CENTRAL INSTITUTE OF PHYSICS

Bucharest, P.O.Box MG-6, ROMANIA

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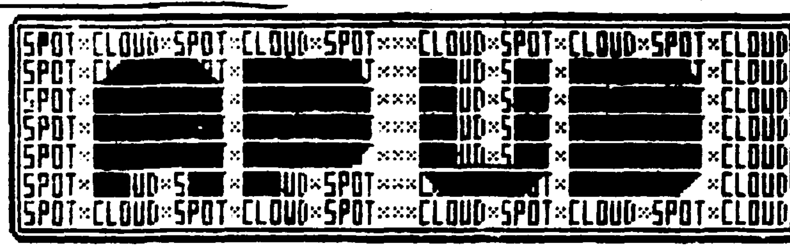

- USER'S MANUAL -

by

D.VAMANU

47 pages.

APUD is an acronym of the Romanian wording for Analysing, Predicting the Consequences of, and Guiding the response to, nuclear emergencies. The conotation to the Latin preposition meaning "After", though unintentional is however appropriate.

APUD is a computer code designed for rough, expeditious assessments of the dispersal of airborne radioactivity discharged, either normally or accidentaly, from nuclear facilities. In particular codes such as APUD may aptly complement the tool-kit required in the adoption of informed contingency plans in case of abnormal nuclear occurences that are accompanied by atmospheric releases of radioactivity. Apart from such extreme circumstances, APUD may profitably be used as a simulation/drill facility. Given adequate inputs, APUD may also work on any sort of industrial atmospheric emissions.

APUD is one product of a Coordinated Research Programme initiated in the summer of the year 1986 by Professor Ioan Ursu, under the auspices and with the logistic support of Romania s National Committee for Science and Technology*, and features one topic in the profile of this country's Central Institute of Physics. Other components of the Program are concerned with dose assessment, nuclide migration into the environment and the food chain, the overall impact of nuclear facilities on biosphere a.s.o. Program Coordinator is Professor Ioan Ursu, First Vice President of the National Committee for Science and Technology, Senior Researcher with the National Centre for Physics at Măgurele-Bucharest. APUD's Physics, program design and coding, by Dan Vamanu. The permanent scientific guidance and comprehensive assistance by the Program Coordinator is gratefully acknowledged.

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* Mailing address: The National Committee for Science and Technology, 1, Piaţa Victoriei, 71202 Bucharest, Romania

CONTENTS

GENERAL

The assessment of a nuclear emergency involving radioactivity releases into the environment is a many-task job. Inter alia, the analyst may be bound to determine core inventories at the release time; predict dispersal of airborne activity; infer fallout, land and water contamination, animal and human intakes and doses - and, on this basis, recommend to decidents appropriate alert levels, in time and over territories. This stands true not only for crisis situations, but also, and increasingly, for planning the nuclear development and improving nuclear emergency preparedness.

This APUD component does not endeavour to cover all these. It is deliberately confined to the prediction of the airborne activity dispersal over time intervals in the order of a few days, and territories in the range of national, or sub-continental, areas. Assuming this restriction, APUD shares the opinion according to which the atmospheric dispersal is "the most critical pathway, to be quickly estimated in the early phase of an accident"*.

As it is, APUD was designed to provide

(i) the time-profile of the activity excursion, at given spots; and

(ii) the pattern of radioactive clouds/plumes, at given moments into the release time.

Recent experience has also highlighted the notion of "assessment-under-crisis", implying excessive stress over analysts and decidents, and severe time constraints. As a consequence, apart from highly elaborated codes requiring top-class hardware to run, a clear need emerged also for codes that should work on, or be readily adaptable to, a wide class of simple, unexpensive personal/home (!) computers, operable wherever the need occurs on the theatre of action. Such codes would necessarily work on boldly simplifying physical and mathematical assumptions to give, in minutes, rushes on the relevant information, that may be highly praised <u>because</u> delivered at the right time, in the right place.

APUD is an exercise to outline the design of such a code. Demonstratively, this version of the program was meant to work on

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* International Atomic Energy Agency. Techniques and Decision Making in the Assessment of Off-Site Consequences of an Accident in a Nuclear Facility, IAEA Safety Guides, Safety Series No.86, IAEA, Vienna, 1987.

one of the smallest though brave - home computer, the 48K Sinclair SPECTRUM and compatibles, currently produced, or marketed, in many countries worldwide. It takes a couple of minutes for APUD be loaded from tape, about one minute to be properly fed with input data, less than five minutes to trace, via 200 points, the time-profile of the activity excursion in a User-selected place, and around ten minutes to deliver a bulk of 704 data, spelling and mapping the distribution of activity in a radioactive cloud - its most comprehensive job.

In its current version, APUD is essentially concerned with South-East Europe, which it covers by nine, partially overlapping maps, but can well accomodate release sources that fall beyond the borders of its reference map. Moreover, there is no principial difficulty to adapt APUD to other territories.

APUD delivers its answers in the form of four varieties of listings and four varieties of graphic pictures, as requested, on screen and hardcopy.

While doing these,APUD would in no way pretend to substitute for more elaborated, experienced, and therefore reliable models, and codes, currently in the libraries of those interested. In fact, as it looks now, APUD does not endeavour to be a ready-to-market commercial item, but rather a homework hinting at an attitude - one based on the belief that nuclear safety training and environmental challenges should become a part of the daily preoccupations of those many active in these, and correlative, fields.

This candid exercise is willingly open to criticism and - hopefully - amendments, transcription on more ambitious machines, and development.

THE PHYSICS

This is a User's manual. Therefore, the present text will not enter a detailed presentation of the dispersal model designed for the description of the evolving in time and over territories of the released radioactivity. When brought to these by necessity, the User is kindly invited to apply to the reference paper attached (RP), and its citations.

For the sake of this briefing, it suffices to say that APUD employs a diffusion-translational model of dispersal, so devised as to accomodate a comprehensive variety of releases, from Lagrangian puffs to Gaussian plumes. The capital User-defined functions of the program are given by the equations (2.3) and (2.5) in the RP.

The following table of correspondences will help the User correlate the code names of those APUD's variables that surface out at the User/machine interface - for instance in the table of inputs (CLOUDBUS) - with the physical variables in the model description given in the RP:

Table 1

Code variable (APUD)	Physical variable (RP)	Comments
Disp.act (Ci)	α	A source term. Total expected dispersed activity. v. RP eq.(2.2), and the comments to eq.(2.4). On using other, appropriate, units, APUD may monitor various industrial releases.
Blast factor (1/h)	β	A source term. Fixes the time-profile of the release. Larger β - puffs, smaller β - plumes
Elevation (km)	H	A source term. The height above sea level of the virtual centre of dispersal, on the vertical of the actual source of release (v. also RP´s Fig.2).
Halflife (days)	-	A source term. Decay depletion effects were not taken into account in the RP. That paper had concentrated rather upon defining the dispersal model and solving the so-called "inverse problem". However APUD takes care of the decay, in the sense that the decay-corrected activity is obtained by multiplying the uncorrected one by exp (-dc.t), where dc = ln 2/halflife - both time quantities being taken in days. For many purposes it is convenient to first estimate an average halflife, that would fit cloud´s isotopic composition. Note that a halflife in the order of hundreds of thousands days or more would also fit the description of the dispersal of other industrial, non-radioactive, aerosols.
Wind vel. (km/h)	v	The wind velocity.
Wind dir. (radians)	-	The wind direction, measured with respect to an axis that has its origin in the release source and points North. Irrelevant in the model´s Physics, it is not invoked in RP
Depletion (1/h)	-	As with the radioactive decay, cloud/plume depletion through fallout and precipitation washdown was not discussed in RP. Such effects were also taken care of by APUD. Essentially, the depleted activity is obtained by multiplying the undepleted one

(table 1, continued)

Code variable (APUD)	Physical variable (RP)	Comments
		by a factor (1 - dp.t), where variable dp is precisely what APUD calls "depletion" in its table of inputs.
Downwnd.dif. (sqkm/h)	D_x	The downwind effective diffusion coefficient introduced by eq.(1.1) in RP. In RP's ref.4 it is explained that D_x is "effective" in the sense that (i) it is supposed to be an average over the time of observation and the territory under scrutiny, and (ii) it also accounts for the effects of local turbulence that may spread aerosols beyond what a pure, *molecular*, diffusion would do. This may explain why in this model the horizontal diffusion coefficients can take indeed large values. Whenever $D_x = 0$ the program will invoke eq.(2.5). Otherwise, eq.(2.3) is used.
Crsswnd.dif. (sqkm/h)	D_y	The crosswind effective diffusion coefficient. V. the comment above.
Vert.dif. (sqkm/h)	D_z	The vertical effective diffusion coefficient. The finiteness of the atmosphere on the vertical may express itself as large differences in the magnitudes of the horizontal vs. the vertical coefficients.
Green alert (pCi/c.m.)	-	Irrelevant in RP, alert grades given as conventional thresholds on the scale of the activity concentration in air are, by contrast, of essence for APUD. The "cloud" itself is in fact an abstraction, its boundaries obviously extending well-beyond the mildest, "green" limit. APUDs cloud must therefore be taken as an acceptable cutoff on reality. For other types of industrial releases appropriate units should be used. The green grade would usually indicate the attention limit.
Yellow alert (pCi/c.m.)	-	V. the comments above. The intermediate among three conventional thresholds. Usually taken as the warning limit.
Red alert (pCi/c.m.)	-	V.the comments above. The highest threshold. Usually taken as the action-station limit.

It is apparent from the table above that, as expected, APUD is much more oriented to practical applications than its physical and mathematical counterpart - the RP. On the other hand, the User may wish to note that, in comparison with the fan of basic problems approached in the RP, this version of APUD does not tackle the inverse problem (v. RP's Section 3). It was found indeed that the inference from field-collected data of the source terms and effective diffusion parameters would better fit a separate code.

THE STRUCTURE

APUD's logical structure is represented in Figure 1.

The program sections as indicated perform the following main functions:

The INPUT section

Confronts the User with program's INPUT variables that were explained in the preceding chapter of this manual. Performs primary processing on the input variables, in order to eliminate as far as possible unnecessary, essentially scaling operations from the executive loops, thus reducing the time expenses of the main routines to follow. At the User/machine interface it manifests itself as the synoptic INPUT table, code-named CLOUDBUS, displayed as in in Fig.2a, accompanied by appropriate INPUT messages at the bottom of the display.

The DISPATCHER section

Provides convenient access, on a strike-a-key basis, to the two regions of the program - the EXECUTIVE routines, and the ANCILLARY routines. At the User/machine interface it casts a window (v.Figs.2c and 3) that dispays the options made available to the User. Because the said window can also be invoked, whenever during the execution of the executive routines, by calling for HELP (key h), it will be known in the sequel as "the HELP window".

The ANCILLARY section

Comprises the tool-kit available at the User/machine interface. Thus,

- the VIEW command invokes, on request (key v), all the essential INPUT data in current use, in the form of a window (the VIEW window, Fig.3), whenever during the execution of the main executive routines, SPOT and CLOUD.

- The RESET command (key R) would bring the User back to a fresh INPUT table, clearing out old variables and thus truly resetting the program.

- The N(E)W MAP command (key M) would open a channel to an external memory - currently a magnetic tape - storing APUDs nine working maps, wherefrom a map can be chosen at will.

- The RESUME command (key 0) would force APUD to continue the execution from the point it left it fór the HELP window.

- The HALT command (key .) is active only during the execution of the SPOT and CLOUD executive routines, when it actually halts the computing, providing for closer examination of the data that are continually generated on the display, and also reminding the User moments in time and map coordinates relevant for the respective cases.

- The HELP command would bring the HELP window on display, and the program on its option turntable, as described.

The EXECUTIVE section

This is APUD´s raison d´etre. Comprises the SPOT routines, and the CLOUD routines.

(i) The SPOT routines are FOR-NEXT loops that calculate and display the evolving in time of the activity excursion as determined by the radioactive cloud passage over a given spot, identified via its coordinates on APUD´s Reference Map - that is explained in the Appendix. There is a SPOT-computing routine, presenting the User with a listing of time instants and corresponding activity concentrations, scrolling-up on the display and reproducible as hardcopy; and a SPOT-drawing routine that features a picture in time-vs.-concentration orthogonal axes, of the activity excursion. 200 time-instants are scanned, at a time resolution determined by the User. The instant of maximum activity is captured, together with the respective value. Through HALT, the User can closer-examine the results during the execution of the computing routine, and ask for interim hardcopies of the relevant displays. HELP is also accessible as usually (key h), with all its open options. To recall to memory the inputs, User should call for HELP, then order VIEW (key v).

(ii) The CLOUD routines are FOR-NEXT loops that do a screening of the working maps, Northward and Eastward, determining the concentration of the airborne activity over the territory covered by the respective maps. Map quadrants, the local representative altitudes vs. sea level, and the activity concentrations at the centre of each map quad, are listed on display, and scrolled-up till the entire territory is screened. Like with the SPOT routines, in the process the HELP is readily accessible, together with all its open options. Also available is the HALT command - that, unlike VIEW, works without prior calling for HELP. Again, there is a CLOUD-computing routine, generating a listing, and a CLOUD-drawing routine, effectively displaying, in green, yellow and red as required by the alert grades, the radioactive cloud on the working map, and singling out the quad of maximum concentration across the cloud.

THE OPERATION

This chapter gives a straightforward description of a typical APUD session.

LOAD"" With this standard command the User calls the program from tape. The LOADing sequence comprises the following components:

		Length (bytes)
APUD ´89	Header	371
G	Front page	6912
M	Map #5	8505
B	The Code	20506

Following the LOADing procedure, the program will run iteself automatically.

INPUT The CLOUDBUS table is now on display (Fig.2a). Messages at the bottom of the display request USER to fill in the various input data. The appropriate units are conveniently indicated. Note that all map coordinates are in pixels, on the Reference Map. At this point in the manual the User will perhaps find it necessary to get better acquainted with APUD´s maps, described in the Appendix.

COPY After the last input is performed (Fig.2b), a bottom message asks: "COPY? (Y/N)", that is, whether a hardcopy of the display is wanted. If the answer is No (N), then the HELP window appears on display (Fig.2c), inviting the User to place his orders (v. THE STRUCTURE). If the answer is Yes (Y) - and the requisite printer is on - then first a hardcopy is delivered, and then the HELP window comes up.

At this stage a compulsory branching point is reached in the program. Let us examine the different options available, first starting with the ancillary routines.

VIEW Obtained by striking key v, with HELP on display. The VIEW window is displayed (Fig.3), reminding the User its current inputs.

RESET Obtained by striking key R (capital, for better protection), with HELP on display. Resets the program, displaying again the CLOUDBUS table. All previous inputs are lost.

NW MAP Obtained by striking key M (capital), with HELP on display. A bottom message will ask: "NEW MAP? (Y/N)". If the answer is No (N), then the previous display reappears and the program remains open to another option. If the answer is Yes (Y), then the display is cleared and a new bottom message asks: "MAP # ? (1-9, or 0)". The User will fill in the number of the new map desired, whereas the program will bring the machine into the the mode LOAD "" SCREEN$, waiting for the tape that stores the maps to be started. If the current map on tape does not bear the required number, the machine will reject it, waiting again for the right map. If the current map on tape is the one already in the RAM, a bottom message will say so (e.g. "Map # 5 already RAMed!"). If the map on tape is right, the machine will properly store it into the reserved RAM, making it the current working map of the program. Upon doing this, APUD will appropriately switch the origin of the coordinates, so that the computation remain safe, sparing the User the effort to readjust the coordinates. More about APUD's maps - in the Appendix.

RESUME Obtained by striking key 0, with HELP on display. The HELP window - and also the VIEW window, if displayed - are erased from display and program will continue from the point at which the HELP was invoked. At this point the User may wish to note that HELP and View are true windows, in the sense that these come on and off without affecting the original picture on display.

HALT Obtainable only during SPOT and CLOUD computing routines, that is, without HELP on display, by striking key ".". As already indicated (v. THE STRUCTURE), upon this command the program will pause, allowing for close-examination of data on display. Also during HALT a flashing bottom message will ask:"COPY? (Y/N)". If Y, a hardcopy of the current display is produced. If the answer is N, the the respective computing procedure will continue. During HALT, the headings of the respective routines appear at the bottom of the display, reminding useful information.

HELP Obtainable practically at any point in the program, keying h. Displays the HELP window and opens up its options.

And now about the executive routines:

SPOT Obtained by striking key s, with HELP on display. In a first phase, APUD will bring on display the current working map, while bottom messages will indicate that the program is on the so-called "Cursor" mode (v.Fig.3). A cursor, "+", first displayed in the bottom-left corner of the picture, is made available to the USER, who can move it by pressing down keys 1, 2, 3, 4, 6, 7, 8, 9, in the directions that correspond to the following positions of the respective keys:

7	8	9
4		6
1	2	3

To accelerate the cursor, User will press key q, whereas to slow it down the neighbouring key w shall be used. In this way User will bring the cursor at the precise spot on the map where there is an interest for the determination of the evolving in time of the airborne activity excursion during the radioactive cloud's passage over that spot. As soon as the User is satisfied with cursor's position (Fig.4), he may strike key 5 to exit cursor mode.

```
SPOT, at x=215, y=225, z=0.575
    Time (h)     Activity (pCi/cm)
    0.5          0
    1            0
    1.5          0
    2            0
```

At this, the display is cleared and the first line in the header above appears on screen, indicating that the SPOT computing routine is now on.

At the same time a bottom message - "Time resolution (h) =" - will ask User to define the time interval, in hours, between two consecutive determinations of the activity, at the given spot. At this stage User may wish to proceed on the knowledge that, irrespective to the time resolution chosen, the SPOT computation loop will execute 200 consecutive determinations.

