DANIEL F. MERRIAM, Editor

FORTRAN IV PROGRAM FOR MATHEMATICAL SIMULATION OF MARINE SEDIMENTATION WITH IBM 7040 OR 7094 COMPUTERS

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Editor's Remarks

Geological modeling has assumed considerable importance in the last two years and shows evidence of becoming more important in the future. Because the original simulation program published in this series (J.W. Harbaugh, 1966, COMPUTER CONTRIBUTION 1) is almost out-of-print and most institutions have no facility for running BALGOL programs, it was decided to translate it to FORTRAN IV. This report contains all information necessary to operate the program and interpret the results.

The model will "...imitate the behavior of sediments as they are transported and deposited within a marine sedimentary basin." This is important to the geologist who is attempting to interpret the history of an area. By adjusting the model and observing the responses, some insight into the formative processes can be made. Although modeling is still in an infant stage of development, it offers a very promising area for future research in geology.

> The computer is a symbol of change - of innovation - of the future. Those with the greatest stake in the future and those who are psychologically most open to it are the people with the greatest interest and enthusiasm about the machines.
>
> Robert S. Lee, 1966
> Datamation, v. 12,
> no. 12, p. 34

The Kansas Geological Survey is the only geological organization known to be actively distributing computer program decks as well as data decks. The programs are sold for a limited time at a nominal cost. Versions of the programs have been executed on Burroughs B5500, CDC 3400, Elliott 803C, GE 625, and IBM 1620, 7040, 7090 and 7094 computer systems. For a limited time, the Survey will make available the card deck of the simulation program in FORTRAN IV for $20.00. An up-to-date list of available decks can be obtained by writing, Editor, COMPUTER CONTRIBUTIONS, at the Survey offices in Lawrence.

Comments and suggestions concerning the COMPUTER CONTRIBUTION series are welcome and should be addressed to the Editor. An up-to-date list of publications is available on request.

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JOHN W. HARBAUGH and **WARREN J. WAHLSTEDT**

ABSTRACT

Utilizing an IBM 7040 or 7094 computer, a mathematical model of marine sedimentation imitates the behavior of sediments as they are transported and deposited within a marine sedimentary basin. By mathematical means, in symbolic three-dimensional space, the model imitates the processes of tectonic warping, winnowing of sediments along beaches, formation of deltas, and growth and interaction of organism communities, including algal banks and coral reefs that populate the sea floor. The model is operated by assuming a set of external controlling conditions and feeding these into the computer as numerical data. The model is then run forward, by increments, through geologic time. Several million years of geologic history can be recreated in an hour or less of IBM 7040 computer time.

Output from the program representing the model is in the form of lithofacies maps, structure maps, biofacies maps, water depth maps, and up to six geologic cross sections that show both structure and facies relationships. An additional feature provides the output of mirror images of the cross sections if construction of a three-dimensional display is desired. A series of maps and cross sections can be printed for each increment of geologic time, making it possible to observe progressive geologic changes as they occur.

The model is used as an experimental tool for observing the response to a set of assumptions. When a change in the data used to control the program is made, the model responds dynamically within a few seconds of computer time. Deltaic deposits, ancient beaches, algal reefs, and other sedimentary features develop progressively and undergo structural deformation with startling realism.

The principal objective in geological mathematical modeling is to produce symbolic geologic products (such as sedimentary strata) by imitating the principal geologic processes that produce the products. There is, however, uncertainty as to the mode of operation and relative importance of many processes. Consequently, assumptions may be made and tested on a trial and error basis. If the results of a computer run with the model do not agree well with reality (i.e. the symbolic deposits do not accord well with real sedimentary deposits that are being imitated), the assumptions can be progressively changed, and new runs made until the model begins to perform realistically.

The mathematical model is embodied in a FORTRAN IV computer program which has been successfully run on an IBM 7040 and IBM 7094 with satisfactory results. With minor modifications, the program can probably be used with computers of other manufacturers, and with IBM System 360 computers.

INTRODUCTION

Computer modeling provides a means of exploring a series of different sets of assumptions. The series of assumptions may be thought of as forming a kind of multidimensional continuum within which there are an infinity of possible combinations, some more plausible than others. According to this view, each variable may be regarded as a dimension of the continuum. Just as a line contains an infinite number of points, a multidimensional continuum also contains an infinity of points or, in this case, possible states of the model, each state representing an interpretation. Such a continuum may be visualized in two dimensions as an ordinary probability density function, which is commonly known as the bell-shaped frequency distribution curve or "normal" curve (Fig. 1). In three dimensions, the continuum may be viewed as a bell-shaped surface representing the probability "density" of two variables (Fig. 2). In four or more dimensions visualization is impossible, but the idea is similar.

The purpose of carrying out simulation experiments with the program described here is to "explore" a multidimensional continuum formed by the different variables incorporated in the program. In most problems of geology, as for example, those dealing with interpretation of ancient environments, there is no single, "right" answer. Instead, there are multiple answers, some of which may seem reasonable whereas others may be less reasonable. The important fact to realize, however, is that these possible answers are neither discrete nor sharply separated from each other. Instead, we can regard them as intergrading to form a continuum, within which there are an infinity of possible answers, each differing by an infinitesimal amount.

For example, the mathematical model embodied in the computer program described here may be used to explore the responses of a particular marine organism community to different assumed values of water depth and to influx of mud. Assume that the community is a mud-loving community, but that too much mud is disadvantageous, just as too little mud is detrimental. If the community is both depth sensitive and mud-influx sensitive, then its performance (other factors disregarded) may be thought of as being described by a probability density surface which portrays the different probabilities associated with different values of depth and mud influx (Fig. 3). The purpose of mathematical simulation, restated, is to provide a means of exploring this surface by enabling an investigator to assume different values of depth and mud influx, and to explore the results yielded by these values in conjunction with the assumed behaviorial properties of the organism community with respect to depth and mud influx. Thus, mathematical simulation is a means of exploring the effects of different sets of assumptions - no more and no less.

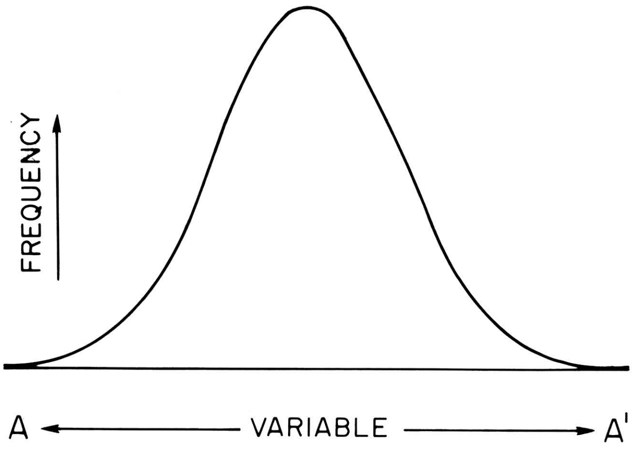

Figure 1.- Normal frequency distribution curve representing a probability distribution function. Variable is assumed to range continuously from a to a'. Height of curve at any point is proportional to frequency of occurrence at value of variable at that point.

The FORTRAN IV program representing the mathematical model which is described here was originally written in a variety of ALGOL 58 (called SUBALGOL or BALGOL) by Harbaugh (1966). Because of the relative lack of use of the ALGOL 58 computer language at most computer installations, it was decided to translate the program to FORTRAN IV.

The FORTRAN IV version was developed using the IBM 7040 computer at The University of Kansas. The program also has been tested on the IBM 7094 computer. With minor modifications, it can be used with other computers for which FORTRAN IV language systems are available, although minor modifications of the program will probably be required.

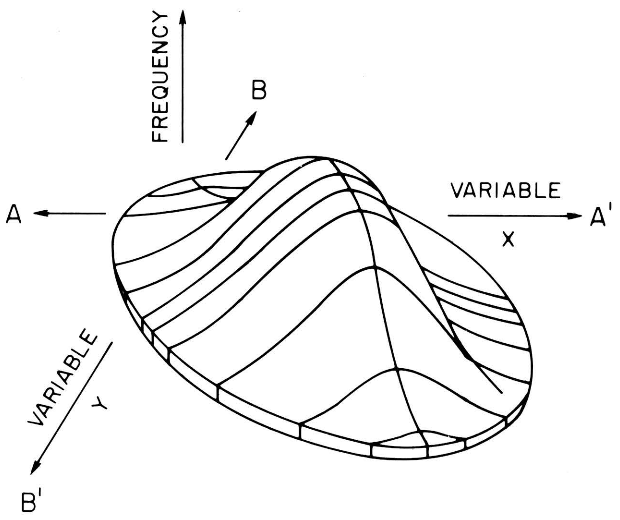

Figure 2.- Surface representing probability distribution function of two variables. Variables x and y are assumed to range continuously from A to A' and B to B', respectively. Height of surface at any point defined by values assigned to X and Y is proportional to probability of occurrence at that point.

An explanation of the geological rationale of the program is provided in the Appendix, which is taken from Computer Contribution 1 and also from another paper by Harbaugh (1967).

Acknowledgments.-The authors thank Daniel F. Merriam for continued encouragement and support. Mrs. Nan Carnahan Cocke typed the preliminary manuscript and prepared the final typescript. Part of the work was supported by the Kansas Geological Survey. Computer facilities used in developing the program were provided by The University of Kansas Computation Center. The original BALGOL version of the program was developed at Stanford University, with facilities provided by Stanford University Computation Center, with financial support by National Science Foundation Grant GP-4514, the Shell Fund for Fundamental Research, and the American Chemical Society through Petroleum Research Fund Grant PRF-1117-A2.

PRINCIPAL COMPONENTS OF PROGRAM

A listing of the FORTRAN statements of the simulation program are shown in Table 1. The program is divided into a main program, five subroutines and one function. Each line, representing one punched card, is numbered.

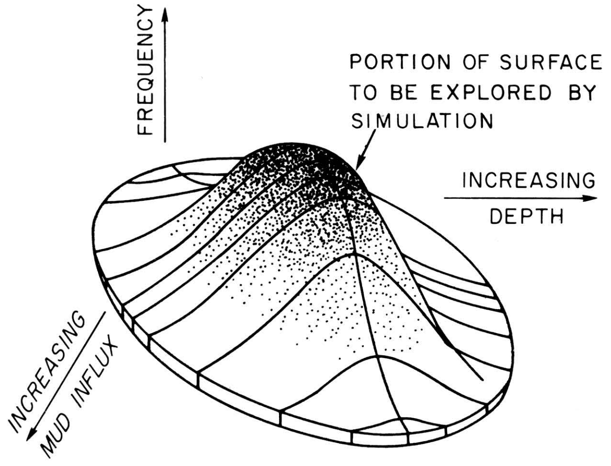

Figure 3.- Surface representing hypothetical probability density function relating response in terms of frequency of occurrence of an organism community to variations in depth and to mud influx. Shading emphasizes high parts of surface where "exploration" is desirable.

Main Program

The main program may be conveniently divided into two sections.

Section I which is listed immediately below, contains cards numbered 1 to 158. Section I consists principally of statements pertaining to input of data that are used to control the program, and for printing out of these data before the simulation operations begin. Key statements in this section are identified by number, as follows:

8-10 Type declarations.
11-17 Common statement (one blank common is used for all subroutines except subroutine 'Short'. Entry to it is through an argument list).
18-20 Dimensions of arrays used only in main program.
24 Input for variable formats.
25 Input for plotting symbols.
28 Input for random number generator
30 Input for legend.
33-34 Input for control of the program.
38 Input for CPX array.
44 Input for CFC array.
55 Input for FAV and FF values.
58 Input for MAP array.
70 Input BTR, HT, LTH, and WID values.
73 Input PTH array.
83 Input for data stored in TCT array.
88 Input for data stored in DPT array.
93 Input for SED array.
96 Input for DPL array.
117 Input for UPBND and LOWBND values.
120 Input for SAND and MUD arrays.
122 Input for TER array.
142 Input for SUB array.
150 Input for SECTOP array.

Section II pertains to the dynamic part of the program in which the model is moved forward through increments of time. Key components are identified by card numbers as follows:

165-177 If WEST equals 1, extend the geographic distribution of a favored organism community so as to mimic the effect of wind-driven currents in displacing organism communities.
178-198 If DELTAO equals 1, perform calculations whose effect is to mimic the effect of a river creating deltaic deposits flowing from left to right (on maps), bringing mud and/or sand to depositional basin.
199-214 Output information pertaining to amount of terrestrially derived sediment potentially available.
215-225 Determine numerical separation between organism communities in each cell in the two preceding time increments.
226-245 Calculate feedback values, to be stored in TEND array which regulate the "vitality" or competitive ability of organism communities and are influenced by variations in depth, mud influx, and sand influx.
246-548 Subroutine calls used for selection of organism communities to occupy cells during next time increment.
549-614 Check of organism communities previously selected for depth ranges, adjust if necessary, and calculate increment of terrestrial sediment deposited, increment of sediment of organic origin deposited, and new depth values.
615-634 Calculate contour values for structure map.
634-642 Calculate values for output of organic increment map.
643-672 Calculate lithology data for subsequent output in vertical sections.
673-681 Output of facies and organism community maps.
682-800 Calculation of thickness data followed by output of vertical sections.

Subroutine MAPLOT

This subroutine is used in conjunction with the main program for printing of maps produced by the program that use plotting symbols.

Subroutine SHORT

This subroutine is used in the incremental filling of array KPF from which the organism community for the next time increment will be drawn at random.

Subroutine FAVDEP

This subroutine is used in calculation of the relative degree of favorability for an organism community with respect to depth and influx of mud and of sand.

Subroutine VALSHO

This subroutine is used in the selection of an organism community from the KPF array to occupy each cell during the next generation, employing a pseudorandom number generator.

Subroutine FB3SHO

This subroutine is used in conjunction with subroutine SHORT for filling of KPF array.

Function IDKOD

This function is used to decode values stored in the PPP and PVP arrays for subsequent output as vertical geologic sections.

