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Title	A Computer Program for the Calculation of Geomagnetic Field Changes due to an Inclined Rectangular Fault in a Half Space
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Citation	Journal of the Faculty of Science, Hokkaido University. Series 7, Geophysics, 10(2), 295-310
Issue Date	1997-02-28
Doc URL	<a href="https://hdl.handle.net/2115/8821">https://hdl.handle.net/2115/8821</a>
Type	departmental bulletin paper
File Information	10(2)_p295-310.pdf



# A Computer Program for the Calculation of Geomagnetic Field Changes due to an Inclined Rectangular Fault in a Half Space

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( Received December 9, 1996 )

## Abstract

It has been reported that the geomagnetic changes were accompanied with seismic activities. To estimate the seismomagnetic effect, Sasai (1991) presented the analytical solution of piezomagnetic potential in case of a vertical faulting. We expanded Sasai's method to an inclined faulting with arbitrary dip angle and developed a FORTRAN program to calculate the geomagnetic field changes.

## 1. Introduction

We established an analytic form of seismomagnetic effect due to an inclined rectangular fault with uniform slip (Utsugi et al., in preparation). As the mathematical expression is somewhat complicated, we present the FORTRAN program MGCAL for the sake of user's convenience. The program allows us to calculate the geomagnetic field changes in the northward, eastward and downward components, as well as the total force.

## 2. Formulation of piezomagnetic potential

### 2.1. Piezomagnetic potential due to an inclined fault

In the present section, we show an expression of the piezomagnetic potential due to an inclined fault briefly. Sasai (1991) formulated the elementary piezomagnetic potential  $\omega_{lm}^k$ , i.e. piezomagnetic potential due to a point dislocation source.  $\omega_{lm}^k$  is given by the integral over the surface of magnetized region of the medium ;

$$\omega_{lm}^k(\mathbf{r}, \boldsymbol{\xi}) = C_k \iint_S \left[ \mathbf{S}_{lm}^k(\mathbf{r}', \boldsymbol{\xi}) \cdot \mathbf{n} \frac{1}{|\mathbf{r} - \mathbf{r}'|} + \tau_{lm}^k(\mathbf{r}', \boldsymbol{\xi}) \frac{\partial}{\partial n} \frac{1}{|\mathbf{r} - \mathbf{r}'|} \right] dS_{r'} \quad (1)$$

$$C_k = \frac{1}{2} \beta J_k \mu \frac{3\lambda + 2\mu}{\lambda + \mu}, \quad (2)$$

where  $\boldsymbol{\xi}$  and  $\mathbf{r}$  denote source point and observation point, respectively.  $\tau_{lm}^k$  is the  $k$ -th component of displacement vector produced by point dislocation source of type  $(l, m)$ .  $\mathbf{S}_{lm}^k$  is the stress-induced magnetization vector.  $\lambda$  and  $\mu$  are the Lamé constants,  $\beta$  is the stress sensitivity,  $J_k$  is the  $k$ -th component of initial magnetization of crustal rock, and  $C_k$  is the  $k$ -th component of seismomagnetic moment produced by the piezomagnetic effect.

For the finite fault, we can obtain the piezomagnetic potential as the following integral over the fault plain  $\Sigma$ ;

$$W^k(\mathbf{r}) = \iint_{\Sigma} \Delta u_l(\boldsymbol{\xi}) \cdot \omega_{lm}^k(\mathbf{r}, \boldsymbol{\xi}) \cdot \nu_m(\boldsymbol{\xi}) d\Sigma_{\boldsymbol{\xi}}, \quad (3)$$

where  $W^k$  indicates the piezomagnetic potential produced by  $k$ -th component of initial magnetization of crustal rock,  $\Delta u_l$  is the dislocation vector (its  $l$ -th component) and  $\nu_m$  is a unit vector normal to the fault plain (its  $m$ -th component).