As soon as the time resolution is fixed, the second line of the header above will appear, and the computation will start. Lines like those immediately following the header will follow each other at a rate somewhat higher than one per second, till the display is filled up. Than the picture is automatically scrolled up until completion of the series of 200 determinations.

Whenever User feels like freezing the scrolling picture, he would strike ".", for HALT (Fig.5,a,b,c).

When the SPOT computing is finished, User may rely on having all 200 activity values duly stored in a reserved RAM segment. At this point a bottom message will ask: "COPY? (Y/N)". If N, then the program will automatically continue with the SPOT-drawing routine. If Y, then a full listing of the 200 moments in time and the respective activity concentrations is delivered by the printer, before APUD's passing to the SPOT-drawing routine.

Entering SPOT-drawing routine APUD will first display a system of axes with the time in abscissa and the activity concentration on the y axis (v.Fig.6). The User will note that the abscissa is marked in days, depending on the time resolution chosen at the start of the SPOT computing routine. Accordingly, the graphical resolution in indicated by a bottom message (1 pix = ...). It is also important to note that the graphical representation was designed so as to assign the same, maximum available height on display, to the maximum activity recorded during the SPOT computing. This aspect is particularly relevant when the maximum activity is in the order of tens, or less, pCi/c.m., when it may happen that the picture take a marked stepwise shape, in contrast with the bellshaped curve chosen as an illustration in Fig.6.

Immediately after the frame of axes was drawn, and the resolution was indicated, a histogram of the stored values of activity concentration is drawn, giving a graphic picture of the evolving in time of the activity concentration during the radioactive cloud passage over the chosen spot.

As the diagram is completed a bottom message asks, as usually: "COPY? (Y/N)". If N, the HELP window is brought on display, and the program is at its second compulsory branching point. If Y, a hardcopy of the histogram and its accessories is produced, before the HELP window is brought on. Considering the fact that all the other options were explained already, it is natural to assume now that the User option would be CLOUD, that he would invoke by striking key c.

CLOUD at 61 h,and level 0

Quad	H(km)	Act.(pCi/cm)
9E/11N	0.8	2
9E/12N	1.87	3
9E/13N	1.2	4
9E/14N	2.065	5

CLOUD

As the second executive routine of the program, CLOUD would first run its computing component. As with SPOT-computing, a heading is displayed (v. above), starting with the segment "CLOUD at", accompanied by the bottom message "Hours (into the release time) =". As User declares the moment,´t´, at which the cloud is to be calculated, the heading becomes "CLOUD at ´t´ h, and level", while a new bottom message asks: "Height, km (0, if at grnd.) =", meaning "At what height is APUD to cut a section into the cloud, horizontally, and calculate activity concentrations in the respective plane?" Now, if a certain, nonzero, figure is filled in, the Z variable in the RP equations (2.3,5) is set to that particular value, which will duly, and repeatedly, appear in the column "H (km)", on display. If, on the other hand, the machine is given a 0 (zero), APUD will understand that User asks for the activity concentrations at the ground level, so that the program will set variable Z at the representative altitude (vs.sea level) that is stored in the Map section of the RAM, for the respective map quadrate (quad), duly changing the figure during the screening procedure according to the correct local altitude.

As the desired altitude, or a 0, are filled in, the CLOUD computing will start. Map quads, altitudes, and activities are now displayed and scrolled up, till the completion of the working map screening, at the 704th quad.

A sample of display is given in Fig.7, which also illustrates how HALT (key .) works into the CLOUD computing routine. Needless to say, HELP is also available, thus providing convenient exits from CLOUD-computing, if so desired. At a rate of approximately one line per second, CLOUD-computing is the most time-consuming procedure of the program.

CLOUD computing ends with the bottom message "COPY? (Y/N)". If N, the program will automatically proceed with CLOUD-drawing. If Y, a hardcopy is first delivered, and then the CLOUD drawing is automatically invoked.

CLOUD drawing starts by APUD's displaying its current working map. If the source of release falls within the confines of the working map, then a circular mark is displayed at the appropriate place (v.Fig.8a). At this point it is important to emphasize that there is no need that the source be within the limits of the working map, for the program would always take rightly its coordinates into consideration when doing the computing. In fact, this was one good reason for introducing an interplay of nine working maps, which allows ample space for tracking clouds over larger territories, by passing from one working map to another, and then clipping maps as appropriate. An example of the kind is given in Fig.8, where the frames 8a and 8b represent the final products of the CLOUD-computing routines on maps #2 and 5, respectively, while frame 8c gives the result of those maps clipping.

Cloud maps in Figs.8 were obviously obtained by answering Y(es) to the bottom message "COPY? (Y/N)", that would always close a CLOUD-drawing procedure.

After delivering the hardcopy, as well as in the case the answer to the copying invitation is N(o), the program would go again into the Cursor mode. However in this case, with the cloud displayed, by moving the cursor at will across the map, the User will find out not only the coordinates of various spots - as with the Cursor on at the inception of the SPOT procedure - but also, and essentially, what activity concentration is in the cloud, either at the cloud's sectional altitude or at ground level (option 0 in the CLOUD-computing heading), an asset which may beneficially complement the original SPOT procedure.

Exiting the Cursor mode by striking key 5, the User would bring on display the HELP window, thus creating the third, and final, branching point into the program. All the executive and ancillary options are now again available. At this stage USER should feel free to reiterate SPOT, or CLOUD, or to re-VIEW the inputs, or to opt for a N(E)W MAP, or to RESET the program in view of new inputs - for his first run with APUD is now in fact completed.

If User is to take full benefit of the COPY options, he will end up a run with the following hard documentation at hand:

- A copy of the CLOUDBUS table of inputs.

- A listing of 200 values of the airborne activity concentration at a given spot, at as many moments into the release time.

- A histogram of the above, also featuring the top value of activity at the spot under scrutiny, and the moment in time when this is reached.

- A listing of 704 values of the airborne activity concentration in each and every of the 704 quadrates of the working map; this includes the values that fall beyond the lowest, "green", alert level.

- A picture of the radioactive cloud passing over the territory covered by the working map, the cloud being conventionally defined as limited to values in excess of the lowest, "green", alert level.

- An ad-libitum number of interim copies of special, relevant, situations during the SPOT-computing and CLOUD-computing procedures.

The facility offered to User-analysts, to re-run the executive routines SPOT and CLOUD over the same input data would allow one to zero-in over the most expressive cases, of special interest for the decidents.

SOME TIPS FOR THE USER

In its present version, the program has available the interruption via BREAK. If CONTINUE would not, however, yield the expected result, a new BREAK is commendable, followed by one of the follwing main exists from such a dead end:

GO TO 370 This command would bring over the HELP window, with all its dispatcher functions available. The original CLOUDBUS is preserved.

GO TO 100 This command would bring over the CLOUDBUS display, meaning implicitely that all the original inputs are lost.

GO TO 2000 This command would start the CLOUD-computing routine, clearing implicitely all previously computed quad radioactivities - if any, as well as all SPOT results.

GO TO 2067 This command will activate the CLOUD-drawing routine, that will work on data stored via CLOUD-computing, if prior CLOUD-computing was properly conducted. Especially useful when, for various reasons, there is need to contemplate again a cloud, after it was erased from the display, but not from RAM.

GO TO 3000 This command will start the SPOT routines by displaying the current working map and switching on the Cursor mode, here required in order to chose a place where SPOT computing be conducted.

GO TO 3011 This command will initiate the SPOT-computing procedure. Implicitely, it will erase from RAM all previous SPOT-computing, and CLOUD-computing, results.

GO TO 3100 This command will activate the SPOT-drawing routine, that will work on data stored via SPOT-computing, if prior SPOT-computing was properly conducted. Especially useful when, for various reasons, there is need to contemplate again a SPOT histogram, after it was erased from the display, but not from RAM.

A User interested in equipping the program with an alternative set of maps may find it useful to know the memory map of the 48K RAM machines for which the present version of APUD was designed. The memory map follows:

Table 2

RAM addresses	Contents
0... 16383	The BASIC interpreter
16384 ... 22527	The display file
22528 ... 23295	The display attributes
23296 ... 23551	The PRINT file
23552 ... 23733	The system variables
23765 ... 44270	The 'B' BASIC text
44271 ... 49999	Program's variables, workspace etc.
49999	RAMTOP
50000 ... 56911	Virtual display. Serves as a buffer for temporary saving the actual display during windowing and Cursor procedures
56960 ... 56971	Carry routine: display-to-virtual display
56980 ... 56991	Carry routine: virtual display-to-display
57000 ... 57011	Carry routine: mapstore-to display
57025 ... 57728	Mapstore, altitudes: height-256.INT(height/256)
57735 ... 58438	Mapstore, altitudes: INT(height/256)
58445 ... 65356	Mapstore, workmap's picture file
65368	Mapstore, workmap's tag: map number
65368 ... 65535	The User-defined graphics file: unused, with the exception of the first address, 65368, borrowed to host working map tags

FIGURE CAPTIONS

Figure 1 APUD's simplified flow-chart.

Figure 2 CLOUDBUS - APUD's INPUT table, as it meets the User (a), filled-in by the User - here with a set of demonstration data - (b), and after the branching COPY? (Y/N) has been settled. Note in frame a) that Map # 5 is conveniently RAMed, its scale 1 pixel = 4.125 km. Frame c) features the HELP window acting as an option dispatcher.

Figure 3 The VIEW (right) and, inevitably, HELP (left) windows impressed upon Map # 5, on User's request (keys h, then v.), during SPOT-ting a location where APUD will be called to deliver the time-profile of the activity excursion. Option RESUME (key 0) will restore the screen intact and APUD ready to continue the spotting procedure.

Figure 4 Location SPOT-ted - in this case the Romanian city of Suceava, at coordinates 215 East and 225 North (pixels) with respect to the origin of the Reference Map, and at a representative altitude of 0.575 km above sea level. By striking key 5, User will drive APUD into deriving the time-profile of the activity excursion at the chosen spot.

Figure 5 Interim hardcopies during the execution of the SPOT-computing procedure, capturing a) the inception of the activity excursion, at 26.5 hours into the release time, and the time for green alert, at 33.5 hours into the release time; b) the culmination of the activity excursion, at 4863 pCi/cm and 55-55.5 hours into the release time; and c) the gradual exit from the alert episodes - at 77 hours back to yellow alert and at 82 hours back to green alert. Like in Fig.4, the spot selected is Suceava, at 215 pix East and 225 pix North, with respect to the origin of the Reference map. Hardcopies obtained through HALT (key .). When on screen, colours of activity figures vary according to alert grades - green, yellow, and red, respectively.

Figure 6 Hardcopy of the result of the SPOT-drawing procedure - a histogram offering a synoptic view of the activity excursion at the spot of the coordinates given in the heading. Line 2 gives the absolute maximum, of 4863 pCi/c.m., at 55.5 hours into the release time. The bottom line is a reminder of the time resolution chosen at the inception of the SPOT-computing procedure.

Figure 7 Interim copy showing a sample of screen listing during the execution of the CLOUD-computing procedure. Hardcopy obtained through HALT (key.). When on screen, colours of activity figures vary according to alert grades - green, yellow and red, respectively.

Figure 8 Samples of clouds mapped as a result of the CLOUD-drawing procedure. The CLOUD was appropriately tracked on Map # 2 (a), where also the source of release is marked in the top-right corner. Then, to visualize the front of the cloud, Map #5 was called from tape via HELP/NW MAP, and the same cloud, at 61 hours into the release time, was computed and drawn (b). Frame c) demonstrates how integral cloud patterns can be easily obtained from the two products above, through map-clipping.

Caveat: The data used throughout this text and figures for demonstration may not necessarily make the best choice. The disp.act. taken at 25000000 Ci is about one third of the sum-total of the contributions reportedly brought to the integral release at Chernobyl, between 26 April and May the 6th, 1986, by the first 16 nuclides quoted in Table 4.14 of reference 1 of the RP. Likewise, the halflife taken at 225 days is the weighted average of the halflifes of the said nuclides. Needless to say, the actual chronology and meteorology of the Chernobyl event may have less in common with the example here.

FIGURE 1

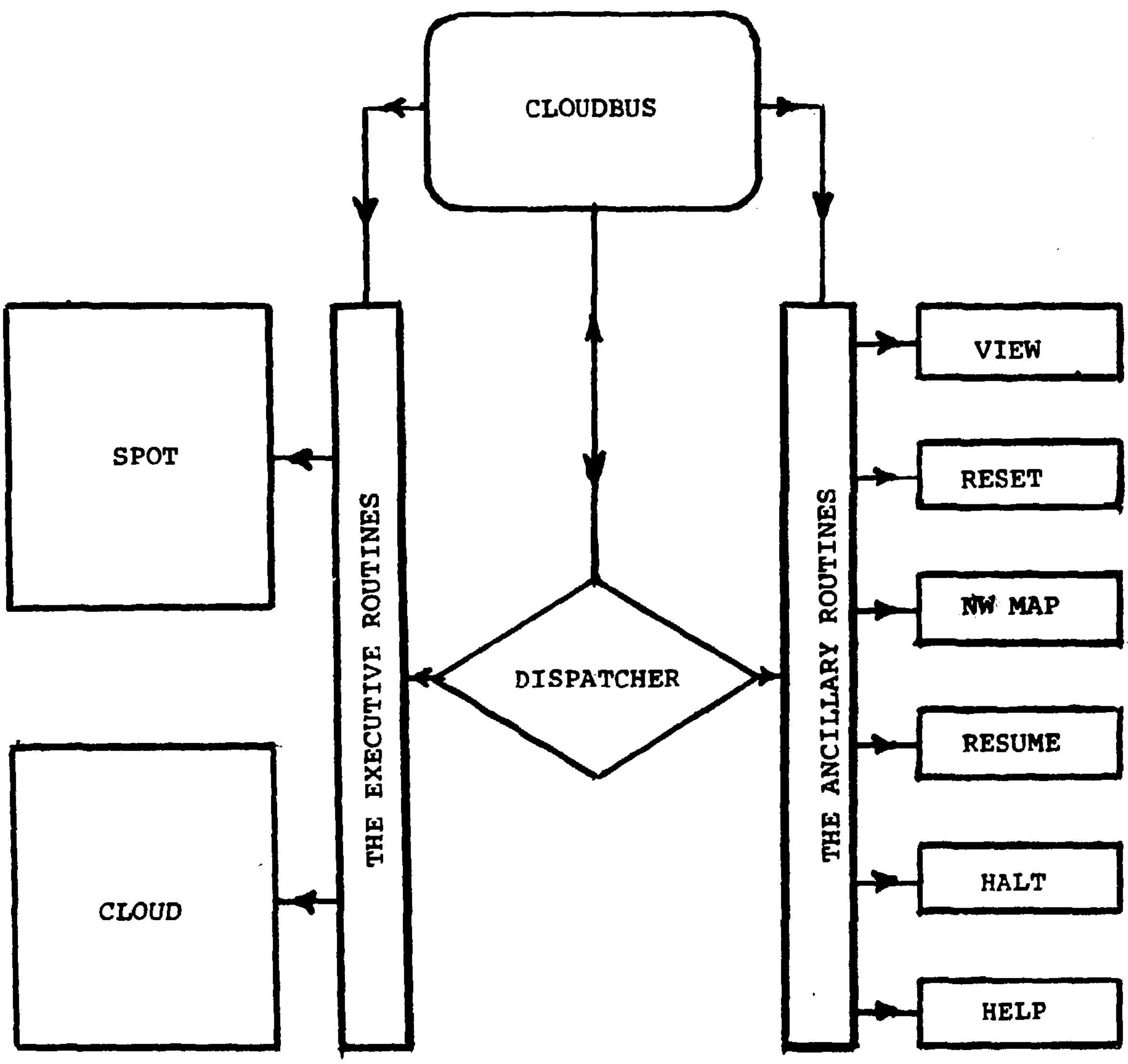

CLOUDBUS
SPOT
THE EXECUTIVE ROUTINES
DISPATCHER
THE ANCILLARY ROUTINES
VIEW
RESET
NW MAP
RESUME
HALT
HELP
CLOUD

FIGURE 2

************ CLOUDBUS ************

# MAP	#1
scale	1pix=4.125km
# EVENT	
site (E/N)	
time	
# SOURCE	
disp.act	
blast factor	
elevation	
halftime	
# METEO	
wind vel.	
wind dir.	
depletion	
downwnd.dif.	
crsswnd.dif.	
vert.dif.	
# ALERT GRADES	
green alert	
yellow alert	
red alert	

a)

************ CLOUDBUS ************

# MAP	#1
scale	1pix=4.125km
# EVENT	
site (E/N)	260/336 pix
time	1h 23 m
# SOURCE	
disp.act	25000000 Ci
blast factor	.001 1/h
elevation	1 km
halftime	225 d
# METEO	
wind vel.	20 km/h
wind dir.	3.6 rad
depletion	1E-6 1/h
downwnd.dif.	400 sqkm/h
crsswnd.dif.	400 sqkm/h
vert.dif.	0.5 sqkm/h
# ALERT GRADES	
green alert	100 pCi/cm
yellow alert	500 pCi/cm
red alert	1000 pCi/cm

b)

(Figure 2, continued)