Table 1.- Listing of FORTRAN IV statements in simulation program.

```
C***********************************************************************MAIN   1
C                                                                       MAIN   2
C        THREE-DIMENSIONAL SEDIMENT/ORGANISM COMMUNITY SIMULATION PROGRAMAIN   3
C        TRANSLATED FROM A BALGOL PROGRAM BY J.W.HARBAUGH,STANFORD UNIV MAIN   4
C        BY W.J.WAHLSTEDT,KANSAS GEOLOGICAL SURVEY                      MAIN   5
C                                                                       MAIN   6
C                                                                       MAIN   7
      INTEGER DLT,FAV,CLN,DPLOT,SECTOP,PPP,PVP,SEP,CT,TPL,DATOP,WEST,DELMAIN   8
     2TAO,TECTOP,STRUC,HOR,CIND,THKFX,WTRFX,S1,S2,S3,SUM,SMB            MAIN   9
      REAL LOWBEA,LOWBND,MUDFAC,ME,MUD,MUDINC,LFL,LTH,MF                MAIN  10
     0 COMMON  TCT(20,40),DPL(8,10),SED( 10,10),DPT(20,40),SAND(20),TER(MAIN  11
     120,40),SANDIN(20,40),TERINC(20,40),ORGINC(20,40),STRUCT(20,40),TENMAIN  12
     2D(20,40),CPX(5,5),TF(5),CFC(20,10),SUB(6,10),TEMP(20,40),MAP(20,40MAIN  13
     3,3),KPF(1000),PTH(20,2),LFL,LTH,MF,SUM, FB1,FB2,FB3,FB4,I,J,LX,LX1MAIN  14
     4,LX2,DTH,FAV,CLN,DPLOT(127),SECTOP(20),COMCON,DLT ,SEP(20,40,2),  MAIN  15
     5 CT(8),L,M,N,SF,LIMIT,TPL,DATOP,WEST,DELTAO,TECTOP,STRUC,HOR,SMB(3MAIN  16
     60),CIND,S1,S2,S3,LOWBEA,LOWBND,MUDFAC,MUD(20),MUDINC(20,40)       MAIN  17
      INTEGER FMT1(5),FMT2(5),FMT3(5),FMT4(5),FMT5(5),FMT6(5),FMT7(5),FMMAIN  18
     1T8(5),FMT9(5),BLANK,   ALFA1(13),PPP(40,20,3),PVP(20,20,3)        MAIN  19
      DIMENSION KK1(3),KD1(3),MIROR(6)                                  MAIN  20
C                                                                       MAIN  21
      DATA BLANK/6H      /                                              MAIN  22
C                                                                       MAIN  23
 4444 READ(5,5)     FMT1,FMT2,FMT3,FMT4,FMT5,FMT6,FMT7,FMT8,FMT9        MAIN  24
   11 READ(5,9) SMB                                                     MAIN  25
    9 FORMAT(30A2)                                                      MAIN  26
    2 FORMAT (I1)                                                       MAIN  27
      READ (5,10) TF                                                    MAIN  28
   10 FORMAT(5F7.0)                                                     MAIN  29
      READ(5,FMT1) ALFA1                                                MAIN  30
      WRITE(6,3) ALFA1                                                  MAIN  31
    3 FORMAT(1H1,/1X,13A6//)                                            MAIN  32
      READ(5,FMT2) N,M,LIMIT,NC,TPL,LWL,DATOP,WEST,DELTAO,TECTOP,CLN,   MAIN  33
     1STRUC,HOR,FB1,FB2,FB3,FB4,SCALE,BASE,KK1,KD1,MIROR                MAIN  34
      DO 7 J=1,8,1                                                      MAIN  35
    7 CT(J)=5*J                                                         MAIN  36
      NP=5                                                              MAIN  37
      READ(5,FMT3)((CPX(I,J),J=1,NP,1),I=1,NP,1)                        MAIN  38
      WRITE(6,8)                                                        MAIN  39
    8 FORMAT(/40X, 15H THE CPX ARRAY          /)                        MAIN  40
```

```
      WRITE(6, 6)((CPX(I,J),J=1,NP,1),I=1,NP,1)
    6 FORMAT(20X,5F10.2)
   12 FORMAT(/20X,11F10.2)
   13 READ(5,FMT3) (( CFC(I,J),J=1,NC),I=1,CLN)
   15 WRITE(6,16)
   16 FORMAT( / 50X,37HORGANISM COMMUNITY FACTORS FOR CYCLE ,// )
      DO 17 I=1,CLN,1
   17 WRITE(6,12)(CFC(I,J),J=1,NC,1)
C         FILL SEPARATION ARRAY FOR INITIAL OPERATION
      DO 386 I =1,N
      DO 386 J =1,M
      SEP(I,J,1)=TPL
      SEP(I,J,2)=LWL
  386 CONTINUE
      IF(WEST.EQ.1) READ(5,FMT4) FAV,FF
C         FILL INITIAL MAP ARRAY
      IF(DATOP.NE.1) GO TO   397
      READ(5,FMT5)((MAP(I,J,1),J=1,M,1),I=1,N,1)
      DO 396 I =1,N
      DO 396 J =1,M
  396 MAP(I,J,2) = MAP(I,J,1)
      GO TO 339
C         SECTION FOR INPUT OF ARRAY CONTAINING DELTA AND ARRAY CONTAININ
C         PATH OF DELTA AS GOES THROUGH CYCLE
  397 WRITE(6,398)
  398 FORMAT(80H1YOU WILL HAVE TO WRITE YOUR OWN SECTION TO SIMULATE THI
  3981S. ROTS OF RUCK CHARLIE       )
  339 IF(DELTAO.NE.1) GO TO   413
C         INPUT INFORMATION CONTROLLING GEOMETRY OF DELTA
      READ(5,FMT6)BTR,HT,LTH,WID
C         LEFT COLUMN OF PTH ARRAY CONTAINS ROW INDEX COORDINATE INCREMEN
C         RIGHT COLUMN CONTAINS COLUMN INDEX INCREMENTS
      READ(5,FMT7)((PTH(I,J),J=1,2,1),I=1,CLN,1)
      WRITE(6,405)
  4050FORMAT(   108H0COORD. INDEX VALUES FOR PATH OF DELTA FOR EACH PHAS
  4051E IN CYCLE, ROW COORD IN LEFT COL, COLUMN COORD IN RIGHT /    )
      WRITE(6,  412) ((PTH(I,J),J=1,2),I=1,CLN,1)
  412 FORMAT(/20X,F15.2,F15.2)
C         SECTION FOR INPUT OF TECTONIC WARPING,INITIAL WATER DEPTH, SEDI
C         INCREMENT, AND DEPTH LIMIT ARRAYS
  413  IF(TECTOP.EQ.0) GO TO   476
      DO 417 I =1,N
      READ(5,FMT8)(DPLOT(J),J=1,M)
      DO 417 J =1,M
      TCT(I,J)=DPLOT(J)
  417 TCT(I,J) = TCT(I,J)*.1
      DO 421 I =1,N
      READ(5,FMT8)(DPLOT(J),J=1,M)
      DO 421 J =1,M
  421 DPT(I,J)=DPLOT(J)
C         INPUT SEDIMENT INCREMENT VALUES FOR EACH COMMUNITY(IN COLUMNS)
C         FOR EACH PHASE IN CYCLE (IN) ROWS
      READ(5,FMT3 )((SED(I,J),J=1,NC,1),I=1,CLN,1)
C         INPUT UPPER AND LOWER DEPTH LIMITS FOR EACH SEDIMENT / ORGANISM
C         COMMUNITY.
      READ(5,FMT3 )((DPL(I,J),J=1,NC,1),I=1,3,1)
      DO 428 J =1,NC
      DPL(4,J)=DPL(3,J)-DPL(1,J)
  428 DPL(5,J)=DPL(2,J)-DPL(3,J)
      WRITE(6,430)
```

```
  430 FORMAT(/90H0SEDIMENT INCREMENT VALUES FOR EACH COMMUNITY (IN COLS)
  4301 FOR EACH PHASE IN CYCLE (IN ROWS)    /)
      DO   433 I=1,CLN,1
  433 WRITE(6,   12)(SED(I,J),J=1,NC,1)
      WRITE(6,435)
  4350FORMAT(/91H0UPPER AND LOWER DEPTH LIMITS, AND MOST FAVORABLE DEPTH
  4351, IN UNITS WITH RESPECT TO SEA LEVEL ,/ 63H0(IN ROWS) FOR EACH SED
  4352IMENT/ ORGANISM COMMUNITY (IN COLUMNS)    /)
      DO 441 I=1,3
  441 WRITE(6,   12)(DPL(I,J),J=1,NC,1)
      WRITE(6,96)
      DO 445 I=1,N
      DO 446 J=1,M
  446 DPLOT(J)=TCT(I,J)*10.0
  445 WRITE(6,682)( DPLOT(J),J=1,M)
C         INPUT DATA ON TERRESTRIALLY-DERIVED SEDIMENT
      READ(5,FMT3 ) UPBND,LOWBND
      DIFF=LOWBND-UPBND
      DO 451 I =1,CLN
  451 READ(5,FMT3 ) SAND(I),MUD(I)
       IF(DELTAO.EQ.1) GO TO   458
      READ(5,FMT3 ) (( TER(I,J),J=1,M,1),I=1,N,1)
   96 FORMAT(/55H1WARPING INCREMENTS IN UNITS PER CYCLE MULTIPLIED BY 10
   961////)
  458 WRITE(6,459)
  4590FORMAT(  52H1INCREMENT VALUES FOR TERRESTRIALLY-DERIVED SEDIMENT ,
  4591/ 21X, 19H PHASE  SAND    MUD      )
      DO   461 I=1,CLN,1
  461 WRITE(6,  460)I,SAND(I),MUD(I)
  460 FORMAT(/20X,I4,2F7.2)
      L=0
      IF(DELTAO.EQ.1) GO TO 473
      WRITE(6,462) L,UPBND,LOWBND
  4620FORMAT( 63H1RELATIVE RANGES OF TERRESTRIALLY-DERIVED SEDIMENT, MAP
  4621 NUMBER ,I4,/ 49H WITH TRANSITION DEPTH RANGE FROM UPPER LIMIT OF
  4622,F6.1, 20H AND LOWER LIMIT OF ,F7.1,6H UNITS, /)
      DO 472 I=1,N
      DO 471 J=1,M
  471 DPLOT(J) =TER(I,J)*10.0
  470 FORMAT(/I3,2X,40I3)
  472 WRITE(6,  470) I , (DPLOT(J),J=1,M,1)
  473 READ(5,FMT3 ) (( SUB(I,J),J=1,NC,1),I=1,4,1)
      WRITE(6,465)
  4650FORMAT(//120H SEDIMENT TOLERANCE LIMITS OF ORGANISM COMMUNITIES FO
  4651R MIN AND MAX SAND VALUES (UPPER TWO ROWS) AND MUD (LOWER TWO ROWS
  4652)  )
      DO  466J=1,NC
      SUB(5,J)=SUB(2,J)-SUB(1,J)
  466 SUB(6,J)=SUB(4,J)-SUB(3,J)
      DO 467 I=1,4
  467 WRITE(6,12)(SUB(I,J),J=1,NC)
      READ(5,FMT9)(SECTOP(I),I=1,LIMIT)
  476 IF(SECTOP(1).EQ.2) GO TO   480
      WRITE(6,475)
  475 FORMAT(  47H1INITIAL DISTRIBUTION OF ORGANISM COMMUNITIES    )
      WRITE (6,4) ALFA1
    4 FORMAT(1H0/20X13A6//)
      CALL MAPLOT (1)
  480 DO 809 L=1,LIMIT
      LX1=MOD(L,2)+1
      LX2=3-LX1
```

```
      LX=LX1                                                            MAIN162
      CIND=MOD(L,CLN)                                                   MAIN163
      IF(CIND.EQ.0) CIND=CLN                                            MAIN164
C         SECTION FOR INFLUENCE OF WIND FROM NORTH                      MAIN165
      IF(WEST.EQ.1.AND.CFC(CIND,FAV).GE.FF) GO TO   488                 MAIN166
      GO TO 499                                                         MAIN167
  488 DO   497 I=1,N                                                    MAIN168
      DO 497 J =5,M                                                     MAIN169
      IF(MAP(I,J,LX1).NE.FAV) GO TO   497                               MAIN170
      IF(MAP(I+1,J-1,LX1).NE.FAV) GO TO   489                           MAIN171
      MAP(I+8,J-4,LX1) =FAV                                             MAIN172
      MAP(I+4,J-3,LX1)=MAP(I+8,J-4,LX1)                                 MAIN173
  489 IF(MAP(I+1,J+1,LX1).NE.FAV) GO TO   497                           MAIN174
      MAP(I+4,J+3,LX1)=FAV                                              MAIN175
      MAP(I+8,J+4,LX1)=FAV                                              MAIN176
  497 CONTINUE                                                          MAIN177
  499 IF(DELTAO.NE.1) GO TO   521                                       MAIN178
      BTR=SAND(CIND)+MUD(CIND)                                          MAIN179
      TT=HT+BTR                                                         MAIN180
      IF(BTR.EQ.0.0) GO TO   502                                        MAIN181
      SANDFA=SAND(CIND)/BTR                                             MAIN182
      MUDFAC=MUD(CIND)/BTR                                              MAIN183
  502 DO   503 I=1,N,1                                                  MAIN184
      DO 503 J=1,M                                                      MAIN185
  503 TER(I,J)=BTR                                                      MAIN186
      DO 513 J=1,M                                                      MAIN187
      AJ =J                                                             MAIN188
      IF(AJ.GT.PTH(CIND,2).AND.AJ.LT.(PTH(CIND,2)+LTH)) GO TO   512     MAIN189
      GO TO 513                                                         MAIN190
  512 DO 513 I=1,N                                                      MAIN191
      P=I                                                               MAIN192
      Q=J                                                               MAIN193
      IF(P.GT.(PTH(CIND,1)-WID).AND.P.LT.(PTH(CIND,1)+WID))GO TO   510  MAIN194
      GO TO 513                                                         MAIN195
  5100TER(I,J)=((HT-(((Q-PTH(CIND,2))/LTH)*HT))*(1.0-ABS(P-PTH(CIND,1)) MAIN196
  5101/WID)) +BTR                                                       MAIN197
  513 CONTINUE                                                          MAIN198
  521 IF(SECTOP(CIND).NE.1) GO TO    530                                MAIN199
      WRITE(6,516) L,UPBND,LOWBND,BTR,TT,LTH,WID,PTH(CIND,2),PTH(CIND,1)MAIN200
  5160FORMAT(67H1RELATIVE RANGES OF TERRESTRIALLY-DERIVED SEDIMENT.     MAIN201
  5161MAP NUMBER  I3,36H (VALUES HAVE BEEN MULTIPLIED BY 10)///43H TRANSMAIN202
  5162ITION DEPTH RANGE FROM UPPER LIMIT OF,F6.1,19H AND LOWER LIMIT OF,MAIN203
  5163F6.1,26H UNITS. BASE-RATE VALUE IS,F6.1,17H MAXIMUM VALUE IS,F6.2 MAIN204
  5164//23H0E/W LENGTH OF DELTA IS,F7.2,18H N/S HALF-WIDTH IS,F7.2,35H UMAIN205
  5165NITS. E/W COORD VALUE OF MOUTH IS,F7.2 ,19H N/S COORD VALUE ISF7.2MAIN206
  5166)                                                                 MAIN207
      WRITE(6,  345)(CT(J), J=1,8,1)                                    MAIN208
  345 FORMAT(//,5X8I15)                                                 MAIN209
      DO 530 I=1,N                                                      MAIN210
      DO 528 J=1,M                                                      MAIN211
  528 DPLOT(J)=TER(I,J)*10.0                                            MAIN212
      WRITE(6,  470) I , (DPLOT(J),J=1,M,1)                             MAIN213
  530 CONTINUE                                                          MAIN214
      DO 1500 I=1,N,1                                                   MAIN215
      DO 1500 J=1,M,1                                                   MAIN216
      MPX =MAP(I,J,LX1)                                                 MAIN217
      MPV =MAP(I,J,LX2)                                                 MAIN218
      S1=IABS(NC-MAP(I,J,LX1)+MAP(I,J,LX2))                             MAIN219
      S2=IABS(MAP(I,J,LX1)-MAP(I,J,LX2))                                MAIN220
      S3=IABS(NC+MAP(I,J,LX1)-MAP(I,J,LX2) )                            MAIN221
```

```
      SEP(I,J,LX1) =IABS(MIN0(S1,S2,S3))+1
      IF(SEP(I,J,LX1).GT.5) SEP(I,J,LX1) = 5
      ISEP=SEP(I,J,LX1)
      JSEP=SEP(I,J,LX2)
      TEND(I,J)=(CFC(CIND,MPX))** (CPX(ISEP,JSEP))
      COMCON=TEND(I,J)
      IF(DPT(I,J).GE.DPL(1,MPX).AND.DPT(I,J).LE.DPL(3,MPX)) GO TO 9000
      IF(DPT(I,J).GE.DPL(3,MPX).AND.DPT(I,J).LE.DPL(2,MPX)) GO TO 8998
      TEND(I,J)=0.03
      GO TO 1500
 8998 COMCON =COMCON*((-DPT(I,J)+DPL(2,MPX))/(DPL(5,MPX)))
      GO TO 9001
 9000 COMCON =COMCON*((DPT(I,J)-DPL(1,MPX))/DPL(4,MPX))
 9001 IF(SF.GE.SUB(2,MPX).OR.MF.GE.SUB(4,MPX)) GO TO 1505
      IF(SF.GT.SUB(1,MPX).OR.MF.GT.SUB(2,MPX)) GO TO 1504
      GO TO 1500
 1504 TAMP =COMCON-(COMCON*((SF-SUB(1,MPX))/SUB(5,MPX)))
      TIMP =COMCON-(COMCON*((MF-SUB(3,MPX))/SUB(6,MPX)))
      IF(TAMP.LT.0.03) TAMP=0.03
      IF(TIMP.LT.0.03) TIMP=0.03
      TEND(I,J) = AMIN1(TAMP,TIMP)
      GO TO 1500
 1505 TEND(I,J) =1.0
 1500 CONTINUE
C          PICK NEW MAP ELEMENTS
      NN =N-2
      MM =M -2
      DO 9998 I=3,NN,1
      DO 9998 J=3,MM,1
C    CONPRO
      SUM=0
      IW=I-2
      IWW=I+2
      JW=J-1
      JWW=J+1
      DO 8169IFD=IW,IWW,4
      DO 8169 JFD=JW,JWW,2
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)
 8169 CONTINUE
      IW=I-1
      IWW=I+1
      JW=J-2
      JWW=J+2
      DO 8170 IFD=IW,IWW,1
      DO 8170 JFD=JW,JWW,4
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)
      CALL FB3SHO
 8170 CONTINUE
      CALL VALSHO
 9998 CONTINUE
      NN=N-2
      DO 9997 I=3,NN,1
      J=2
C    LEINED
      SUM=0
      IW=I-1
      IWW=I+1
      JWJ=J+2
      DO 8369 IFD =IW,IWW,1
      CALL SHORT(LX,FB4,IFD,JWJ,TEND,MAP,SUM,KPF)
 8369 CONTINUE
```

```
      IW=I-2                                                            MAIN283
      IWW=I+2                                                           MAIN284
      JW=J-2                                                            MAIN285
      JWW=J+2                                                           MAIN286
      DO 8370  IFD=IW,IWW,4                                             MAIN287
      DO 8370 JFD=JW,JWW,1                                              MAIN288
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN289
      CALL FB3SHO                                                       MAIN290
 8370 CONTINUE                                                          MAIN291
      CALL VALSHO                                                       MAIN292
      J=M-1                                                             MAIN293
C     RIINED                                                            MAIN294
      SUM=0                                                             MAIN295
      IW=I-1                                                            MAIN296
      IWW=I+1                                                           MAIN297
      JWJ =J-2                                                          MAIN298
      DO 8410 IFD=IW,IWW,1                                              MAIN299
      CALL SHORT(LX,FB4,IFD,JWJ,TEND,MAP,SUM,KPF)                       MAIN300
 8410 CONTINUE                                                          MAIN301
      IX=I-2                                                            MAIN302
      IXX=I+2                                                           MAIN303
      JZ=J-1                                                            MAIN304
      JZZ=J+1                                                           MAIN305
      DO 8411IFD=IX,IXX,4                                               MAIN306
      DO 8411 JFD=JZ,JZZ,1                                              MAIN307
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN308
      CALL FB3SHO                                                       MAIN309
 8411 CONTINUE                                                          MAIN310
      CALL VALSHO                                                       MAIN311
      J=M                                                               MAIN312
C     RIOUED                                                            MAIN313
      SUM=0                                                             MAIN314
      IW=I-1                                                            MAIN315
      IWW=I+1                                                           MAIN316
      JWJ=J-2                                                           MAIN317
      DO 8510 IFD=IW,IWW,1                                              MAIN318
      CALL SHORT(LX,FB4,IFD,JWJ,TEND,MAP,SUM,KPF)                       MAIN319
 8510 CONTINUE                                                          MAIN320
      IX=I-2                                                            MAIN321
      IXX=I+2                                                           MAIN322
      JX=J-1                                                            MAIN323
      JXX=J                                                             MAIN324
      DO 8511 IFD=IX,IXX,4                                              MAIN325
      DO 8511 JFD=JX,JXX,1                                              MAIN326
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN327
 8511 CONTINUE                                                          MAIN328
      IZ=I-1                                                            MAIN329
      IZZ=I+1                                                           MAIN330
      JWX=J-1                                                           MAIN331
      DO 8512 IFD=IZ,IZZ,2                                              MAIN332
      CALL SHORT(LX,FB3,IFD,JWX,TEND,MAP,SUM,KPF)                       MAIN333
 8512 CONTINUE                                                          MAIN334
      IWX=I-1                                                           MAIN335
      IWXX=I+1                                                          MAIN336
      DO 8513 IFD=IWX,IWXX,2                                            MAIN337
      CALL SHORT(LX,FB2,IFD,J,TEND,MAP,SUM,KPF)                         MAIN338
      CALL SHORT(LX,FB2,I,JWX,TEND,MAP,SUM,KPF)                         MAIN339
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)                           MAIN340
 8513 CONTINUE                                                          MAIN341
      CALL VALSHO                                                       MAIN342
      J=1                                                               MAIN343
```

```
C     LEOUED
      SUM=0
      IW=I-2
      IWW=I+2
      JW=J
      JWW=J+1
      DO 8269 IFD=IW,IWW,4
      DO 8269 JFD=JW,JWW
 8269 CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)
      IW=I-1
      IWW=I+1
      JWJ=J+2
      DO 8270 IFD=IW,IWW,1
      CALL SHORT(LX,FB4,IFD,JWJ,TEND,MAP,SUM,KPF)
 8270 CONTINUE
      JWJ=J+1
      DO 8271 IFD=IW,IWW,1
      CALL SHORT(LX,FB3,IFD,JWJ,TEND,MAP,SUM,KPF)
 8271 CONTINUE
      JWJ=J+1
      DO 8272 IFD=IW,IWW,2
      CALL SHORT(LX,FB2,IFD,J,TEND,MAP,SUM,KPF)
      CALL SHORT(LX,FB2,I,JWJ,TEND,MAP,SUM,KPF)
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)
 8272 CONTINUE
      CALL VALSHO
 9997 CONTINUE
      DO 9996 I=1,2,1
      DO 9996 J=1,2,1
C     UPLECO
      SUM =0
      DO 7110 IFD=1,4,1
      JFD=5-IFD
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)
 7110 CONTINUE
      DO 7111 IFD=1,3,1
      JFD=4-IFD
      CALL SHORT(LX,FB3,IFD,JFD,TEND,MAP,SUM,KPF)
 7111 CONTINUE
      DO 7112 IFD=1,2,1
      JFD=3-IFD
      CALL SHORT(LX,FB2,IFD,JFD,TEND,MAP,SUM,KPF)
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)
 7112 CONTINUE
      CALL VALSHO
 9996 CONTINUE
      LW=N-1
      LLW=M-1
      DO 9995 I=LW,N
      DO 9995 J=1,2,1
C     LOLECO
      SUM =0
      IW=I-3
      DO 7210 IFD =IW,I,1
      JFD=IFD-I+4
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)
 7210 CONTINUE
      IWW=I-2
      DO 7211 IFD=IWW,I,1
      JFD =IFD-I+3
      CALL SHORT(LX,FB3,IFD,JFD,TEND,MAP,SUM,KPF)
```

```
 7211 CONTINUE                                                          MAIN405
      IWL =I-1                                                          MAIN406
      DO 7212 IFD=IWL,I,1                                               MAIN407
      JFD=IFD-I+2                                                       MAIN408
      CALL SHORT(LX,FB2,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN409
 7212 CONTINUE                                                          MAIN410
      IFD=I                                                             MAIN411
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)                           MAIN412
      CALL VALSHO                                                       MAIN413
 9995 CONTINUE                                                          MAIN414
      DO 9994 I=LW,N,1                                                  MAIN415
      DO 9994 J=LLW,M,1                                                 MAIN416
C     LORICO                                                            MAIN417
      SUM =0                                                            MAIN418
      IW=I-3                                                            MAIN419
      DO 7410 IFD=IW,I,1                                                MAIN420
      JFD=J+IFD-I                                                       MAIN421
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN422
 7410 CONTINUE                                                          MAIN423
      IW=I-2                                                            MAIN424
      DO 7411 IFD=IW,I,1                                                MAIN425
      JFD=J-I+IFD                                                       MAIN426
      CALL SHORT(LX,FB3,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN427
 7411 CONTINUE                                                          MAIN428
      IW=I-1                                                            MAIN429
      DO 7412 IFD=IW,I,1                                                MAIN430
      JFD=J-I+IFD                                                       MAIN431
      CALL SHORT(LX,FB2,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN432
 7412 CONTINUE                                                          MAIN433
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)                           MAIN434
      CALL VALSHO                                                       MAIN435
 9994 CONTINUE                                                          MAIN436
      DO 9993 I=1,2,1                                                   MAIN437
      DO 9993 J=LLW,M,1                                                 MAIN438
C     UPRICO                                                            MAIN439
      SUM =0                                                            MAIN440
      DO 7310 IFD=1,4,1                                                 MAIN441
      JFD=(J-4+IFD)                                                     MAIN442
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN443
 7310 CONTINUE                                                          MAIN444
      DO 7311 IFD=1,3,1                                                 MAIN445
      JFD=J-3+IFD                                                       MAIN446
      CALL SHORT(LX,FB3,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN447
 7311 CONTINUE                                                          MAIN448
      DO 7312 IFD =1,2,1                                                MAIN449
      JFD=J-2+IFD                                                       MAIN450
      CALL SHORT(LX,FB2,IFD,JFD,TEND,MAP,SUM,KPF      )                 MAIN451
 7312 CONTINUE                                                          MAIN452
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)                           MAIN453
      CALL VALSHO                                                       MAIN454
 9993 CONTINUE                                                          MAIN455
      MM=M-2                                                            MAIN456
      DO 9992 J=3,MM,1                                                  MAIN457
      I=2                                                               MAIN458
C     UPINED                                                            MAIN459
      SUM=0                                                             MAIN460
      JW=J-1                                                            MAIN461
      JWW=J+1                                                           MAIN462
      IWI=I+2                                                           MAIN463
      DO 8610 JFD =JW,JWW                                               MAIN464
      CALL SHORT(LX,FB4,IWI,JFD,TEND,MAP,SUM,KPF)                       MAIN465
```

```
 8610 CONTINUE                                                          MAIN466
      IW=I-1                                                            MAIN467
      IWW=I+1                                                           MAIN468
      JWX=J-2                                                           MAIN469
      JWY=J+2                                                           MAIN470
      DO 8611 IFD =IW,IWW                                               MAIN471
      DO 8611 JFD =JWX,JWY,4                                            MAIN472
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN473
      CALL FB3SHO                                                       MAIN474
 8611 CONTINUE                                                          MAIN475
      CALL VALSHO                                                       MAIN476
      I=1                                                               MAIN477
C    UPOUED                                                             MAIN478
      SUM=0                                                             MAIN479
      IWI=I+2                                                           MAIN480
      IWII=I+1                                                          MAIN481
      IW=I+1                                                            MAIN482
      JW=J-2                                                            MAIN483
      JWW=J+2                                                           MAIN484
      DO 8710 IFD=I,IW                                                  MAIN485
      DO 8710 JFD =JW,JWW,4                                             MAIN486
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN487
 8710 CONTINUE                                                          MAIN488
      JW1=J-1                                                           MAIN489
      JW2=J+1                                                           MAIN490
      IW2=I+2                                                           MAIN491
      DO 8711 JFD=JW1,JW2                                               MAIN492
      CALL SHORT(LX,FB4,IW2,JFD,TEND,MAP,SUM,KPF)                       MAIN493
 8711 CONTINUE                                                          MAIN494
      DO 8712 JFD=JW1,JW2,2                                             MAIN495
      CALL SHORT(LX,FB3,I1I,JFD,TEND,MAP,SUM,KPF)                       MAIN496
 8712 CONTINUE                                                          MAIN497
      DO 8713 JFD=JW1,JW2,2                                             MAIN498
      CALL SHORT(LX,FB2,I,JFD,TEND,MAP,SUM,KPF)                         MAIN499
      CALL SHORT(LX,FB2,I1I,J,TEND,MAP,SUM,KPF)                         MAIN500
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)                           MAIN501
 8713 CONTINUE                                                          MAIN502
      CALL VALSHO                                                       MAIN503
      I=N-1                                                             MAIN504
C     LOINED                                                            MAIN505
      SUM =0                                                            MAIN506
      IW =I-1                                                           MAIN507
      IWW=I+1                                                           MAIN508
      JW =J-2                                                           MAIN509
      JWW =4+2                                                          MAIN510
      IWI =I-2                                                          MAIN511
      DO 8810 IFD=IW,IWW,1                                              MAIN512
      DO 8810 JFD=JW,JWW,4                                              MAIN513
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN514
 8810 CONTINUE                                                          MAIN515
      JW1=J-1                                                           MAIN516
      JW2=J+1                                                           MAIN517
      DO 8811 JFD=JW1,JW2                                               MAIN518
      CALL SHORT(LX,FB4,IWI,JFD,TEND,MAP,SUM,KPF)                       MAIN519
      CALL FB3SHO                                                       MAIN520
 8811 CONTINUE                                                          MAIN521
      CALL VALSHO                                                       MAIN522
      I=N                                                               MAIN523
C    LOOUED                                                             MAIN524
      SUM =0                                                            MAIN525
      IW =I-1                                                           MAIN526
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      JW =J-2                                                           MAIN527
      JWW=J+2                                                           MAIN528
      DO 8910 IFD =IW,I                                                 MAIN529
