data would be required per message would depend on the particular representation used in the computer. It is not unusual for the organizational data to require nearly as much storage as the operational data which they manage. It should be noted that nothing has been said about the storage requirements of the program necessary to manipulate the data. Thus, storage of the entire exercise would require either (1) a very large machine, or (2) extensive use of secondary storage media. One, or possibly both, of these alternatives will be required of any system that is to be used in the field. However, both should be avoided, if possible, in the test-bed effort to develop display procedures.

The most obvious way to reduce the storage requirements is to store only a subset of the 15,000 messages. The subset of messages that was used to generate the displays discussed in the current report is comprised of approximately 3,000 messages, which is closer to manageable size. Each of the messages in this subset has been put into the format shown in Figure 1 and the subset is sufficiently rich in information to permit the generation of non-trivial displays.

If even this data base proves to be too large for the computer that is used in an initial simulation effort, certain economies can be realized in the organizational data requirements. For example, the data could be considered complete and the data base treated as a stable information structure. This would decrease the organizational data requirements by avoiding problems of updating and purging. These problems would have to be faced in time, of course, but in an initial facility it might make good sense to concentrate on the problem of generating displays from a data base that is not changing. A second economy relating to organizational data can be realized by reliance on search algorithms, rather than on organizational schemes which minimize search and increase data storage requirements. This step presupposes that speed is less critical for an initial facility than manageable storage requirements.

These trade-offs seem to be reasonable in order to expedite the initial development of an interactive display capability. The unit of stored information (the datum) in the initial system should be a message thought of as having a name (message number) and a list of properties. If the base is considered static, the messages could be stored sequentially with the properties of each message following the message name. By reserving a fixed number of bits to represent each property, the need for organizational data could be eliminated altogether. As a rough rule of thumb, the amount of organizational data required will be inversely proportional to the rigidity of the data base structure; it is suggested the data base initially should be very rigid.

Clearly, such oversimplification would be adequate only for a preliminary test-bed system; it should be used to develop an initial facility with which to generate the sort of displays discussed above. Once the initial interactive display capability is realized, the data base can be restructured to permit updating and purging and to reduce search requirements.

SUMMARY

After an appropriate data base scenario had been selected and the messages coded, various types of computer-based displays were considered. Lower-level displays were developed from large time-slice activities concerning armor, artillery, APC, and troop movements. Higher-level displays employed techniques for showing centers of mass, activity clusters, and common activity areas. In addition, special displays showed direction of movement, radius of action, terrain, and roads. Finally, the computer requirements needed to support a display capability were considered, particularly the problem of computer storage capacity.

This report suggests several types of computer generated displays which the analyst can interactively use to evaluate aggressor activity. The analyst can develop a sequence of displays based on information gleaned from each individual display, choosing the displays which he wants to see by collaborating in real time with a computer that provides various displays on command.

Precisely what types of displays an analyst would find most useful are not known at this point. The best suggestions concerning the desirable features and capabilities of a system are most likely to come from analysts as a result of interacting with some such system -- even if relatively primitive in design. A test-bed system with initial display capabilities along the lines of those described in the current report could be implemented and made available for analysts to interact with under controlled conditions. The most promising suggestions for extension and elaboration to emerge as a consequence of the interactions could be empirically evaluated. Those for which evaluations proved favorable could be integrated with the basic repetoire as part of the paradigm for evolving an increasingly more powerful and effective system.

APPENDIX

APPENDIX A:

EXAMPLE OF A DISPLAY TECHNIQUE

The following is from an exercise taken from the U.S. Army Intelligence School Training Manual PE 67210 (D/NRI) and contains a dialogue that might be carried on between an intelligence analyst and a computer in generating situation map displays. Four groups of overlays were developed, applying to the four types of analyses: Artillery, Armor, Patrol, and Vehicle Traffic. Figure A-1 is the map of the area of tactical activity, and the remaining figures (A-2 through A-30) are overlays that were used in conjunction with this map. The italicized statements represent questions that the analyst had in mind in generating the displays specified in parentheses. The figures used for the examples illustrate how a display can be focused to areas with the greatest amount of relative activity within the area of general interest.

A. Artillery Analysis. (Figures A-2 through A-6). Figure A-2 shows total activity.

Is the availability of artillery changing with time?
(Figure A-3 -- First 15 days)
(Figure A-4 -- Second 15 days)

What is the location of enemy rockets and missiles?
(Figure A-5)

Does the aggressor have much heavy (140 mm and above)artillery available
(Figure A-6)

Conclusions: The aggressor artillery positions are located well forward toward the front line. The types of artillery are well distributed between heavy rockets and guided missiles, and heavy and lighter artillery. The plots indicate attempts to break minefields by fire located on the flanks. The report of a 203 mm gun/how. indicates a nuclear capability and its central position indicates that it can be used against virtually the whole sector of the line.

B. Armor Analysis. (Figures A-7 through A-12). Figure A-7 shows total sightings.

Where are armor movements occurring?
(Figure A-8)

How much aggressor armor is protected (revetments) against fire or direct attack?
(Figure A-9)

How is availability of armor changing with time?
(Figure A-10 -- First 15 days)
(Figure A-11 -- Second 15 days)

What armor activities have been occurring at night?
(Figure A-12)

Conclusions: The indications are that reconnaissance and reconnoitering of the front lines is being pursued. Probing is occurring along the front, particularly on the flanks. There is some apparent massing on the flanks.

C. Patrol Analysis. (Figures A-13 through A-17). Figure A-13 shows total patrol activity.

Is the frequency of patrols increasing with time?
(Figure A-14 -- First 15 days)
(Figure A-15 -- Second 15 days)

Are most patrols occurring at night?
(Figure A-16)

Is the enemy actively seeking out our front line position?
(Figure A-17)

Conclusions: The analysis of patrol activity shows that the aggressor is increasing his level of effort. The activities indicate that he is interested in determining the locations of both minefields and front line positions. Reconnaissance of terrain to the rear of friendly lines is now occurring. Night probing of front lines is relatively frequent. The enemy is showing a willingness to fight for information.

D. Vehicle Traffic Analysis. (Figure A-18 shows total picture). (Figure A-19 shows major convoy sightings).

How are the supply convoys changing with time?
(Figure A-20 -- First 10 days)
(Figure A-21 -- Second 10 days)
(Figure A-22 -- Third 10 days)

What is the status of supply convoys for each supply class?
(Figure A-23 -- Ammunition)
(Figure A-24 -- Petroleum)

During what time of day does the enemy move supply convoys?
(Figure A-25 -- Total darkness)
(Figure A-26 -- Partial darkness)
(Figure A-27 -- Daytime)

What transportation routes is the enemy using for supply convoys?

(Figure A-28 -- Major roads)

(Figure A-29 -- Minor roads)

How accessible are the aggressor's storage areas?

(Figure A-30)

Conclusions: Supply rate is increasing with time. Traffic has nearly doubled in the second 10 days. The size of convoys has greatly increased in the last period of time and is being more concentrated in the Eastern sector. The continuous buildup suggests a capability of supporting a more active posture than just defense. Enemy traffic is moving forward mainly at night, which provides an additional suggestion of taking up an attack posture.