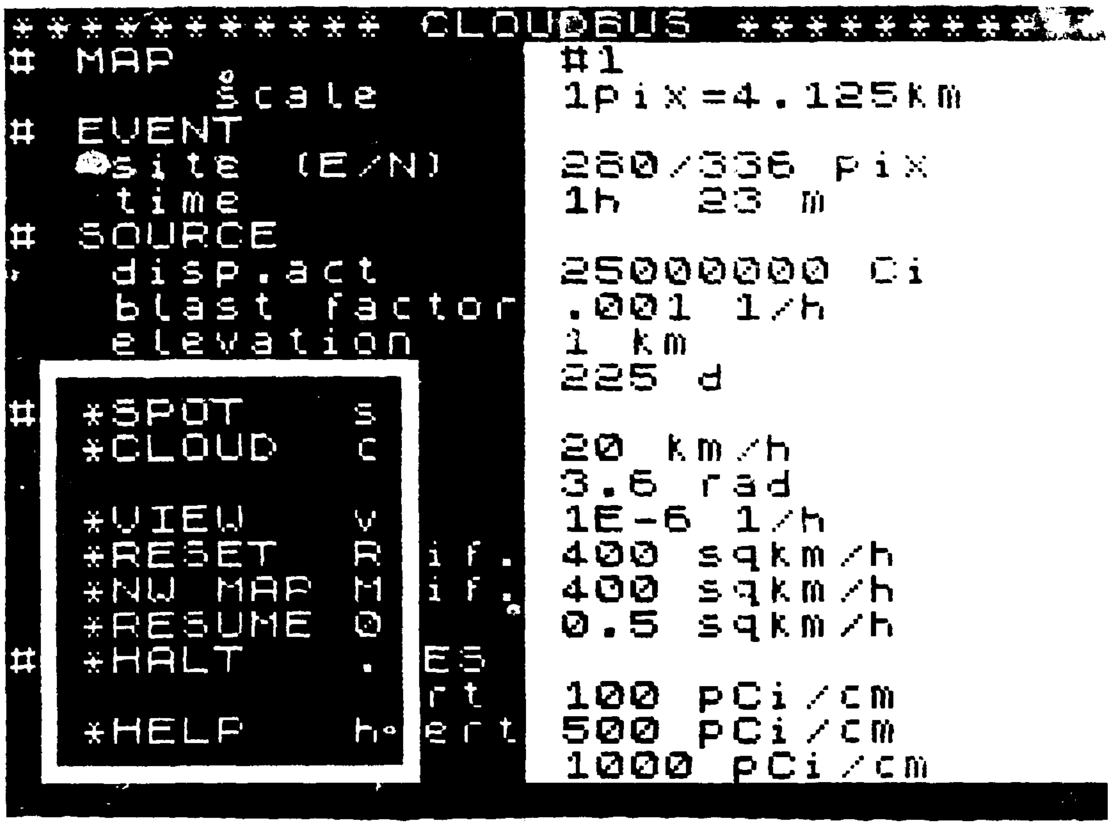


FIGURE 3

*SPOT s
*CLOUD c
*VIEW v
*RESET R
*NW MAP M
*RESUME 0
*HALT .
*HELP h
Map #5
Scl 1px=4.125km
Sit 280,336
Act 25000000 Ci
Bls .001 1/h
Elv 1 km
Hfl 225 d
Vel 20 km/h
Dir 3.5 rad
Dpl 1E-6 1/h
Dwd 400 sqkm/h
Cwd 400 sqkm/h
Vtd 0.5 sqkm/h
Gal 100 pCi/cm
Yal 500 pCi/cm
Ral 1000 pCi/cm

FIGURE 4

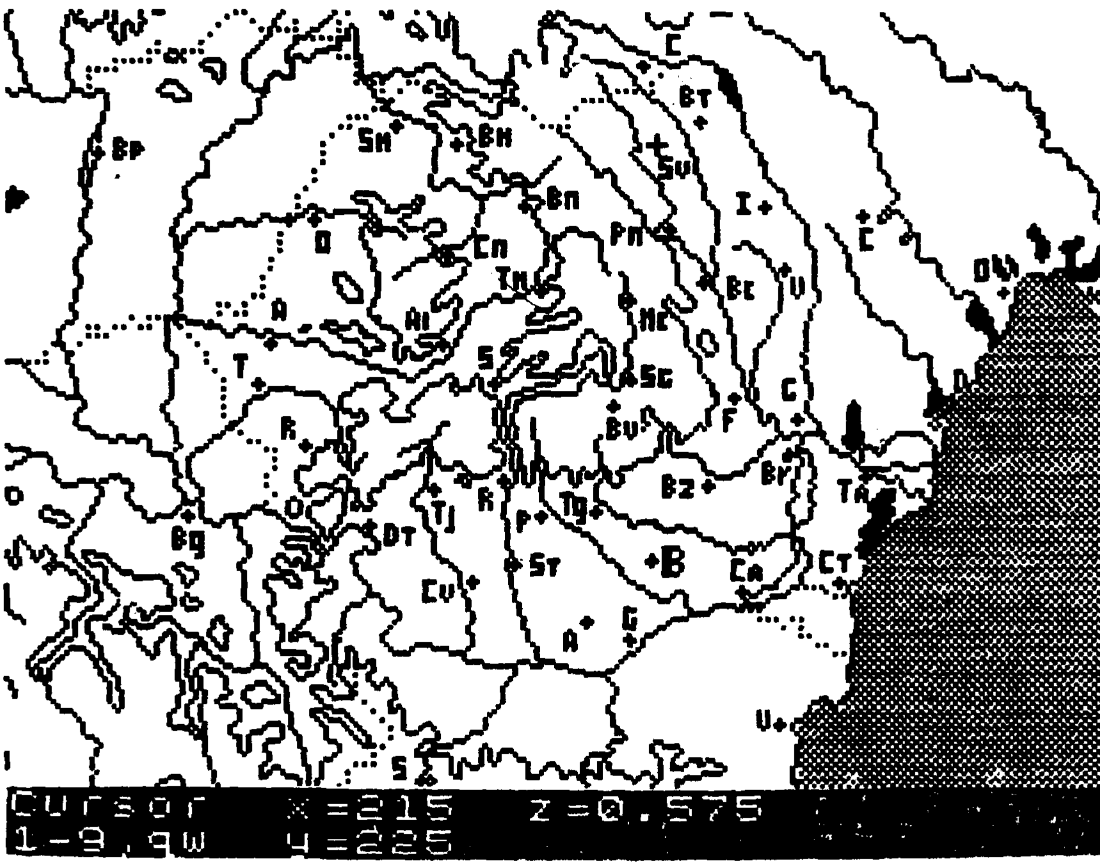


FIGURE 5

a)

Time(h)	Act.(pCi/cm)
25.5	0
26	0
26.5	1
27	1
27.5	2
28	4
28.5	6
29	8
29.5	12
30	17
30.5	23
31	31
31.5	41
32	54
32.5	70
33	90
33.5	114
34	143
34.5	177
35	217
35.5	264
36	318

SPOT, x=215,y=225,z=0.575

b)

Time(h)	Act.(pCi/cm)
51	4435
51.5	4530
52	4614
52.5	4686
53	4746
53.5	4794
54	4829
54.5	4852
55	4863
55.5	4863
56	4851
56.5	4828
57	4794
57.5	4751
58	4698
58.5	4636
59	4565
59.5	4487
60	4402
60.5	4310
61	4213
61.5	4111

SPOT, x=215,y=225,z=0.575

(Figure 5, continued)

Time (h)	Act. (pCi/cm)
75	1239
75.5	1166
76	1097
76.5	1031
77	968
77.5	908
78	851
78.5	797
79	746
79.5	697
80	651
80.5	608
81	567
81.5	529
82	492
82.5	458
83	426
83.5	396
84	368
84.5	342
85	317
85.5	294

SPOT, x=215, y=225, z=0.575

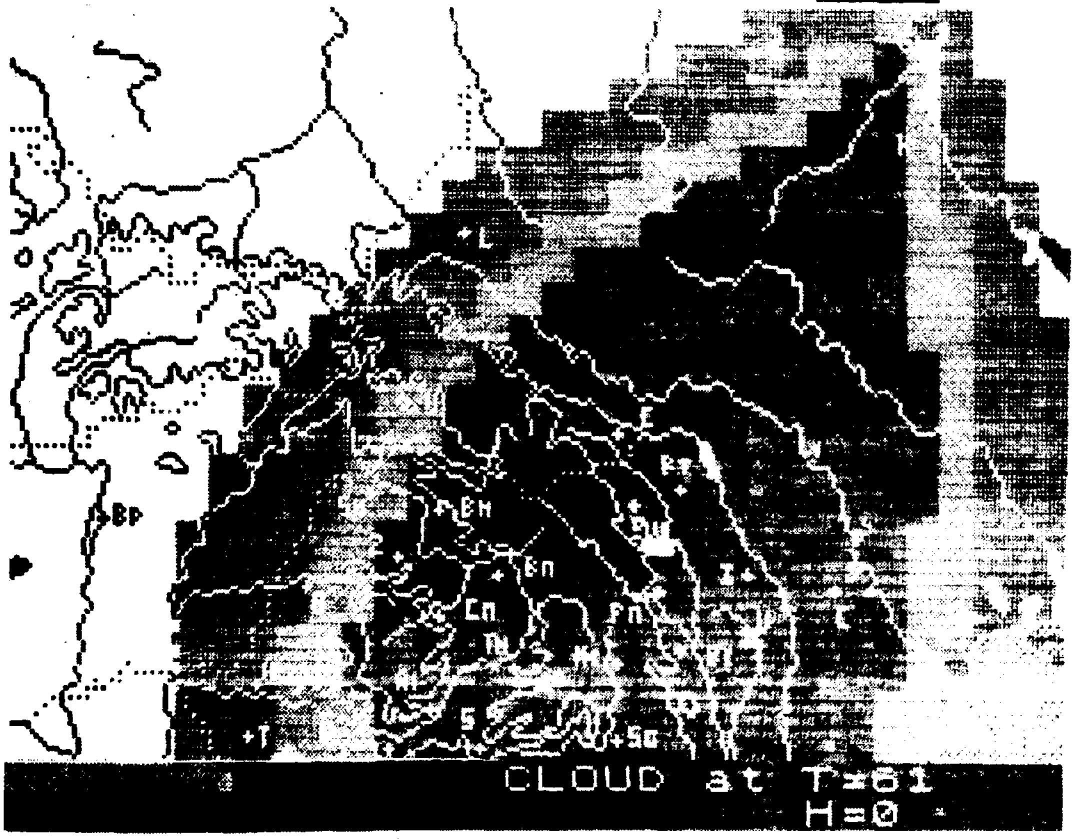
c)

FIGURE 7

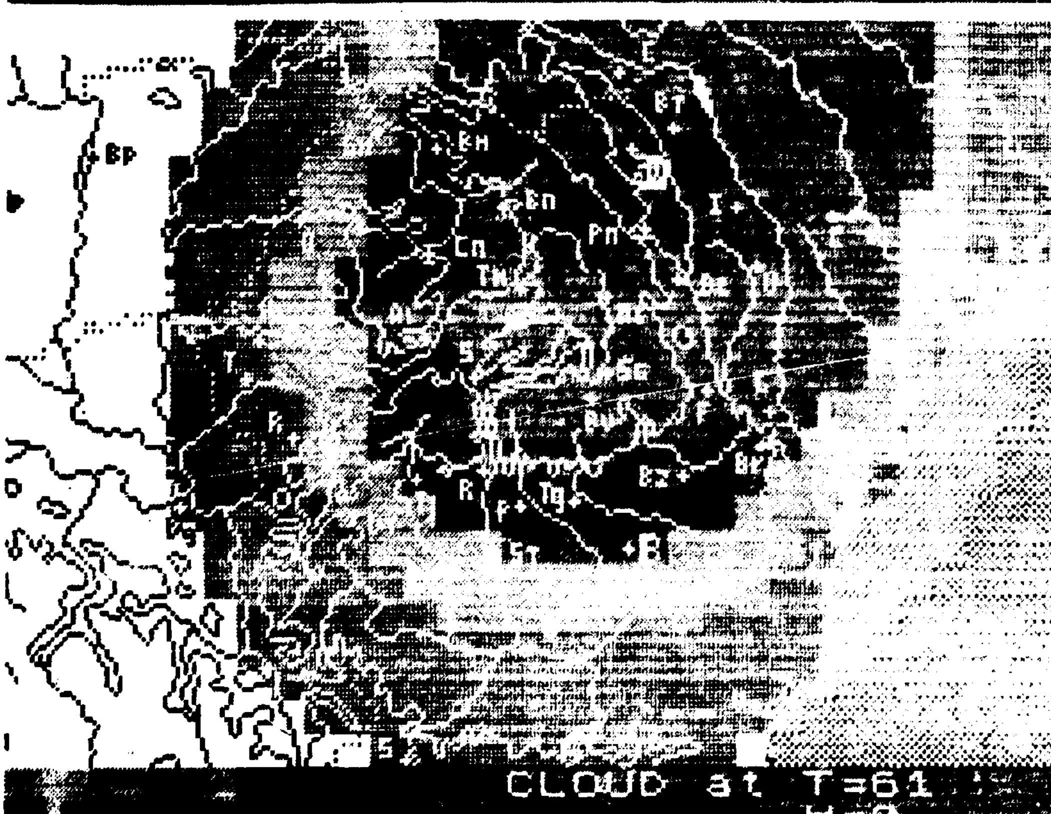
Quad	H(km)	Act.(pCi/cm)
26E/25N	1	3809
26E/26N	1.345	3942
26E/27N	1.25	3978
26E/28N	1.1	3904
26E/29N	1	3722
26E/30N	0.8	3440
26E/31N	0.4	3063
26E/32N	0.3	2650
27E/11N	0.45	122
27E/12N	0.3	245
27E/13N	0.35	349
27E/14N	0.175	423
27E/15N	0.1	556
27E/16N	0.1	871
27E/17N	0.125	1132
27E/18N	0.2	1439
27E/19N	0.3	1786
27E/20N	0.65	2180
27E/21N	1.2	2585
27E/22N	0.7	2979
27E/23N	0.7	3358
27E/24N	1.1	3705

CLOUD at 61 h, level 0

FIGURE 8

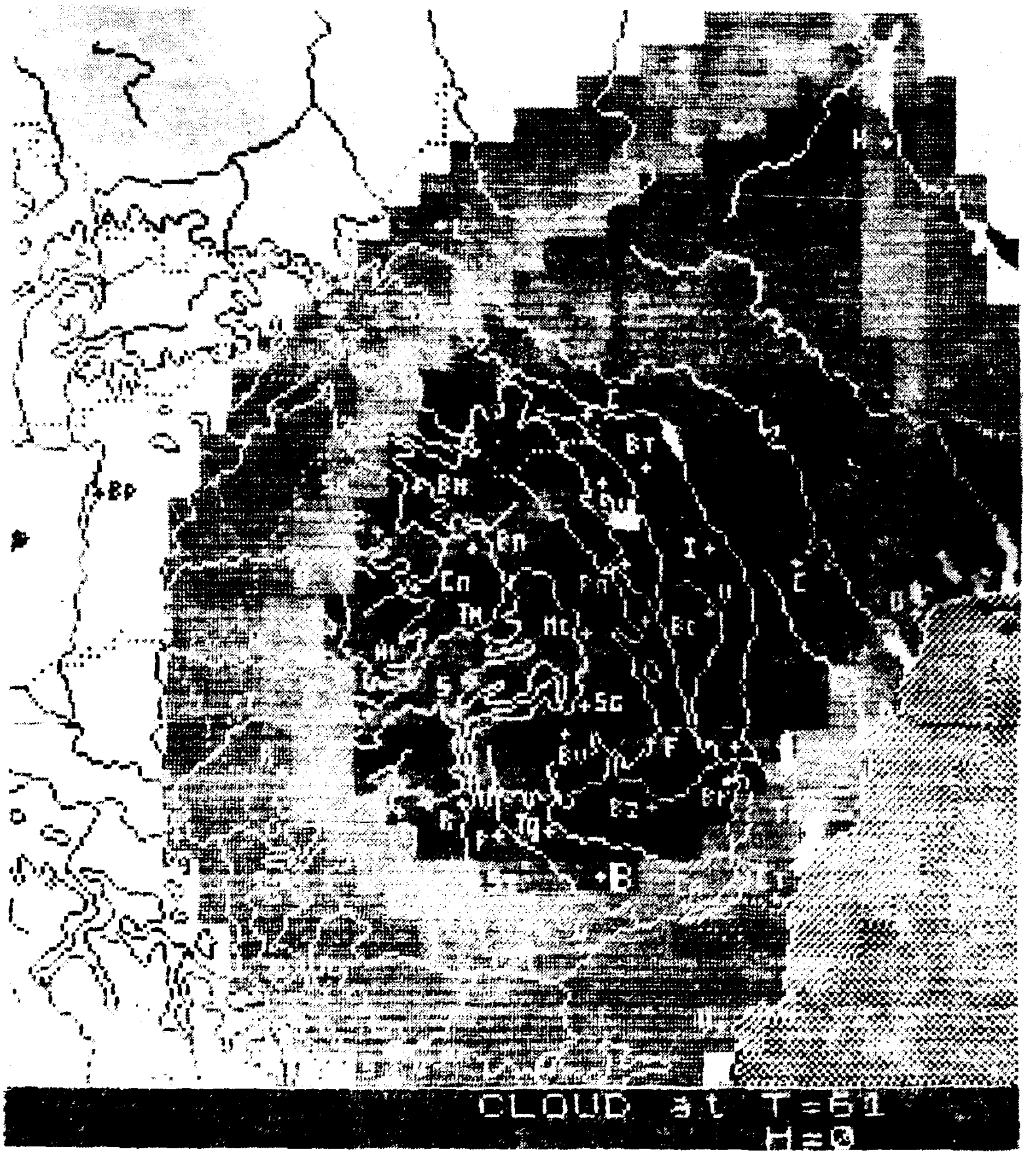


a)



b)

(Figure 8, continued)



APPENDIX: APUD's MAPS

In this manual frequent reference was made to a "reference", and "working", maps. This section explains these.