      DO 8910 JFD=JW,JWW,4                                              MAIN530
      CALL SHORT(LX,FB4,IFD,JFD,TEND,MAP,SUM,KPF)                       MAIN531
 8910 CONTINUE                                                          MAIN532
      JX =J-1                                                           MAIN533
      JXX=J+1                                                           MAIN534
      IWI=I-2                                                           MAIN535
      DO 8911 JFD=JX,JXX,1                                              MAIN536
      CALL SHORT(LX,FB4,IWI,JFD,TEND,MAP,SUM,KPF)                       MAIN537
 8911 CONTINUE                                                          MAIN538
       DO 8912 JFD=JX,JXX,2                                             MAIN539
      CALL SHORT(LX,FB3,IW,JFD,TEND,MAP,SUM,KPF)                        MAIN540
 8912 CONTINUE                                                          MAIN541
      DO 8913 JFD=JX,JXX,2                                              MAIN542
      CALL SHORT(LX,FB2,I,JFD,TEND,MAP,SUM,KPF)                         MAIN543
      CALL SHORT(LX,FB2,IW,J,TEND,MAP,SUM,KPF)                          MAIN544
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)                           MAIN545
 8913 CONTINUE                                                          MAIN546
      CALL VALSHO                                                       MAIN547
 9992 CONTINUE                                                          MAIN548
      DO 130 I=1,N                                                      MAIN549
      DO 130 J=1,M                                                      MAIN550
      K=1                                                               MAIN551
      IW=MAP(I,J,LX2)                                                   MAIN552
  120 IF(DPT(I,J).GE.DPL(1,IW).AND.DPT(I,J).LE.DPL(2,IW)) GO TO 130     MAIN553
      MAP(I,J,LX2)=MOD(MAP(I,J,LX2),NC)+1                               MAIN554
      K=K+1                                                             MAIN555
      IF(K.EQ.(NC+1)) GO TO 130                                         MAIN556
      GO TO 120                                                         MAIN557
  130 CONTINUE                                                          MAIN558
      IF(TECTOP.NE.1) GO TO   689                                       MAIN559
      IF(SECTOP(CIND).EQ.2) GO TO   689                                 MAIN560
      WRITE(6,131)         L                                            MAIN561
  131 FORMAT(36H1DEPTH IN TENS OF UNITS, MAP NUMBER ,I3   )             MAIN562
      WRITE(6,345)(CT(J),J=1,8)                                         MAIN563
  132 FORMAT(//3X,8I15)                                                 MAIN564
      DO 135 I=1,N                                                      MAIN565
      DO 4069 J = 1,M,1                                                 MAIN566
      MPX =MAP(I,J,LX1)                                                 MAIN567
      MPV =MAP(I,J,LX2)                                                 MAIN568
      TEMP(I,J)=DPT(I,J)+TCT(I,J)                                       MAIN569
      DTH=TEMP(I,J)                                                     MAIN570
      K=1                                                               MAIN571
      IF(DTH.LT.UPBND) GO TO 4001                                       MAIN572
      IF(DTH.GE.UPBND.AND.DTH.LE.LOWBND) GO TO 4002                     MAIN573
      DTH=DTH-TER(I,J)                                                  MAIN574
      GO TO 110                                                         MAIN575
 4001 TERINC(I,J)=0.0                                                   MAIN576
      GO TO 4000                                                        MAIN577
 4002 DTH =DTH-(TER(I,J)*((DTH-UPBND)/DIFF))                            MAIN578
  110 IF(DTH.LT.UPBND) DTH=UPBND                                        MAIN579
      TERINC(I,J)=TEMP(I,J)-DTH                                         MAIN580
 4000 SF=SANDFA*TER(I,J)                                                MAIN581
      MF=MUDFAC*TER(I,J)                                                MAIN582
      CALL FAVDEP                                                       MAIN583
      DEPTH=DTH-COMCON                                                  MAIN584
      MPV =MAP(I,J,LX2)                                                 MAIN585
      IF(DEPTH.GE.DPL(1,MPV).AND.DEPTH.LE.DPL(2,MPV)) GO TO   674       MAIN586
      IF(DEPTH.LT.DPL(1,MPV).AND.DTH.GE.DPL(1,MPV)) GO TO   677         MAIN587
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      DO    673 IDUM=1,1000,1                                           MAIN588
      MPV =MAP(I,J,LX2)                                                 MAIN589
      K=K+1                                                             MAIN590
      IF(DEPTH.GE.DPL(1,MPV).AND.DEPTH.LE.DPL(2,MPV)) GO TO   674       MAIN591
      IF(K.EQ.(NC+1))GO TO   676                                        MAIN592
      MAP(I,J,LX2)=MOD(MAP(I,J,LX2),NC)+1                               MAIN593
      MPV=MAP(I,J,LX2)                                                  MAIN594
      CALL FAVDEP                                                       MAIN595
      MPV =MAP(I,J,LX2)                                                 MAIN596
      DEPTH=DTH-COMCON                                                  MAIN597
      IF(DEPTH.LT.DPL(1,MPV).AND.DTH.GE.DPL(1,MPV)) GO TO   675         MAIN598
  673 CONTINUE                                                          MAIN599
      GO TO 674                                                         MAIN600
  676 DPT(I,J)=DTH                                                      MAIN601
      GO TO 678                                                         MAIN602
  674 DPT(I,J) = DEPTH                                                  MAIN603
      GO TO 678                                                         MAIN604
  677 DPT(I,J)=DPL(1,MPV)                                               MAIN605
      GO TO 678                                                         MAIN606
  675 DPT(I,J)=DPL(1,MPV)                                               MAIN607
  678 DPLOT(J)=DPT(I,J)                                                 MAIN608
      ORGINC(I,J)=TEMP(I,J)-DPT(I,J)-TERINC(I,J)                        MAIN609
 4069 CONTINUE                                                          MAIN610
      IF(SECTOP(CIND).EQ.2) GO TO   689                                 MAIN611
  682 FORMAT(/1X,43I3)                                                  MAIN612
      WRITE(6,  470)I,(DPLOT(K),K=1,M,1)                                MAIN613
  135 CONTINUE                                                          MAIN614
  689 IF(STRUC.NE.1) GO TO 704                                          MAIN615
      IF(L.NE.HOR) GO TO   692                                          MAIN616
      DO 691 I =1,N                                                     MAIN617
      DO 691 J=1,M                                                      MAIN618
  691 STRUCT(I,J) =DPT(I,J)                                             MAIN619
  692 IF(L.LE.HOR)GO TO 695                                             MAIN620
      DO 693 I =1,N                                                     MAIN621
      DO 693 J =1,M                                                     MAIN622
  693 STRUCT(I,J)=STRUCT(I,J)+TCT(I,J)                                  MAIN623
  695 IF(SECTOP(CIND).NE.1) GO TO   704                                 MAIN624
      WRITE(6,694) L                                                    MAIN625
  694 FORMAT( 15H1STRUCTURE MAP ,I3 //)                                 MAIN626
      WRITE(6,  345)(CT(J), J=1,8,1)                                    MAIN627
      DO 703I=1,N                                                       MAIN628
      DO 702 J=1,M                                                      MAIN629
  702 DPLOT(J)=STRUCT(I,J)                                              MAIN630
  703 WRITE(6,470)I,(DPLOT(J),J=1,M)                                    MAIN631
  704 LOWBEA=5.0                                                        MAIN632
      BEACHF=10.0                                                       MAIN633
      IF(SECTOP(CIND).EQ.2) GO TO   713                                 MAIN634
  7060FORMAT( 55H1ORGANIC INCREMENT VALUES MULTIPLIED BY 10, MAP NUMBER MAIN635
  7061,I4)                                                              MAIN636
      WRITE(6,706)    L                                                 MAIN637
      WRITE(6,  345)(CT(J), J=1,8,1)                                    MAIN638
      DO 711 I=1,N                                                      MAIN639
      DO 710 J=1,M                                                      MAIN640
  710 DPLOT(J)=ORGINC(I,J)*10.0                                         MAIN641
  711 WRITE(6,470)I,(DPLOT(J),J=1,M)                                    MAIN642
  713 DO 743 I=1,N                                                      MAIN643
      DO 743 J=1,M                                                      MAIN644
      SANDCO=SAND(CIND)                                                 MAIN645
      IF(DPT(I,J).GE.0.0.AND.DPT(I,J).LE.LOWBEA) SANDCO=SANDCO+(LOWBEA- MAIN646
     1DPT(I,J))*BEACHF                                                  MAIN647
      SUMTER=MUD(CIND)+SANDCO                                           MAIN648
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     IF(SUMTER.NE.0.0) GO TO   721                                     MAIN649
     RATIO=TERINC(I,J)/(MUD(CIND)+SANDCO)                              MAIN650
     GO TO 722                                                         MAIN651
 721 RATIO =1.0                                                        MAIN652
 722 MUDINC(I,J)=MUD(CIND)*RATIO                                       MAIN653
     SANDIN(I,J)=SANDCO*RATIO                                          MAIN654
     HV = AMAX1(ORGINC(I,J),MUDINC(I,J),SANDIN(I,J))                   MAIN655
     IF(HV.NE.ORGINC(I,J)) GO TO   732                                 MAIN656
     MAP(I,J,3)=MAP(I,J,LX2)                                           MAIN657
     DO 736 I1I =1,3                                                   MAIN658
     IF(J.EQ.KK1(I1I)) PVP(I,L,I1I) =MAP(I,J,LX2)                      MAIN659
 736 IF(I.EQ.KD1(I1I)) PPP(J,L,I1I) =MAP  (I,J,LX2)                    MAIN660
     GO TO 743                                                         MAIN661
 732 IF(HV.NE.MUDINC(I,J)) GO TO 739                                   MAIN662
     MAP(I,J,3) =11                                                    MAIN663
     DO 737 I2I =1,3                                                   MAIN664
     IF(J.EQ.KK1(I2I)) PVP(I,L,I2I) =11                                MAIN665
 737 IF(I.EQ.KD1(I2I)) PPP(J,L,I2I) =11                                MAIN666
     GO TO 743                                                         MAIN667
 739 MAP(I,J,3)=7                                                      MAIN668
     DO 742 I3I =1,3                                                   MAIN669
     IF(J.EQ.KK1(I3I)) PVP(I,L,I3I) =7                                 MAIN670
 742 IF(I.EQ.KD1(I3I)) PPP(J,L,I3I) =7                                 MAIN671
 743 CONTINUE                                                          MAIN672
     IF(SECTOP(CIND).EQ.2) GO TO   751                                 MAIN673
 745 FORMAT(11H1FACIES MAP )                                           MAIN674
 746 FORMAT(23H1ORGANISM COMMUNITY MAP )                               MAIN675
     WRITE(6,745)                                                      MAIN676
     WRITE (6,4) ALFA1                                                 MAIN677
     CALL MAPLOT (3)                                                   MAIN678
     WRITE(6,746)                                                      MAIN679
     WRITE (6,4) ALFA1                                                 MAIN680
     CALL MAPLOT (LX2)                                                 MAIN681
 751 IF(SECTOP(CIND).LE.0) GO TO   809                                 MAIN682
     DO 808 IREP=1,2                                                   MAIN683
     DO 750 IBUN=1,127                                                 MAIN684
 750 DPLOT(IBUN)=BLANK                                                 MAIN685
     DO 783 I4I =1,3                                                   MAIN686
     IF(KK1(I4I).LE.0) GO TO 783                                       MAIN687
     KK =KK1(I4I)                                                      MAIN688
 757 FORMAT(/2XI2,1X127A1)                                             MAIN689
 7530FORMAT( 22H1STRATIGRAPHIC SECTIONI4,14H ALONG COLUMN I2,27H SCALEDMAIN690
 7531 SO THAT 1/10 INCH = ,F5.2, 39H   THICKNESS UNITS, AND BASE IS SETMAIN691
 7532 AT ,F5.2,  6H UNITS  )                                           MAIN692
     IF(IREP.EQ.2.AND.MIROR(I4I).LE.0) GO TO 783                       MAIN692A
     WRITE(6,  753) L,KK,SCALE,BASE                                    MAIN693
     IF(IREP.EQ.1) WRITE(6,999)                                        MAIN694
     IF (IREP.EQ.2.AND.MIROR(I4I).GT.0) WRITE(6,778)                   MAIN695
 778 FORMAT(17H0IN MIRROR IMAGE       )                                MAIN696
 999 FORMAT(1H0)                                                       MAIN697
     WRITE (6,4) ALFA1                                                 MAIN698
     DO 782 I=1,N                                                      MAIN699
     IF(IREP.EQ.2) GO TO 763                                           MAIN700
     THKFL1=(TEMP(I,KK)-DPT(I,KK))*SCALE                               MAIN701
     THKFX=THKFL1                                                      MAIN702
     THKFL2=THKFX                                                      MAIN703
     IF(THKFL1-THKFL2.GT.0.5) THKFX=THKFX+1                            MAIN704
     PVP(I,L,I4I) =PVP(I,L,I4I)+(THKFX*100)                            MAIN705
 763 IF(DPT(I,KK).LE.BASE) GO TO   769                                 MAIN706
     WATER=(DPT(I,KK)-BASE)*SCALE                                      MAIN707
     WTRFX=WATER                                                       MAIN708
```

```
      WTRFL=WTRFX                                                       MAIN709
      IF(WATER-WTRFL.GT.0.5)WTRFX=WTRFX+1                               MAIN710
      DO 768 J =1,WTRFX                                                 MAIN711
  768 DPLOT(J) =SMB(26)                                                 MAIN712
      KTR=WTRFX                                                         MAIN713
      GO TO 770                                                         MAIN714
  769 KTR =0                                                            MAIN715
  770 ILW =L                                                            MAIN716
      DO 777 JXJ =1,ILW                                                 MAIN717
      JJ = (ILW+1)-JXJ                                                  MAIN718
      IMXT=IDKOD(PVP(I,JJ,I4I),1)                                       MAIN719
      IPV=IDKOD( PVP(I,JJ,I4I),2)                                       MAIN720
      DO 777 LL=1,IMXT                                                  MAIN721
      KTR=KTR+1                                                         MAIN722
      DPLOT(KTR) =SMB(IPV)                                              MAIN723
  777 CONTINUE                                                          MAIN724
      IF(KTR.GT.127) KTR=127                                            MAIN725
      IF(IREP.EQ.1) GO TO 781                                           MAIN726
      IF(MIROR(I4I).LE.0) GO TO 782                                     MAIN727
      DO 780 MZP=1,64                                                   MAIN728
      MZPP=128-MZP                                                      MAIN729
      ITMPRY =DPLOT(MZPP)                                               MAIN730
      DPLOT(MZPP)=DPLOT(MZP)                                            MAIN731
  780 DPLOT(MZP)=ITMPRY                                                 MAIN732
      WRITE(6,779) DPLOT,I                                              MAIN733
  779 FORMAT(/2X127A1,1XI2)                                             MAIN734
      DO 2778 MZQ=1,127                                                 MAIN735
 2778 DPLOT(MZQ)=BLANK                                                  MAIN736
      GO TO 782                                                         MAIN737
  781 WRITE(6,757)I,(DPLOT(J),J=1,KTR)                                  MAIN738
  782 CONTINUE                                                          MAIN739
  783 CONTINUE                                                          MAIN740
  784 DO 807 I6I=1,3                                                    MAIN741
      IF(KD1(I6I).LE.0) GO TO  807                                      MAIN742
      KD =KD1(I6I)                                                      MAIN743
  786 FORMAT( 23H1STRATIGRAPHIC SECTION ,I4,12H ALONG ROW  ,I2,28H SCALEMAIN744
  7861D SO THAT 1/10 INCH = ,F5.2, 37H THICKNESS UNITS , AND BASE IS SETMAIN745
  7862 AT,F5.2,6H UNITS       )                                         MAIN746
      IF(IREP.EQ.2.AND.MIROR(I6I+3).LE.0) GO TO 807                     MAIN746A
  818 WRITE(6,  786)L,KD,SCALE,BASE                                     MAIN747
      IF(IREP.EQ.1) WRITE(6,999)                                        MAIN748
      IF(IREP.EQ.2.AND.MIROR(I6I+3).GT.0) WRITE(6,778)                  MAIN749
      WRITE (6,4) ALFA1                                                 MAIN750
      DO 806 JQ1=1,M                                                    MAIN751
      J =M+1-JQ1                                                        MAIN752
      IF(IREP.EQ.2) GO TO 790                                           MAIN753
      THKFL1=(TEMP(KD,J)-DPT(KD,J))*SCALE                               MAIN754
      THKFX=THKFL1                                                      MAIN755
      THKFL2=THKFX                                                      MAIN756
      IF(THKFL1-THKFL2.GT.0.5) THKFX=THKFX+1                            MAIN757
      PPP(J,L,I6I)=PPP(J,L,I6I)+(THKFX*100)                             MAIN758
  790 IF(DPT(KD,J).LE.BASE) GO TO   795                                 MAIN759
      WATER=(DPT(KD,J)-BASE)*SCALE                                      MAIN760
      WTRFX=WATER                                                       MAIN761
      WTRFL=WTRFX                                                       MAIN762
      IF(WATER-  WTRFL.GT.0.5) WTRFX=WTRFX+1                            MAIN763
      DO 794 I=1,WTRFX                                                  MAIN764
  794 DPLOT(I) =SMB(26)                                                 MAIN765
      KTR=WTRFX                                                         MAIN766
      GO TO 796                                                         MAIN767
  795 KTR =0                                                            MAIN768
```

```
  796 ILXW =L                                                            MAIN769
      DO 802 JUG =1,ILXW                                                 MAIN770
      JJ =(ILXW+1)-JUG                                                   MAIN771
      ISO1=IDKOD(PPP(J,JJ,I6I),1)                                        MAIN772
      IGUESS=IDKOD(PPP(J,JJ,I6I),2)                                      MAIN773
      DO 802 LL =1,ISO1                                                  MAIN774
      KTR=KTR+1                                                          MAIN775
      DPLOT(KTR) = SMB(IGUESS)                                           MAIN776
  802 CONTINUE                                                           MAIN777
      IF(KTR.GT.127) KTR=127                                             MAIN778
      IF(IREP.EQ.1) GO TO 801                                            MAIN779
      IF(MIROR(I6I+3).LE.0) GO TO 805                                    MAIN780
      DO 804 MZP=1,64                                                    MAIN781
      MZPP=128-MZP                                                       MAIN782
      ITMPRY =DPLOT(MZPP)                                                MAIN783
      DPLOT(MZPP)=DPLOT(MZP)                                             MAIN784
  804 DPLOT(MZP)=ITMPRY                                                  MAIN785
      WRITE(6,779) DPLOT,J                                               MAIN786
      DO 803 MZQ=1,127                                                   MAIN787
  803 DPLOT(MZQ)=BLANK                                                   MAIN788
      GO TO 805                                                          MAIN789
  801 WRITE(6,757)J,(DPLOT(I),I=1,KTR)                                   MAIN790
  805 CONTINUE                                                           MAIN791
  806 CONTINUE                                                           MAIN792
  807 CONTINUE                                                           MAIN793
  808 CONTINUE                                                           MAIN794
  809 CONTINUE                                                           MAIN795
      READ(5,2) ITEST                                                    MAIN796
    5 FORMAT(5A6)                                                        MAIN797
      IF(ITEST-1) 810,4444,11                                            MAIN798
  810 CALL EXIT                                                          MAIN799
      END                                                                MAIN800

      SUBROUTINE MAPLOT(LL)                                              MAPL   1
      INTEGER DLT,FAV,CLN,DPLOT,SECTOP,PPP,PVP,SEP,CT,TPL,DATOP,WEST,DELMAPL   2
     2TAO,TECTOP,STRUC,HOR,CIND,THKFX,WTRFX,S1,S2,S3,SUM,SMB             MAPL   3
      REAL LOWBEA,LOWBND,MUDFAC,ME,MUD,MUDINC,LFL,LTH,MF                 MAPL   4
     0 COMMON   TCT(20,40),DPL(8,10),SED(10,10),DPT(20,40),SAND(20),TER(MAPL   5
     120,40),SANDIN(20,40),TERINC(20,40),ORGINC(20,40),STRUCT(20,40),TENMAPL   6
     2D(20,40),CPX(5,5),TF(5),CFC(20,10),SUB(6,10),TEMP(20,40),MAP(20,40MAPL   7
     3,3),KPF(1000),PTH(20,2),LFL,LTH,MF,SUM, FB1,FB2,FB3,FB4,I,J,LX,LX1MAPL   8
     4,LX2,DTH,FAV,CLN,DPLOT(127),SECTOP(20),COMCON,DLT ,SEP(20,40,2),  MAPL   9
     5 CT(8),L,M,N,SF,LIMIT,TPL,DATOP,WEST,DELTAO,TECTOP,STRUC,HOR,SMB(3MAPL  10
     60),CIND,S1,S2,S3,LOWBEA,LOWBND,MUDFAC,MUD(20),MUDINC(20,40)        MAPL  11
C        SUBROUTINE MAPLOT PLOTS ALPHAMETRIC SYMBOLS REPRESENTING SEDIMEMAPL  12
C        / ORGANISM COMMUNITY ELEMENTS.                                  MAPL  13
      WRITE(6,2) L                                                       MAPL  14
    2 FORMAT(/ 50X,10HMAP NUMBER  ,I4 )                                  MAPL  15
    3 WRITE(6,4)(CT(JW),JW=1,8)                                          MAPL  16
    4 FORMAT(// ,3X,8I15    )                                            MAPL  17
      DO 5 IW =1,N                                                       MAPL  18
      DO 6 JW =1,M                                                       MAPL  19
      IGUESS =MAP(IW,JW,LL)                                              MAPL  20
    6 DPLOT(JW) = SMB(IGUESS)                                            MAPL  21
    5 WRITE(6,7) IW,(DPLOT(JW),JW=1,M)                                   MAPL  22
    7 FORMAT(/ I3,2X,42A3 )                                              MAPL  23
      RETURN                                                             MAPL  24
      END                                                                MAPL  25
      SUBROUTINE SHORT(LX,FBX,I,J,TEND,MAP,SUM,KPF)                      SHOR   1
      INTEGER  SUM                                                       SHOR   2
      DIMENSION TEND(15,40),MAP(15,40,3), KPF(1000)                      SHOR   3
```

```
      INTEGER SUM,MAP,KPF
      SUM=SUM+2
      KPF(SUM-1)=FBX*TEND(I,J)
      KPF(SUM)=MAP(I,J,LX)
      RETURN
      END
      SUBROUTINE  FAVDEP
      INTEGER DLT,FAV,CLN,DPLOT,SECTOP,PPP,PVP,SEP,CT,TPL,DATOP,WEST,DEL
     2TAO,TECTOP,STRUC,HOR,CIND,THKFX,WTRFX,S1,S2,S3,SUM,SMB
      REAL LOWBEA,LOWBND,MUDFAC,ME,MUD,MUDINC,LFL,LTH,MF
     0 COMMON    TCT(20,40),DPL(8,10),SED(10,10),DPT(20,40),SAND(20),TER(
     120,40),SANDIN(20,40),TERINC(20,40),ORGINC(20,40),STRUCT(20,40),TEN
     2D(20,40),CPX(5,5),TF(5),CFC(20,10),SUB(6,10),TEMP(20,40),MAP(20,40
     3,3),KPF(1000),PTH(20,2),LFL,LTH,MF,SUM, FB1,FB2,FB3,FB4,I,J,LX,LX1
     4,LX2,DTH,FAV,CLN,DPLOT(127),SECTOP(20),COMCON,DLT ,SEP(20,40,2),
     5 CT(8),L,M,N,SF,LIMIT,TPL,DATOP,WEST,DELTAO,TECTOP,STRUC,HOR,SMB(3
     60),CIND,S1,S2,S3,LOWBEA,LOWBND,MUDFAC,MUD(20),MUDINC(20,40)
      MW=MAP(I,J,LX2)
      IF(DTH.GE.DPL(1,MW).AND.DTH.LE.DPL(3,MW)) GO TO 99
      IF(DTH.GE.DPL(3,MW).AND.DTH.LE.DPL(2,MW)) GO TO 102
   98 COMCON=0.0
      RETURN
   99 COMCON =((DTH-DPL(1,MW))/DPL(4,MW))*SED(CIND,MW)
      GO TO 103
  102 COMCON =((-DTH+DPL(2,MW))/DPL(5,MW))*SED(CIND,MW)
  103 IF(SF.GE.SUB(2,MW).OR.MF.GE.SUB(4,MW)) GO TO 98
      IF(SF.GT.SUB(1,MW).OR.MF.GT.SUB(2,MW)) GO TO 105
  104 RETURN
  105 TAMP=COMCON-(COMCON*(SF-SUB(1,MW))/SUB(5,MW))
      TIMP=COMCON-(COMCON*(MF-SUB(3,MW))/SUB(6,MW))
      IF(TAMP.LT.0.0) TAMP=0.0
      IF(TIMP.LT.0.0) TIMP=0.0
      COMCON = AMIN1(TAMP,TIMP)
      RETURN
      END
      SUBROUTINE  VALSHO
      INTEGER TOTAL,SUM,VLL,CHOICE
      INTEGER DLT,FAV,CLN,DPLOT,SECTOP,PPP,PVP,SEP,CT,TPL,DATOP,WEST,DEL
     2TAO,TECTOP,STRUC,HOR,CIND,THKFX,WTRFX,S1,S2,S3,SUM,SMB
      REAL LOWBEA,LOWBND,MUDFAC,ME,MUD,MUDINC,LFL,LTH,MF
     0 COMMON    TCT(20,40),DPL(8,10),SED(10,10),DPT(20,40),SAND(20),TER(
     120,40),SANDIN(20,40),TERINC(20,40),ORGINC(20,40),STRUCT(20,40),TEN
     2D(20,40),CPX(5,5),TF(5),CFC(20,10),SUB(6,10),TEMP(20,40),MAP(20,40
     3,3),KPF(1000),PTH(20,2),LFL,LTH,MF,SUM, FB1,FB2,FB3,FB4,I,J,LX,LX1
     4,LX2,DTH,FAV,CLN,DPLOT(127),SECTOP(20),COMCON,DLT ,SEP(20,40,2),
     5 CT(8),L,M,N,SF,LIMIT,TPL,DATOP,WEST,DELTAO,TECTOP,STRUC,HOR,SMB(3
     60),CIND,S1,S2,S3,LOWBEA,LOWBND,MUDFAC,MUD(20),MUDINC(20,40)
      LX1=3-LX2
      ISUM=SUM-1
      DO 10 K=1,ISUM,2
      TOTAL=TOTAL+KPF(K)
   10 CONTINUE
      KPF(SUM+1)=TOTAL/10
      KPF(SUM+2)=MOD(MAP(I,J,LX1),NC)+1
      TOTAL=TOTAL+KPF(SUM+1)
      ATOTAL =TOTAL+KPF(SUM+1)
      IF(TF(5).GT.0.0) GO TO 4
      TF(5)=10.0
      Y=AMOD((TF(1)*TF(3)+TF(2))*1.0E-8,1.)
      GO TO 6
    4 Y=AMOD((TF(1)*X+TF(2))*1.0E-8,1.)
```

```
    6 X=1.0E+8*Y                                                        VALS  27
      VAL =Y*ATOTAL                                                     VALS  28
      IF(VAL.LT.1.0) VAL =1.0                                           VALS  29
      VLL = VAL                                                         VALS  30
      CHOICE = KPF(1)                                                   VALS  31
      DO 12 K =3,1000,2                                                 VALS  32
      IF(CHOICE.GE.VLL) GO TO 15                                        VALS  33
      CHOICE =CHOICE +KPF(K)                                            VALS  34
   12 CONTINUE                                                          VALS  35
   15 MAP(I,J,LX2) = KPF(K+1)                                           VALS  36
      RETURN                                                            VALS  37
      END                                                               VALS  38
      SUBROUTINE  FB3SHO                                                FB3S   1
      INTEGER DLT,FAV,CLN,DPLOT,SECTOP,PPP,PVP,SEP,CT,TPL,DATOP,WEST,DELFB3S   2
     2TAO,TECTOP,STRUC,HOR,CIND,THKFX,WTRFX,S1,S2,S3,SUM,SMB            FB3S   3
      REAL LOWBEA,LOWBND,MUDFAC,ME,MUD,MUDINC,LFL,LTH,MF                FB3S   4
     0 COMMON   TCT(20,40),DPL(8,10),SED(10,10),DPT(20,40),SAND(20),TER(FB3S   5
     120,40),SANDIN(20,40),TERINC(20,40),ORGINC(20,40),STRUCT(20,40),TENFB3S   6
     2D(20,40),CPX(5,5),TF(5),CFC(20,10),SUB(6,10),TEMP(20,40),MAP(20,40FB3S   7
     3,3),KPF(1000),PTH(20,2),LFL,LTH,MF,SUM, FB1,FB2,FB3,FB4,I,J,LX,LX1FB3S   8
     4,LX2,DTH,FAV,CLN,DPLOT(127),SECTOP(20),COMCON,DLT ,SEP(20,40,2),  FB3S   9
     5 CT(8),L,M,N,SF,LIMIT,TPL,DATOP,WEST,DELTAO,TECTOP,STRUC,HOR,SMB(3FB3S  10
     60),CIND,S1,S2,S3,LOWBEA,LOWBND,MUDFAC,MUD(20),MUDINC(20,40)       FB3S  11
      IW=I-1                                                            FB3S  12
      IWW=I+1                                                           FB3S  13
      JW=J-1                                                            FB3S  14
      JWW=J+1                                                           FB3S  15
      DO 5 IFD=IW,IWW,1                                                 FB3S  16
      DO 5 JFD=JW,JWW,1                                                 FB3S  17
      CALL SHORT(LX,FB3,IFD,JFD,TEND,MAP,SUM,KPF)                       FB3S  18
    5 CONTINUE                                                          FB3S  19
      DO 6 IFD=IW,IWW,1                                                 FB3S  20
      CALL SHORT( LX,FB2,IFD,J,TEND,MAP,SUM,KPF)                        FB3S  21
    6 CONTINUE                                                          FB3S  22
      DO 7 JFD=JW,JWW,1                                                 FB3S  23
      CALL SHORT(LX,FB2,I,JFD,TEND,MAP,SUM,KPF)                         FB3S  24
      CALL SHORT(LX,FB1,I,J,TEND,MAP,SUM,KPF)                           FB3S  25
    7 CONTINUE                                                          FB3S  26
      RETURN                                                            FB3S  27
      END                                                               FB3S  28
      FUNCTION IDKOD(NUMB,I)                                            IDKO   1
      IDKOD=NUMB/100                                                    IDKO   2
      IF(I.EQ.1) RETURN                                                 IDKO   3
      IDKOD=NUMB-(IDKOD*100)                                            IDKO   4
      RETURN                                                            IDKO   5
      END                                                               IDKO   6
```