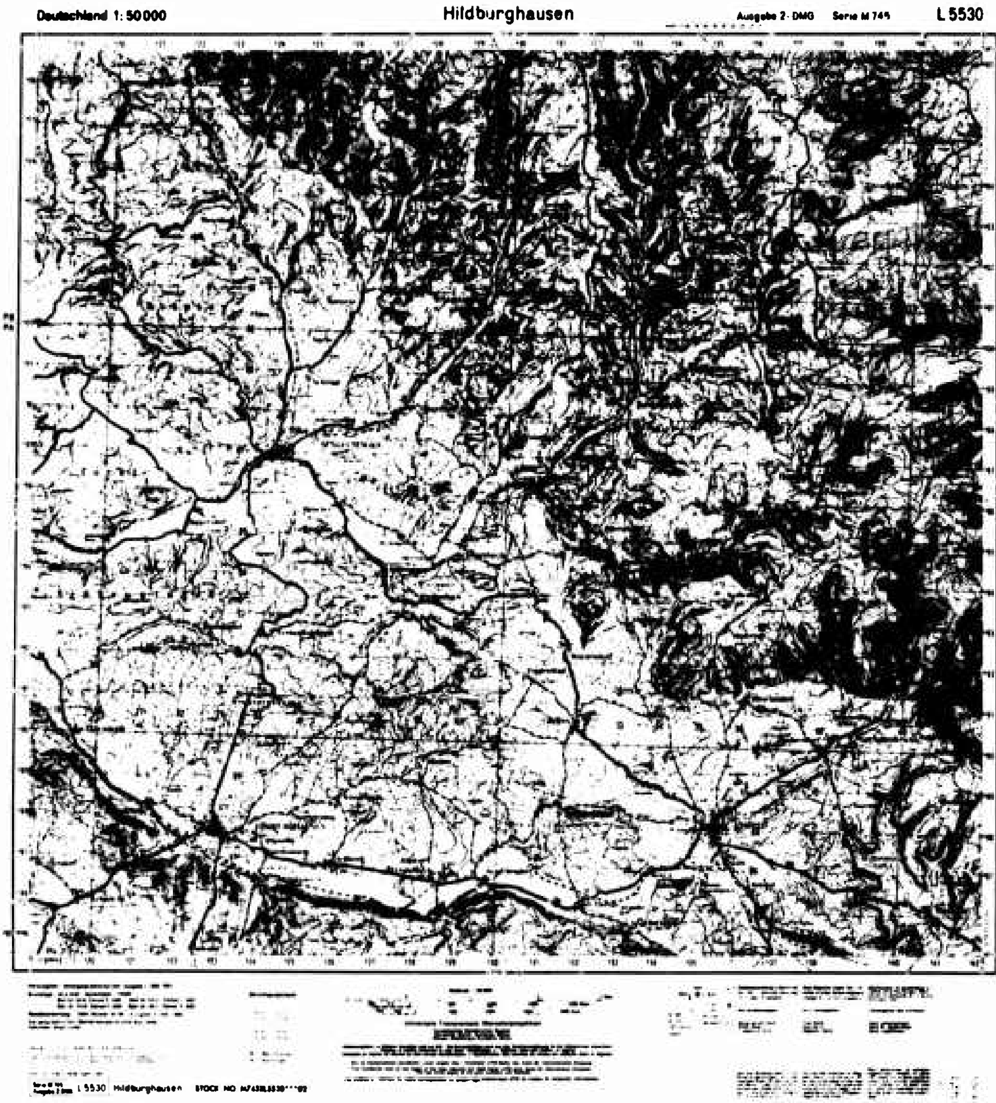

Figure A-1. Area map for overlays A-2 through A-30

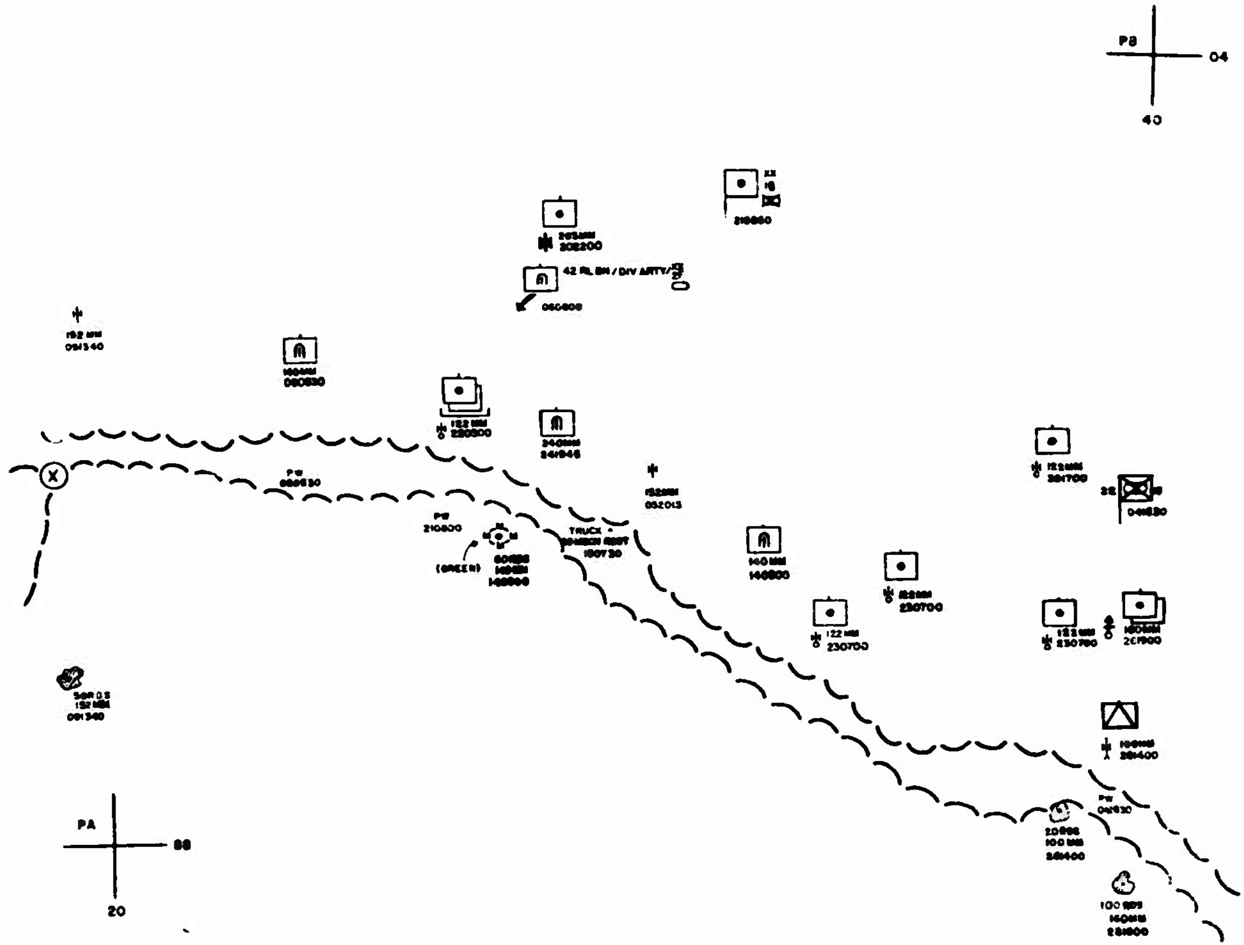

Figure A-2. Total enemy artillery activity

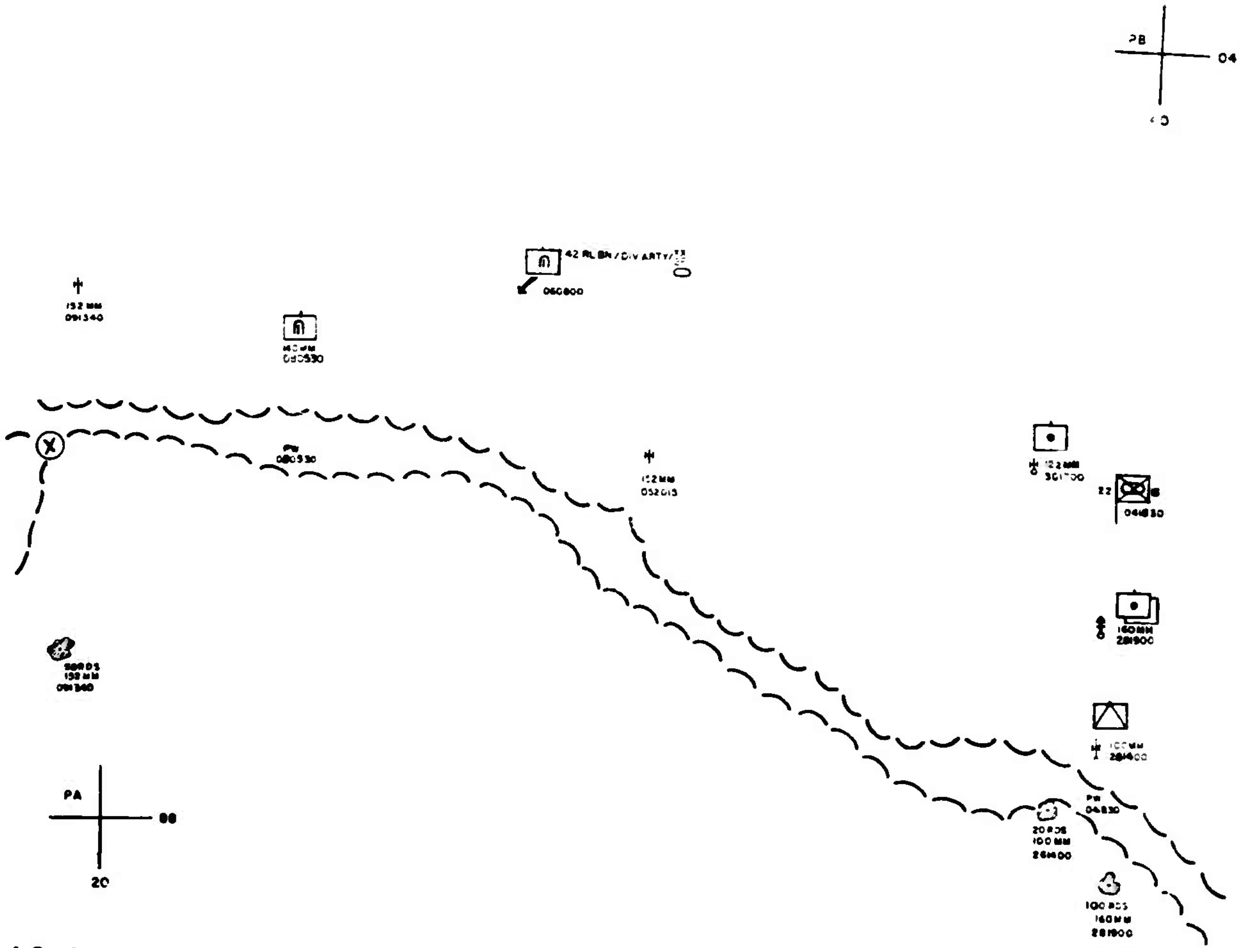

Figure A-3. Availability of artillery, first 15 days

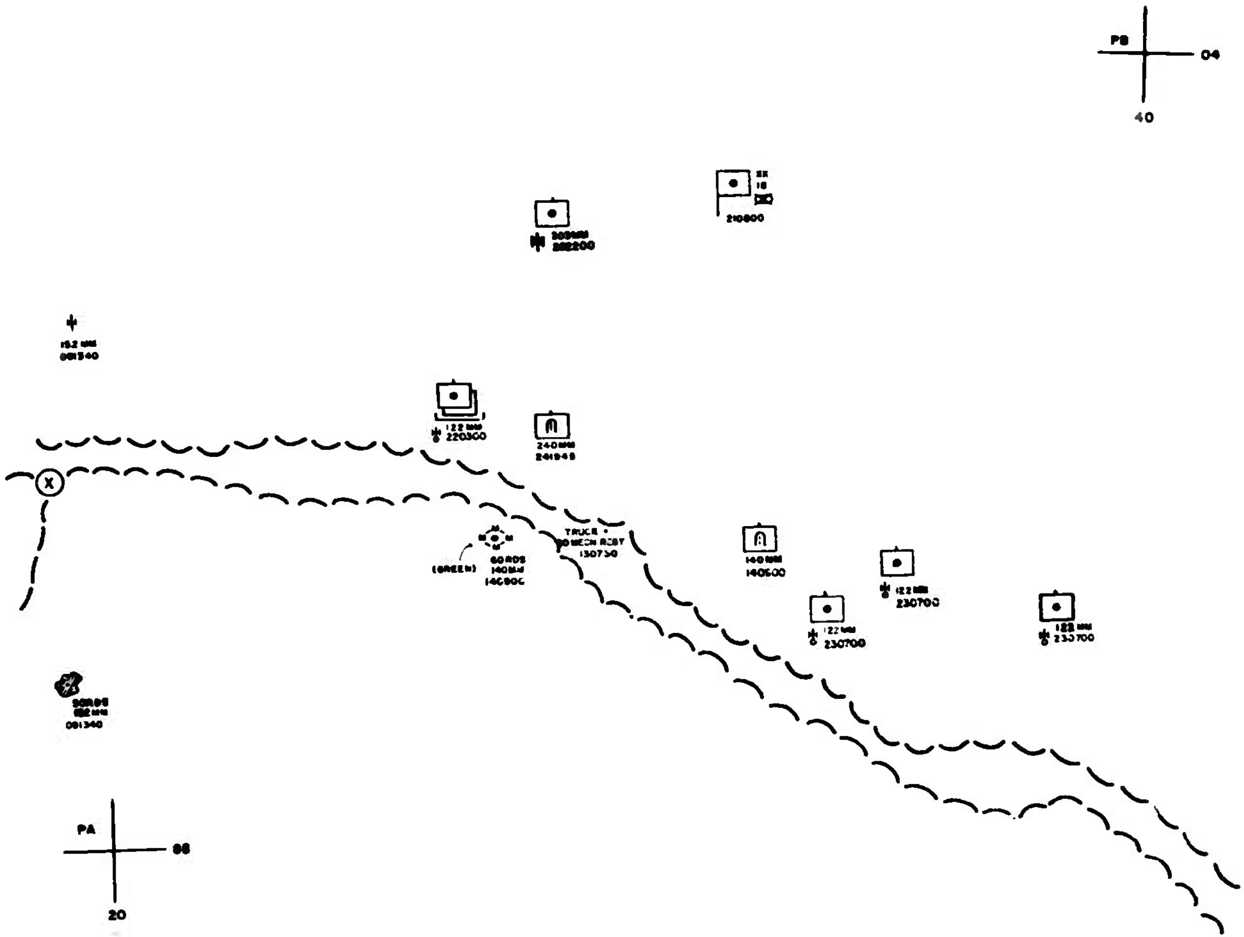

Figure A-4. Availability of artillery, second 15 days

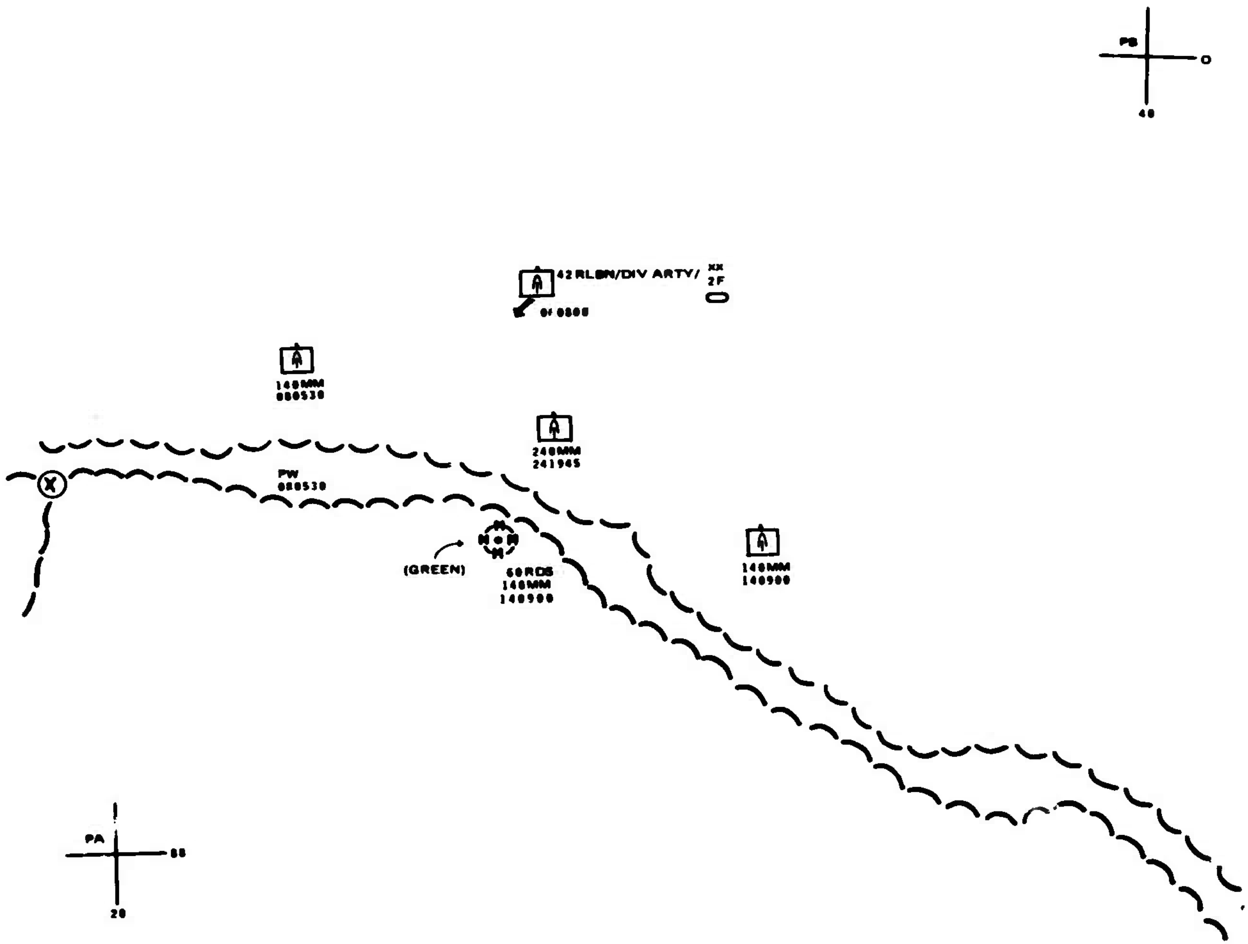

Figure A-5. Location of enemy rockets and missiles

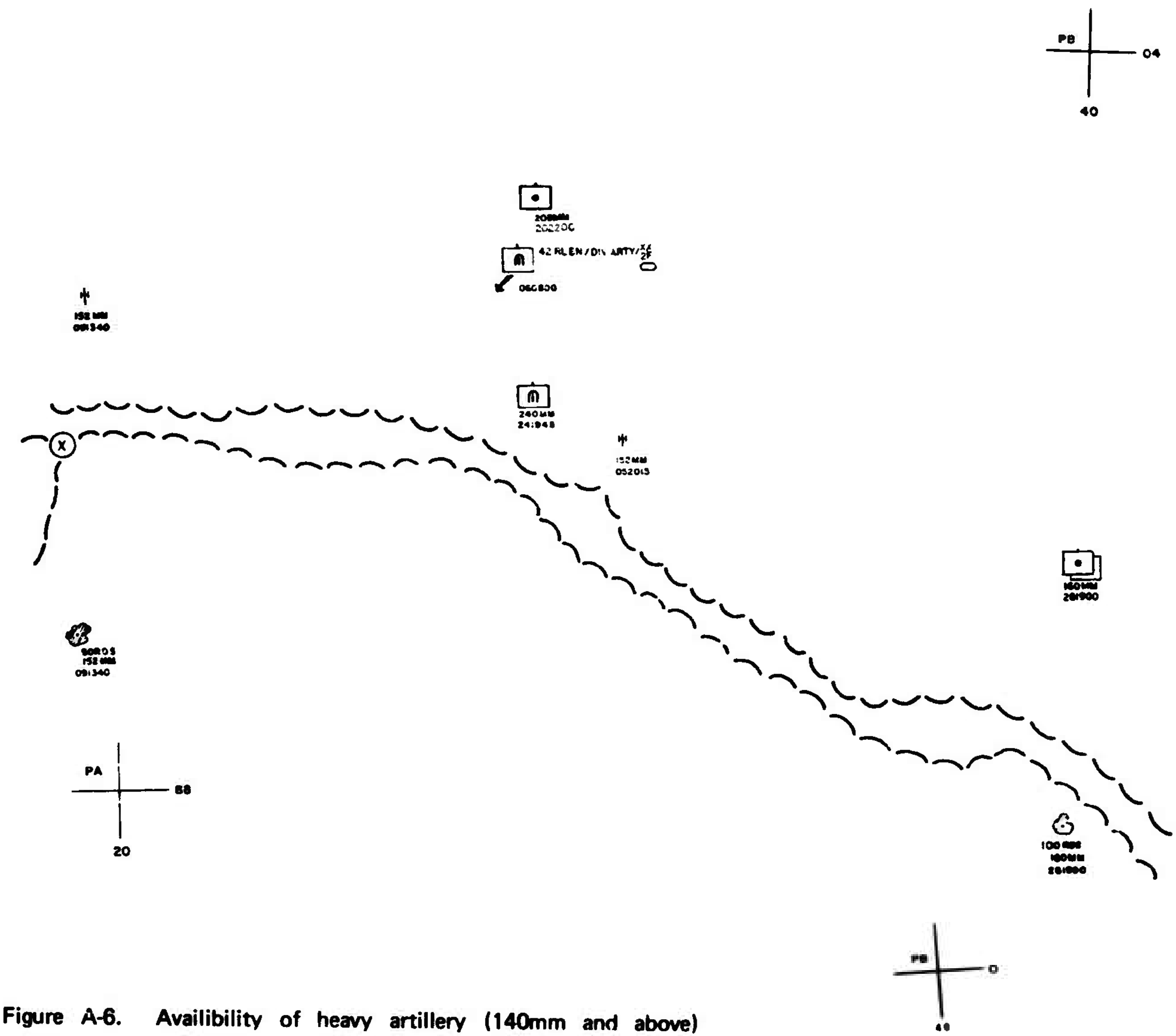

Figure A-6. Availibility of heavy artillery (140mm and above)