APUD was designed to cover a territory that is loosely termed as "the South-East Europe". Loosely indeed, for - as the User may readily see by contemplating the first frame that follows this explanatory text - it streches from as West as Prague, Vienna, Zagreb, and Brindisi, to as East as Simferopol, and from as South as Istanbul and Ankara to as North as Kiev.

The original map was a Lambert conical projection at the scale 1:3000000.

Considering the capability of the display used with the SPECTRUM-compatible machine that served in APUD's design, it turned out that the 255 x 175 pixels display can best be referred to the said map by assigning to each screen a portion the same size as the monitor's screen - notwithstanding screen's curvature, and ignoring the slight conical deformation of the projection, that could not possibly add too much to the models inherent inaccuracies. This path lead to the concept of "working maps" - a set of 9 interchangeable, and partially overlapping, maps, obtained by displacing a rectangular frame the size of the monitor's display over nine cardinal positions on the original, all-encompassing, map.

As a first step, the resulting pictures were translated, via a home-designed drawing program, into the video memory of the SPECTRUM machine, while retaining from the original map only a limited series of relevant detais. These are:

- the representative hidrography;
- the 500-meter isoaltitude;
- major cities, with emphasis on Romania.

Then each working map was transposed into a reserved RAM section (Mapstore, v. the memory map in Table 2), and the respective codes was stored on casette.

In a second step nine hardcopies of the working maps were clipped together with due consideration for their overlapping, to give what was called "APUD's Reference Map" - a fairly faithful, digitized reproduction of the original map.

In the third step a grid was applied on both the Reference, and working maps. Grid's quadrates would correspond to the normal character quads in the video memory of the SPECTRUM machine. Thus there are 32 x 22 = 704 quads per each working map and, overlapping considered, 49 x 43 = 2107 quads on the Reference Map. The map scale as resulted from the process described is 4.125 km per pixel.

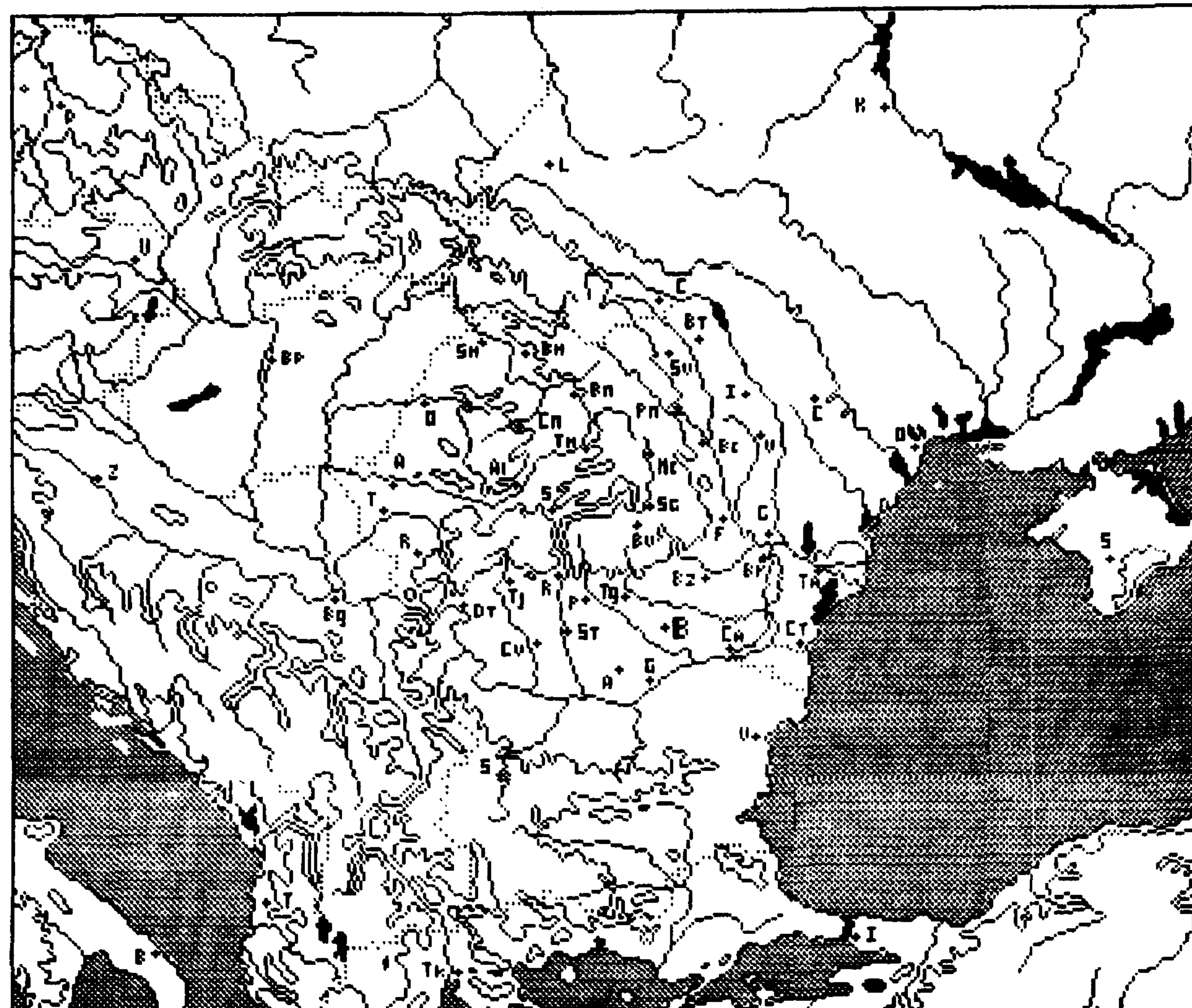
Both the clear-field, and gridded, versions of the Reference and working maps are given in this Appendix. To facilitate map reading, quads and pixels are marked on the borders.

While operating APUD, User will soon find out that he must keep permanently an eye on the Reference, and the current working, maps. One critical phase is, for instance, the CLOUDBUS, when the program will ask for the release source coordinates - on the implicit understanding that these are pixel coordinates on the Reference Map. SPOTting is less demanding as to the explicit declaration of coordinates, this task being assumed by the Cursor procedure. In effect, the User will note that while the cursor moves across a displayed working map, coordinates and altitudes are also displayed at the bottom of the screen (v.Fig.4). Regardless this facility, a good mastering of coordinates is always recommendable.

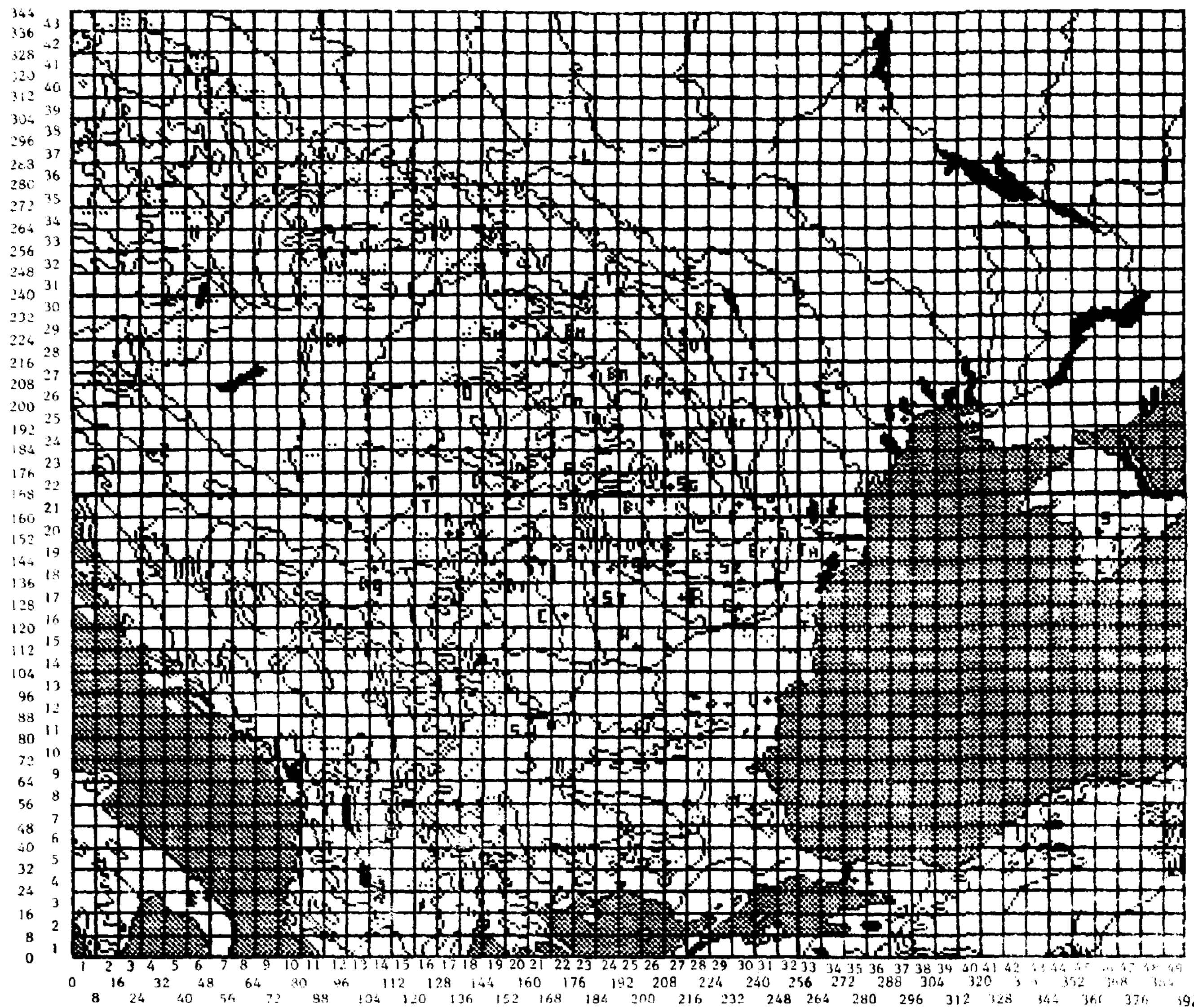
When displayed, such as during the execution of the CLOUD-computing routine, or in the Cursor mode, all quad- and pix-coordinates are those of the Reference Map. As pointed out in the main text of this manual, User should not bother himself with re-adjusting map origins when passing from one working map to another, for the program takes care of this operation. Moreover, since - given the available resolution - gridding unfortunately creates overcrowded viewfields, the grids are never displayed on monitor. It is believed that having the gridded maps aside on the desk would suffice. On the other hand, there was no real use to digitize and manipulate the Reference Map as a whole. Not only would this operation have proved RAM-consuming, but the physical, as well as graphical, resolution would have been so poor, that in the final analysis the product would have occured worthless.

The passing from one working map to another is handled via the ancillary routine NW MAP, as explained in the main text. In case of tape loading errors, do GO TO 370, which will invoke the HELP window, wherefrom NW MAP can be ordered again.