INPUT TO PROGRAM

Table 2 is a listing of a particular set of data cards used as input to the program to produce output which is partially shown in Figures 4 to 10. For convenience the input data cards are either lettered or numbered and may be divided into the following categories for explanatory purposes.

Variable format data cards.- The first nine cards must pertain to input format specifications. The types, integer, decimal-point or alphameric may be determined by examining the examples of cards labeled A to I, as follows:

Card A: Format FMT1 for alphameric heading used for identification punched on card 3.
Card B: Format FMT2 for reading in control values in cards 4 and 5.
Card C: Format FMT3 for reading in CPX array, CFC array, SED array, DPL array, UPBND and LOWBND values, SAND and MUD arrays, SUB array, and TER array.
Card D: Format FMT4 for reading in FAV and FF values.
Card E: Format FMT5 for reading MAP array.
Card F: Format FMT6 for reading BTR, HT, LTH, and WID values.
Card G: Format FMT7 for reading in PTH array.
Card H: Format FMT8 for reading in TCT and DPT arrays.
Card I: Format FMT9 for reading in SECTOP array.

Plotting symbols (card 1).- Symbols for storage in SMB array and subsequent printing out in organism community maps, and in lithofacies maps and cross sections are contained in card 1. The seventh symbol is used as the symbol for sand, and the eleventh symbol for mud. Up to 30 symbols may be read in under format 30A2.

Data for random-number generator (card 2).- This card contains three values, read in under format 3F7.0, for random number initial values. The first number should be 101.0, the second number may be any large positive decimal-point number (within limits of format), and the third number should be 0.0.

Identification (card 3).-This card may have any combination of letters, numbers, blanks or other symbols used for identification purposes and printed out at the top of map and sections. Read in under format FMT1 as specified on card A.

Control data (cards 4 and 5).- Values to be read in here, under format FMT2, are assigned in sequence to the following identifiers, which have the following significance:

Card 4

(1) An integer (N) specifying the number of rows in the map arrays (limited to a maximum of 20 unless the array dimensions are changed).
(2) An integer (M) specifying the number of columns in the map arrays (limited to a maximum of 40 unless the array dimensions are changed).
(3) An integer (LIMIT) specifying the number of increments of time through which the simulation model is to be run forward. Value must not exceed that assigned to CLN.
(4) An integer (NC) specifying the number of organism communities. The maximum number is 30.
(5) An integer (TPL), specifying the numerical separation between the set of organisms read in initially and a hypothetical preceding set that occupied the area prior to the first time increment, is needed to get the simulation model started. A value of 1 is ordinarily appropriate.
(6) An integer (LWL) specifying the numerical separation between the first and second hypothetical sets of organism communities that occupied the map area prior to the set read in as data. A value of 2 seems appropriate.
(7) An integer (DATOP) specifying whether integers representing organism communities are to be read in as data, as follows:
  1 Read in data.
  2 Generate the distribution of organism communities by a function, which would have to be written and inserted at an appropriate place in the program. Unless this is done, it is essential to use 1.
(8) An integer (WEST) specifying whether the effect of currents (possibly wind-driven) is to be simulated, as follows:
  0 Do not simulate currents.
  1 Simulate currents.
(9) An integer (DELTAO) specifying whether data controlling deltaic deposition is to be read in as data:
  0 Do not read data (i.e., delta building will not be simulated)
  1 Read in as data.
(10) An integer (TECTOP) specifying whether tectonic warping and accumulation of sediment are to be simulated:
  0 Do not simulate.
  1 Simulate.
  In general, TECTOP will be assigned a value of 1 when the program is used. If assigned a value of 0, the program could be used for experiments with hypothetical organism communities, ignoring such aspects as tectonic

warping, water depth, etc. Provision for appropriate output would have to be made in the modified program.

(11) An integer (CLN) used to control the maximum number of time increments that are permissible. The number of time increments in an actual run (LIMIT) can be less than that assigned here.

(12) An integer (STRUC) specifying whether the structure of a specified horizon is to be calculated.
0 Do not calculate.
1 Do calculate.

(13) An integer (HOR) specifying the number of the time increment at which the structure calculations are to begin. At the specified time increment, the structural configuration will be set equal to the "topographic" (marine and/or subaerial) configuration prevailing at that moment.

(14 to 17) Four decimal-point numbers (a decimal-point number will be called simply a "decimal" hereafter); FB1, FB2, FB3, FB4, which specify the relative weighting of the organism communities occupying individual cells in the center and surrounding cells (see Figure 9 of Appendix for explanation). Values of 50.0, 10.0, 3.0 and 1.0 (for weightings for cells labelled I, II, III, and IV respectively), have been used successfully, but different values may be used to adjust the competitive influence of adjacent communities. Increasing the latter values (FB4 and FB3) with respect to the former values (FB1 and FB2) would increase the distance over which organism communities influence their neighbors.

(18) A decimal (SCALE) specifying the scaling factor to be used in printing of vertical geologic sections.

(19) A decimal (BASE) specifying value of base of vertical sections (a value of 0.0, representing sea level, would ordinarily be used).

Card 5

(1 to 6) Integers (KK1 and KD1 arrays) which control the selection of vertical sections, the number of the rows and columns desired being listed. For example, the following sequence, 15, 25, 35, 4, 10, 14 specifies that vertical sections are to be printed pertaining to columns 15, 25, 35 (KK1 array) and vertical sections to rows 4, 10, 14 (KD1 array). A maximum of three columnar and three row vertical sections is permitted. If fewer than three of each are selected, zeroes are placed in the appropriate positions as specified by format FMT2.