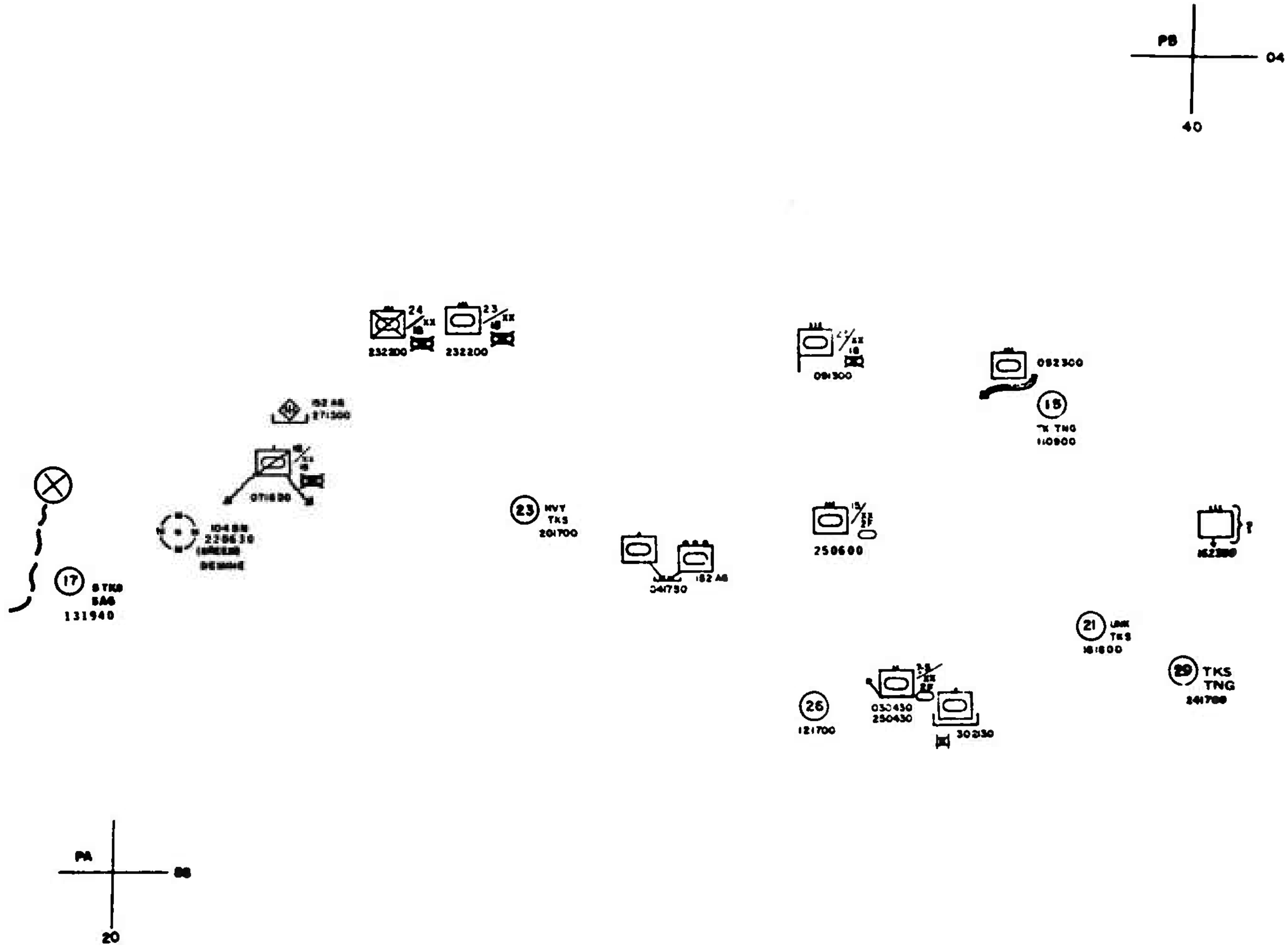

Figure A-7. Total sightings of enemy armor

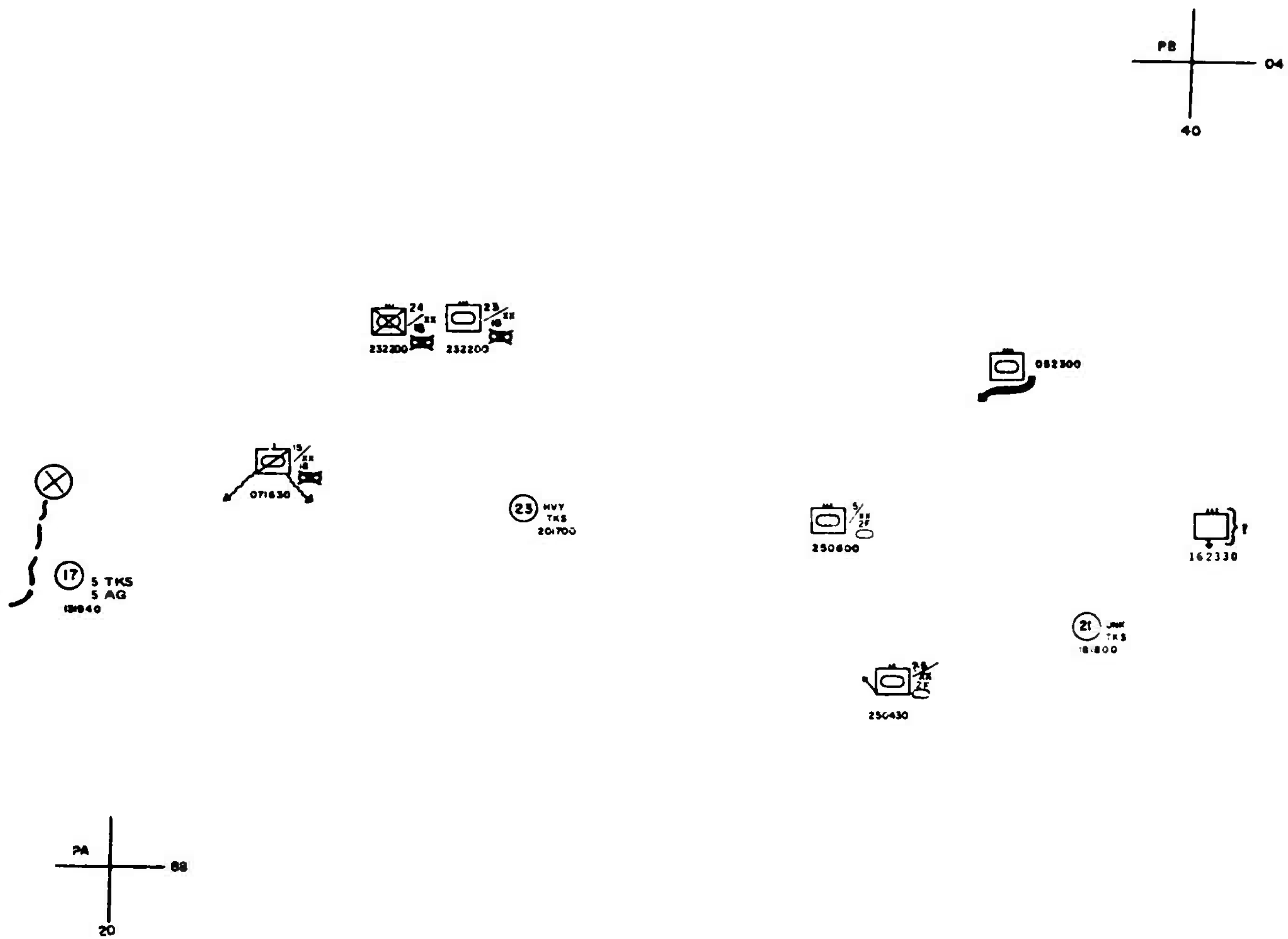

Figure A-8. Location of armor movements

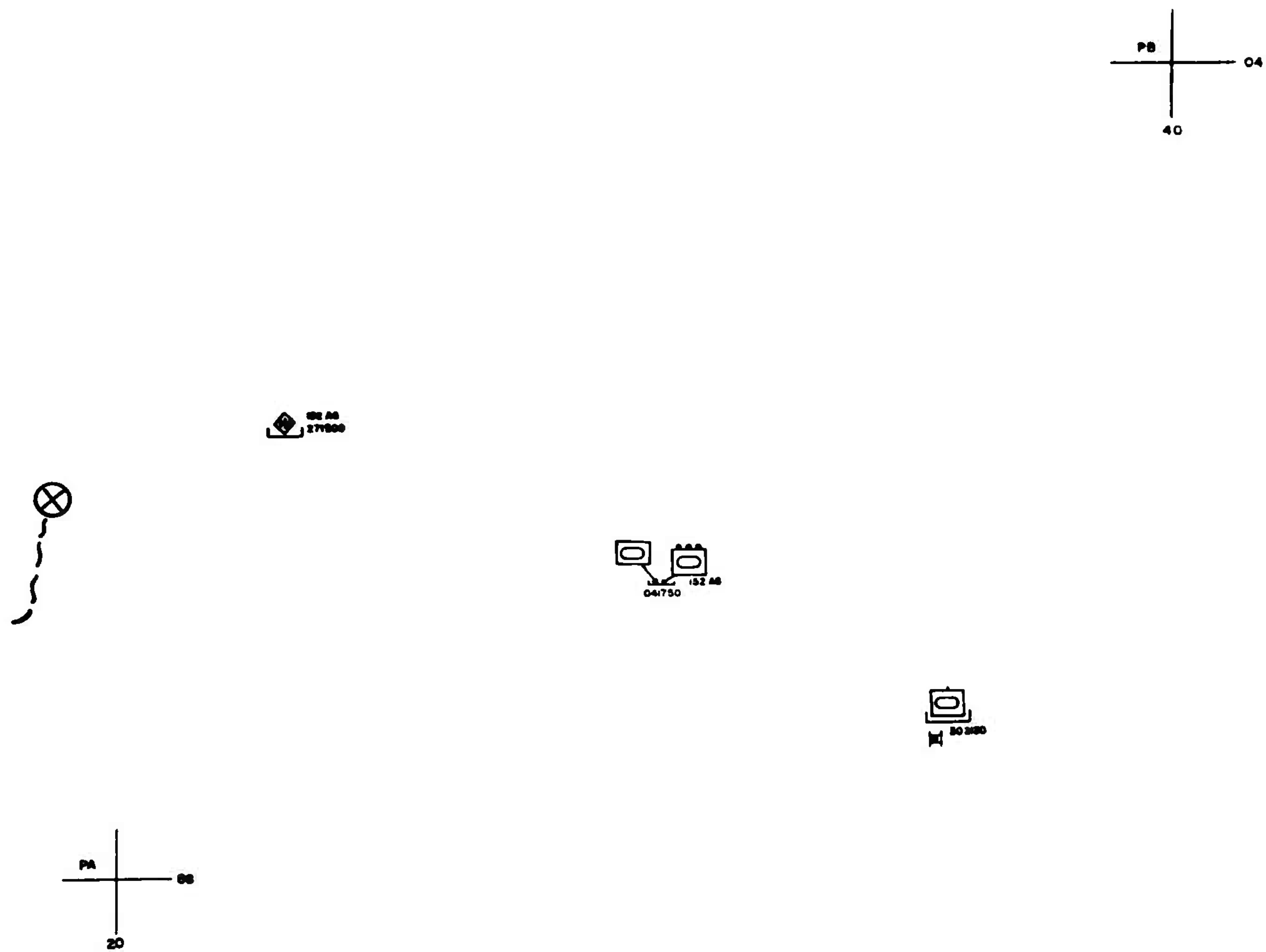

Figure A-9. Location of armor revetments

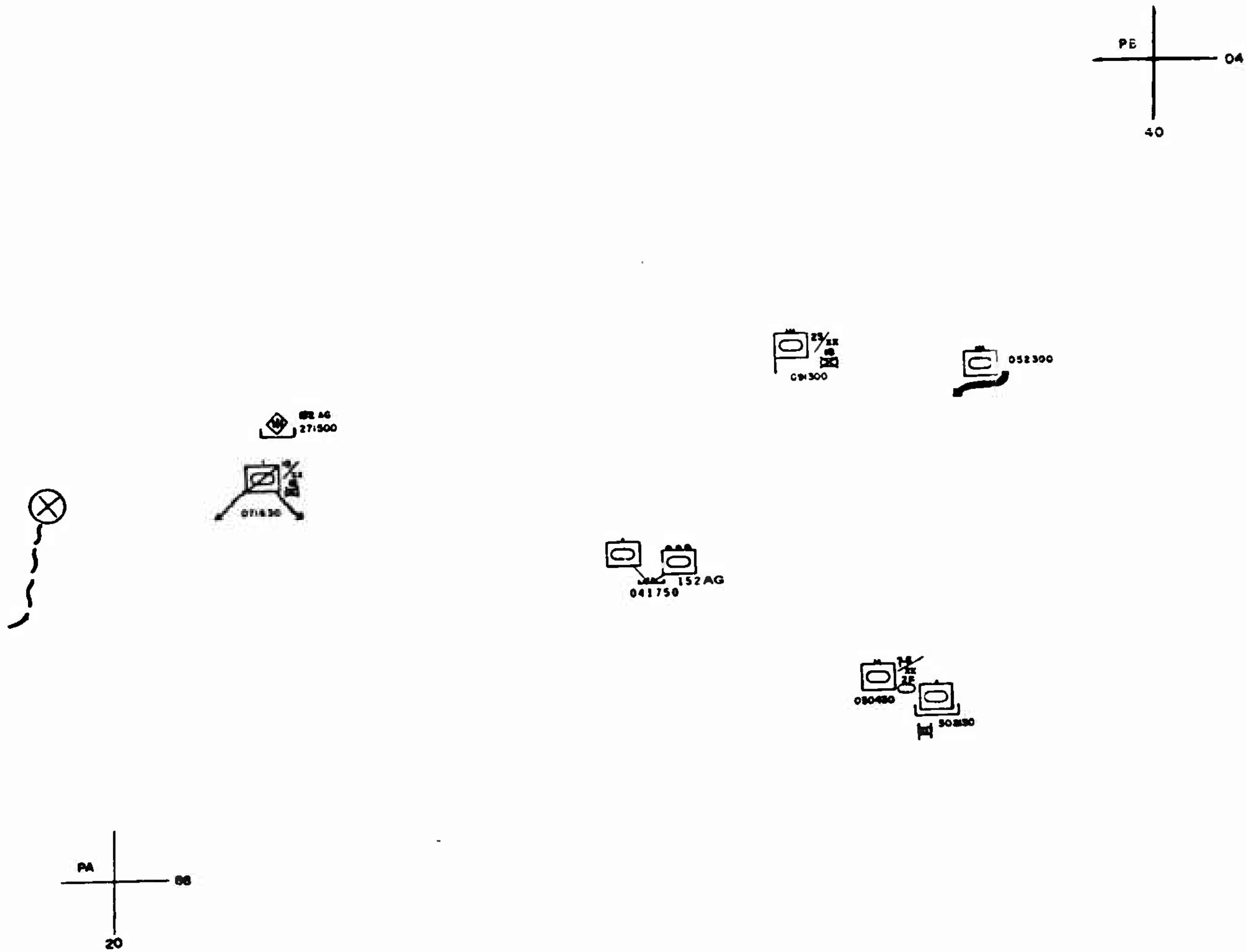

Figure A-10. Availability of armor, first 15 days