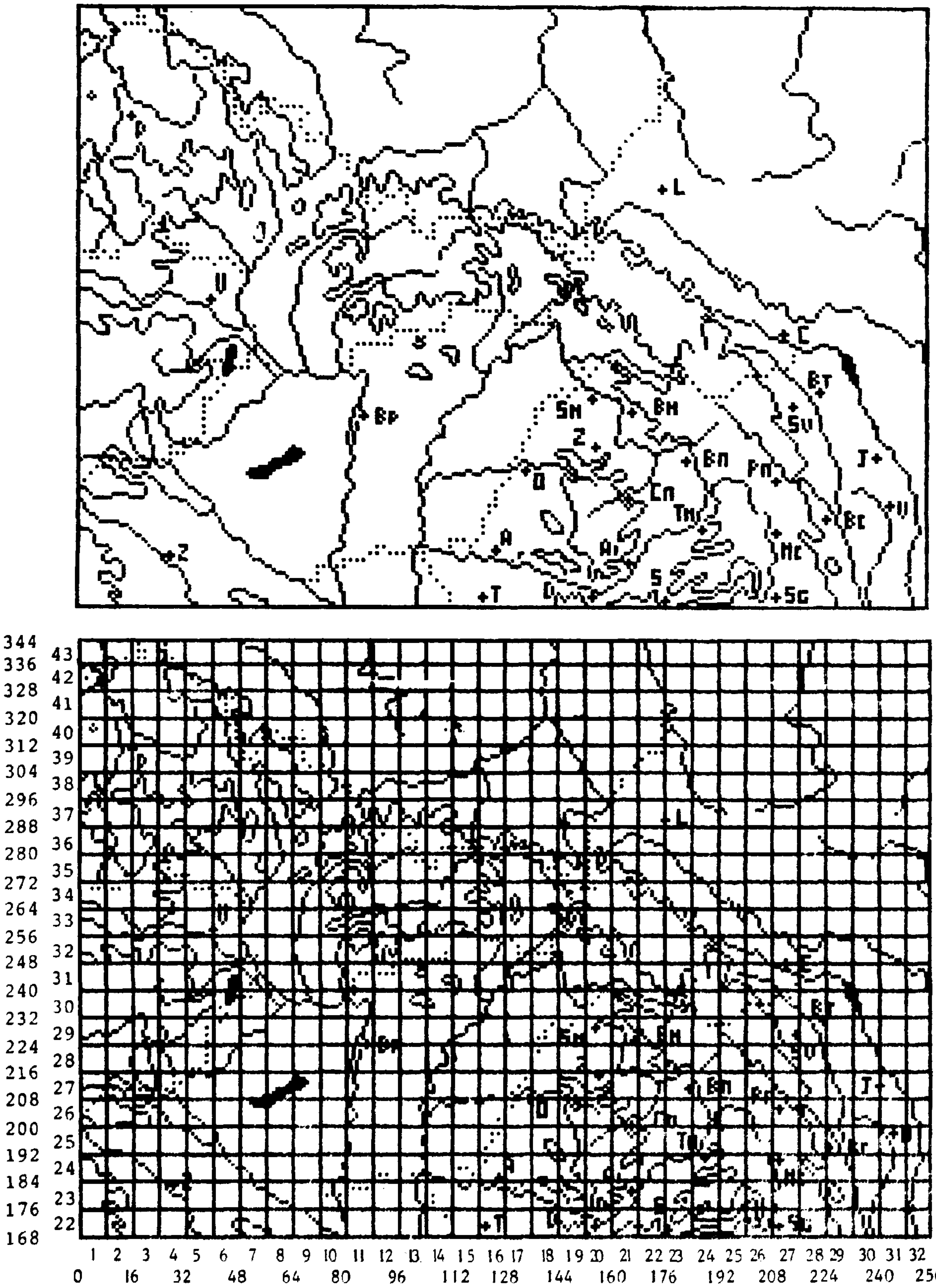
APUD's REFERENCE MAP



APUD's REFERENCE MAP AND GRID



MAP # 1



+L
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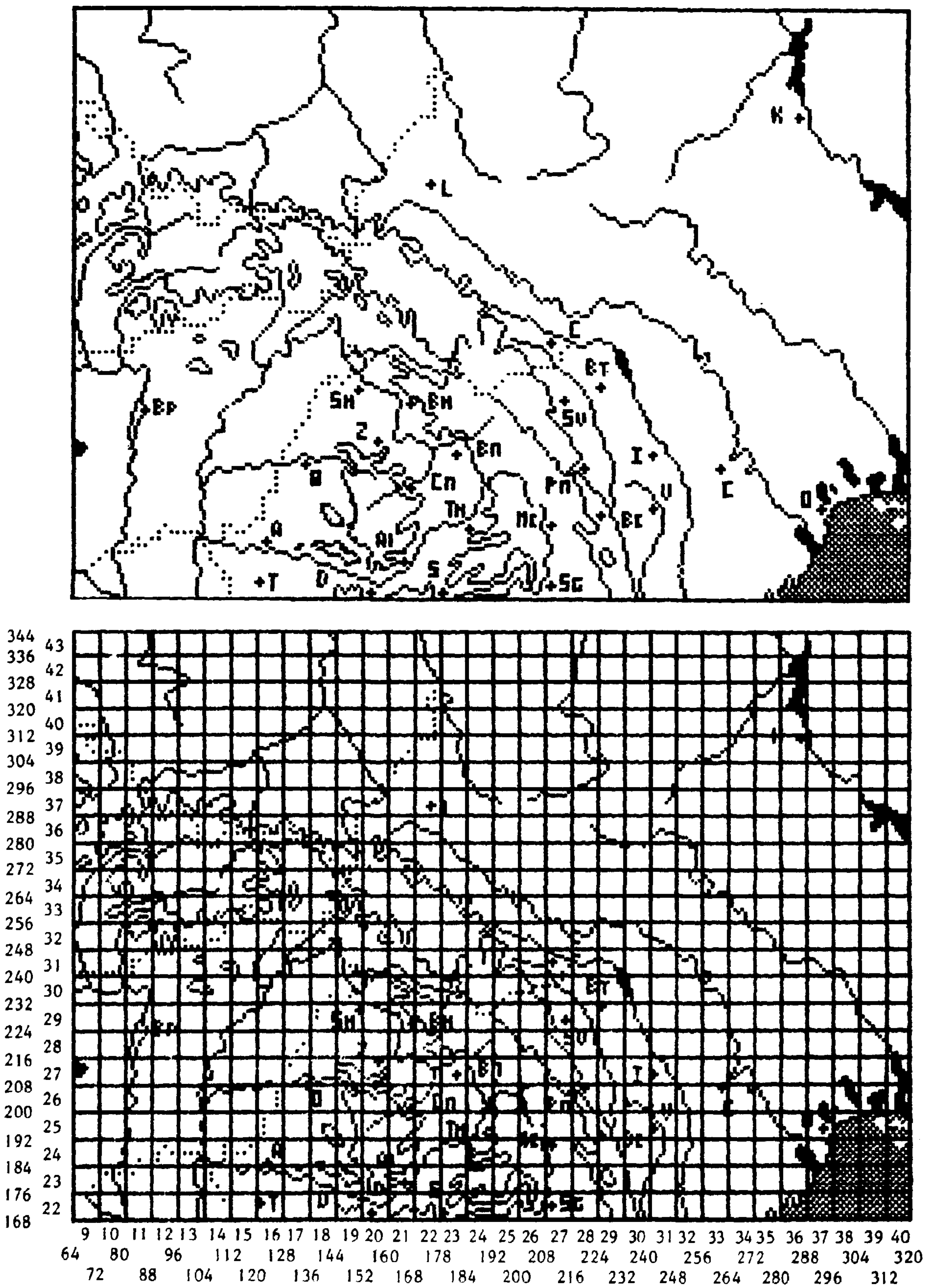
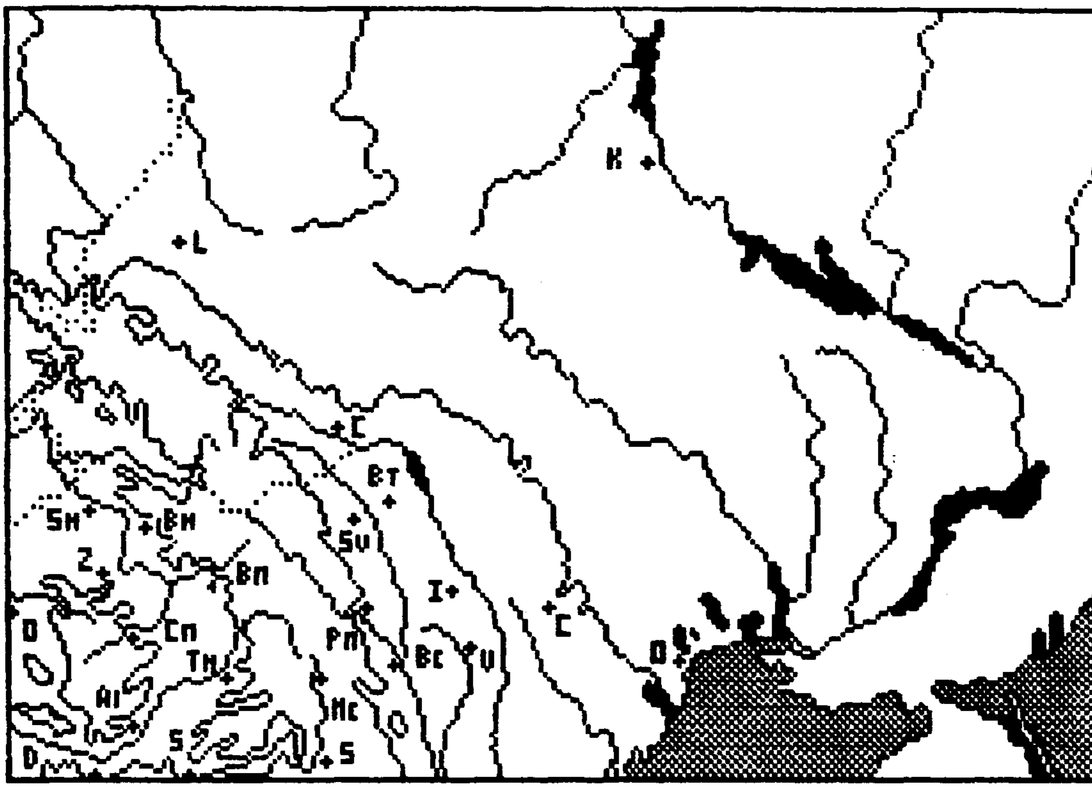
344 336 328 320 312 304 296 288 280 272 264 256 248 240 232 224 216 208 200 192 184 176 168
43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
0 16 32 48 64 80 96 112 128 144 160 176 192 208 224 240 256
8 24 40 56 72 88 104 120 136 152 168 184 200 216 232 248

MAP # 2



MAP # 3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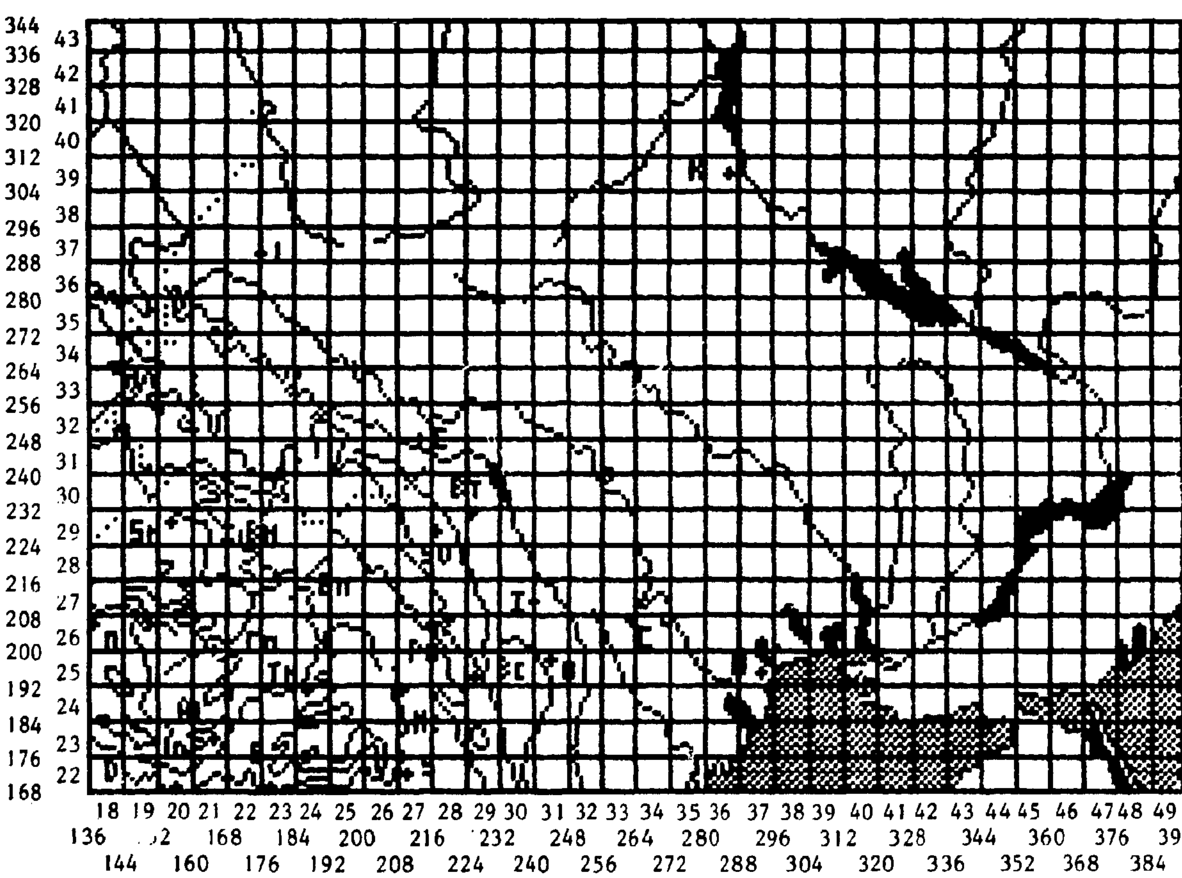
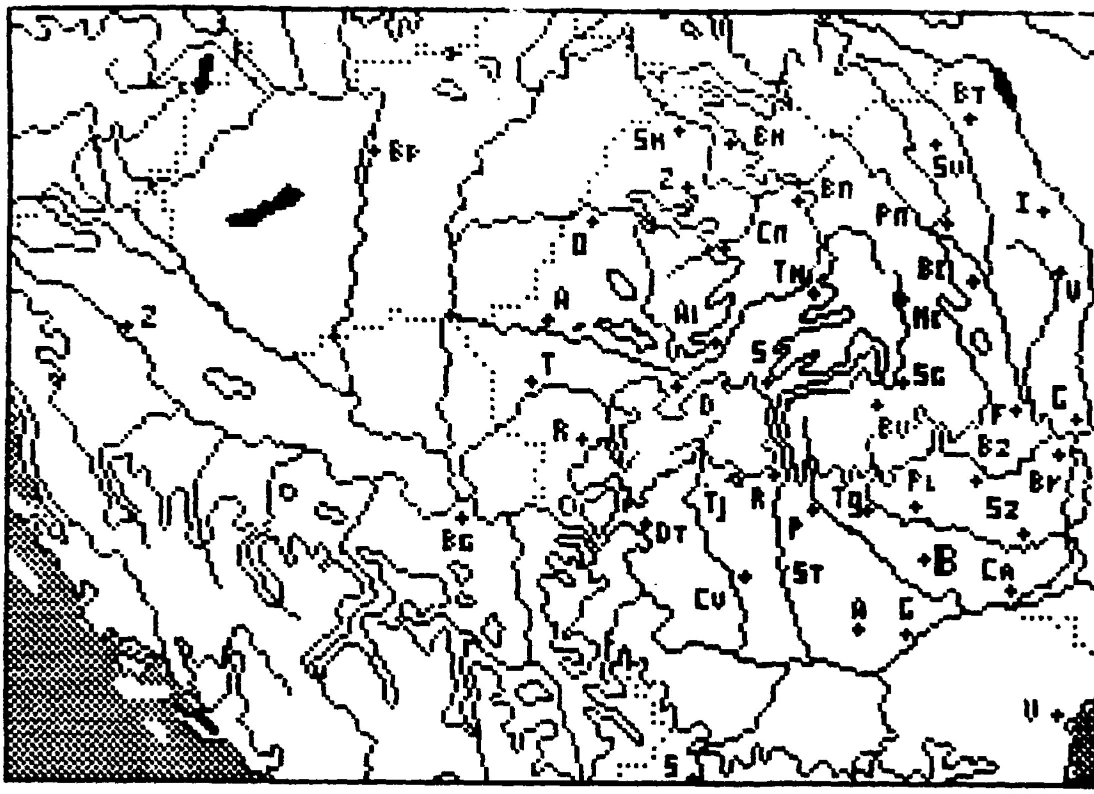

344 336 328 320 312 304 296 288 280 272 264 256 248 240 232 224 216 208 200 192 184 176 168
43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49
136 168 184 200 216 232 248 264 280 296 312 328 344 360 376
144 160 176 192 208 224 240 256 272 288 304 320 336 352 368 384

MAP # 4



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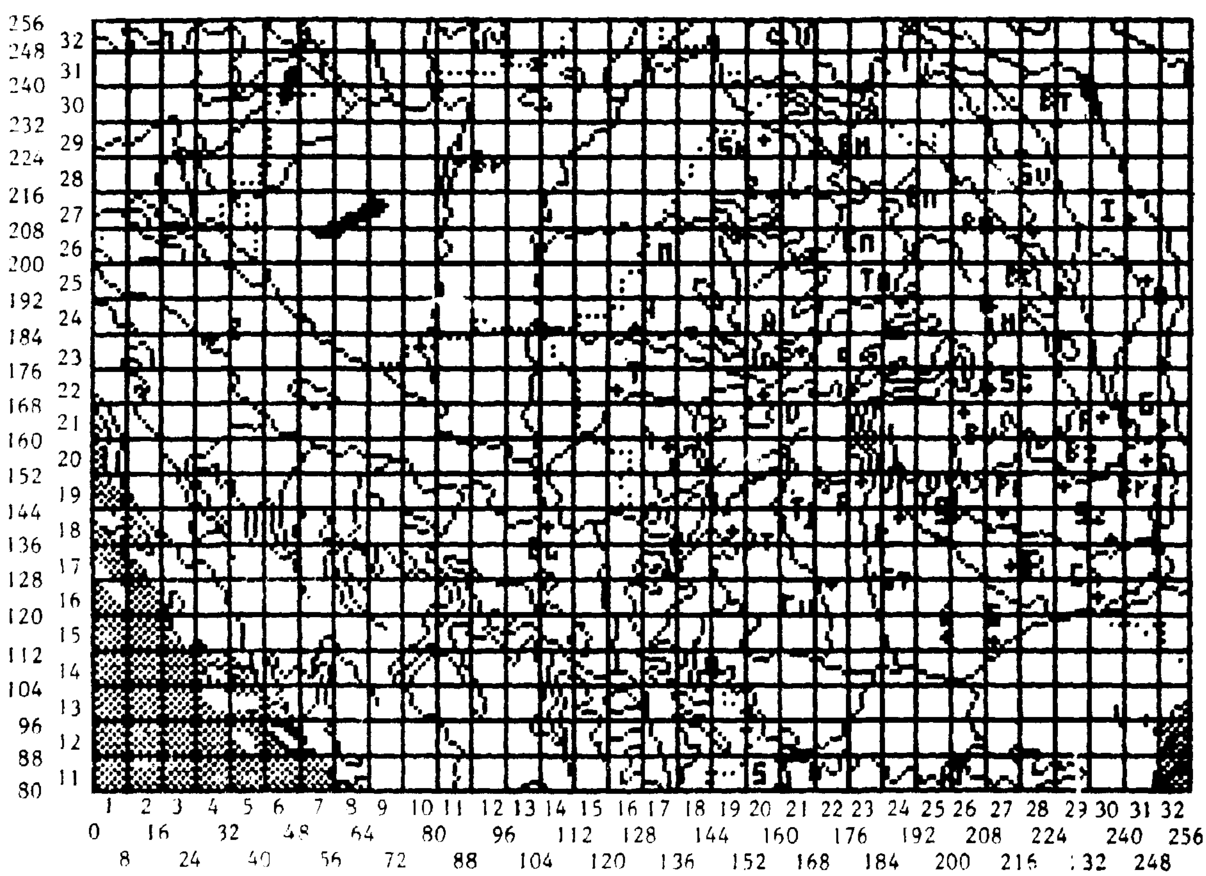

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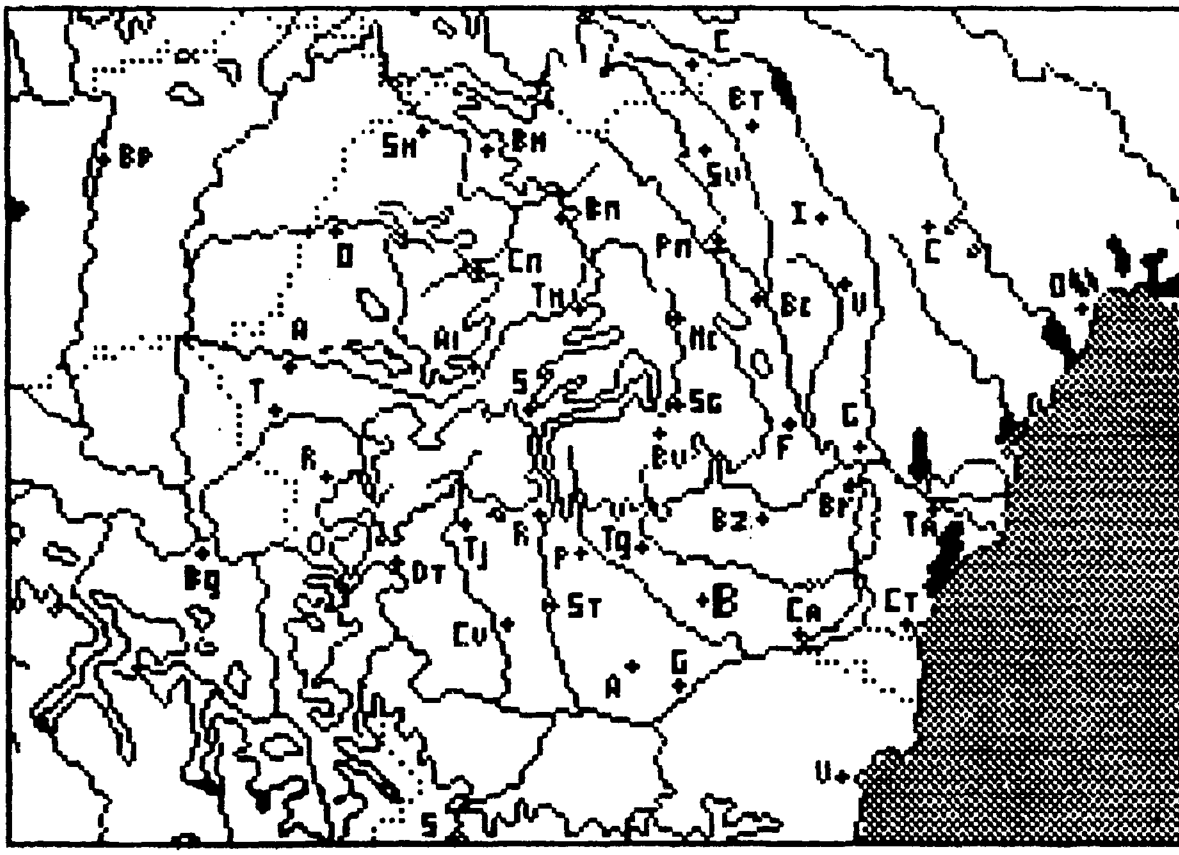
0 16 32 64 80 96 112 128 144 160 176 192 208 224 240 256
8 24 40 56 72 88 104 120 136 152 168 184 200 232 248