(7 to 12) A series of six integers (MIROR array) which permit the "mirror image" of the vertical section that have been calculated previously to be printed as follows:
0 Do not print mirror image.
1 Print mirror image.
For example, if the mirror image of some of the above sections were desired, the following sequence might be used: 1, 0, 0, 1, 1, 0. This would produce mirror images of column 15, and rows 4 and 10. Mirror images of columns 25 and 35 and row 15 would not be output. The sequence of selection is the same as the sequence in arrays KK1 and KD1.

The control values specified in the data set shown in Table 2 are summarized in Table 3.

Values used as exponents in organism community selection.- Decimal values (CPX array), used as exponents in a function that is a component of the method of selecting organism communities, are to be read in at this point. Under format FMT3 the values control the weighting influence that regulates the feedback effect, and in turn, affects the stability of succession of organism communities. The highest value in the array is assigned when identical communities (i.e., zero separation) have occupied the same location for three time increments (i.e., greatest stability), and the lowest value where the organism communities occupying the same location for three successive time increments are separated from each other in an ideal ecologic sequence by four or more communities. Intermediate values of the array pertain to combinations of separation values ranging between zero and four, with higher values in the array pertaining to situations in which the numerical separation between the communities occupying a particular location in the immediate past, and the preceding time increment, is less than the separation between the preceding time increment and the time increment, in turn, that preceded it. Twenty-five values are required to fill the CPX array, and are read in in descending order (cards 5 to 10 in example data set shown in Table 2).

Values controlling cycle length and relative vitality of organism communities in each cycle.- Decimal-point values (CFC array) are read in under format FMT3 to govern the overall general external influence on relative vitality of each organism community during each time increment. If it is desired that there be no general external influence on relative vitality, the values read in can all be

Table 2.- Example data set used to produce output shown subsequently.

```
( 13A6                       )                NEW FMT1                          A
(13I3,6F5.2,/12I2            )                NEW NEW FMT2                      B
(5F5.0                       )                NEW FMT3                          C
(I2,F5.2                     )                NEW FMT4                          D
(40I1                        )                NEW FMT5                          E
(4F5.2                       )                NEW FMT6                          F
(16F4.2                      )                NEW FMT7                          G
(20I3                        )                NEW FMT8                          H
(20I2                        )                NEW FMT9                          I
* $ / + M = . 1 A 2 - B 3 C 4 D 5 E 6 F 7 G 8 H 9 I J K L M                    1
101.    444444.    0.0                                DATA FOR RANDOM NO GENERATOR 2
* =CRINOID, $ =SPONGE, / =ALGAE, + =OSAGIA, M =SWAMP, - =MUD, . =SAND, I=WTR   3
 15 40  8  5  1  2  1  0  1  1  8  1  1 50.0 10.0  3.0  1.0 0.75  0.0          4
152535041014 1 1 1 1 1 1                                                       5
  5.0  4.8  4.6  4.4  4.2                                                      6
  4.0  3.8  3.6  3.4  3.2                                                      7
  3.0  2.8  2.6  2.4  2.2                                                      8
  2.0  1.8  1.6  1.4  1.2                                                      9
  1.0   .8   .6   .4   .2                                                      10
  1.0  1.0  4.0  1.0  1.0                                                      11
  1.0  1.7  8.0  1.0  1.0                                                      12
  1.0  1.4 16.0  1.0  1.0                                                      13
  1.0 1.25 32.0  1.0  1.0                                                      14
  1.0  1.1  8.0  1.0  1.0                                                      15
  1.0  1.0  5.0  1.0  1.0                                                      16
  1.0  1.0  2.4  1.0  1.0                                                      17
  1.0  0.5  0.1  1.0  1.0                                                      18
1111111111111111111111111222222222211111                                       19
1111111111111111111111111222222222211111                                       20
1111111111111111111111112222222222211111                                       21
1111111111111111111111112222222222211111                                       22
1111111111111111111111122222222222111111                                       23
1111111111111111111111222222222222111111                                       24
1111111111111111111112222222222221111111                                       25
1111111111111111111122222222222221111111                                       26
1111111111111111112222222222222211111111                                       27
1111111111111111222222222222222211111111                                       28
1111111111111122222222222222222211111111                                       29
1111111111111222222222222222222211111221                                       30
1111111111112222222222222222222222222222                                       31
1111111111112222222222222222222222222222                                       32
1111111111122222222222222222222222222222                                       33
  0.0 30.0 33.0 10.0                                                           34
 11. -1. 11. -1. 11. -1. 11. -1. 11. -1. 11. -1. 11. -1. 11. -1.               35
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   36
 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20                   37
 10 10 10 11 12 13 14 14 15 16 17 18 19 20 20 20 20 20 20 20                   38
 20 20 20 20 20 20 20 20 20 19 19 19 19 19 20 20 20 20 20 20                   39
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   40
 20 20 20 20 20 20 20 19 19 19 18 18 18 18 19 20 20 20 20 20                   41
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   42
 20 20 20 20 20 20 19 19 19 18 17 17 17 18 18 19 20 20 20 20                   43
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   44
 20 20 20 20 20 20 19 19 18 18 17 16 16 16 17 18 19 19 20 20                   45
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   46
 20 20 20 20 20 20 19 18 18 17 16 15 15 16 17 18 20 20 20 20                   47
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   48
 20 20 20 20 20 19 19 18 17 16 15 14 15 16 17 18 19 20 20 20                   49
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   50
 20 20 20 20 20 19 19 18 17 16 15 14 14 15 16 18 19 19 19 20                   51
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   52
 20 20 20 20 20 19 19 18 17 16 15 14 15 16 16 17 18 19 19 19                   53
 10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   54
 20 20 20 20 19 19 18 18 17 17 16 15 15 16 16 17 18 18 18 18                   55
```

```
10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   56
20 20 20 20 20 20 19 18 18 17 17 16 16 16 16 16 15 16 17 17                   57
10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   58
20 20 20 20 20 20 19 19 18 18 18 18 18 17 17 16 14 13 15 16                   59
10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   60
20 20 20 20 20 20 20 19 19 18 18 18 18 18 17 16 15 12 13 15                   61
10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   62
20 20 20 20 20 20 20 20 19 19 19 19 18 18 18 17 16 13 12 14                   63
10 10 10 11 12 13 14 14 15 16 16 17 18 19 20 20 20 20 20 20                   64
20 20 20 20 20 20 20 19 19 19 19 19 19 18 18 17 16 16 15 15                   65
14 19 28 35 42 50 56 61 64 68 72 74 77 79 81 82 84 84 83 82                   66
81 80 77 75 73 70 68 65 64 62 61 61 63 65 67 69 70 71 72 74                   67
15 20 28 36 43 52 57 61 65 69 72 75 77 80 81 82 83 83 82 81                   68
80 78 75 72 70 67 64 62 60 59 58 59 60 62 65 67 70 71 72 73                   69
15 20 28 37 45 52 57 62 66 70 73 75 78 80 81 82 82 82 81 80                   70
78 75 73 70 67 64 61 59 57 57 57 58 59 61 64 68 70 71 72 72                   71
16 20 28 37 44 52 57 62 66 70 73 75 78 80 81 81 81 81 80 78                   72
76 73 71 68 65 62 59 57 56 56 57 58 59 61 66 69 71 72 72 72                   73
16 20 28 36 44 51 57 62 66 70 72 75 77 79 80 81 80 79 78 76                   74
74 71 69 66 63 60 58 56 54 54 55 58 59 62 67 71 72 72 71 71                   75
16 20 27 35 43 51 56 61 65 70 72 74 76 78 79 79 78 77 76 74                   76
72 70 67 64 61 59 55 52 51 52 55 59 60 66 70 71 71 70 70 69                   77
15 20 26 33 42 50 55 60 65 69 72 74 75 76 75 75 74 72 71 71                   78
70 68 66 63 61 57 52 49 49 52 56 60 66 70 71 70 70 68 66 65                   79
15 19 25 32 40 48 53 59 63 68 71 73 74 73 72 71 70 69 68 67                   80
66 66 65 63 60 54 49 48 49 52 59 65 70 71 70 68 65 63 62 61                   81
14 18 23 30 39 46 52 57 61 66 69 71 72 71 70 69 66 64 62 62                   82
63 63 63 61 59 52 49 48 50 57 62 70 70 70 66 62 60 58 57 56                   83
13 17 22 28 36 42 50 55 60 63 67 70 71 70 67 63 61 59 59 59                   84
60 60 61 60 57 51 48 49 52 60 63 69 69 64 60 57 54 51 50 50                   85
11 16 20 27 32 40 47 52 57 60 63 66 67 63 61 58 55 53 52 53                   86
54 56 57 57 53 50 47 49 54 61 64 66 62 59 55 51 48 45 43 44                   87
10 14 19 24 30 37 42 50 53 58 60 61 61 58 55 52 48 47 47 48                   88
50 52 53 53 51 49 47 49 53 60 62 61 59 54 50 46 42 39 39 40                   89
 9 12 17 21 27 32 40 46 51 53 56 57 56 53 50 43 40 39 40 42                   90
45 47 50 49 47 44 43 47 51 56 58 57 53 50 46 41 36 31 31 32                   91
 7 11 15 20 25 30 35 40 46 50 51 51 50 48 42 38 36 36 37 38                   92
41 43 44 43 40 39 40 43 48 51 52 51 49 46 41 36 30 27 27 28                   93
 6  9 13 19 22 27 31 36 40 43 45 45 44 41 39 36 34 33 34 36                   94
38 39 40 39 37 36 37 39 42 44 45 44 43 40 37 30 28 22 23 24                   95
  3.   3.   6.  14.   4.                                                      96
  4.   4.  15.   8.   4.                                                      97
  5.   5.  30.   6.   4.                                                      98
  6.   6.  45.   4.   4.                                                      99
  6.   5.  25.   2.   4.                                                     100
  5.   4.   8.   6.   4.                                                     101
  4.   4.   4.  12.   4.                                                     102
  3.   2.   2.  24.   2.                                                     103
 40.  25.   3.   2. -15.                                                     104
200.  85.  68.  10.   5.                                                     105
 80.  55.  30.   5.   0.                                                     106
 -5.  50.                                                                    107
 .6   .4                                                                     108
 .2   .3                                                                     109
 .02  .01                                                                    110
 .02  .03                                                                    111
 .5   .4                                                                     112
 1.   5.                                                                     113
15.   10.                                                                    114
 7.    8.                                                                    115
 .5    .5  .8   1.5   5.                                                     116
 2.    2.  3.    3.  25.                                                     117
  .4   1.   .4   1.   5.                                                     118
  1.  1.5   2.   2.  15.                                                     119
1 1 1 1 1 1 1 1                                                              120
THIS IS THE SIGNAL CARD FOR THE END OF THE PROGRAM IT IS BLANK IN COLUMN 1 121
```

Table 3.- Summary of example used to control operation of program. Data are placed on cards 4 and 5.

Card 4	Variable Identifier	Value	Type	Purpose
	N	15	Integer	Number of rows in map.
	M	40	Integer	Number of columns in map.
	LIMIT	8	Integer	Number of time intervals for this run.
	NC	5	Integer	Number of organism communities.
	TPL	1	Integer	Numerical separation of organisms during initial time increment.
	LWL	2	Integer	Numeric separation of organisms between first and second time increments at start of run.
	DATOP	1	Integer	Specifies that distribution of organisms is to be read in.
	WEST	0	Integer	Specifies no current influence in this run.
	DELTAO	1	Integer	Specifies that data for delta control are to be read in.
	TECTOP	1	Integer	Specifies that tectonic warping is to be simulated.
	CLN	8	Integer	Maximum number of time increments allowable for this data set.
	STRUC	1	Integer	Specifies that structure map data are to be calculated and printed.
	HOR	1	Integer	Time increment at which structure calculations are to begin.
	FB1	50.0	Decimal-point	
	FB2	10.0	Decimal-point	Relative weighting of organism communities occupying individual cells in the center and surrounding cells.
	FB3	3.0	Decimal-point	
	FB4	1.0	Decimal-point	
	SCALE	0.75	Decimal-point	Specifies vertical scale factor for sections.
	BASE	0.0	Decimal-point	Specifies value of base for vertical sections.
Card 5	**Variable Identifier**	**Value**	**Type**	**Purpose**
	KK1	15,25,35	Integer	Map columns on which vertical sections are desired.
	KD1	4,10,14	Integer	Map rows on which vertical sections are desired.
	MIROR	1,1,1,1,1,1	Integer	Specifies which of the above rows and columns the mirror image will output.

equal (set at 1.0 for example). The data must be read in as follows (example in cards 11 to 18, Table 2):

(a) For each time increment, there must be values for each organism community in proper order (i.e., if there are organism communities whose sequence is 1 to 5, there must be five values).

(b) There must be as many time increments as specified by CLN. Thus, if there are 8 time increments, and 5 organism communities, a total of 40 values must be read in.

Initial organism community population.- If DATOP on card 4 equals 1, integer values for MAP array are to be read in under format FMT5 (card E). These values represent the geographic distribution of organism communities at the start of the simulation cycle. If DATOP does not equal 1, then a method of generating the geographic distribution of communities must be written and incorporated within the program. Up to thirty different organism communities, each identified by integers ranging from 1 to 30, may be used. The values should be read in row by row, left to right by columns within a row, and downward row by row. Unless array dimensions are changed, the maximum dimensions of the MAP array are 40 columns and 20 rows. The number of cards involved will depend on the dimensions of the MAP array, and the specifications of format FMT5. Values used in the example shown here are contained in cards 19 to 33 of Table 2.

Data to control delta geometry.- If DELTAO equals 1 on the control card, two or more cards containing the following information should be placed in the sequence (cards 34 and 35 of Table 2):

(1) A decimal (BTR) specifying the base value, in arbitrary vertical units, of terrestrially derived sediment to be deposited in each cell per time increment. A value of 0.0 may be convenient to use, because the supply of terrestrially derived sediment can be controlled externally and varied in each time increment. Use format FMT6.

(2) A decimal (HT) indicating the maximum rate of supply of terrestrially derived material at the mouth of the river (which creates the delta). Use format FMT6.

(3) A decimal (LTH) indicating the maximum east-west length of the delta (assuming map is oriented in customary manner) in terms of numbers of cells. Use format FMT6.

(4) A decimal (WID) indicating the north-south half width of the delta in terms of numbers of cells. Use format FMT6.

(5) Beginning on a new card and using one or more cards, place a sequence of pairs of decimal values (PTH array) which list, respectively, the vertical and horizontal geographic coordinate values of the river mouth producing the delta. Use format FMT7. The geographic coordinate origin is assumed to be in the upper left corner of the map. As many pairs of values should be read in as time increments in the cycle (CLN).

Tectonic warping increments.- If TECTOP equals 1, cards should be placed at this point in the sequence, to contain information controlling the amount of tectonic warping per time increment (example in cards 36 to 65 of Table 2). The amount of warping is uniform for each cell from time increment to time increment. The original values should be integers which are ten times the intended values, and should be read in the order of their geographic position beginning with the cell in the upper left corner of the map, and continuing, left to right within each row, and then downward from row to row. They should be read in under format FMT8. Each new row should begin on a new card, but a row can occupy more than one card. Positive values signify downwarping, negative values upwarping. The values are in arbitrary units, and should correspond (except for the tenfold magnification) to the units used in dealing with sediment increments and water depths (in feet, meters, etc.) used elsewhere in the program. The integer values are converted to decimal-point values for computational purposes and are subsequently stored in the TCT array.

Initial depth values.-If TECTOP equals 1, cards should be read in at this point in the data cards sequence to establish the initial water depth values (example in cards 66 to 95 in Table 2). The values should be integers, should be in the desired units (feet, meters, etc.), and should be read in the same geographic order as the tectonic warping increment values, employing format FMT8. The integer values are subsequently converted to decimal-point numbers for computational purposes, and are stored in the DPT array.

Organic sediment increment values.- If TECTOP equals 1, decimal values should be read in under format FMT3 at this point signifying, for each time increment in the cycle, the maximum increment of sediment to be contributed by each organism community (SED array). The values should be in the same units used for water depth and terrestrially derived sediment. The values should be read in successively for the organism communities, beginning with community symbolized by 1, and continuing to the specified number of communities. In the example shown in cards 96 to 103 of Table 2, values (totaling 40) for five organism communities in eight time increments are given.

Organism community depth limits.- If TECTOP equals 1, decimal values (DPL array) specifying the upper depth limit, lower depth limit, and most favorable depth for each organism community, in the same units used to signify depth, should be read in under format FMT3 as follows (for example, cards 104 to 106 of Table 2):

(1) The upper depth limit for each organism community in numerical order of integers symbolizing the organism communities. Positive values denote values below sea level; negative above sea level.

(2) The lower depth limit for each organism community.

(3) The most favorable depth for each organism community.

Terrestrially derived sediment increment boundaries.- If TECTOP equals 1, a card containing two values to regulate accumulation of terrestrially derived sediment should be read in under format FMT3 at this point in the sequence. Positive values denote values below sea level; negative values above. The units should be in the same depth units used elsewhere in the program. An example is given on card 107 of Table 2:

(1) A decimal (UPBND) specifying the upper limit (elevation with respect to sea level), above which terrestrially derived sediment cannot accumulate.

(2) A decimal (LOWBND) specifying the limit, belowwhich deposition of terrestrially derived sediment is not inhibited, but above which deposition is progressively inhibited, declining linearly to zero at the value

assigned to UPBND.

Sand and mud increment values.- If TECTOP equals 1, a series of cards should be read in under format FMT3 at this point (number of cards equal to number of time increments in cycle), each card containing a pair of decimal values which signify the increment of sand and of mud, respectively, to be contributed during each time increment. The values are stored in the SAND and MUD arrays, respectively. The amounts supplied in a particular time increment are equal in all cells regardless of their geographic position. The units should be the same as used in a depth or vertical context elsewhere in the program. An example is shown in cards 108 to 115 of Table 2.

Terrestrially derived sediment.- If DELTAO does not equal 1 (in other words, deltaic deposition is not to be simulated) but TECTOP does equal 1, a series of decimal values (TER array) should be read in under format FMT3 at this point in the sequence. This will supply an amount of terrestrially derived sediment to each cell that is constant for each time increment but may vary from cell to cell. The values read in should be their appropriate geographic positions, beginning in the upper left corner of the map. The values should be in the same units (i.e., no tenfold exaggeration) as used for depth and other sediment values used with the program.

Sand and mud tolerance values.- If TECTOP equals 1, decimal values (SUB array), should be read in under format FMT3 as follows (example given in cards 116 to 119 in Table 2):

(1) The threshold value of tolerance to sand (in units available for deposition) of each organism community, in ascending order of the integers which symbolize the organism communities. The units should be the same as used elsewhere in specifying sediment increment (in feet, meters, etc.) per increment of time. Organism communities are not affected below the threshold level, but are progressively inhibited above it.
(2) Intolerable level of organism communities with respect to sand supply (organism communities are of low vitality above this level and do not contribute organic sediment).
(3) Threshold value with respect to mud.
(4) Intolerable value with respect to mud.

Output options.- If TECTOP equals 1, a series of integers (SECTOP array) should be read in on a separate card which contains a number of values equal to the number of time increments. Each integer specifies the choice of maps and vertical sections to be printed out for the corresponding time increment (example in card 120 of Table 2), as follows:

0 Output, for each time increment, will include depth map, organic-increment map, organism-community map and facies map, but will not include map of rate of supply of terrestrially derived sediment, nor structure map, nor vertical sections.
1 Output, for each time increment, will include all forms of output available from program, with mirror images of vertical sections as specified on card 5.
2 Output, for each time increment, will consist only of vertical sections, with mirror images of vertical sections as specified in card 5.
3 Output, for each time increment, will consist of depth map, organic-increment map, facies map, organism-community map, and vertical sections, but will not include map of rate of supply of terrestrially derived sediment nor the structure map.

Termination card.- An integer value (ITEST) is to be punched in column 1 of the last card of each data set specifying whether the program is to be terminated, or whether a new data set is to be read, as follows:

0 (or blank) Terminate program
1 Read in a new data set, including nine variable format cards preceding the data set.
2 Read in a new data set, omitting the nine variable format cards (the input format specified previously will continue to be used).