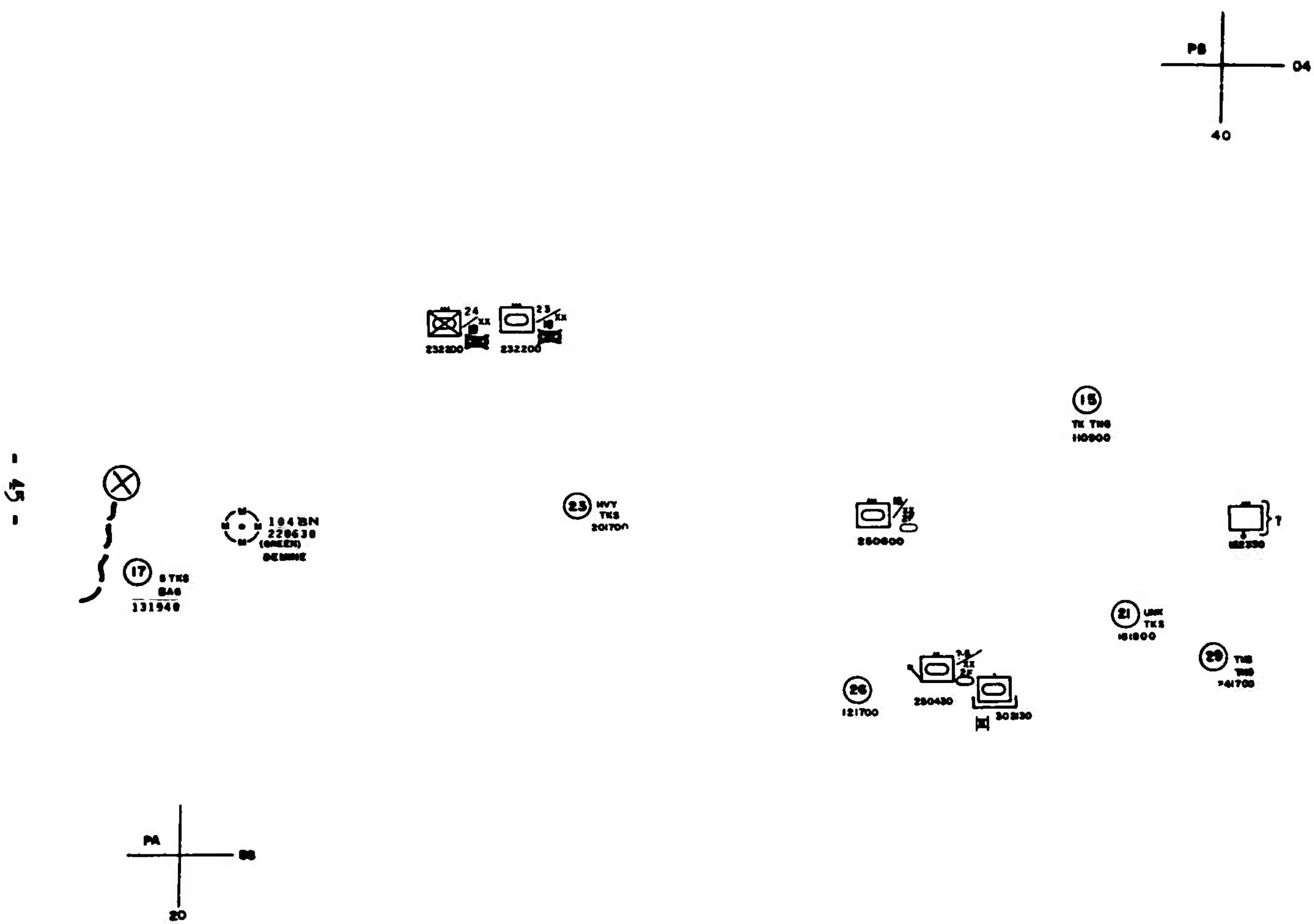

Figure A-11. Availability of armor, second 15 days

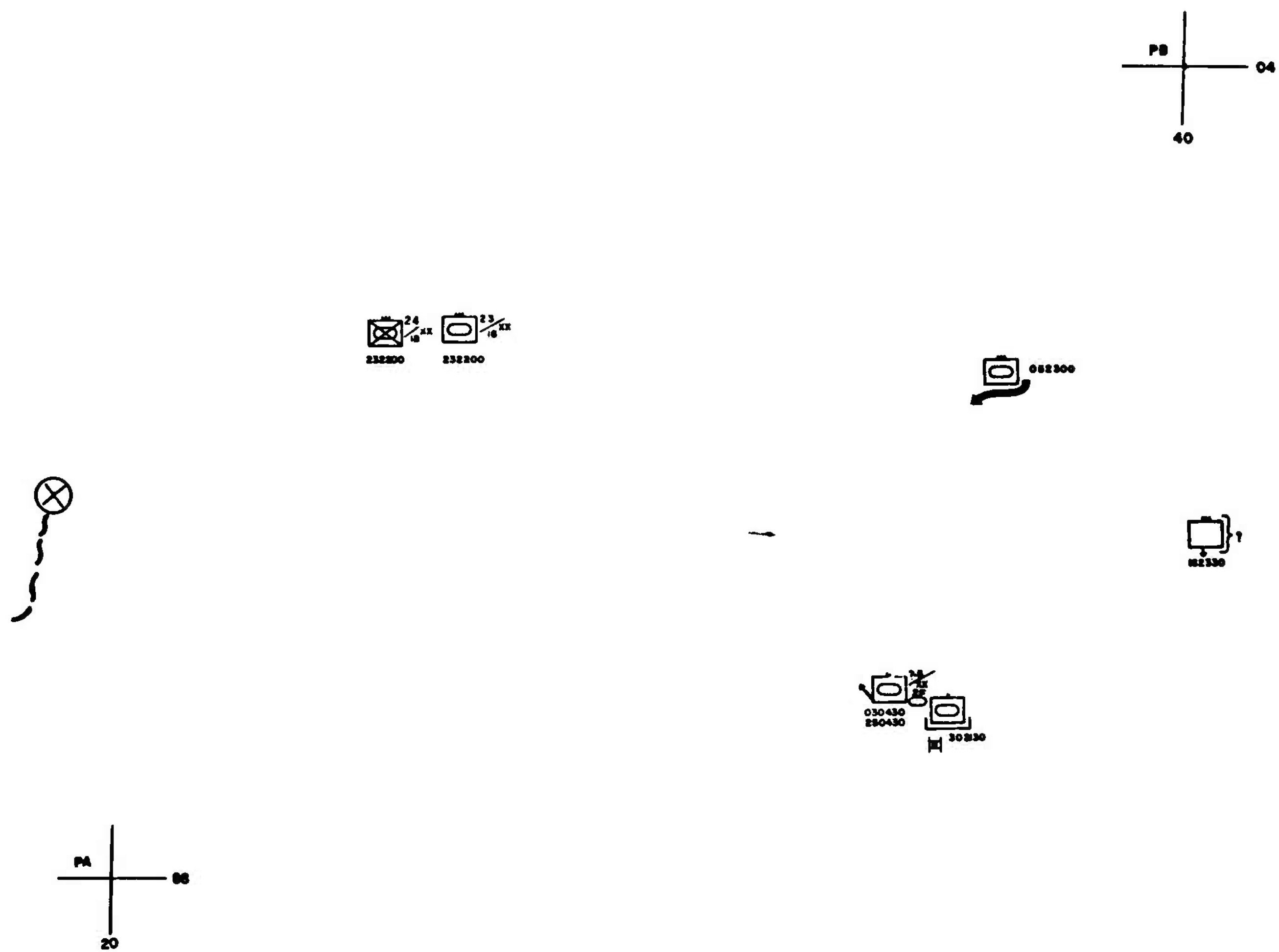

Figure A-12. **Night armor activities**

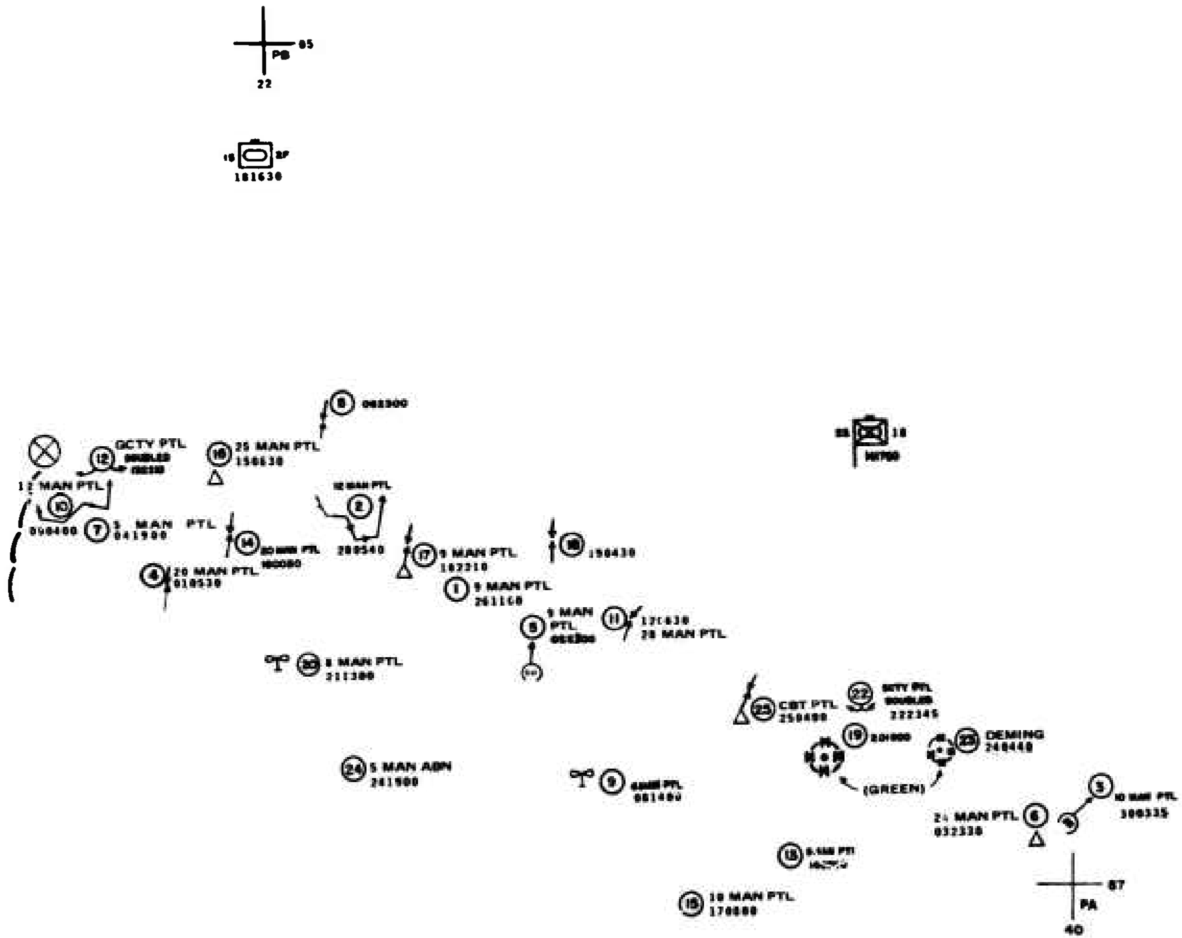

Figure A-13. Total enemy patrol activity

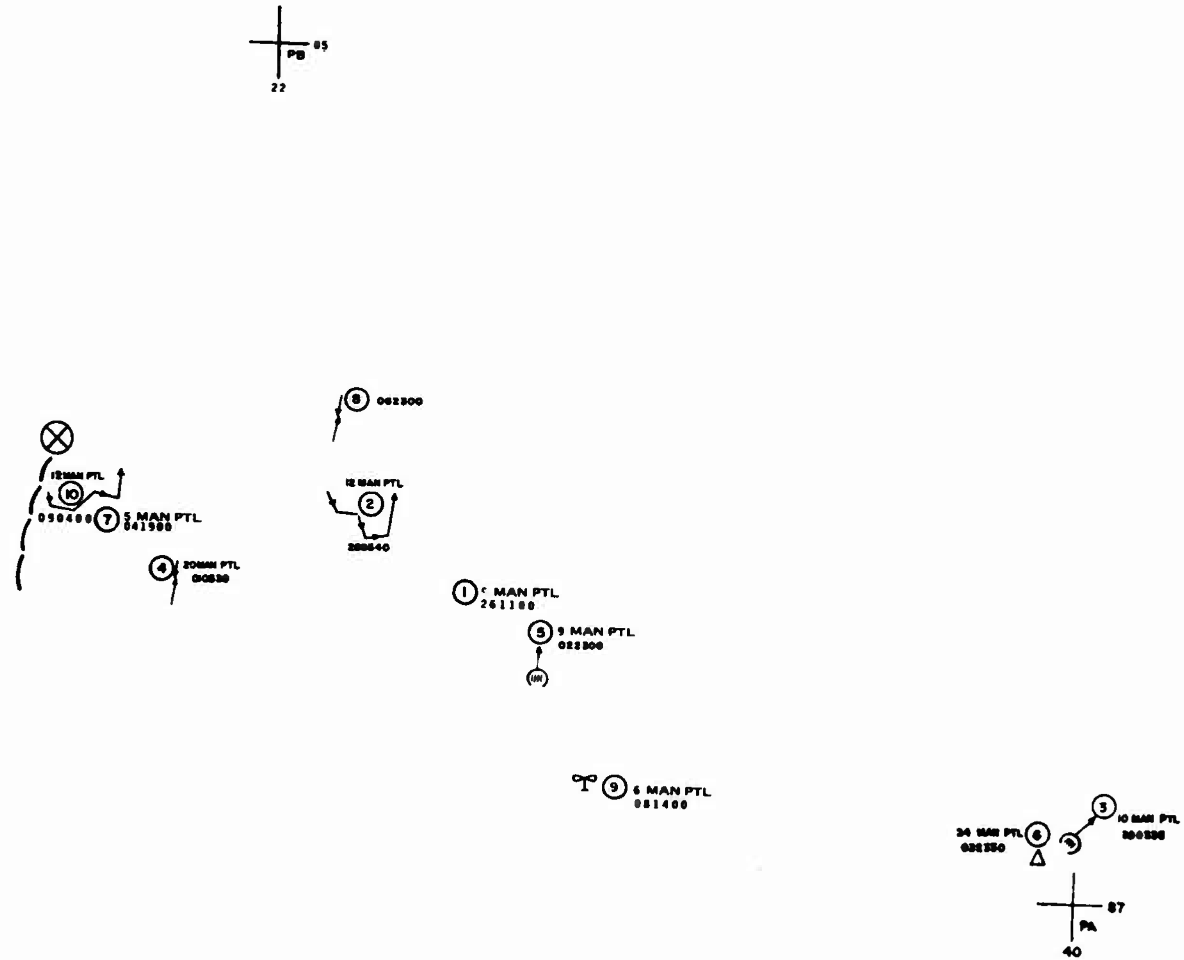

Figure A-14. Frequency of patrols, first 15 days