MAP # 5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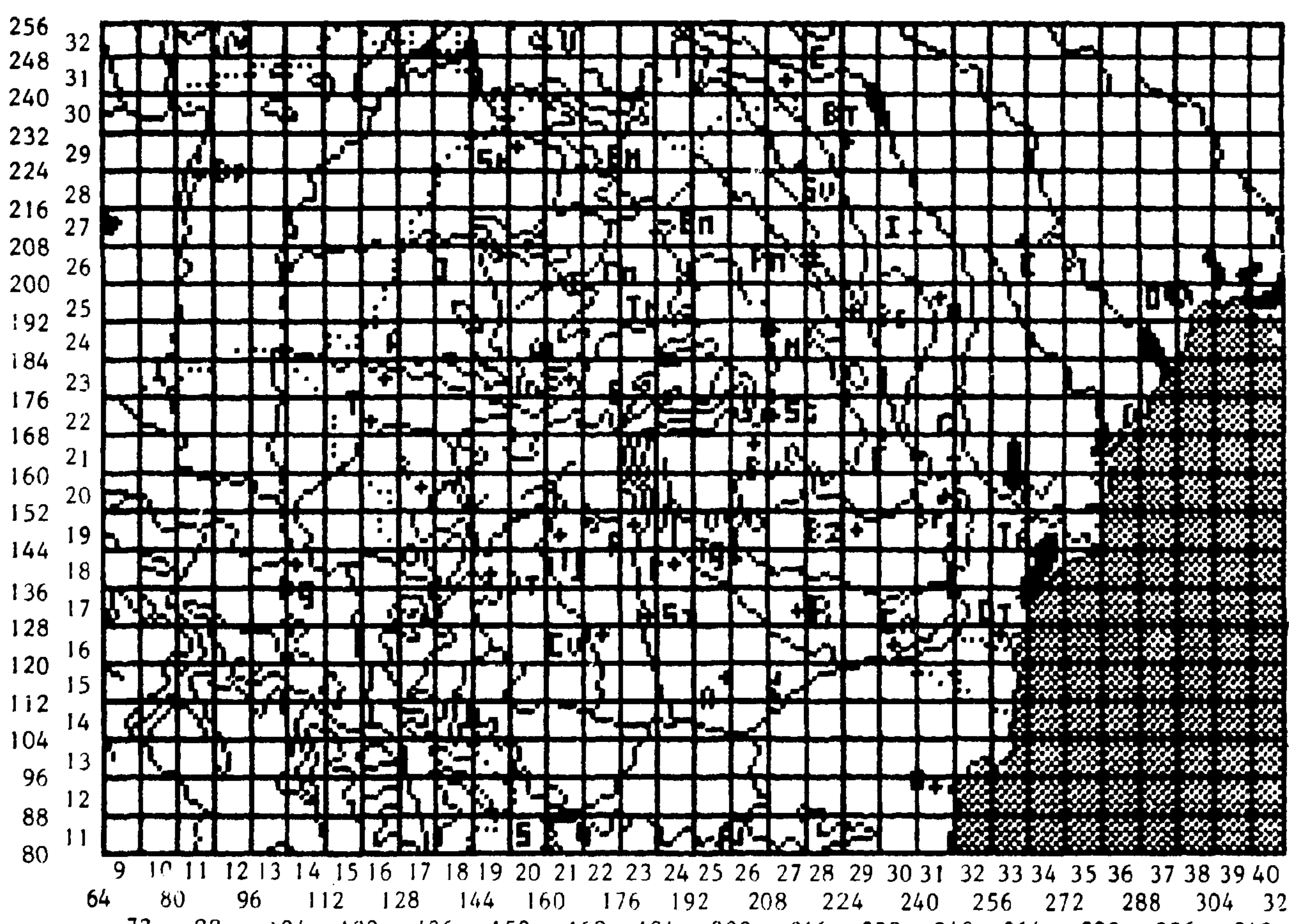
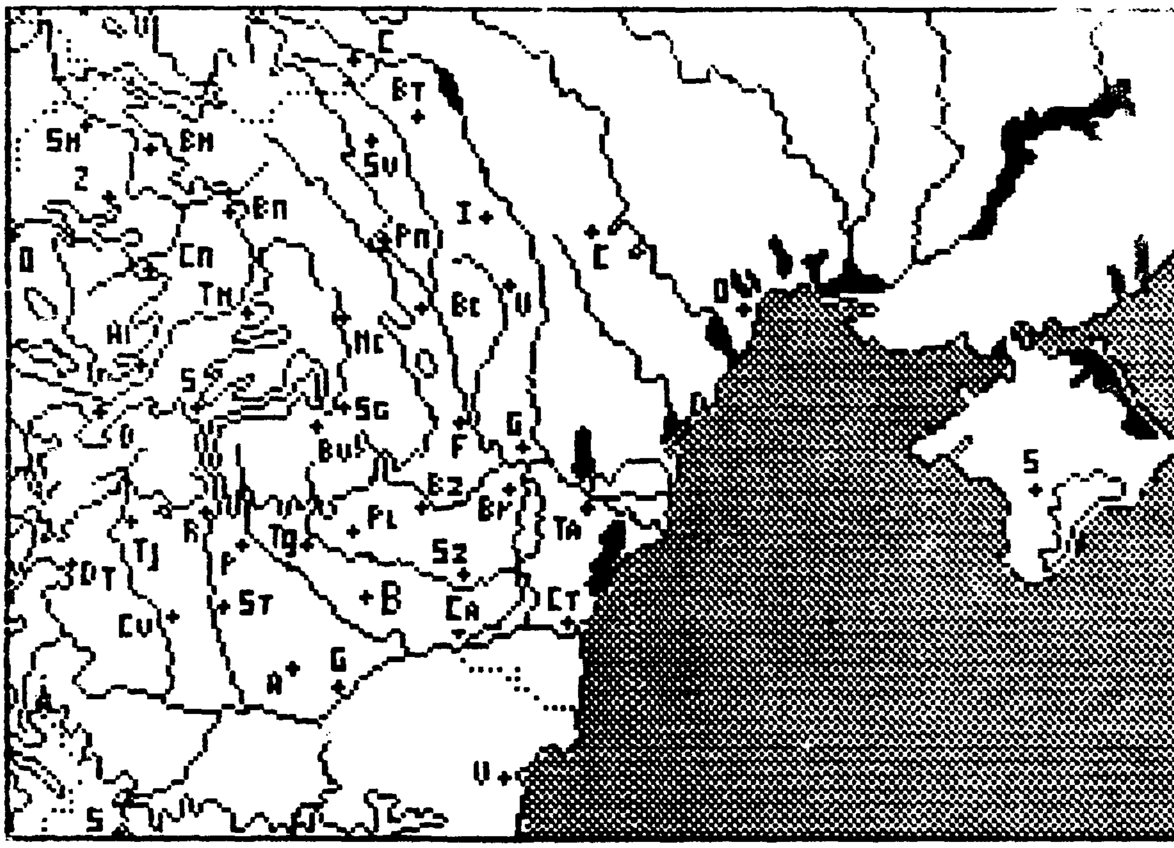


MAP # 6



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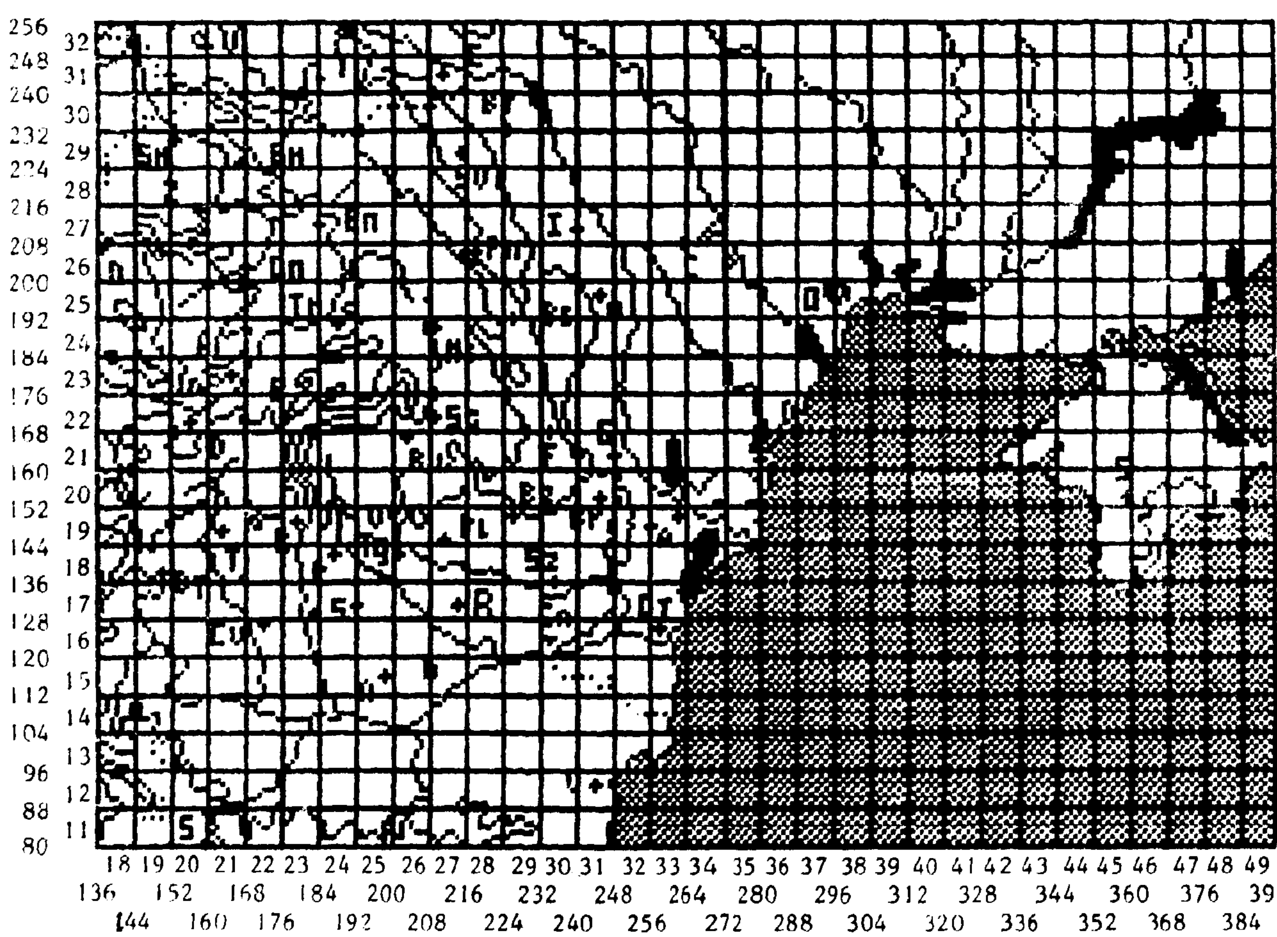
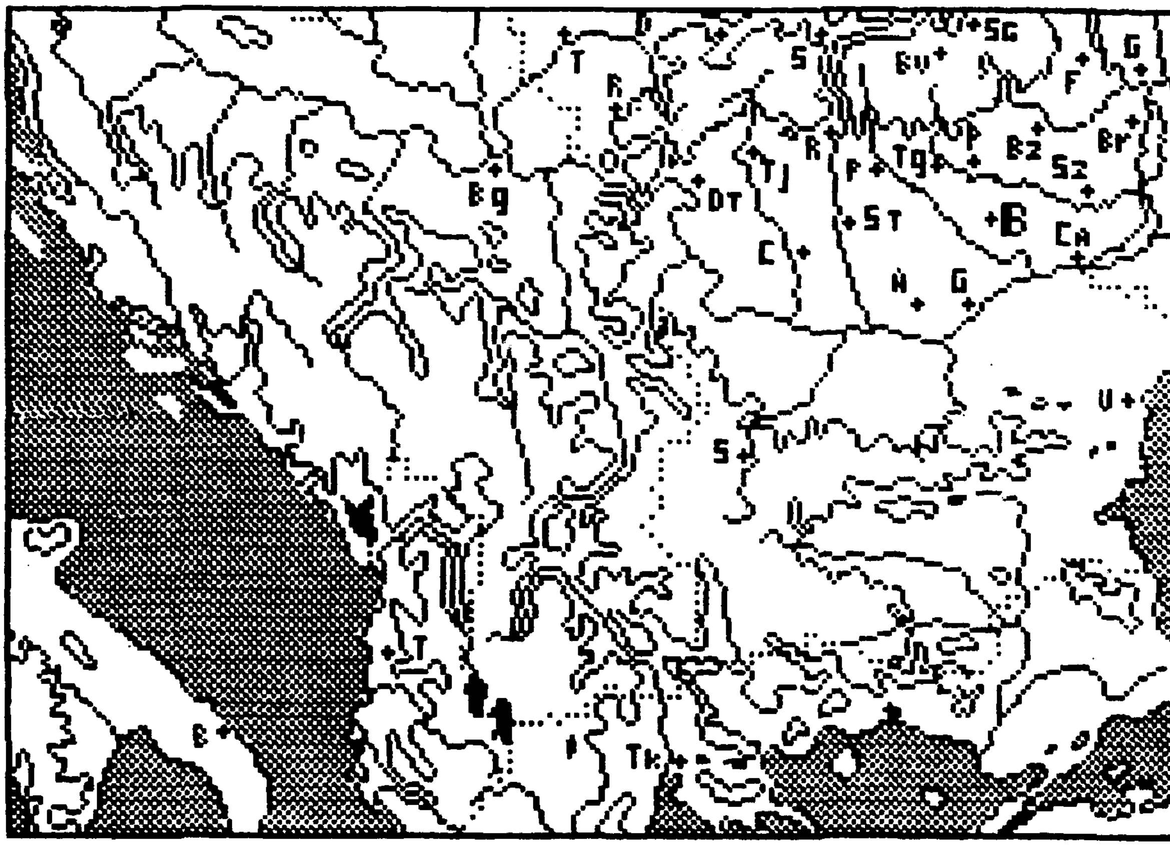


256 248 240 232 224 216 208 200 192 184 176 168 160 152 144 136 128 120 112 104 96 88 80
32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49
136 152 168 184 200 216 232 248 264 280 296 312 328 344 360 376 392
144 160 176 192 208 224 240 256 272 288 304 320 336 352 368 384