OUTPUT FROM PROGRAM

Types of output from the program depend on the options specified in the control cards, and on the number of time increments. Examples of output, based on data listed in Table 2, are given in Figures 4 to 9. The different arrays of numbers printed out in Figures 4 and 5 reiterate data that have been read in, and are part of the output for reference's sake, providing a record of the input controls used to obtain a particular set of results. The following information is part of the output, subject to variations which depend on options exercised in use of the program.

(1) Values used as exponents (CPX array) in selecting organism communities (Fig. 4).
(2) The relative vitalities (labeled "organism community factors for cycle") of organism communities (in columns) for each time increment (in rows) are given (Fig. 4).
(3) The geographic coordinates of river mouth creating delta deposits (Fig. 4).
(4) The maximum increments of sediment contributed by each organism community (in columns) for each time increment (in rows) are given (Fig. 4).
(5) Depth limits for each organism community (in columns) upper depth limit (first row), lower depth limit (second row), and most favorable depth (third row), are given (Fig. 4).
(6) An array showing the geographic location of warping increment values (multiplied by ten) per time increment (Fig. 4).

Table 4.- List of symbols which are substituted for integers in printing out facies maps and organism-community maps using symbols that have been used as input with sample data on card 1 of Table 2.

Integer	Equivalent symbol	Integer	Equivalent symbol	Integer	Equivalent symbol
1	*	11	-	21	7
2	$	12	B	22	G
3	/	13	3	23	8
4	+	14	C	24	H
5	M	15	4	25	9
6	=	16	D	26	I
7	.	17	5	27	J
8	1	18	E	28	K
9	A	19	6	29	L
10	2	20	F	30	M

(7) The increment values of sand and mud supplied per time increment (Fig. 5).

(8) Sediment tolerance limits of organism communities (Fig. 5).

(9) An array showing the geographic location of organism communities which initially populated the area. Symbols (Table 4) have been substituted for the integers which are used for actual representation of the organism communities (Fig. 5).

(10) Arrays showing the rate of supply of terrestrially derived sediment at each geographic cell per time increment (Fig. 6A).

(11) Arrays forming depth maps showing elevation of bottom with respect to sea level during successive time increments. Negative values denote elevations above sea level (Fig. 6B).

(12) Arrays which form structure maps showing elevations of a particular datum with respect to sea level at a time increment (Fig. 6C).

(13) Arrays showing amount of organically derived sediment contributed during a time increment (Fig. 7A).

(14) Arrays forming facies maps showing predominant single lithologic type deposited in each geographic cell during successive time increments (Fig. 7B). Dots represent sand, dashes mud, and the organism community symbols used elsewhere represent organically derived sediment according to the example symbol table read in on card 1 of Table 2, and reproduced in Table 4.

(15) Arrays forming organism community maps or biofacies maps, during successive time increments (Fig. 7C).

(16) From one to three vertical geologic sections along specified rows, and according to options, their mirror images (Fig. 8).

(17) From one to three vertical geologic sections along specified columns, and according to option, their mirror images (Fig. 9). The vertical sections may be linked together to produce a fence diagram (Fig. 10).

REFERENCES

Harbaugh, J.W., 1966, Mathematical simulation of marine sedimentation with IBM 7090/7094 computers: Kansas Geol. Survey Computer Contr. 1, 52 p.

Harbaugh, J.W., 1967, Computer simulation as an experimental tool in geology and paleontology, in Essays in paleontology and stratigraphy: R.C. Moore commemorative volume, edited by Curt Teichert and Ellis Yochelson: Dept. Geology, Univ. Kansas, Lawrence, p. 368-389.

```
* =CRINOID, $ =SPONGE, / =ALGAE, + =OSAGIA, M =SWAMP, - =MUD, . =SAND, I=WTR
                                    THE CPX ARRAY

                         5.00      4.80      4.60      4.40      4.20
                         4.00      3.80      3.60      3.40      3.20
                         3.00      2.80      2.60      2.40      2.20
                         2.00      1.80      1.60      1.40      1.20
                         1.00      0.80      0.60      0.40      0.20
ORGANISM COMMUNITY FACTORS FOR CYCLE

        1.00      1.00      4.00      1.00      1.00       1.00      1.10      8.00      1.00      1.00

        1.00      1.70      8.00      1.00      1.00       1.00      1.00      5.00      1.00      1.00

        1.00      1.40     16.00      1.00      1.00       1.00      1.00      2.40      1.00      1.00

        1.00      1.25     32.00      1.00      1.00       1.00      0.50      0.10      1.00      1.00

COORD. INDEX VALUES FOR PATH OF DELTA FOR EACH PHASE IN CYCLE, ROW COORD IN LEFT COL, COLUMN COORD IN RIGHT
       11.00          -1.00          11.00          -1.00          11.00          -1.00          11.00          -1.00

       11.00          -1.00          11.00          -1.00          11.00          -1.00          11.00          -1.00

SEDIMENT INCREMENT VALUES FOR EACH COMMUNITY (IN COLS) FOR EACH PHASE IN CYCLE (IN ROWS)


       3.00      3.00      6.00     14.00      4.00       6.00      5.00     25.00      2.00      4.00

       4.00      4.00     15.00      8.00      4.00       5.00      4.00      8.00      6.00      4.00

       5.00      5.00     30.00      6.00      4.00       4.00      4.00      4.00     12.00      4.00

       6.00      6.00     45.00      4.00      4.00       3.00      2.00      2.00     24.00      2.00

UPPER AND LOWER DEPTH LIMITS, AND MOST FAVORABLE DEPTH, IN UNITS WITH RESPECT TO SEA LEVEL

(IN ROWS) FOR EACH SEDIMENT/ ORGANISM COMMUNITY (IN COLUMNS)

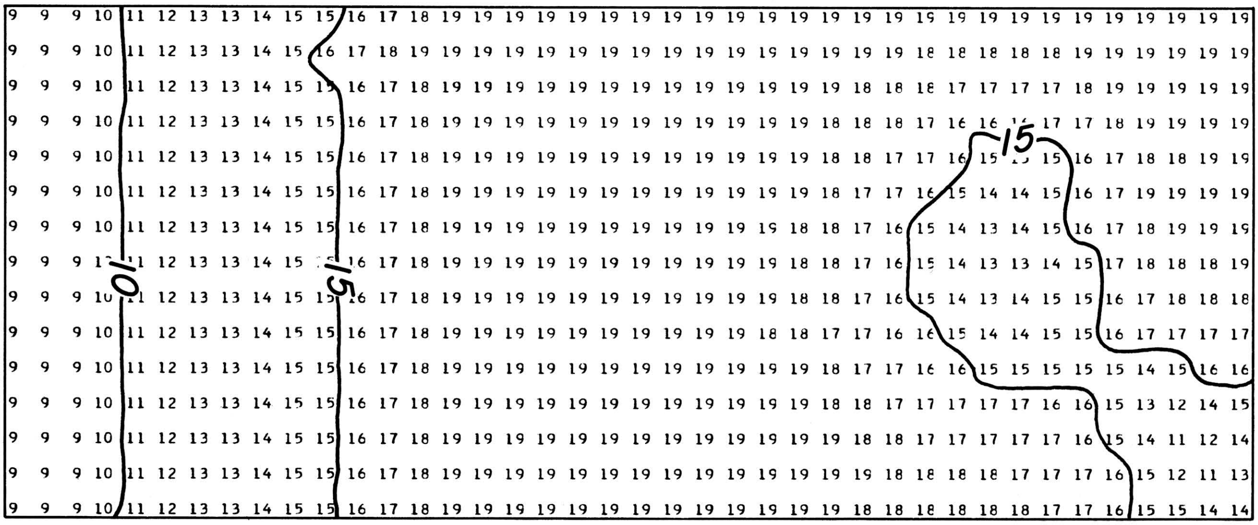
                        40.00     25.00      3.00      2.00    -15.00

                       200.00     85.00     68.00     10.00      5.00

                        80.00     55.00     30.00      5.00      0.00



WARPING INCREMENTS IN UNITS PER CYCLE MULTIPLIED BY 10
```



```
9  9  9 10 11 12 13 13 14 15 15 16 17 18 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19
9  9  9 10 11 12 13 13 14 15 16 17 18 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 18 18 18 18 18 19 19 19 19 19 19
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9  9  9 10 11 12 13 13 14 15 15 16 17 18 19 19 19 19 19 19 19 19 19 19 19 19 19 19 19 18 18 18 18 18 18 17 17 16 15 15 14 14
```

Figure 4.- Output from program consisting of data in arrays that have been read as input data.

```
INCREMENT VALUES FOR TERRESTRIALLY-DERIVED SEDIMENT
                    PHASE  SAND    MUD

                     1    0.60   C.40                5   0.5C   C.40

                     2    0.20   C.30                6   1.00   5.00

                     3    0.C2   C.01                7  15.CC  1C.C0

                     4    0.02   C.03                8   7.C0   E.00

SEDIMENT TOLERANCE LIMITS OF ORGANISM CCMMUNITIES FCR MIN AND MAX SANC VALUES (UPPER TWO ROWS) AND MUD (LOWER TWO RCWS)

                       0.5C      C.50      C.80      1.50      5.00

                       2.CC      2.C0      3.00      3.00     25.00

                       0.40      1.C0      0.40      1.00      5.00

                       1.CC      1.50      2.00      2.00     15.00

INITIAL DISTRIBUTION OF ORGANISM COMMUNITIES


              * =CRINOID, $ =SPONGE, / =ALGAE, + =OSAGIA, M =SWAMP, - =MUD, . =SAND, I=WTR

                                        MAP NUMBER   0
            5         1C        15        20        25        30        35        40
  1 * * * * * * * * * * * * * * * * * * * * * * * * * $ $ $ $ $ $ $ $ $ $ * * * * *
  2 * * * * * * * * * * * * * * * * * * * * * * * * * $ $ $ $ $ $ $ $ $ $ * * * * *
  3 * * * * * * * * * * * * * * * * * * * * * * * * $ $ $ $ $ $ $ $ $ $ $ * * * * *
  4 * * * * * * * * * * * * * * * * * * * * * * * * $ $ $ $ $ $ $ $ $ $ $ * * * * *
  5 * * * * * * * * * * * * * * * * * * * * * * * $ $ $ $ $ $ $ $ $ $ $ * * * * * *
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 15 * * * * * * * * * * * $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $ $
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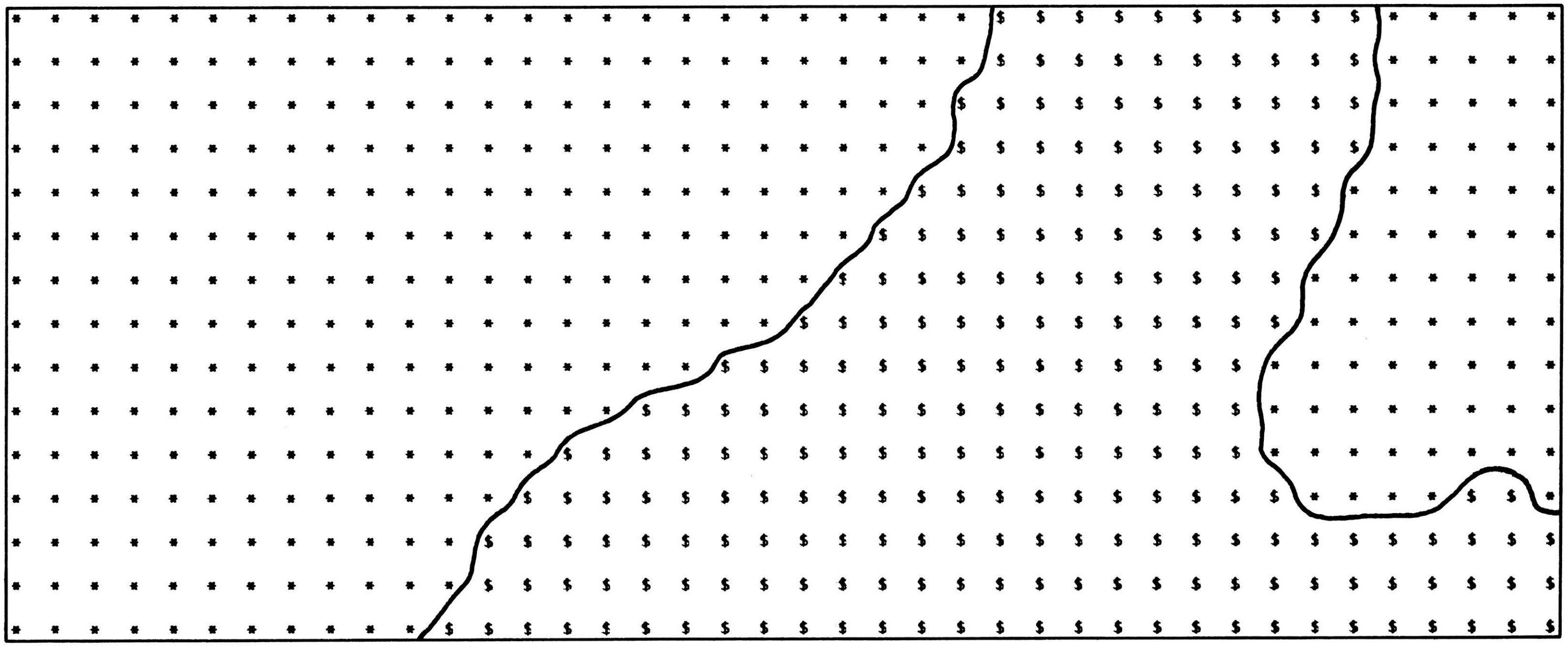
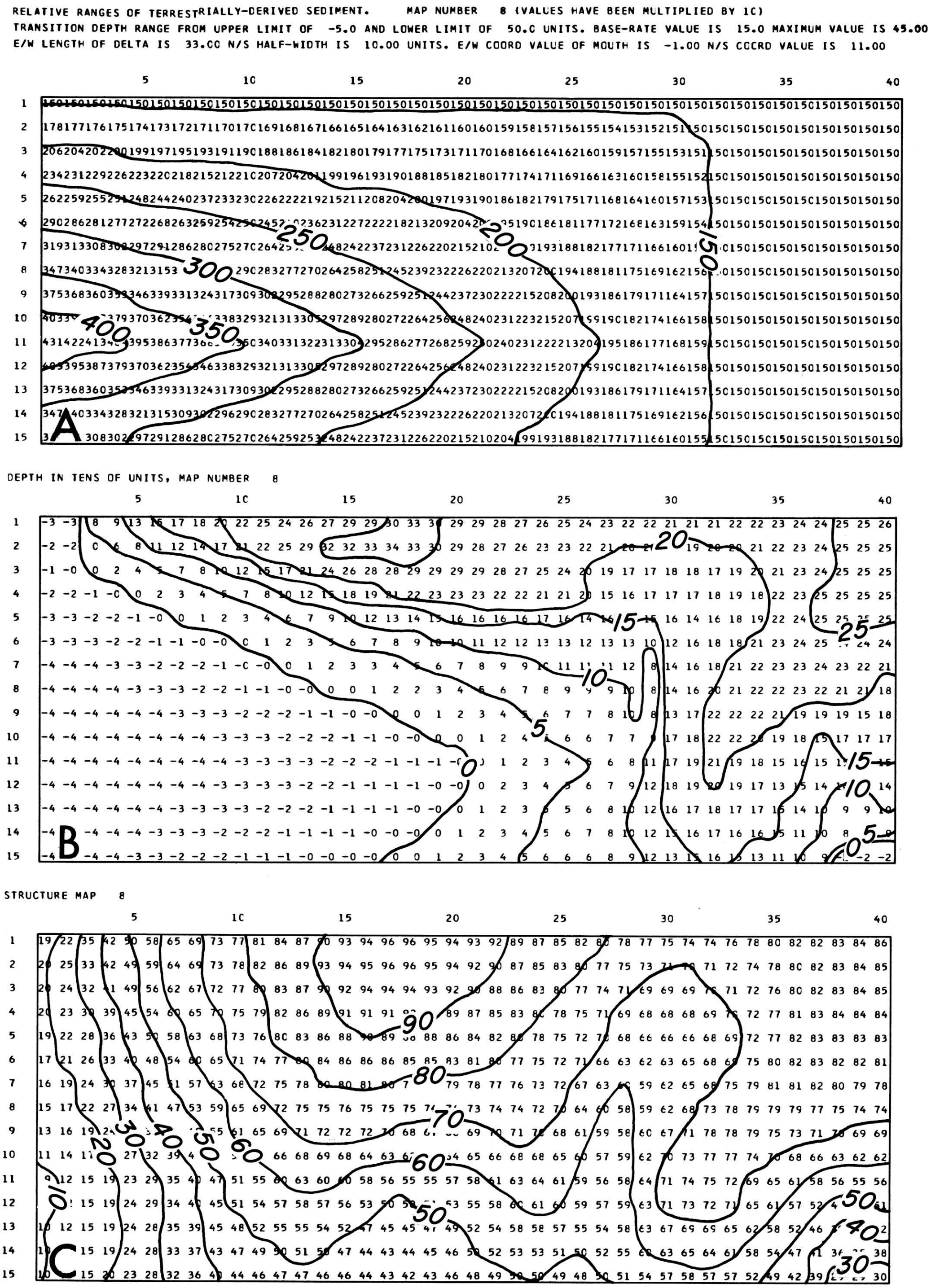


Figure 5.- Output from program consisting of data in arrays that have been read as input data.



```
RELATIVE RANGES OF TERRESTRIALLY-DERIVED SEDIMENT.     MAP NUMBER   8 (VALUES HAVE BEEN MULTIPLIED BY 1C)
TRANSITION DEPTH RANGE FROM UPPER LIMIT OF  -5.0 AND LOWER LIMIT OF  50.C UNITS. BASE-RATE VALUE IS  15.0 MAXIMUM VALUE IS 45.00
E/W LENGTH OF DELTA IS  33.CC N/S HALF-WIDTH IS  10.00 UNITS. E/W COORD VALUE OF MOUTH IS  -1.00 N/S CCCRD VALUE IS  11.00
```