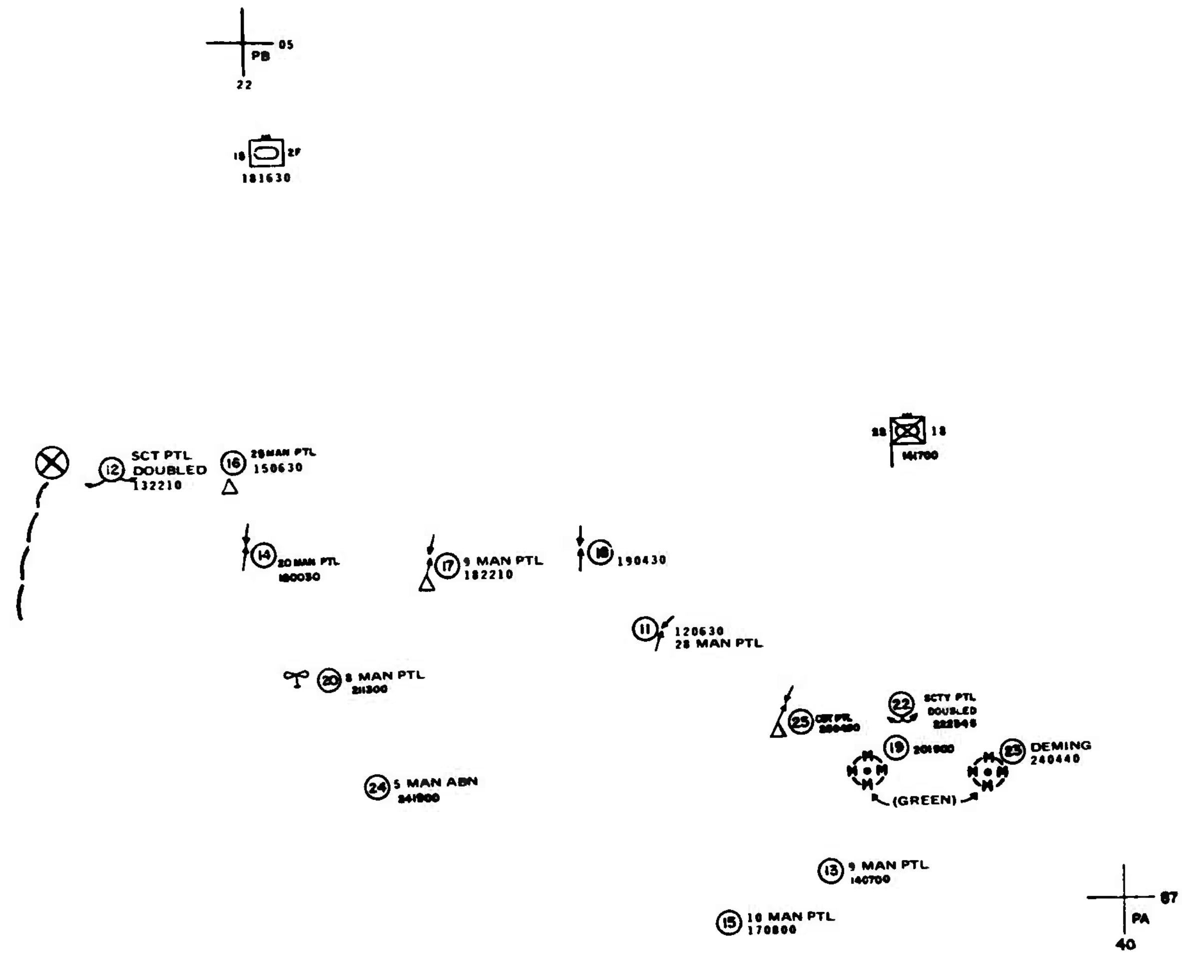

Figure A-15. Frequency of patrols, second 15 days

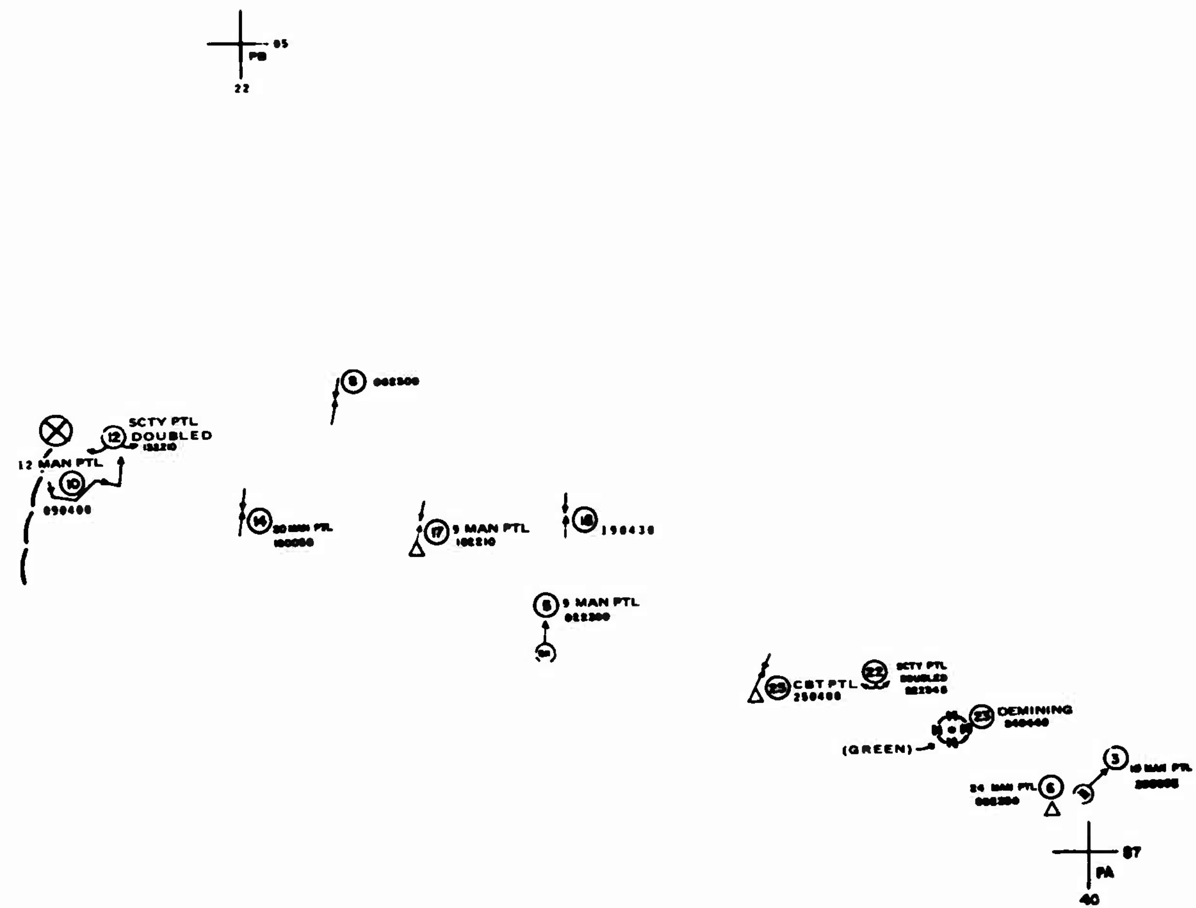

Figure A-16. Night patrol activity

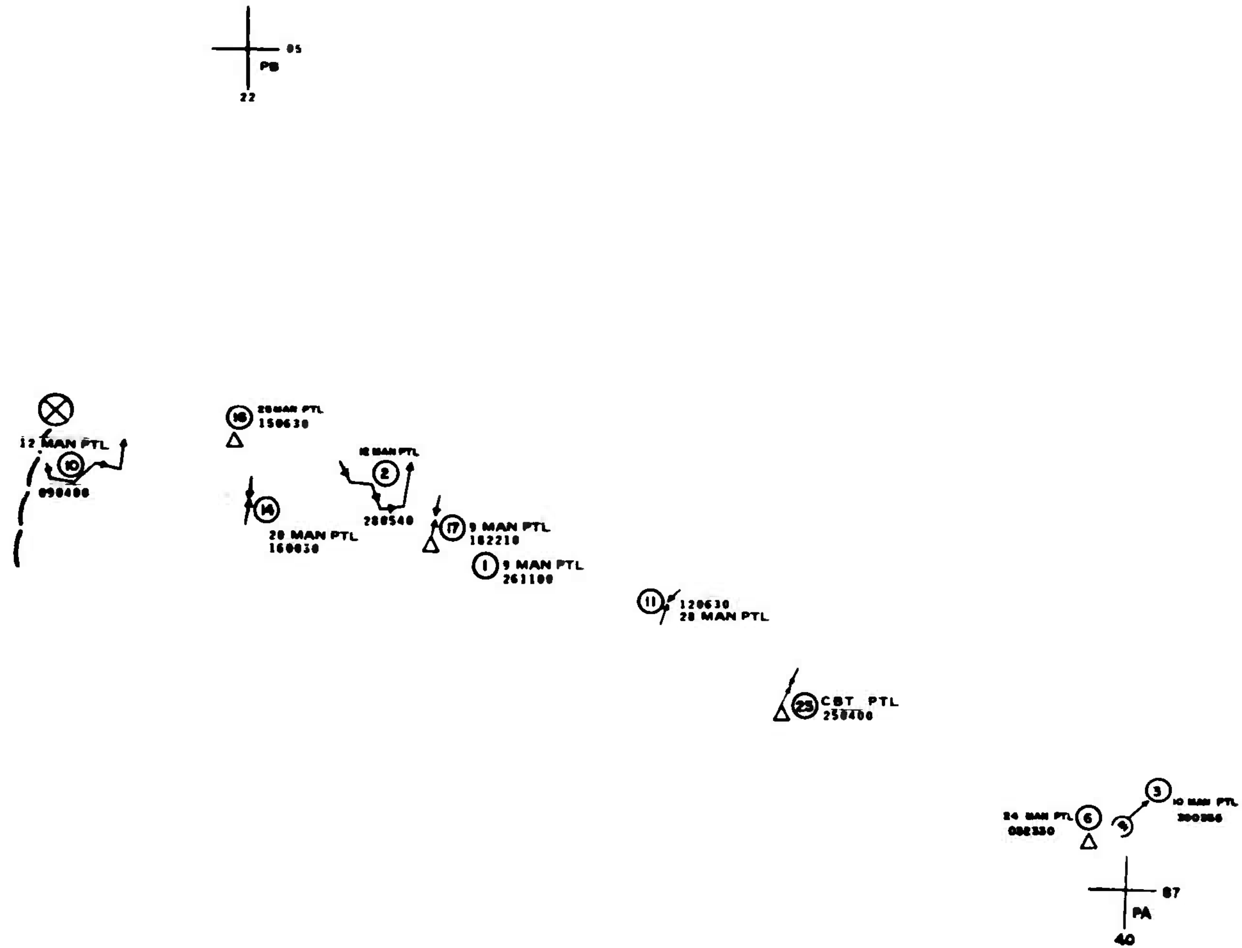

Figure A-17. Enemy patrol activity near friendly front lines

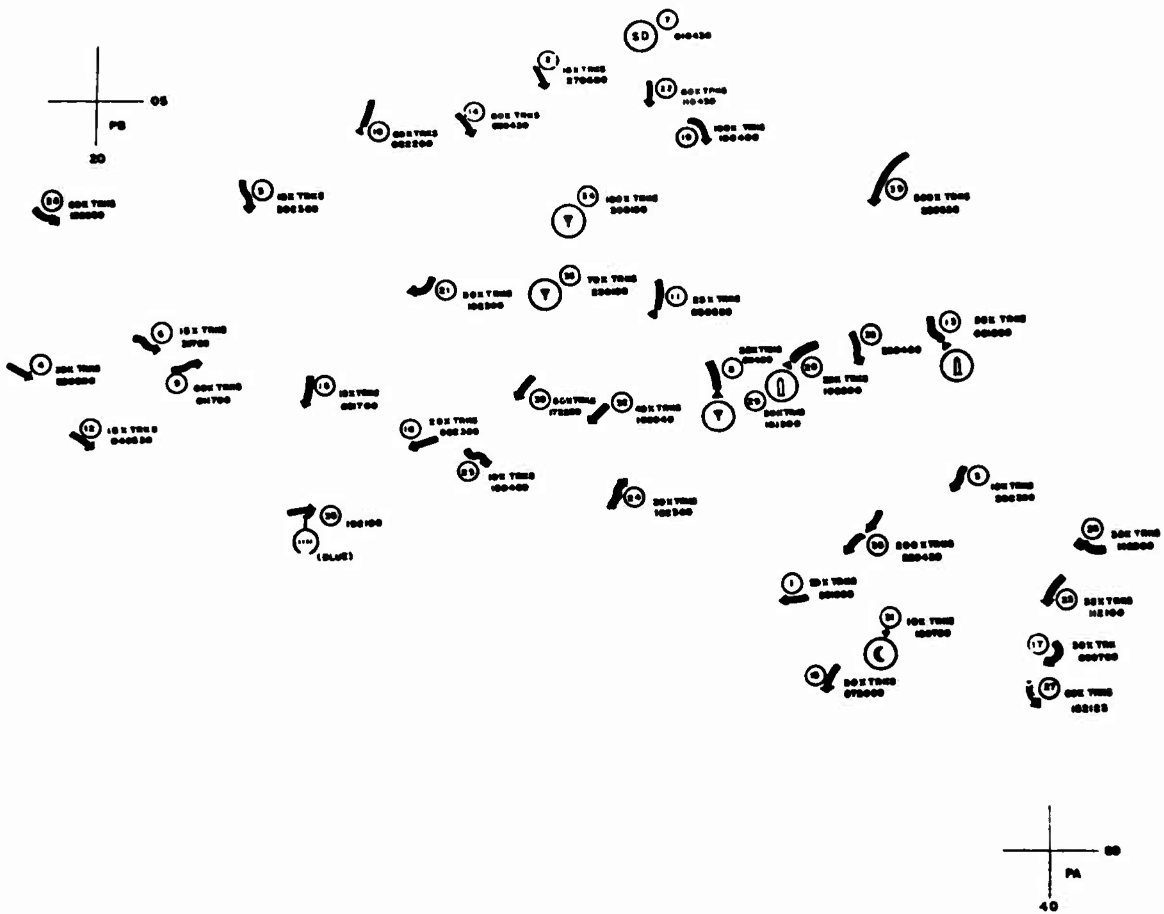

Figure A-18. Total enemy vehicle traffic