MAP # 7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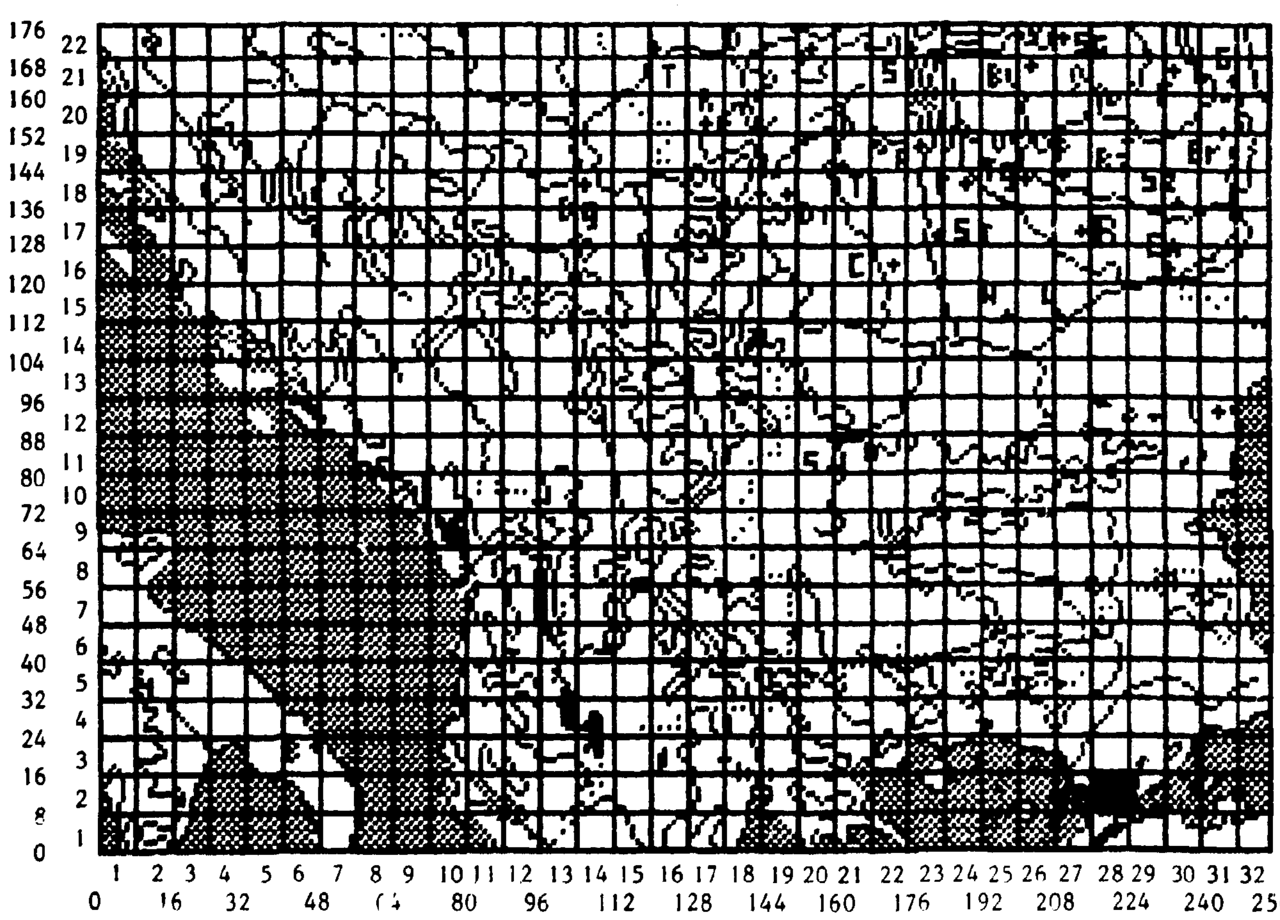
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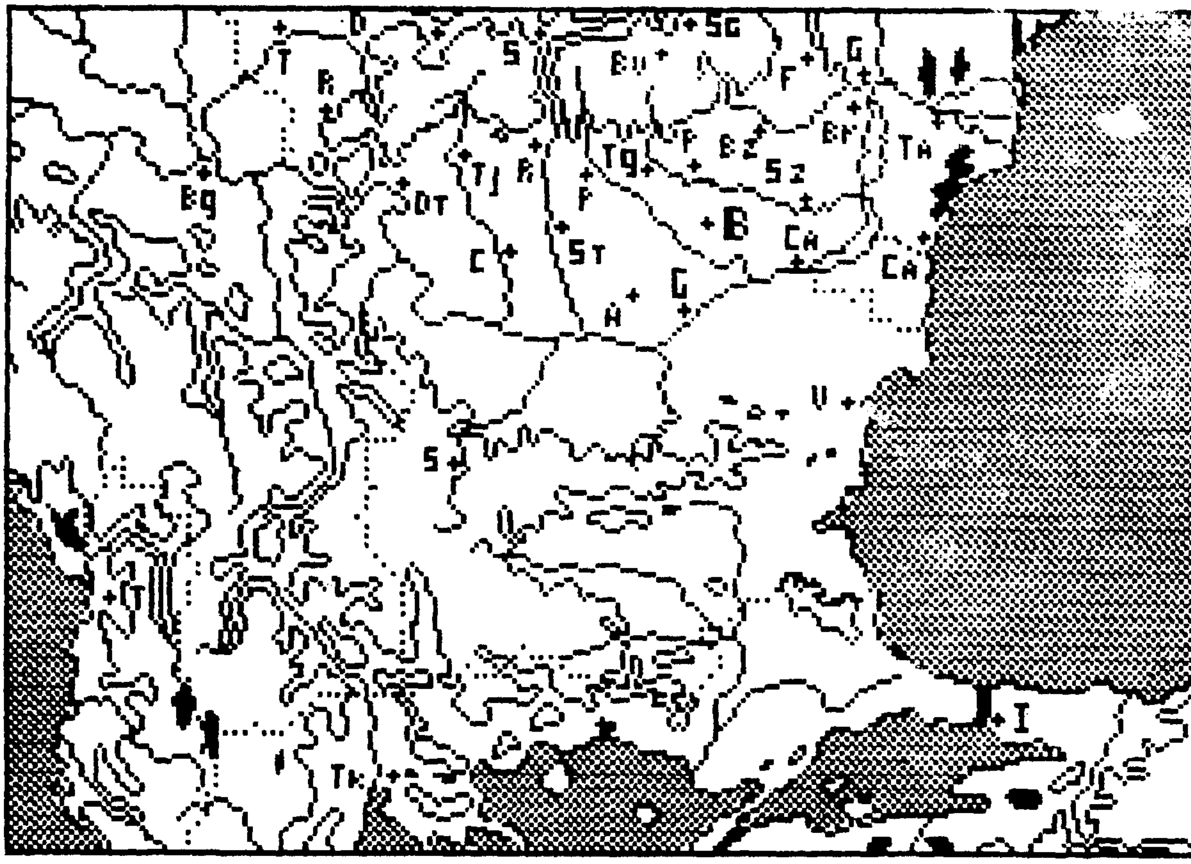
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
0 16 32 48 64 80 96 112 128 144 160 176 192 208 224 240 256
8 24 40 56 72 88 104 120 136 152 168 184 200 216 232 248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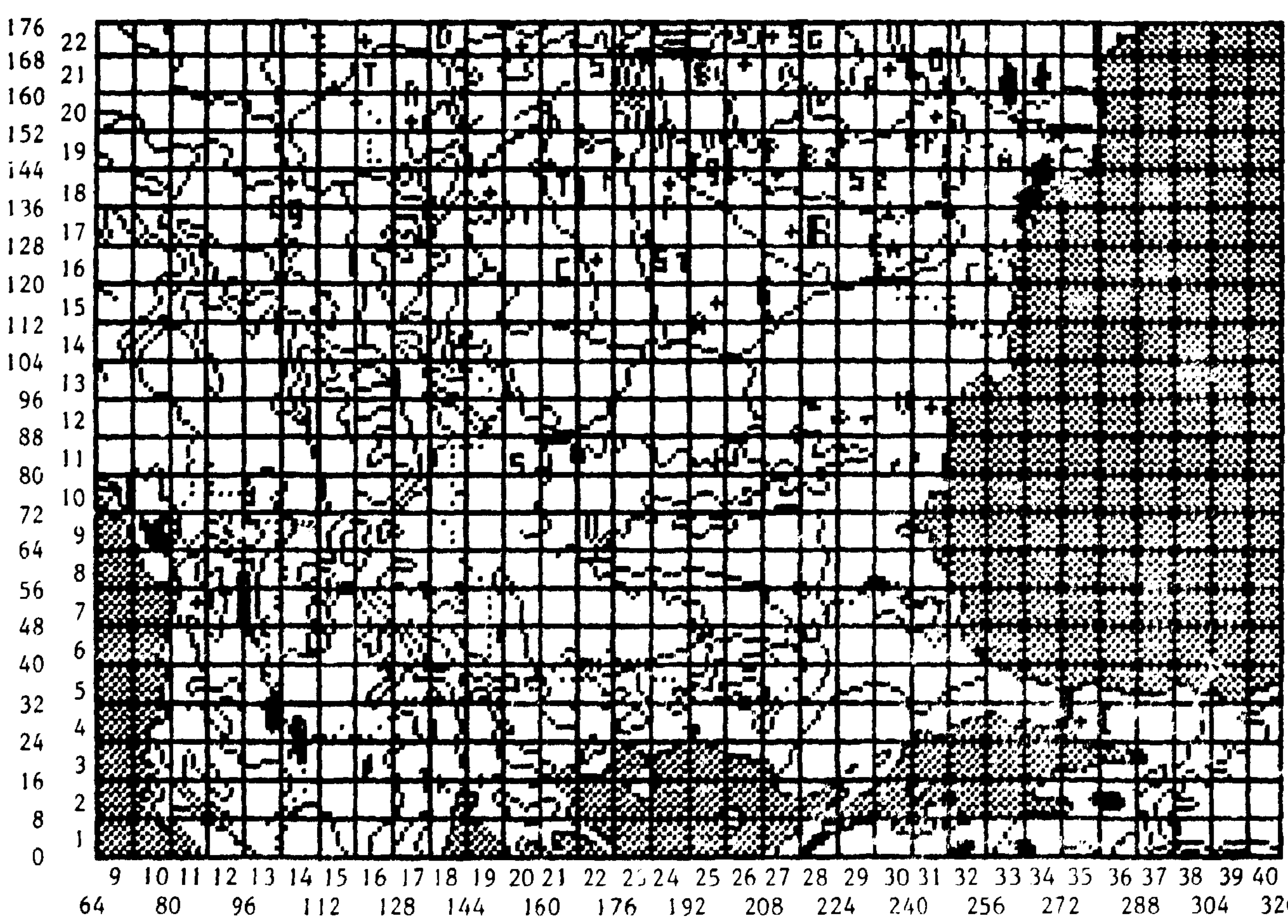
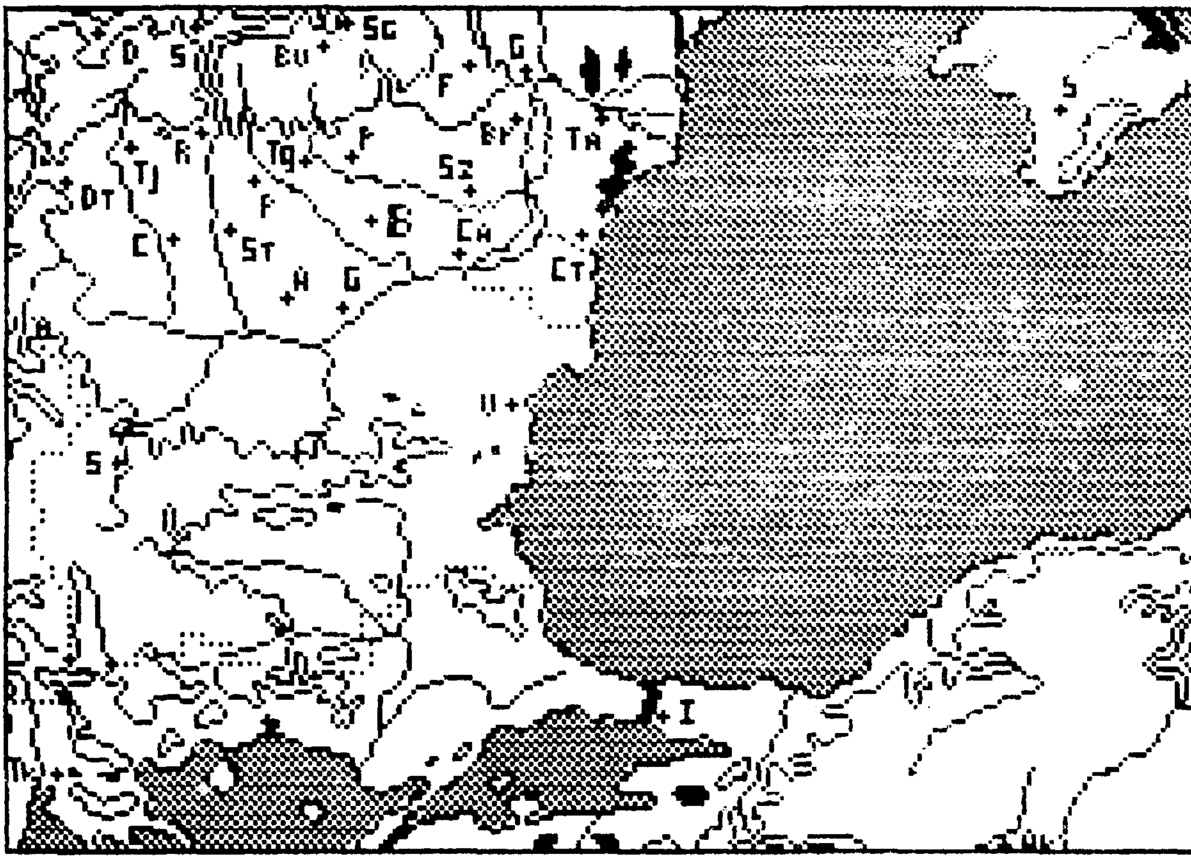
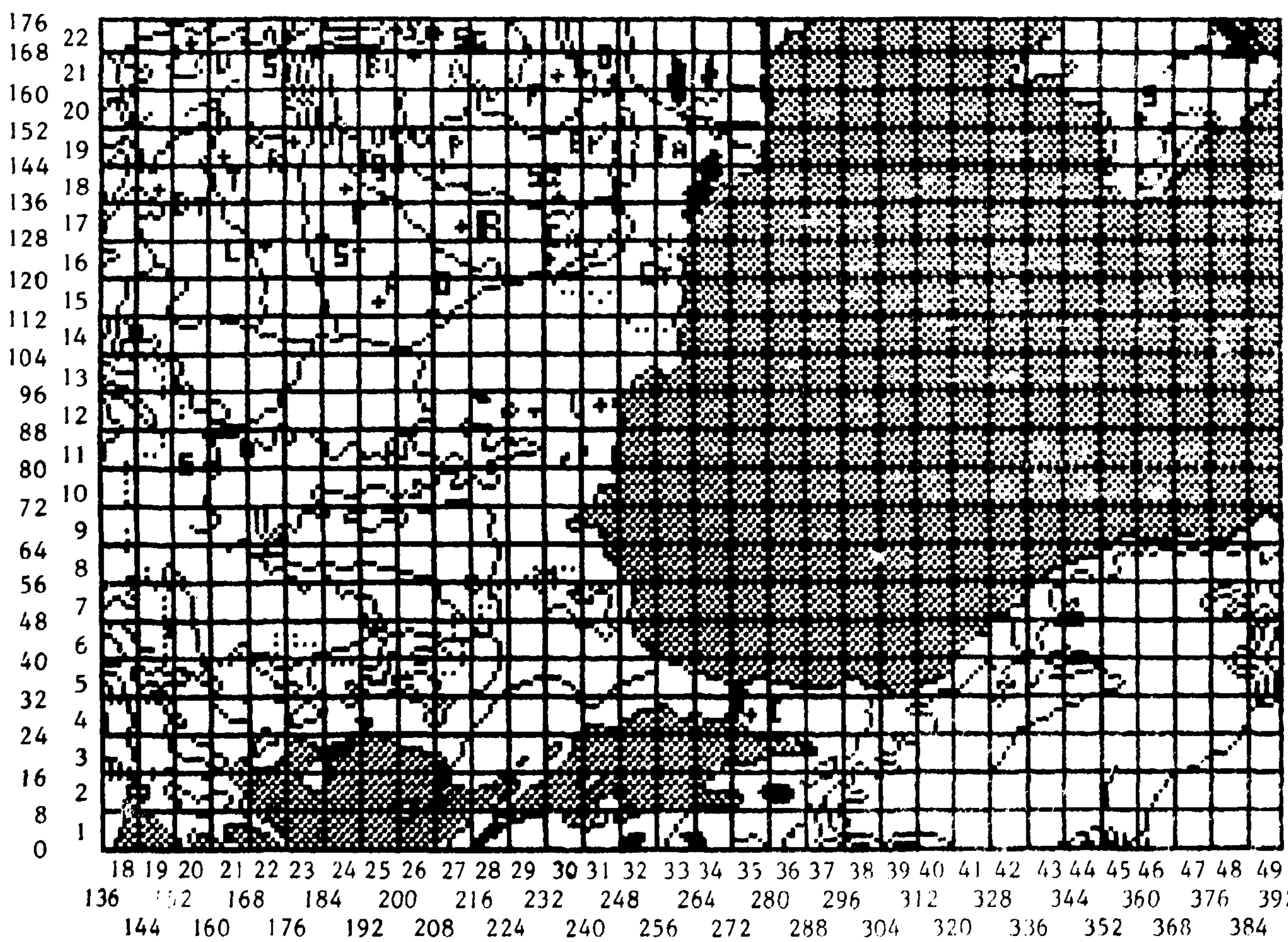

176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8 0
22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
9 10 11 12 13 14 15 16 17 18 19 20 21 22 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
64 80 96 112 128 144 160 176 192 208 224 240 256 272 288 304 320
72 88 104 120 136 152 168 184 200 216 232 248 264 280 296 312

MAP # 9

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22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49
136 168 184 200 216 232 248 264 280 296 312 328 344 360 376 392
144 160 176 192 208 224 240 256 272 288 304 320 336 352 368 384

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TOME 33
1988
Nos 4—6

EDITURA ACADEMIEI REPUBLICII SOCIALISTE ROMÂNIA

Dedicated to Professor IOAN URSU on his 60th anniversary

NOTES ON PROTRACTED RELEASES

D. V. VAMANU

Central Institute of Physics, Institute for Physics and Nuclear Engineering, P. O. Box 5206 Bucharest, Romania*

Analytical solutions are given to the dispersal equation for atmospheric protracted releases featuring fronts of initiation, culminations, and tails of extinction, nearing in the extremes Lagrangian puffs, and Gaussian plumes, respectively. Goniometric measurements provide for inferring source terms and diffusion coefficients. The origin of unaccounted releases can also be determined. Cloud passage predictions may then be conveniently conducted.

1. THE FRAMEWORK

In consideration of recent experience [1, 2], it has been suggested [3] that procedures designed to identify and characterize radioactive releases may need to better provide for the description of *protracted* emissions, of various durations and time-profiles. These notes report on such an exercise [4]. Release modelling, search for source terms, and predictions on the dispersal unfolding apply here to what has been termed ([3], p. 73) "the most critical pathway, to be quickly estimated in the early phase of an accident" – the airborne activity concentration.

Conveniently written in the cloud's reference frame $Oxyz$, (CF), an approximate diffusion equation for the activity concentration $\rho(x, y, z; t)$ is

$$[-D_x\partial^2/\partial x^2 - D_y\partial^2/\partial y^2 - D_z\partial^2/\partial z^2 + \partial/\partial t]\ \rho(x, y, z; t) = \alpha(x, y, z; t), \quad (1.1)$$

where D_x, D_y, D_z are taken as *effective* diffusion coefficients, averaged over the time of observation and the territory in question, down-wind, crosswind, and vertically, respectively, and $\alpha(x, y, z; t)$ is the source strength. Naturally it is assumed that CF moves down-wind in the source's reference frame $OXYZ$, (SF), at the velocity $\mathbf{v}$ of the average, dominant wind.