```
DEPTH IN TENS OF UNITS, MAP NUMBER    8
```

```
STRUCTURE MAP   8
```

Figure 6.- (A) Map pertaining to time-increment 8 of an experimental run showing relative rates of supply of terrestrially derived sediment; (B) depth map, in which positive values denote units below sea level and negative values above sea level; (C) structure elevation values, map in which positive values denote units below sea level and negative above.

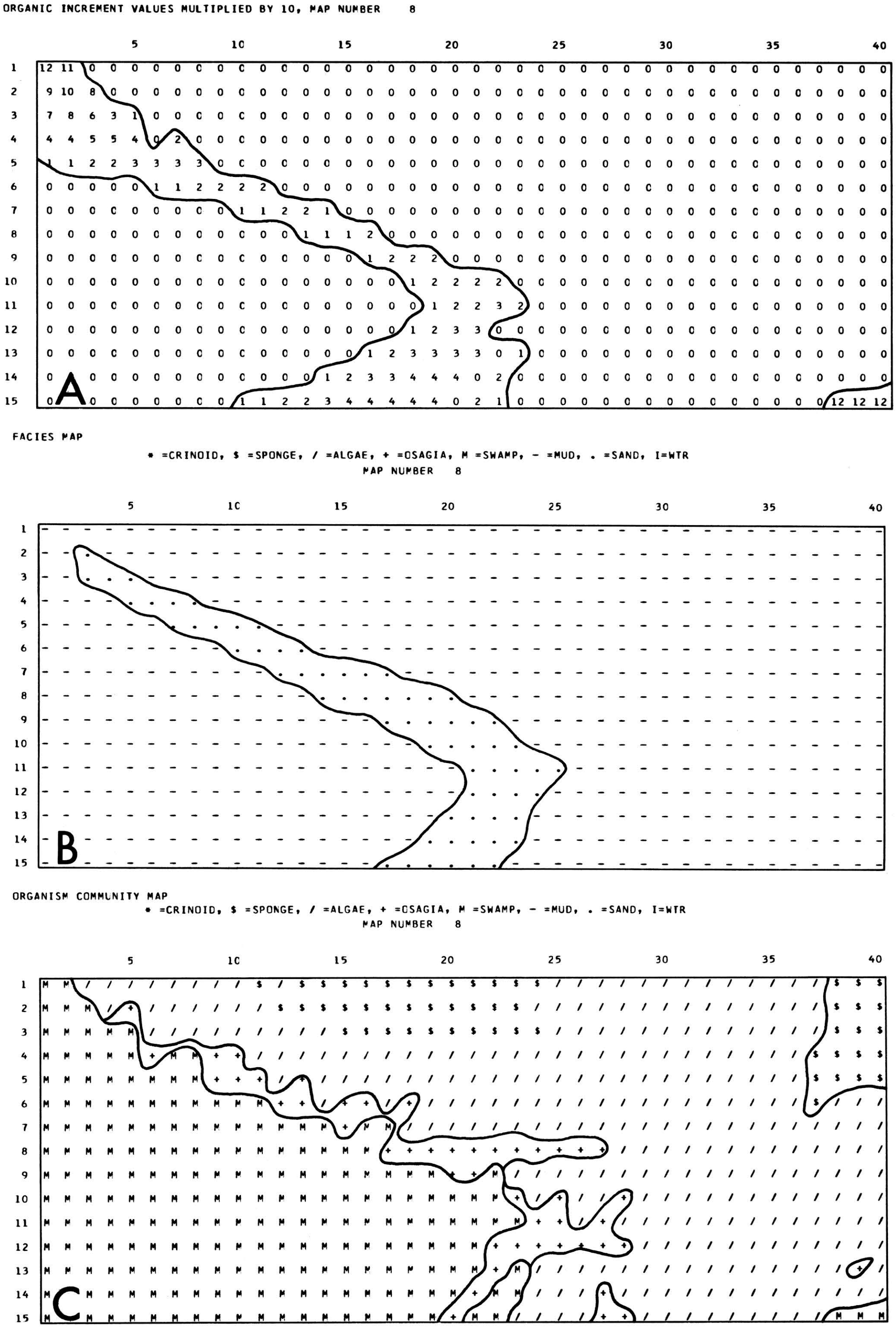
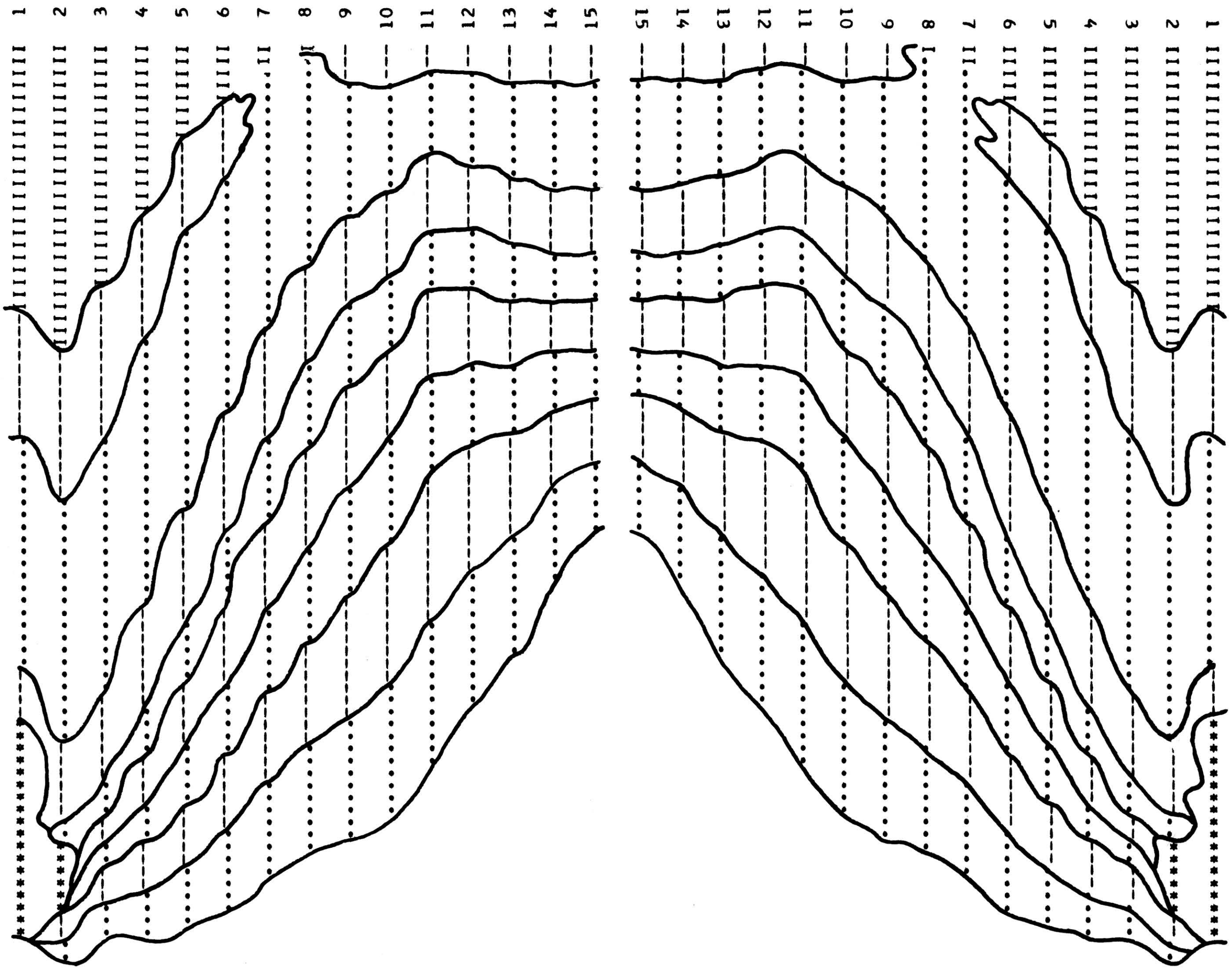


Figure 7.- (A) Map of organic increment values multiplied by ten; (B) lithofacies map; (C) organism community map. Maps pertain to time-increment 8 of an experimental run.

STRATIGRAPHIC SECTION 8 ALONG COLUMN 15 SCALED SO THAT 1/10 INCH = 0.75

THICKNESS UNITS, AND BASE IS SET AT 0.00 UNITS



* =CRINOID, $ =SPONGE, / =ALGAE, + =OSAGIA, M =SWAMP, - =MUD, . =SAND, I=WTR

Figure 8.- Vertical geologic section and its mirror image along a specified column section pertain to time-increment 8 of experimental run.

```
STRATIGRAPHIC SECTION    8 ALONG ROW  10 SCALED SO THAT 1/10 INCH =  0.75 THICKNESS UNITS , AND BASE IS SET AT 0.00 UNITS