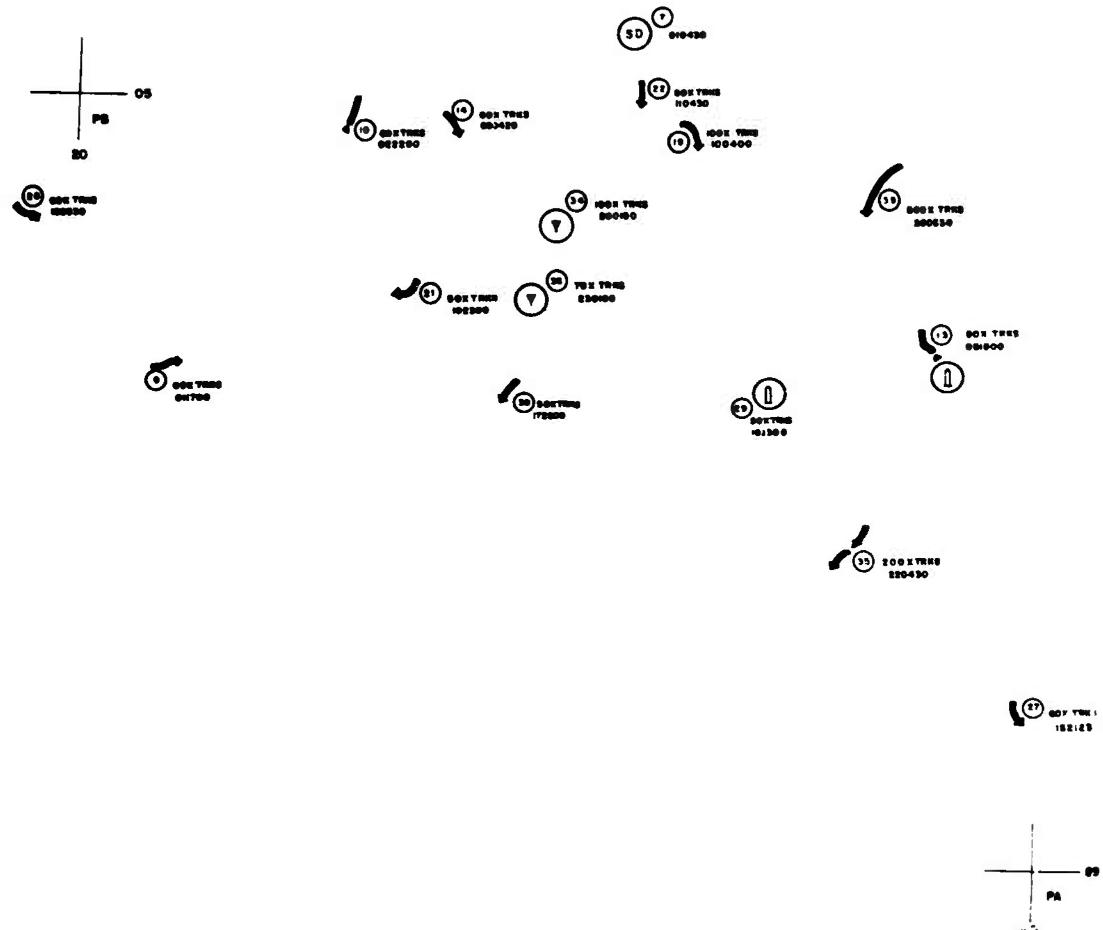

Figure A-19. Major vehicle convoy sightings

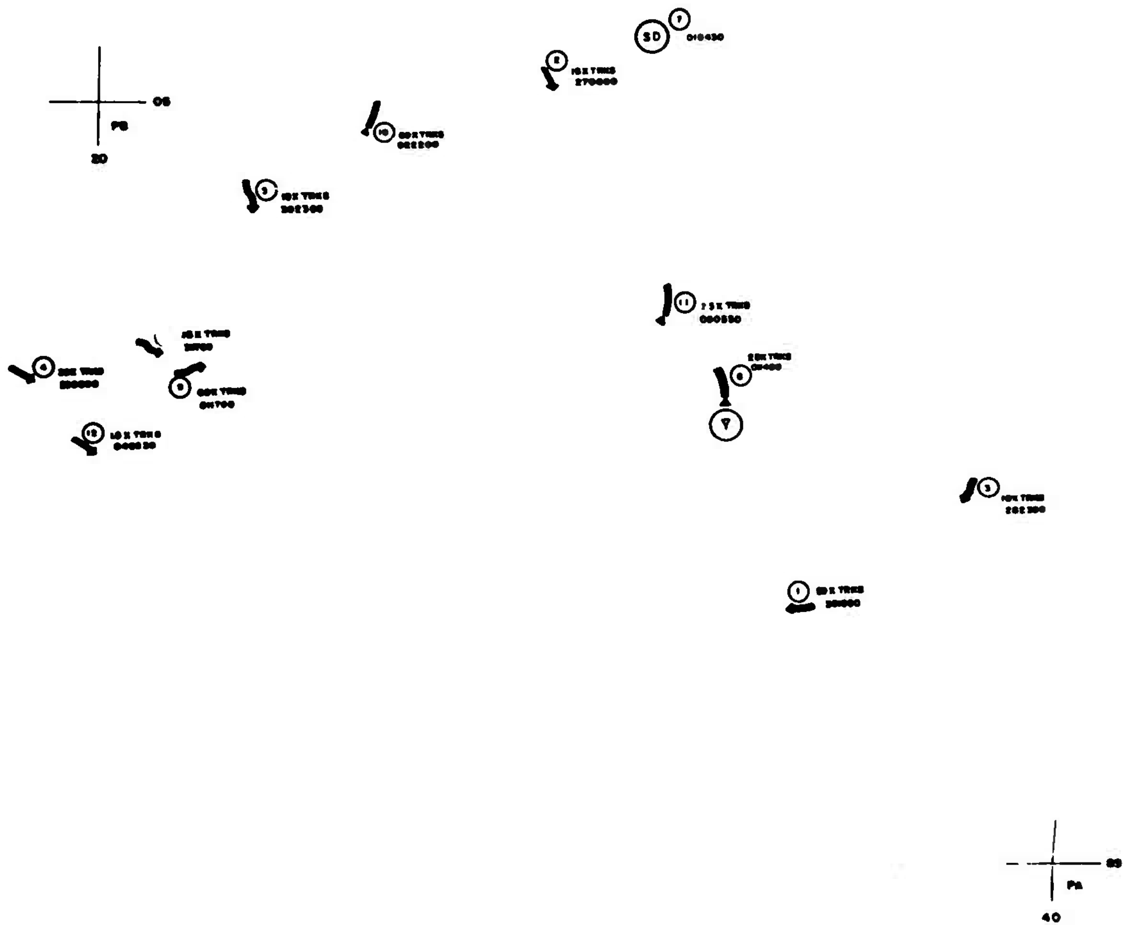

Figure A-20. Convoy activity, first 10 days

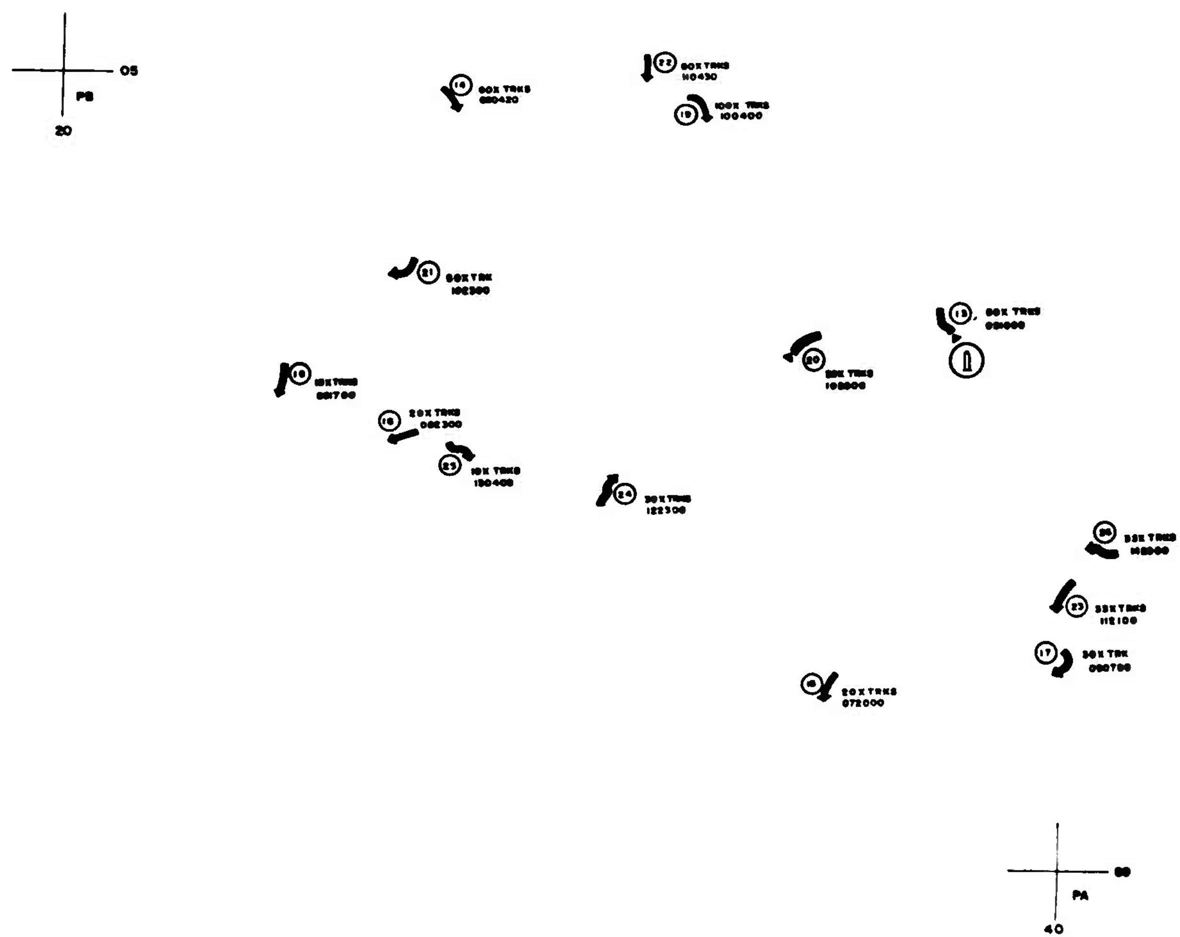

Figure A-21. Convoy activity, second 10 days

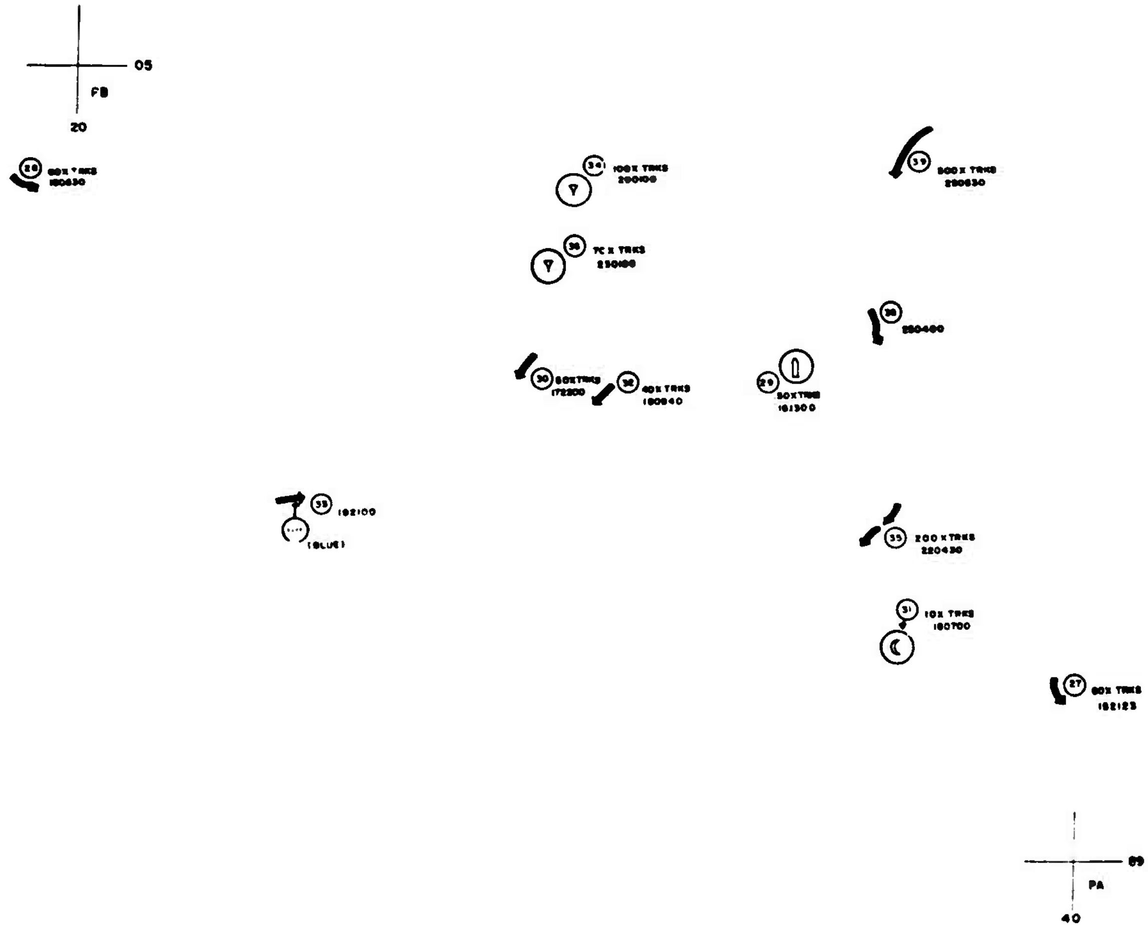

Figure A-22. Convoy activity, third 10 days