When solved [4] via the mathematical Green functions associated to its differential operator in the left-hand side, equation (1.1) gives:

$$\underset{(t\geq 0)}{\rho(x, y, z; t)} = \int_{-\infty}^{\infty} \mathrm{d}x' \int_{-\infty}^{\infty} \mathrm{d}y' \int_{-\infty}^{\infty} \mathrm{d}z' \cdot \int_{-\infty}^{t} \mathrm{d}t' \cdot$$

$$\cdot\, G_x(x - x',\ t - t')\, G_y(y - y',\ t - t')\, G_z(z - z',\ t - t') \cdot \alpha(x', y', z'; t') \quad (1.2)$$

* On leave-of-absence, c/o the National Committee for Science and Technology, 1, Piaţa Victoriei, 71202 Bucharest, Romania; work supported by the NCST.

with the following generic expression for the Green factors involved:

$$G(\xi, t) = \exp[-\xi^2/(4D_\xi t)]/(4\pi D_\xi t)^{1/2}. \tag{1.3}$$

By taking the source strength in the singular form

$$\alpha(X', Y', Z'; t') = Q \cdot \delta(t') \cdot \delta(X')\,\delta(Y) \cdot [\delta(Z' - H) + \delta(Z' + H)] \tag{1.4}$$

where δ are Dirac functions, and defining the standard deviations $\sigma_x = \sqrt{2D_x t}$, $\sigma_y = \sqrt{2D_y t}$, $\sigma_z = \sqrt{2D_z t}$, one can easily see that the solution above meets indeed the minimal requirement of generating, as particular cases, the standard Lagrangian puff as well as the Gaussian plume, in their conventional forms (v.e.g. [3], pp. 63–66, and also [5,6]), reflection considered.

On the other hand, the potential of the solution (1.2, 3) goes beyond such results.

2. MODEL PATTERNS OF PROTRACTED RELEASES

The very notion of a radiological *emergency* implies a disruptive event, featuring a front of initiation, a peak of culmination, and a tail of, more or less protracted, consummation. It is therefore intuitively believed that a plausible, and general, image of a radioactive release ***should emulate the time-profile of the Green function of the dispersal problem*** – that fit the description. One therefore submits that the following function, written in SS, may properly model source strengths:

$$\alpha(X, Y, Z; t) = \theta(t) \cdot \frac{\alpha}{4\sqrt{\pi\beta}} \cdot \frac{\exp(-1/(4\beta t))}{t^{3/2}} \cdot \exp(-v^2 t/(4D_x)) \cdot$$
$$\cdot\, \delta(X) \cdot \delta(Y) \cdot [\delta(Z - H) + \delta(Z + H)]. \tag{2.1}$$

The Heaviside, step function here duly indicates that the release is initiated in the time origin. The second and third, exponential, factors make up a function freely evoking the time-profile of the Green functions. The factor $\exp(-v^2 t/(4D_x))$ would describe a wind-dependent prompt depletion at source, of the cloud – a part of what is conventionally known as "on-site retention" (v.e.g. [3]). The β-factor helps shaping the time-profile of the release. A larger β would place the release peak close to the time origin, while also narrowing the width, and one is thus watching a *blast* (puff), or explosive release; moderate βs feature *blows*, whereas at smaller β the pattern of a quasi-continuous release could be fairly approached, particularly at low wind velocities. In all cases, α will fitfully second β in fixing the profile *and* amplitude of the release.

By integrating the source strength over the entire space and time, one finds the total activity, α_d, expected to be dispersed during the release:

$$\alpha_d = \alpha \cdot \exp(-v/(2\sqrt{\beta D_x})). \tag{2.2}$$

Laplace transforms were used to perform the integrals (1.2) in CS, the activity concentration finally reading, in SS:

$$\rho(X, Y, Z; t) = \frac{\alpha \cdot \exp(vX/(2D_x) - v^2t/(4D_x))}{16\pi^{3/2}(\beta D_x D_y D_z \cdot t^3)^{1/2}} \cdot$$

$$\cdot \left[\beta^{1/2} + \left(\frac{X^2}{D_x} + \frac{Y^2}{D_y} + \frac{(Z-H)^2}{D_z}\right)^{-1/2}\right] \cdot \tag{2.3}$$

$$\cdot \exp\left\{-\frac{1}{4t}\left[\beta^{-1/2} + \left(\frac{X^2}{D_x} + \frac{Y^2}{D_y} + \frac{(Z-H)^2}{D_z}\right)^{1/2}\right]^2\right\}$$

plus a similar, reflection, term that differs only in that H changes into $-H$.

The model above features a full 3-dimensional anisotropic dispersal, being particularly useful at low wind velocities. On the other hand, in cases when the cloud centreline cannot be directly accessed for measurements the use of a 2-dimensional model may be in order. For a 2-d model the following source strength is proposed (in SS):

$$\alpha(X, Y, Z; t) = \theta(t) \cdot \frac{\alpha}{2\sqrt{\pi\beta}} \cdot \frac{\exp(-1/(\beta t))}{t^{3/2}} \cdot$$

$$\cdot \delta(X)\,\delta(Y) \cdot [\delta(Z-H) + \delta(Z+H)]. \tag{2.4}$$

Since it was conjectured that the "on-site retention" factor is connected to the downwind diffusion — which is precisely the aspect that is neglected in a 2-d Gaussian plume ($D_x \to 0$), the absence of that factor is now understandable.

Again the integration over space and time gives the total dispersed activity, $\alpha_d = \alpha$.

With these, and in the limit $D_x \to 0$ solution (1.2) gives

$$\rho_{\substack{(t>0)\\(X>0)}}(X, Y, Z; t) = \theta(t - X/v) \cdot \frac{\alpha \cdot \exp[-1/(\beta(t - X/v))]}{8\pi(\pi\beta D_y D_z)^{1/2} \cdot X \cdot (t - X/v)^{3/2}} \cdot$$

$$\cdot \exp[-vY^2/(4D_yX)] \cdot \exp[-v(Z-H)^2/(4D_zX)] \tag{2.5}$$

plus the similar, reflection, term ($H \to -H$).

The expressions (2.3, 5) have been tested numerically, showing capability to provide coverage for a large variety of releases. Samples are given in figure 1.

3. THE INVERSE PROBLEM

To track a cloud/plume back at the source, a minimal number of field measurements of concentration are required. First, a plane would fly a reconnaissance mission, cross-wind and at various altitudes, taking

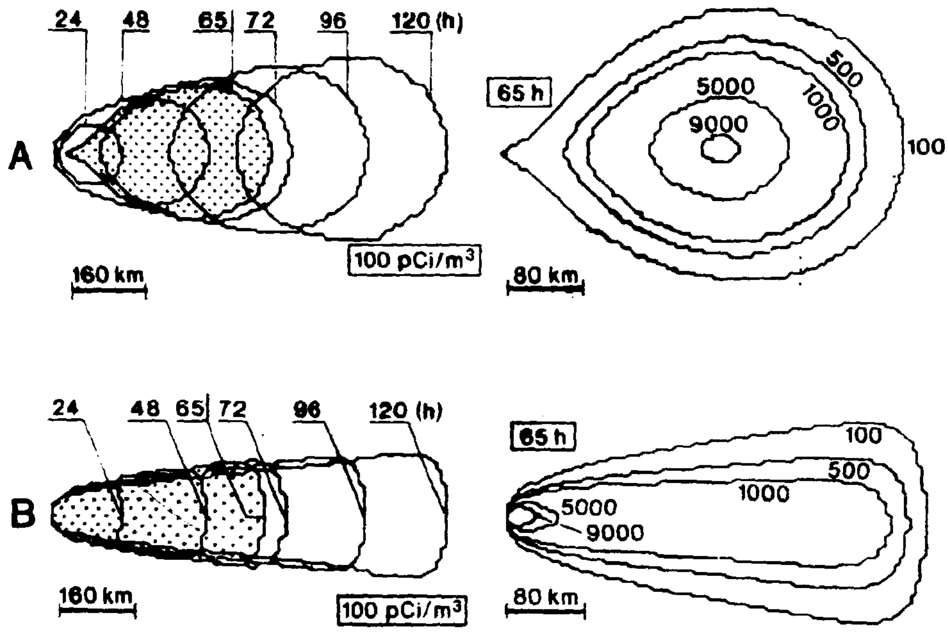

Fig. 1. — Cloud patterns, according to a 3 — d model (A), and a 2 — d model (B); horizontal sections at centreline altitude, at the indicated times. Left: evolvement of the 100 pCi/m³ lines of equal concentration. Right: detailed views of clouds at 65 hours into the release time (dotted areas left). Case A features: $\alpha_d = 10^7$ Ci; $\beta = 0.001$ s^{-1}; $H = 1$ km; $v = 7.2$ km/h; $D_x = D_y = 40$ km^2/h; $D_z = 1$ km^2/h. Case B: $\alpha = 10^7$ Ci; $\beta = 0.04$ s^{-1}; $H = 1$ km; $v = 7.2$ km/h; $D_y = 40$ km^2/h; $D_z = 1$ km^2/h.

peak readings of exposure both cross-wind and vertically, in order to determine whether the cloud centreline crosses the accessible territory, and also its elevation, H.

In case of a ***direct blow*** (centreline crossing accessible territory, 3-d modelling), the inference procedure would require that *five* planes measure three times, at equal intervals, the airborne activity concentration flying cross-wind in the configuration indicated in figure 2A. Assuming that source and assessment theatre are far apart, cloud reflection can be neglected; by the same token one can safely assume the source at barometric height 0.

The following table of inputs can then be drawn:

Measuring unit (coordinates in SS)	Measured concentrations at time T_1	T_2 $(T_3 - T_2 = T_2 - T_1)$	T_3
$M_0(X_0, 0, H)$	ρ_{01}	ρ_{02}	ρ_{03}
$M_1(X_0 + d, 0, H)$	ρ_{11}	ρ_{12}	ρ_{13}
$M_2(X_0 + 2d, 0, H)$	ρ_{21}	ρ_{22}	—
$M_0'(X_0, 0, H + h)$	ρ_{01}'	ρ_{02}'	—
$M_0''(X_0, d, H)$	ρ_{01}''	ρ_{02}''	—

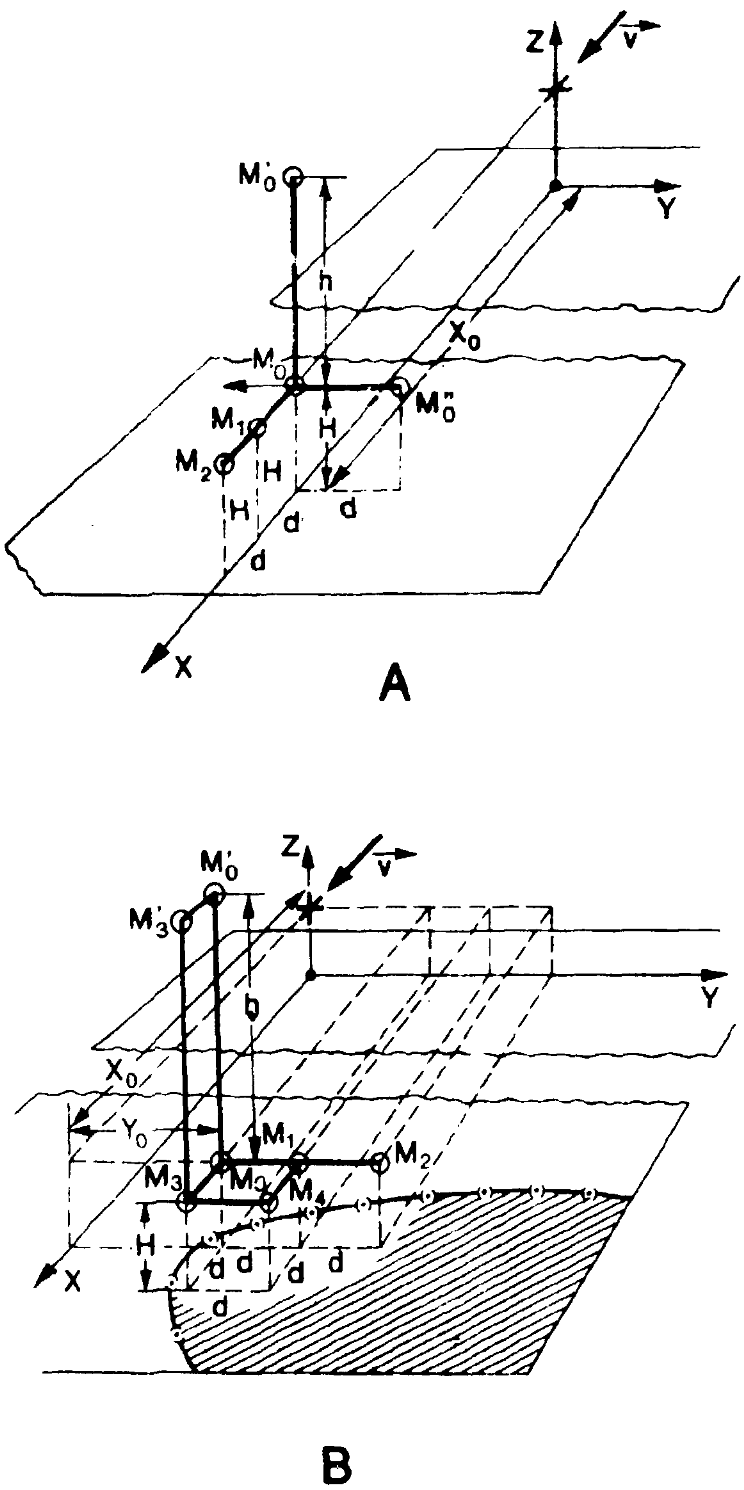

Fig. 2. – Goniometry of direct (A), and indirect (B), blows. Small circles indicate airborne measuring units. Stars locate virtual centres of dispersion, at elevation *H* above sources.

Some appropriate algebra [4] on their explicit expressions proves that these quantities are sufficient for inferring the results given in the following Table of outputs:

Aggregate input data	$L_{01}^{12} = \ln\left(\frac{\rho_{12}}{\rho_{11}}\cdot\frac{\rho_{01}}{\rho_{02}}\right)$; $L_{02}^{12} = \ln\left(\frac{\rho_{22}}{\rho_{21}}\cdot\frac{\rho_{01}}{\rho_{02}}\right)$; $L_{01}^{23} = \ln\left(\frac{\rho_{13}}{\rho_{12}}\cdot\frac{\rho_{02}}{\rho_{03}}\right)$ $M_{012}^{12} = L_{01}^{12}/L_{02}^{12}$; $N_{01}^{123} = L_{01}^{12}/L_{01}^{23}$
Time of origin	$T_0 = (T_3 - T_1\cdot N_{01}^{123})/(1 - N_{01}^{123})$
Down-wind diff. cff.	$D_x = d^2 M_{012}^{12}(T_2 - T_1)[2L_{012}^{12}(1 - 2M_{012}^{12})(T_1 - T_0)(T_2 - T_0)]^{-1}$
Source coordinate	$X_0 = d\cdot\left\{\frac{\frac{\rho_{01}}{\rho_{11}}\exp\left\{-\frac{T_2-T_0}{T_1-T_2}L_{01}^{12}\left[1-\frac{v}{d}(T_1-T_0)\frac{1-2M_{012}^{12}}{M_{012}^{12}}\right]\right\}}{4M_{012}^{12}} - 1\right\}^{-1}$
Blast factor	$\beta = D_x/[d(4M_{012}^{12}-1)(2-4M_{012}^{12})^{-1} - X_0]^2$
Vertical diff. cff.	$D_z = h^2\cdot\left\{\left\{2\sqrt{\frac{(T_1-T_0)(T_2-T_0)}{T_2-T_1}\left\{\ln\left(\frac{T_2-T_0}{T_1-T_0}\right)^{\frac{3}{2}}\cdot\frac{\rho'_{02}}{\rho'_{01}}+\frac{v^2}{4D_x}(T_2-T_1)\right\}} - \frac{1}{\sqrt{\beta}}\right\}^2 - \frac{X_0^2}{D_x}\right\}^{-1}$
Cross-wind diff. cff.	$D_y = h^2\cdot\left\{\left\{2\sqrt{\frac{(T_1-T_0)(T_2-T_0)}{T_2-T_1}\left\{\ln\left(\frac{T_2-T_0}{T_1-T_0}\right)^{\frac{3}{2}}\cdot\frac{\rho''_{02}}{\rho''_{01}}+\frac{v^2}{4D_x}(T_2-T_1)\right\}} - \frac{1}{\sqrt{\beta}}\right\}^2 - \frac{X_0^2}{D_x}\right\}^{-1}$
Source strength parameter	$\alpha = 16\pi^{\frac{3}{2}}\sqrt{D_xD_yD_z}\,(T_1-T_0)^{\frac{3}{2}}\frac{X_0}{\sqrt{\frac{D_x}{\beta}+X_0}}\cdot\exp\left\{\frac{v^2}{4D_x}(T_1-T_0)-\frac{v}{2D_x}X_0+\frac{1}{4(T_1-T_0)D_z}\left(\sqrt{\frac{D_x}{\beta}}+X_0\right)^2\right\}\rho_{01}$
Expected dispersal activity	$\alpha_d = \alpha\cdot\exp(-v/(2\sqrt{\beta D_x}))$

Note: quantities displayed in the order of consecutive construction

In case of an ***indirect blow*** (centreline outside the accessible teritory, 2-d modelling), the inference procedure would require *seven* planes (v. fig. 2B) to probe the air, at one given time — which is natural considering the need to determine one more source coordinate, $\mathbf{Y}_0$. Algebraic manipulation helped, similarly, building tables of inputs and outputs (for details, v. [4]).

All expressions in the output tables can be, of course, subject to further refinements concerning fallout, precipitations, and radioactive decay, depletions. Numerical simulations and comparison with reference data [7–10] have indicated that, in spite of a certain sensitivity of the inferred source terms to the accuracy in the input, this line of action may work satisfactorily to the effect of providing first-run assessments. Moreover, it is remarkably inexpensive as far as computational means, and time. Further model refinements, as well as repeated field probing, good statistics and iterative codes could improve performance and reliability.

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Editorial note

This manual describes the current, 1989 version of APUD.

Map altitudes definition, by Vasile Mărgărit et al.
Hardcopying software, by Dan Pop.