                 * =CRINOID, $ =SPONGE, / =ALGAE, + =OSAGIA, M =SWAMP, - =MUD, . =SAND, I=WTR
```

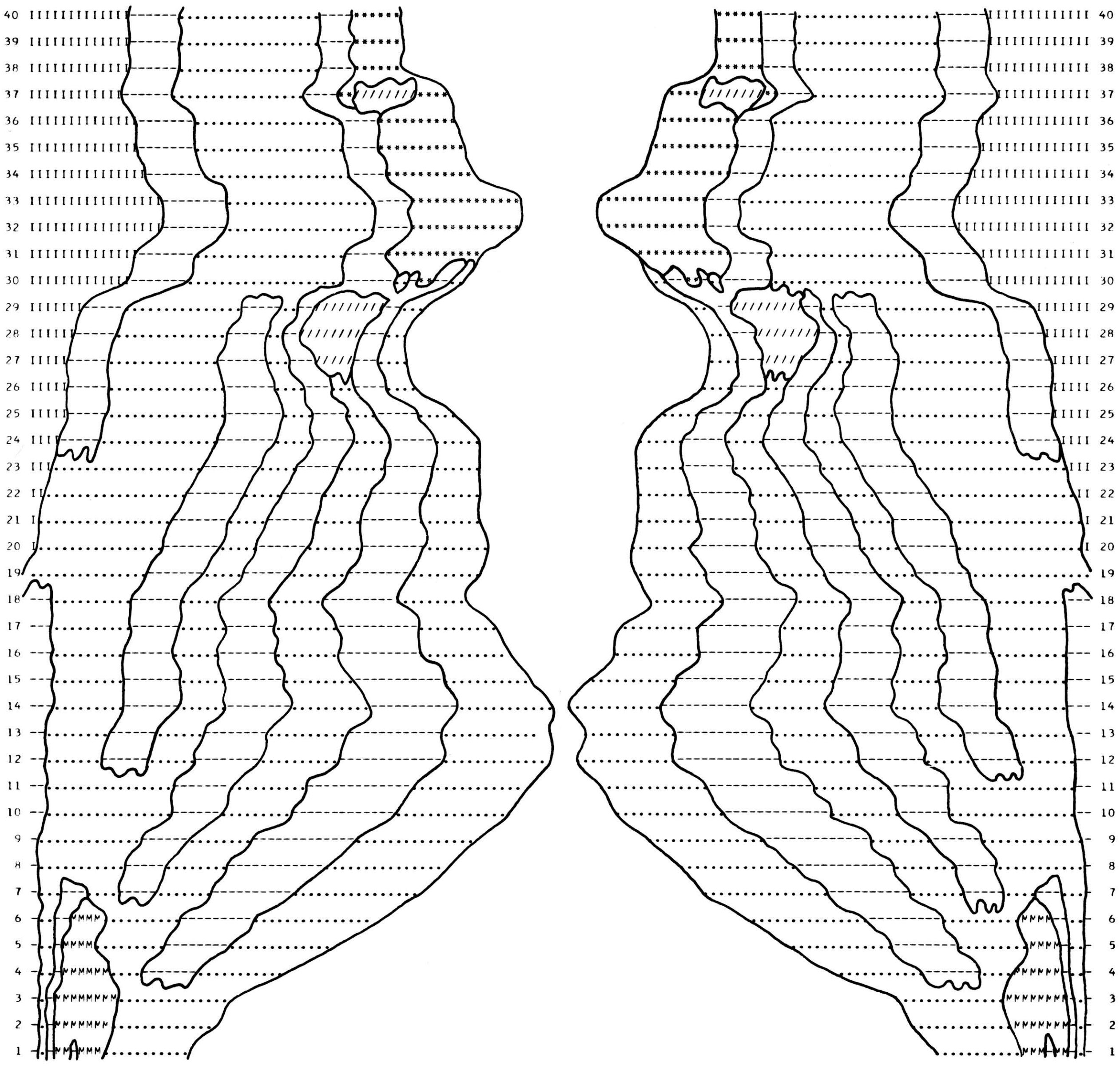


Figure 9.- Vertical geologic section and its mirror image along a specified row. Sections pertain to time-increment 8 of experimental run.

APPENDIX

Explanation of some of principles of program's operation (reproduced from Kansas Geological Survey Computer Contribution 1, 1966).

REPRESENTATION OF GEOLOGIC PROCESSES, FACTORS, AND FEATURES IN PROGRAM

Three-Dimensional Space

Geologic features in three-dimensional space may be readily represented in a digital computer by dividing the space into cells, which may be rectangular or cubic in shape. The qualities of the geologic features that occupy the cells may be represented by different numbers, which, in turn, may be stored as arrays in the computer and subjected to logic and arithmetic manipulations.

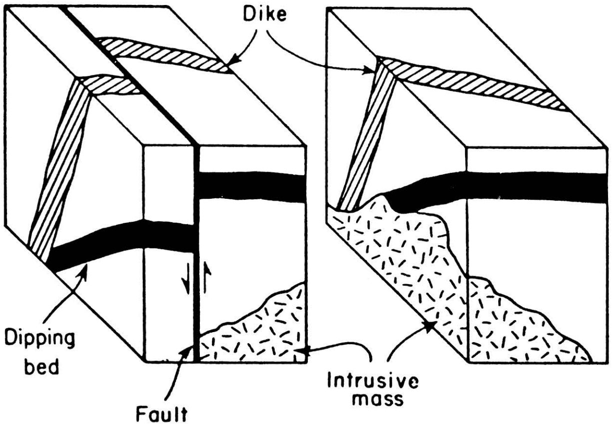


Figure 1.- Block diagram showing geologic features.

An example of numerical representation of geologic features is shown in Figures 1, 2, and 3. In Figure 1, several common geologic features are shown with conventional graphic symbols. In Figure 2, the same features are represented, but the block has been divided into cubes. There is a loss of detail in portraying the features in Figure 2, however, because of the relative coarseness of the cubes. If the cubes were smaller, the loss of detail would be less. In Figure 3, integers 1 to 4, which form a three-dimensional array, have been substituted for the graphic symbols. Information contained in the array is essentially equivalent to that represented in Figure 1. Knowing the key relating numbers and graphic symbols (Fig. 3), a person given only the numerical data in the array (Fig. 3) could reproduce Figure 1, provided that he did a bit of smoothing.

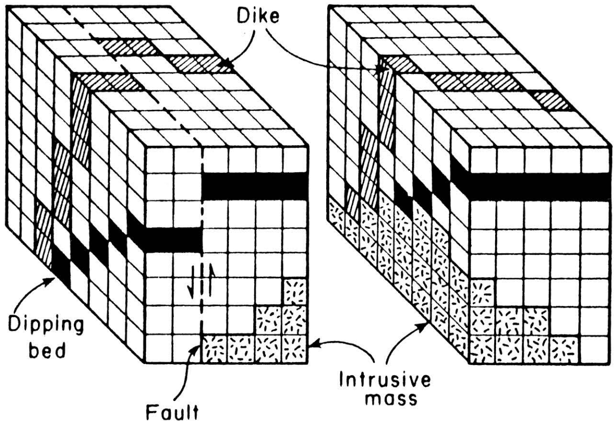


Figure 2.-Block diagram in which geologic features are represented by discrete cells (small cubes), each of which is marked by graphic symbol representing type of feature represented by that cell.

Units

All units in the simulation model are arbitrary, and may be assigned values that are convenient to the user. Four main classes of units are used: (1) units of geographic distance, (2) units that pertain to the vertical dimension (such as tectonic warping increments and sediment increments), (3) time increments, and (4) units that express relative intensity of various processes, such as "relative vitality" in organism communities, intensity of beach winnowing processes, etc. In the examples shown in this report, the geographic units are in miles (each cell occupies one square mile geographically), the vertical dimensions are in feet, and the time increments are unspecified, but might be considered to be on the order of 5 to 10 thousand years each.

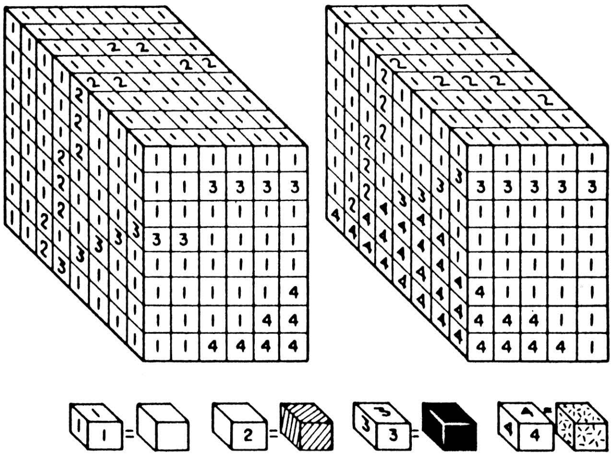


Figure 3.-Block diagram in which numbers (integers) are used instead of graphic symbols. Numbers form a three-dimensional array which may be stored and manipulated by computer.

Tectonic Warping, Deposition of Sediment, and Depth of Water

Tectonic warping is simulated by moving square "columns" upward or downward during each time increment (Fig. 4). The values of the warping increments are specified in an array (Table 2) Vertical motion may take place at each time increment. Depending on the contrast between values in adjacent cells and their algebraic signs, conditions ranging from uniform downwarping or upwarping to complex folding and faulting can be simulated.

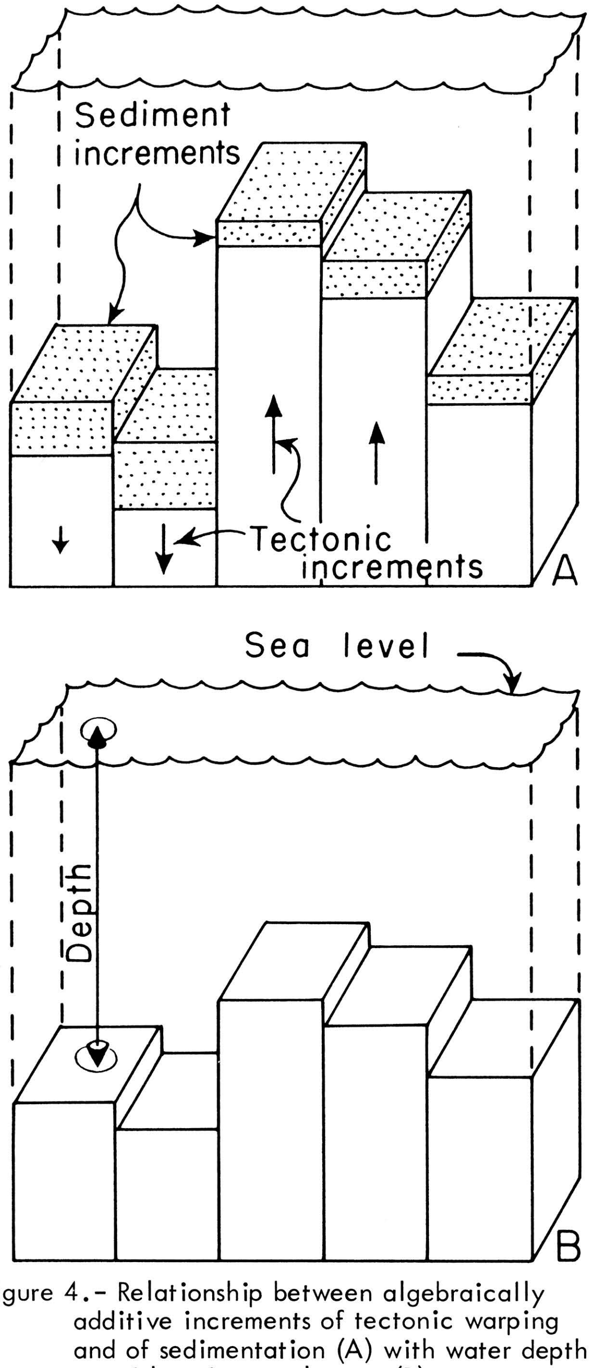


Figure 4.- Relationship between algebraically additive increments of tectonic warping and of sedimentation (A) with water depth as arithmetic complement (B).

Sediment deposition also takes place by increments. The factors and processes that control sedimentation rates are described subsequently, but sedimentation itself is simulated by adding the value of the sediment increment to the pre-existing sea floor (or land) elevation. Water depth is calculated as the difference between the sea floor and sea level. Elevations above sea level (i.e., on land) are denoted with negative signs.

Deltaic Sedimentation

The processes of deltaic sedimentation are simulated by varying the rate of supply of terrestrially derived sediment to mimic the effect of a river bringing sediment to the sea and spreading it out The rate of deposition of terrestrially derived sediment is not necessarily the same as the rate of supply, however. Where the depth of water is less than some specified value, the proportion of sediment deposited is proportionally less than the rate of supply. The proportion deposited declines to zero as a specified elevation (may be above or below sea level) is attained.

These controls over the rate of sedimentation are remarkably effective in simulating deltaic sequences composed of topset, foreset, and bottomset beds.

Winnowing of Fine Particles at Beaches

The effect of winnowing of fine particles at beaches is a function of both water depth and proportions of sand and mud. The relative intensity of the winnowing processes reaches a maximum at sea level and declines linearly to zero at some specified depth (Fig. 5). A nonlinear function might be more appropriate; however, a linear function was used for simplicity.

Representation of Organism Communities

The program provides for continuously populating, through time, the sea floor and adjacent

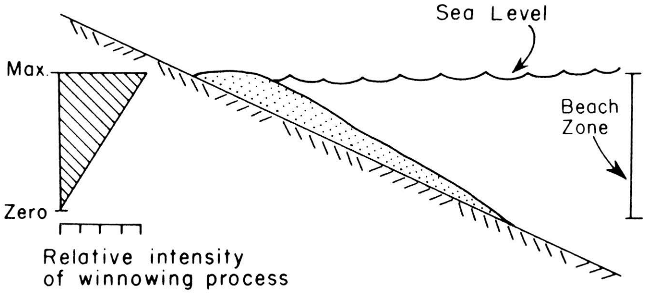


Figure 5.- Relative intensity of winnowing of fines to form beach deposits as function of depth.

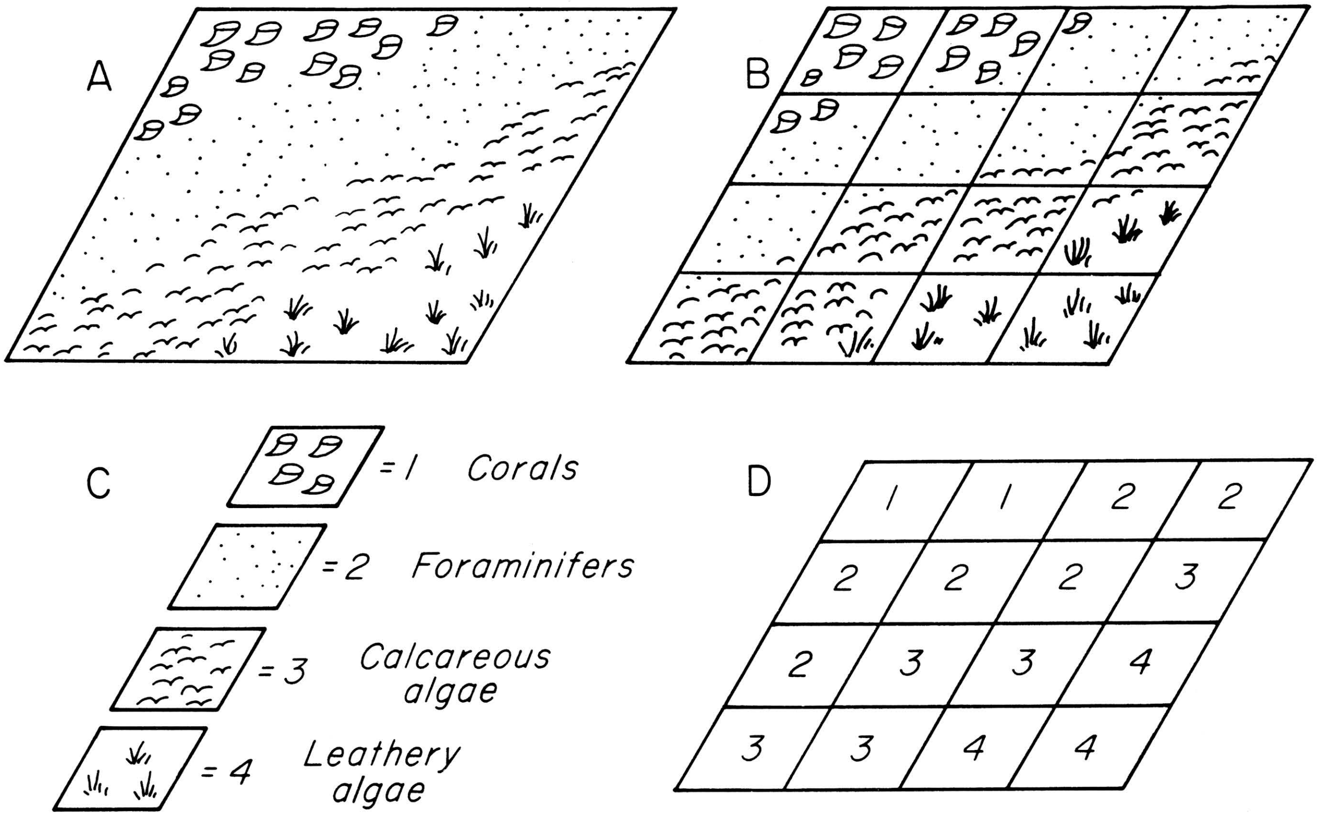


Figure 6.- Means of representing geographic distribution of organism communities: (A) sea floor is populated by different communities which are continuous and which are portrayed graphically; (B) sea floor has been discretized by division into square cells; (C) graphic symbols are assigned numerical equivalents; (D) two-dimensional array of integers contain essentially same information as graphic symbols in A, except for some loss of detail due to relative coarseness of discrete cells.

land areas (if present) with organism communities. Organism communities are defined as consisting of populations of organisms, although a community may be defined as consisting of a population formed by a single type of organism, depending on the assumptions of the user.

The means of representation of organism communities are shown in Figure 6. The sea floor (or land area) is divided into square cells. A single organism community occupies each cell, and is, in turn, represented by an integer.

Competition and Succession of Organism Communities

Organism communities represented in the program are endowed with properties that affect their ability to compete with other organism communities. The degree to which a series of different organism communities tends to form a specific ecologic succession can be specified.

The means by which these processes are imitated centers around selection of the communities that are to occupy the cells at each new increment of time. Selection involves the geographic distribution of organism communities for three preceding time increments, and the "relative vitality" of the organism communities involved. The relative vitality of an organism community is defined here as the degree of fitness of that community for its environment at a specific time and place, relative to other organism communities at the same time and place. Relative vitality, thus, is meaningful only in a comparative sense. Relative vitality is a means of expressing the competitive ability of different organism communities, and also by expressing their ability to contribute sediment (if they are capable of contributing sediment).

The means by which past events influence (but do not rigidly govern) succeeding events (i. e., selection of an organism community to occupy a particular cell) at subsequent time increments are illustrated in Figure 7. Moving forward through increments of short time duration, the most probable organism community to occupy a cell is the same community that occupied that cell immediately before. This assumes that other factors in the environment are relatively unchanged, and that adjacent cells do not harbor communities that would have a strong overpowering influence if present.

The occupation of the cell by a community, one that is next in an ideal ecologic succession, is the next most probable event. Of progressively lower probabilites are occupation of the cell by communities that are progressively further removed in an ideal ecologic succession.

The degree of "closeness" or "farness" in an ecologic succession can be expressed numerically (Fig. 8). For example, if there are 12 communities which are symbolized by numbers such that community 1 is a pioneer community and community 12 is the climax community (for a given set of environmental conditions), given sufficient time increments, the pioneer community (1) should gradually be replaced by communities symbolized by higher and higher numbers until the climax community (12) is reached. Thus, while there is a tendency for the succession to be unidirectional (i. e., toward the climax) momentary reversals can occur as a result of random fluctuations and major reversals can be produced by major changes in environmental factors (including catastrophic events). These reversals can be regarded as matters of probability.

In the program, the selection of the community to occupy each cell for the next time increment is treated as a probabilistic event in which the likelihood of selecting a particular community is proportional to a probability value assigned to each of the communities represented. The selection of the community is made with a pseudorandom number which is used to select a single number from an array of integers (Fig. 8). In this array, the proportion of different integers reflects the probability that a specific integer will be chosen. Inasmuch as the integer array is a component in a loop which is cycled in each time increment, the proportions of integers may be regarded as a feedback influence (Fig. 8).

In filling an array from which a selection will be made for the next time increment, the program considers the existing distribution of communities as well as the two preceding time increments. This provides positive feedback which affects the geographic stability of population through successive time increments. For example, if a given type of organism community has occupied a given cell for three successive time increments, the probability of the same community occupying the same cell in the forthcoming time increment is greater than it would be if different communities had occupied the cell during the three preceding time increments. The effect of this may be likened to inertia in that long-established communities may tend to resist subsequent change much more than communities whose occupation has been brief. Numbers fed in as data are used to control this inertia or feedback effect, so that the degree of stability of communities can be finely regulated.

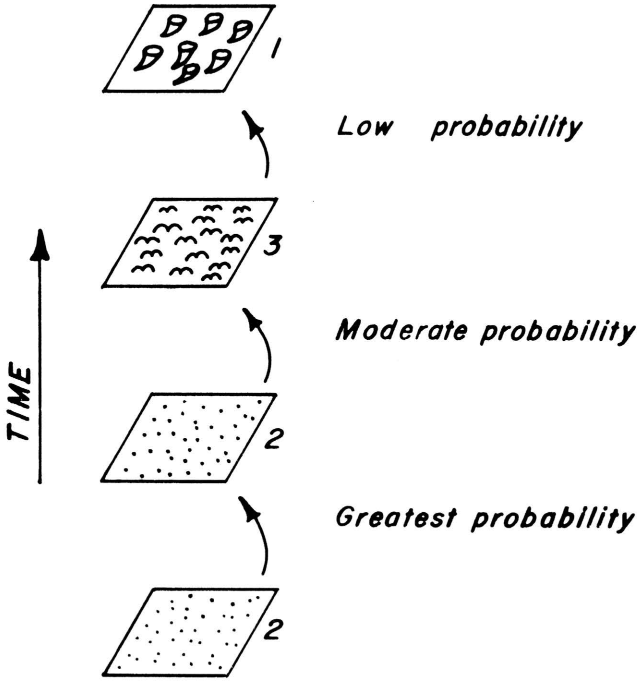


Figure 7.- Relative probabilities of succession of organism communities occupying same cell through time increments of short duration. Numbers adjacent to cells pertain to relative position in ideal ecologic sequence. Probability values pertain to probability of a particular community succeeding another in single time increment.

The selection of any particular community in any cell is influenced by communities in geographically proximate cells. This method is crudely analogous to the seeding effect of land plants, in that the influence of communities progressively declines with increasing distance. Figure 9 shows how this effect is approximated. The four cells (II) which lie immediately adjacent to the central cell (I) are given somewhat less weight than the central cell. The four cells (III) which touch the corners of the central cell are given somewhat less weight, since they lie at slightly greater distance. Finally, the twelve cells labeled IV are given still less weight.

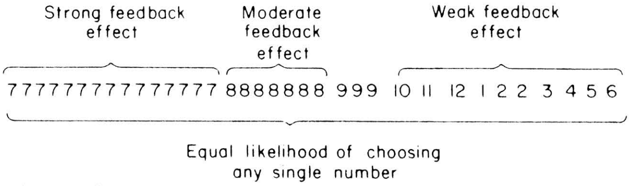


Figure 8.- Use of integer array within feedback loop. Strong positive feedback effect is provided by relatively high proportion of integers of particular value (such as 7's) and vice versa for those of low proportion.

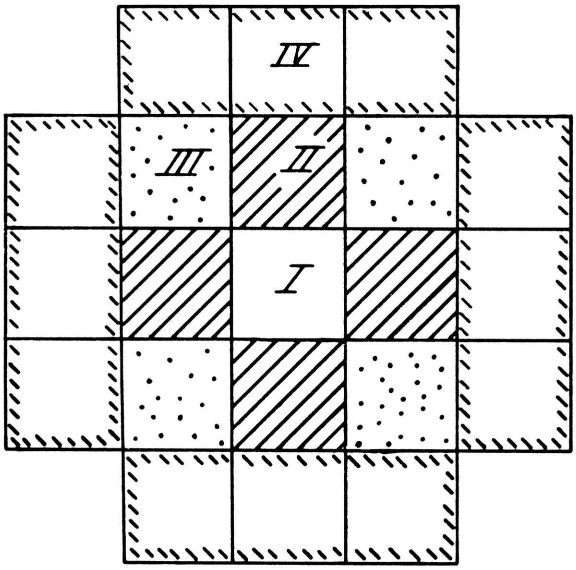


Figure 9.- Method by which communities occupying cells surrounding central cell (labeled I) influence selection of community to occupy cell in next time increment.

The weighting factors are fed in with data used to control operation of the program; consequently the seeding effect may be closely regulated. Cells lying at greater distances are considered to have negligible influence and are neglected. At the edges and corners of the map, special provision is made for the lack of symmetry about the central cell.

The seeding effect resulting from the operations described above provides a means by which communities can migrate geographically, competing for space and interacting with other communities. This causes a community which is better adapted for a given set of environmental conditions (i.e., has high "relative vitality") to gradually replace another community that has lower relative vitality (Fig. 10).

Tolerance of Organism Communities for Depth and for Terrestrially Derived Sediment

The manner in which the relative vitality of organism communities is affected by variations in depth of water is shown in Figure 11. The influence of depth is assumed to vary linearly between three points (Fig. 11): (1) an upper depth limit, above which a particular organism community cannot survive, (2) a lower depth limit below which the community cannot survive, and (3) a most favorable depth, where the community is best able to compete (other conditions remaining equal) and produce the greatest amount of sediment. A nonlinear (Gaussian, for example) function could be used to link the three points.

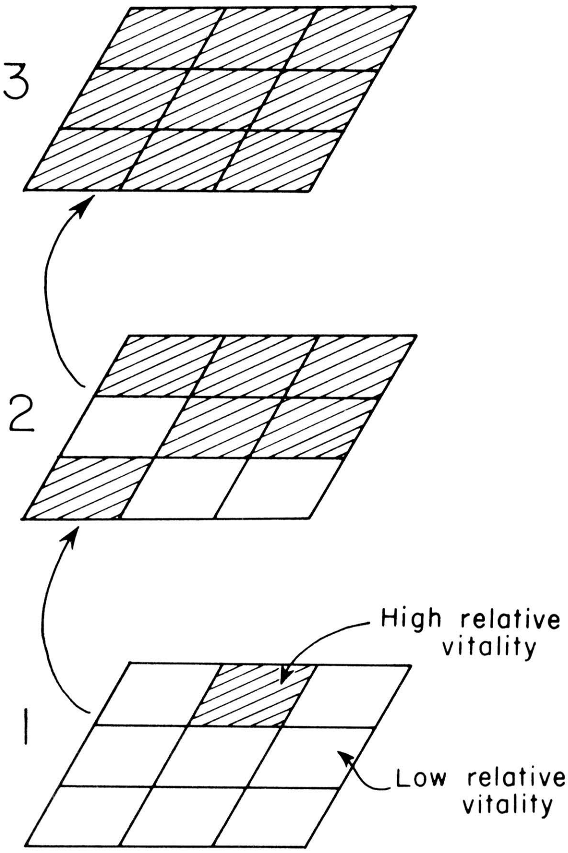


Figure 10.- Replacement of organism community of low relative vitality by one of high vitality through progressive time increments 1, 2, and 3.

The rate of supply of terrestrially derived sediment affects the vitality of an organism community in a slightly different manner. The rate of supply (in vertical units per time increment) is assumed to have no influence on the community until a specified threshold level is reached (Fig. 12). Above this level, increases in rate of supply cause the relative vitality of the community to decrease linearly until an intolerable sediment level is reached, where relative vitality reaches zero (or very nearly

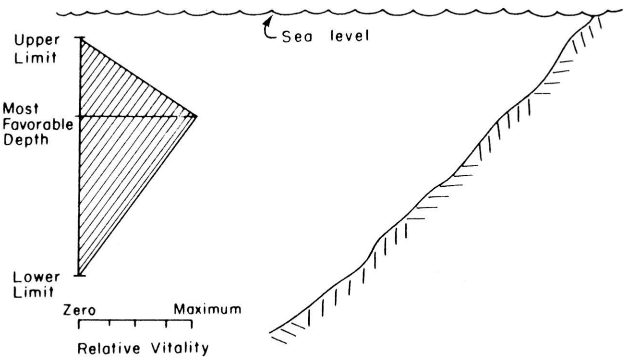


Figure 11.- Effect of variation in depth on relative vitality of organism community.

so). Production of sediment by the organism community is zero above the intolerable level, and the ability of the community to compete is reduced to a very low level. If, however, there is little or no competition from other organism communities, the community may survive even though the rate of supply of terrestrially derived sediment is above the intolerable level.

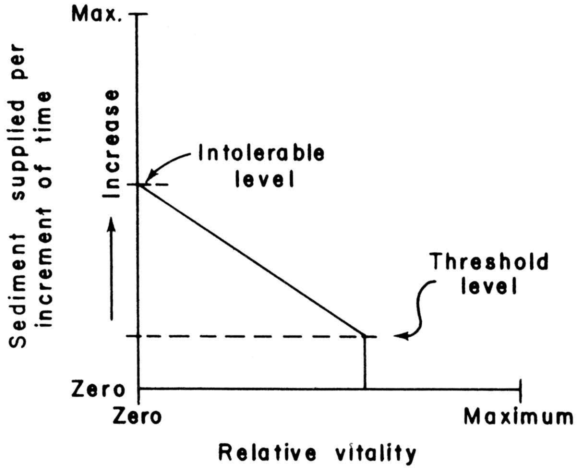


Figure 12.- Effect of variations in rate of supply of terrestrially derived sediment on relative vitality of organism community.

Cyclicity

An assumption of a sedimentary cycle of a prescribed number of time increments is incorporated in the program. The influence of parameters that control external environmental factors (such as supply of terrigenous sediment, etc.) are repeated from cycle to cycle. The cycle may be of any specified number of time increments, although it is currently limited to a maximum of 20 in the program (this limit could readily be increased by changing array dimensions).

The representation of rhythmic repetition of sedimentary cycles is suggested by cyclically bedded sediments of late Paleozoic age in many parts of the world. Presumably, these cyclic sediments reflect variations in ancient depositional environmental conditions that varied in more or less rhythmic fashions. Therefore, in the simulation program, provision is made for cyclic variation of external environmental factors. This does not imply, however, that the response of the model will be perfectly rhythmic from cycle to cycle. The model's response is affected by many factors, including its previous history with respect to organism communities. Because of the "inertia" effect of previous historical events, the model's response may be quite different from cycle to cycle.

VALIDITY OF SIMULATION MODEL

There are few, if any, rigorous means to determine the validity of assumptions incorporated in this simulation model. Instead, its validity must be established on a trial-and-error basis. The best that can be done is to incorporate assumptions concerning processes and factors in the model that seem reasonable from general scientific considerations, and to cause these processes to interact in an appropriate manner. If results (symbolic products) are obtained that accord consistently well with real geologic features, then the model may be judged to be reasonably valid.

KANSAS GEOLOGICAL SURVEY COMPUTER PROGRAM
THE UNIVERSITY OF KANSAS, LAWRENCE

PROGRAM ABSTRACT

Title (If subroutine state in title):

FORTRAN IV program for mathematical simulation of marine sedimentation with IBM 7040 or 7094 computers

Computer: IBM 7040 / IBM 7094

Date: December 25, 1966

Programming language: FORTRAN IV

Author, organization: J.W. Harbaugh and W.J. Wahlstedt
Stanford University and Kansas Geological Survey

Direct inquiries to: Authors or

Name: D.F. Merriam

Address: Kansas Geological Survey, Univ. of Kansas
Lawrence, Kansas 66044

Purpose/description: Mimic geologic processes involved in marine sedimentation, delta building, and development of marine organism communities.

Mathematical method: Numerical simulation of geologic processes.

Restrictions, range: Maximum size of map output is 20 x 40 cells.

Storage requirements:

Equipment specifications: Memory 20K____ 40K____ 60K____ 32 K X

Automatic divide: Yes____ No____ Indirect addressing Yes____ No____

Other special features required

Additional remarks (include at author's discretion: fixed/float, relocatability; optional: running time, approximate number of times run successfully, programming hours) This program has been run many times on 7040 and 7094 computers with no problems. However, due to variations in compilers, minor modifications may be necessary.

COMPUTER CONTRIBUTIONS

Kansas Geological Survey
University of Kansas
Lawrence, Kansas

Computer Contribution

1.	Mathematical simulation of marine sedimentation with IBM 7090/7094 computers, by J.W. Harbaugh, 1966.	$1.00
2.	A generalized two-dimensional regression procedure, by J. R. Dempsey, 1966	$0.50
3.	FORTRAN IV and MAP program for computation and plotting of trend surfaces for degrees 1 through 6, by Mont O'Leary, R.H. Lippert, and O.T. Spitz, 1966	$0.75
4.	FORTRAN II program for multivariate discriminant analysis using an IBM 1620 computer, by J.C. Davis and R.J. Sampson, 1966	$0.50
5.	FORTRAN IV program using double Fourier series for surface fitting of irregularly spaced data, by W.R. James, 1966	$0.75
6.	FORTRAN IV program for estimation of cladistic relationships using the IBM 7040, by R.L. Bartcher, 1966	$1.00
7.	Computer applications in the earth sciences: Colloquium on classification procedures, edited by D.F. Merriam, 1966	$1.00
8.	Prediction of the performance of a solution gas drive reservoir by Muskat's Equation, by Apolonio Baca, 1967	$1.00
9.	FORTRAN IV program for mathematical simulation of marine sedimentation with IBM 7040 or 7094 computers, by J.W. Harbaugh and W.J. Wahlstedt, 1967	$1.00

Reprints (available upon request)

Finding the ideal cyclothem, by W.C. Pearn (reprinted from Symposium on cyclic sedimentation, D.F. Merriam, editor, *Kansas Geological Survey Bulletin* 169, v. 2, 1964)

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