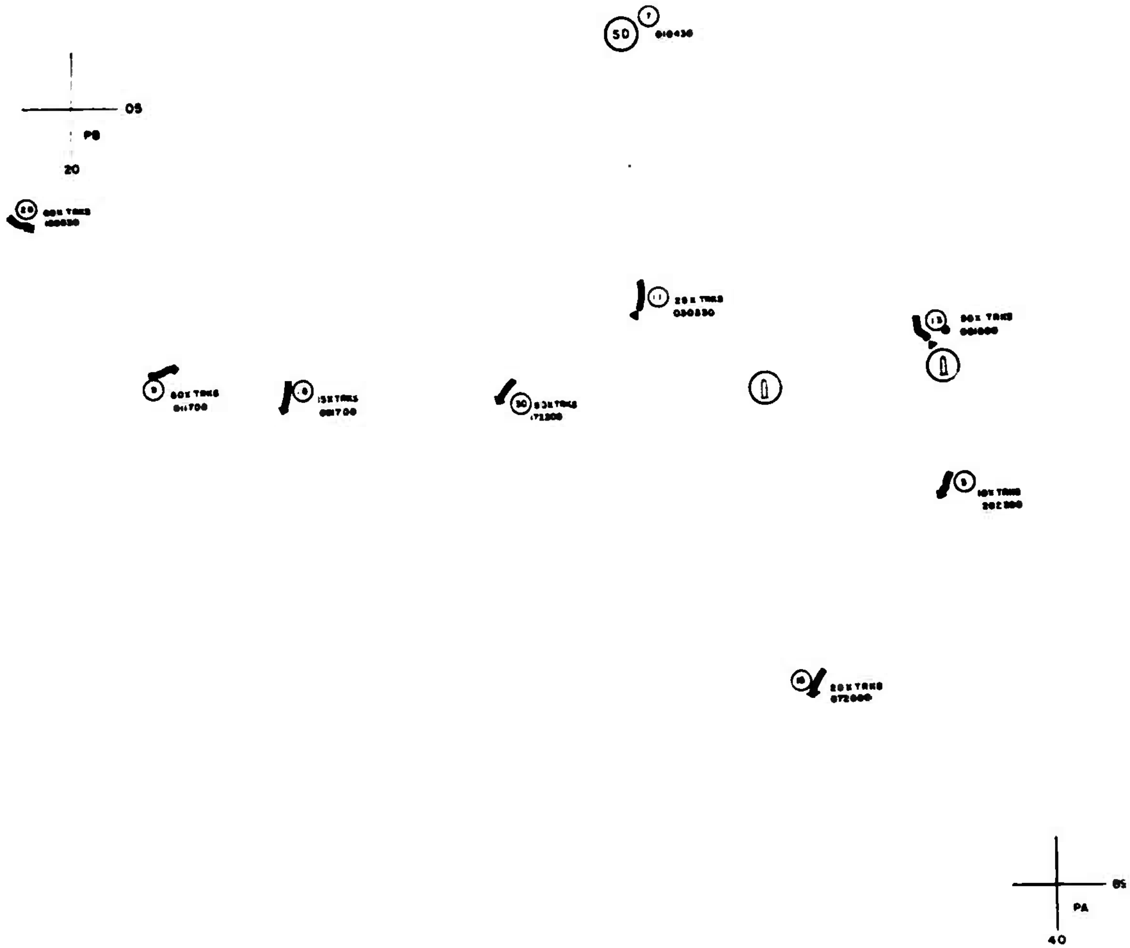

Figure A-23. Ammunition convoys

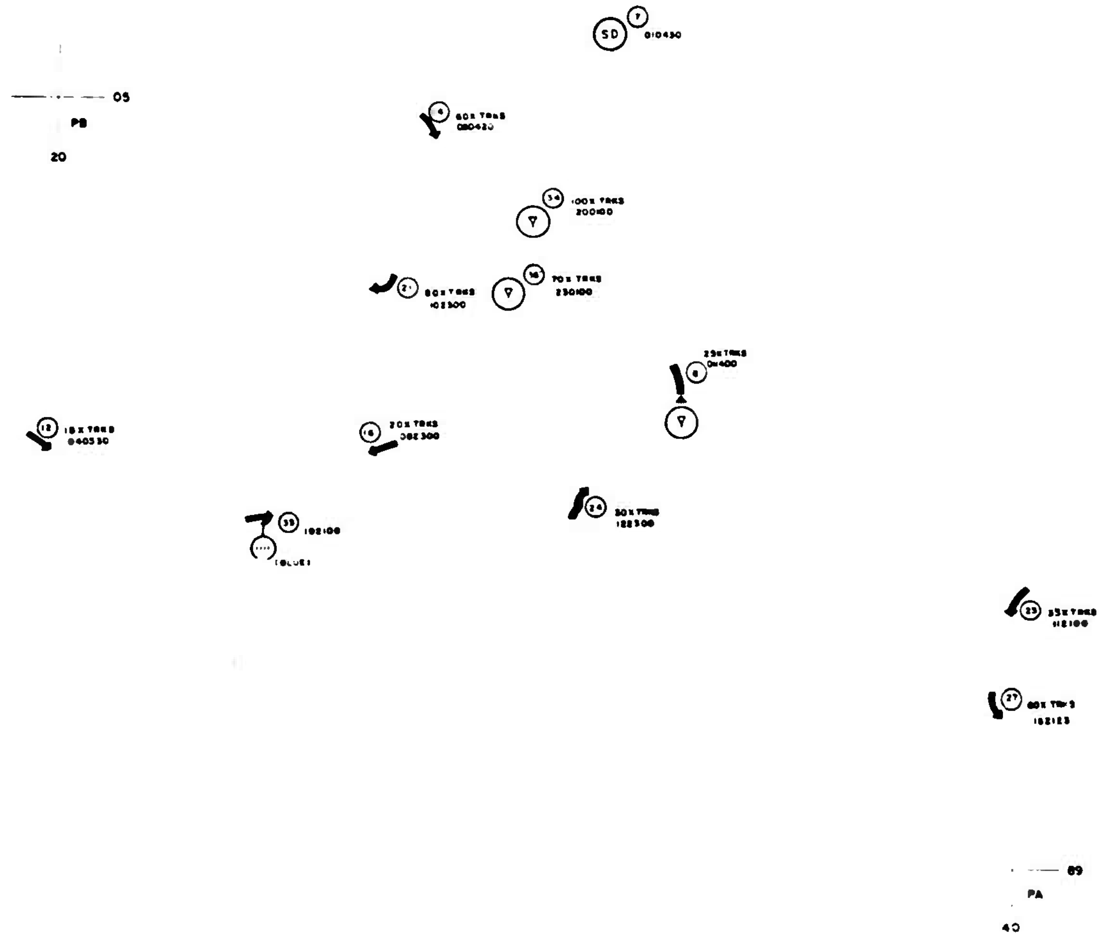

Figure A-24. Petroleum convoys

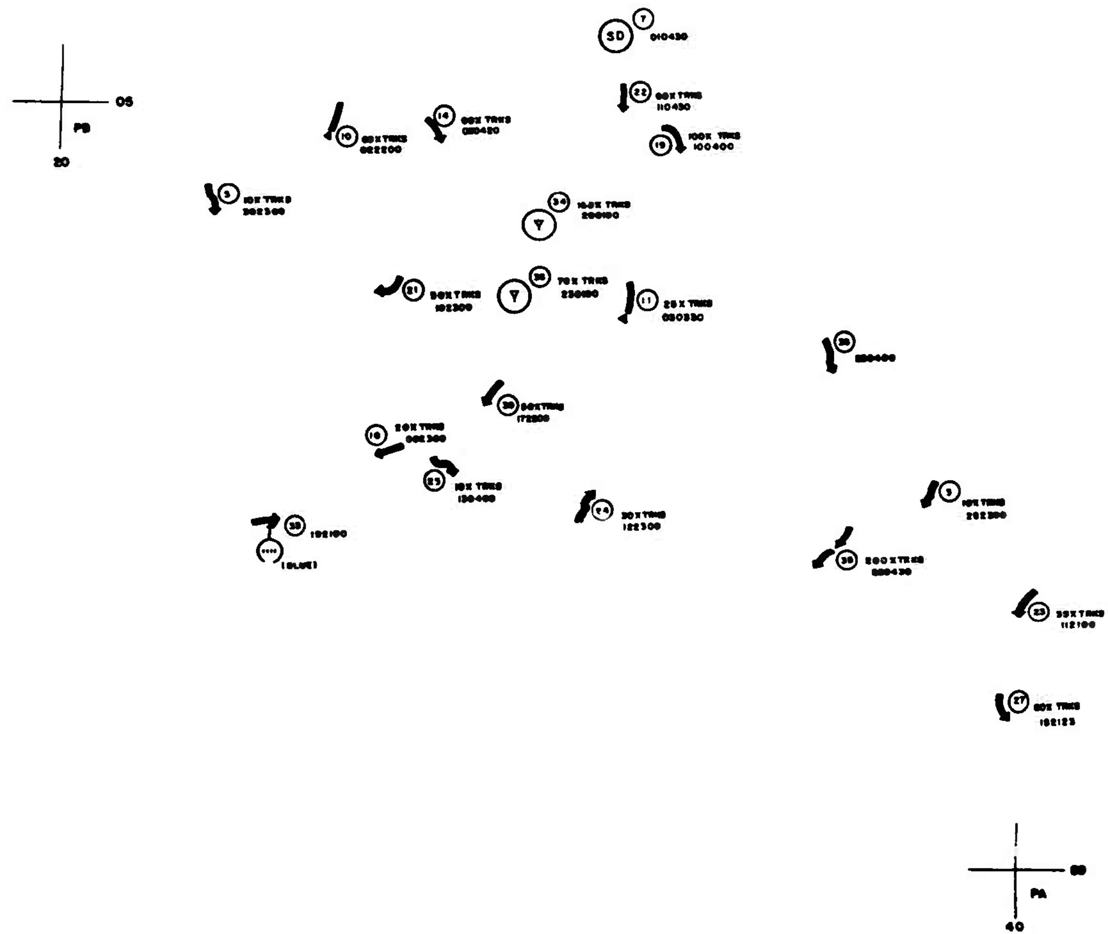

Figure A-25. Convoys moving during total darkness

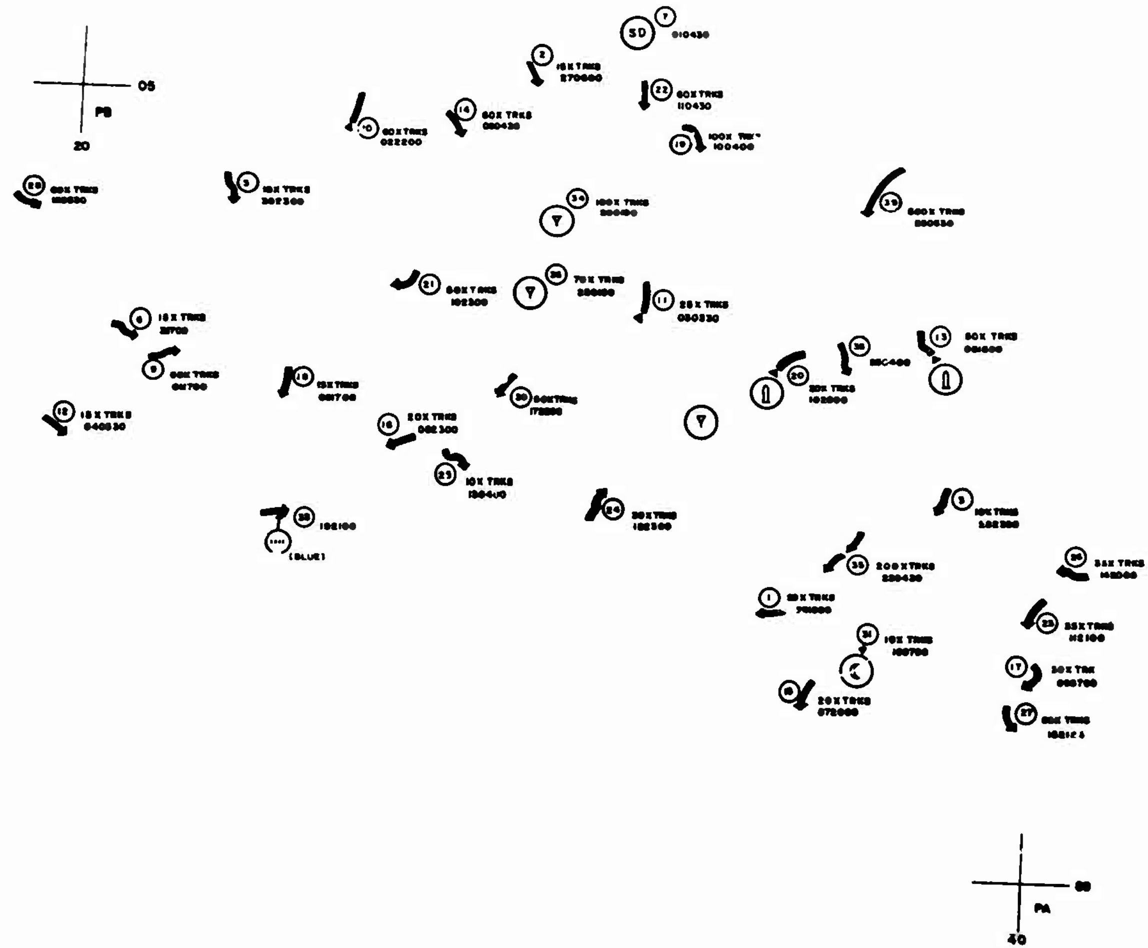

Figure A-26. Convoys moving during partial darkness

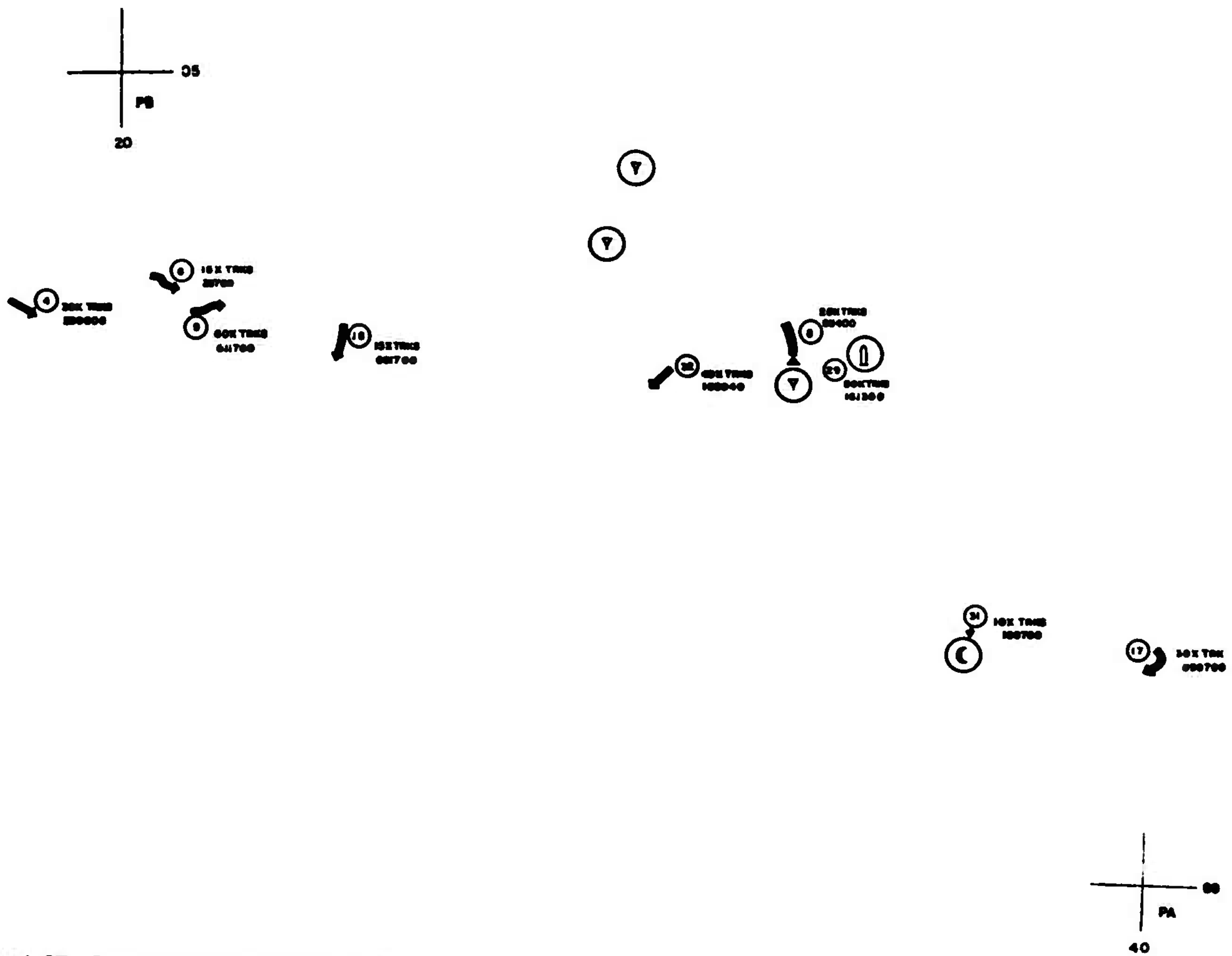

Figure A-27. Convoys moving during daytime

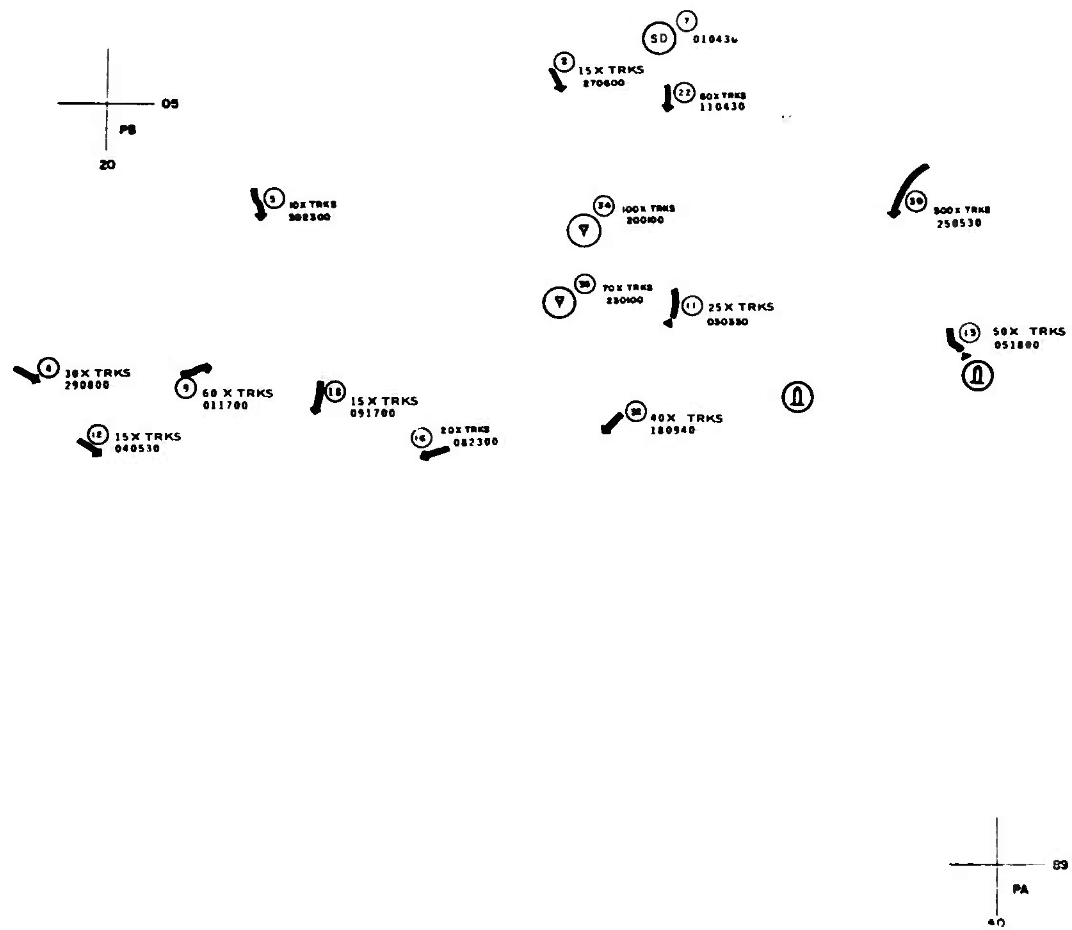

Figure A-28. Convoys using major roads

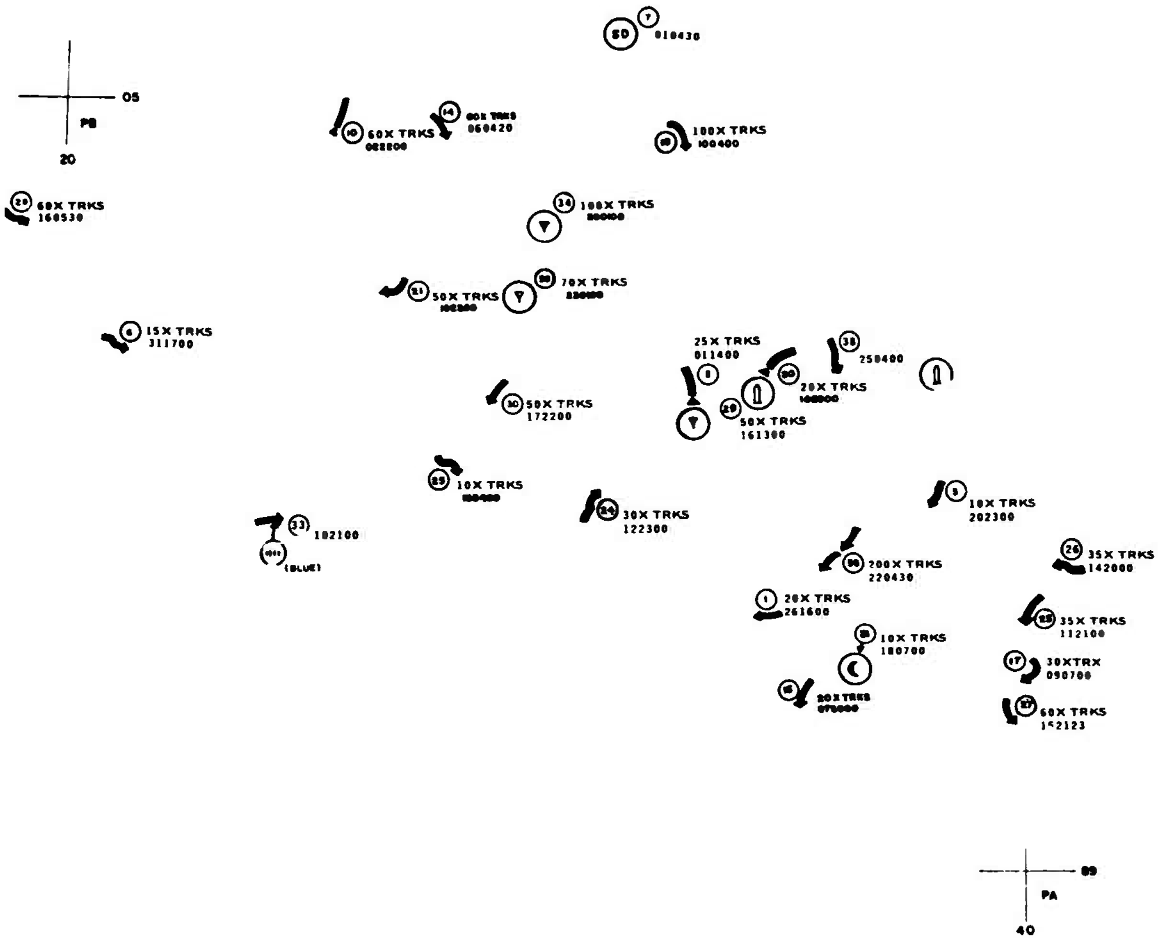

Figure A-29. Convoys using minor roads

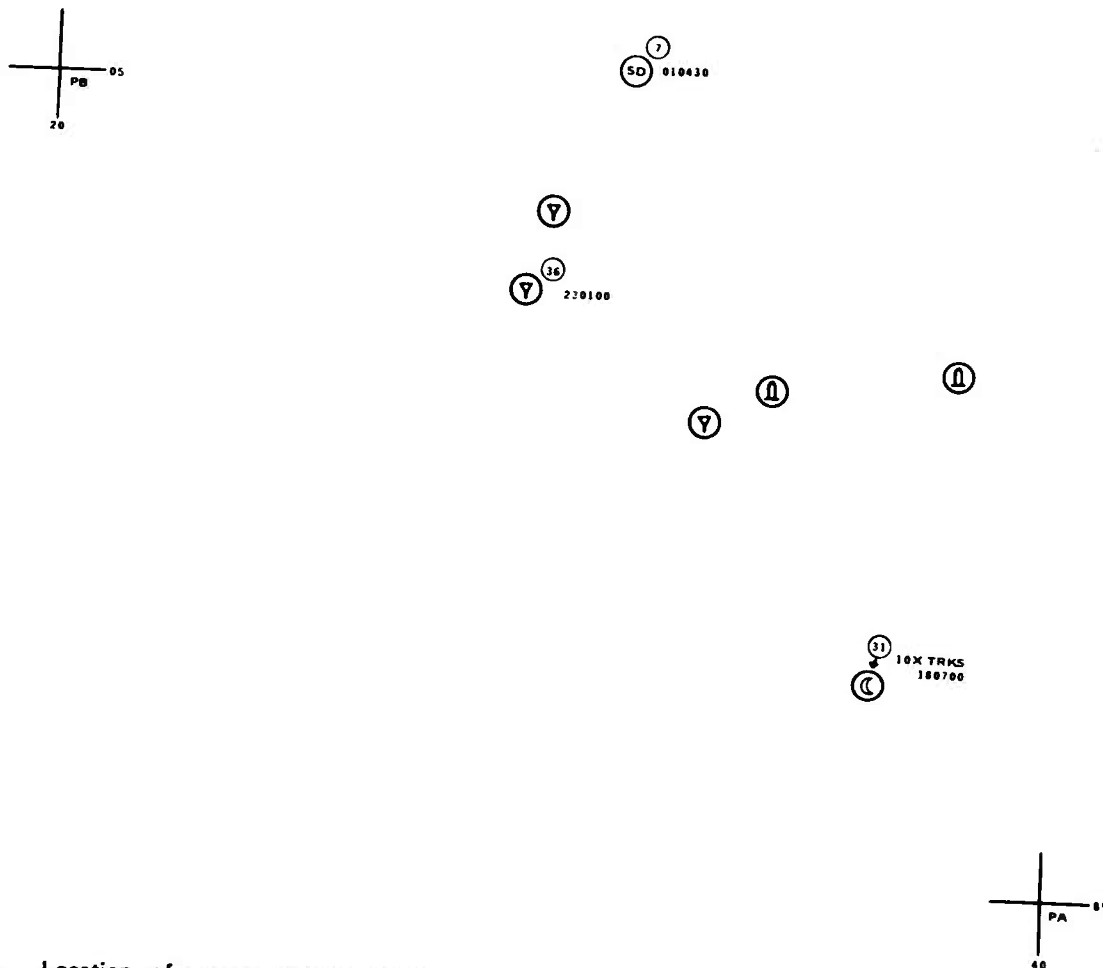

Figure A-30. Location of enemy storage areas