For an inclined rectangular fault (length  $L$ , width  $W$ , depth  $d$  and dip-angle  $\delta$ ) with uniform slip ( $U_1, U_2, U_3$ ) (Fig. 1), eq. (3) can be written in the following form;

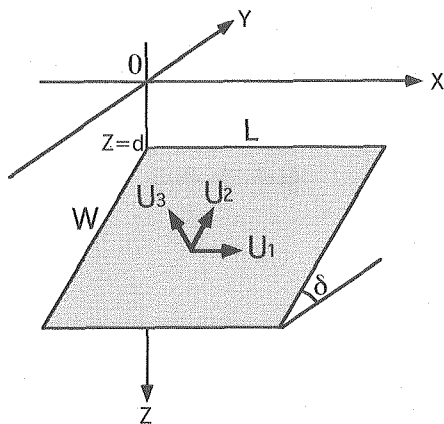


Fig. 1. Geometry of the fault model. Positive  $U_1, U_2$  and  $U_3$  with  $0 < \delta < \pi/2$  indicate left-lateral slip, thrusting slip and tensile opening, respectively.

$$W^k(\mathbf{r}) = U_1 \cdot S^k(\mathbf{r}) + U_2 \cdot D^k(\mathbf{r}) + U_3 \cdot T^k(\mathbf{r}) \quad (4)$$

where  $S^k$ ,  $D^k$  and  $T^k$  indicate the piezomagnetic potentials due to strike-slip, dip-slip and tensile opening faulting, respectively. These potentials can be written by the integral of  $\omega_{im}^k$  over the fault plain (Utsugi et al., in preparation).

2.2. Earth model

We assume the earth as a homogeneous and isotropic elastic half-space having a uniformly magnetized upper layer with a constant piezomagnetic stress sensitivity. We also assume the observation point is outside the medium.

We introduce a Cartesian coordinate as shown in Fig. 2, where  $X$ ,  $Y$  and  $Z$  axes are directed east, north and downward, respectively. A point above the left edge of the fault is taken to be the origin of the coordinate as shown in Fig. 2.  $X'$  and  $Y'$  are parallel and perpendicular axes to the strike direction of the fault.

A semi-infinite elastic medium occupies  $Z \geq 0$  and magnetized region is limited within a layer  $0 \leq Z \leq H$ , where  $H$  is the depth of the Curie point isotherm. Then we have to calculate  $\omega_{im}^k$  of eq. (1) over the free-surface ( $S_0$ ), the fault plain ( $\Sigma$ ) and the plain  $Z=H(S_H)$ . Therefore,  $W^k$  of eq. (3) can be written by the summation of the contributions from  $S_0$ ,  $\Sigma$  and  $S_H$ . As  $W^k$

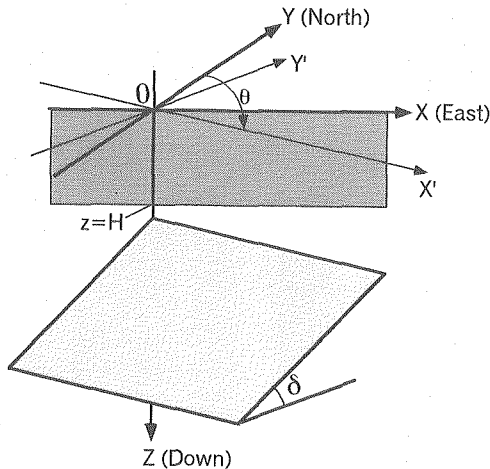


Fig. 2. Coordinate system.  $X$ ,  $Y$  and  $Z$  axis direct eastward, northward and downward, respectively.  $\theta$  and  $H$  mean strike-angle and depth of Curie point isotherm, respectively.

depends on the fault depth, we write  $W^k$  as the following form ;

$$W^k = W_{S_0+\Sigma}^k + W_{H_0}^k + \begin{cases} W_{HI}^k & (d + W \sin \delta > H) \\ W_{HII}^k & (d < H) \end{cases}$$

For this earth model, we can obtain the analytical solution of  $W^k$  as well as  $S^k$ ,  $D^k$  and  $T^k$ . The geomagnetic changes can be obtained by differentiating  $W^k$  with respect to  $X$ ,  $Y$  and  $Z$ . The analytical solution of geomagnetic changes are listed in Utsugi et al. (in preparation). As these solutions become singular when dip angle  $\delta = \pi/2$  (i.e. vertical fault), we cannot calculate geomagnetic changes. In this case, we should use the solution for vertical faulting presented by Sasai (1991).

### 3. Program

#### 3.1. Design of the program

The program MGCAL is designed for the analytical calculation of geomagnetic field changes due to an inclined rectangular fault. This program consists of a main program and 14 subroutines. The complete source list is given in Appendix.

The main program MGCAL calls subroutine CALCON1 and PIEZ. CALCON1 calculates seismomagnetic moment and constants with respect to medium included in  $S^k$ ,  $D^k$  and  $T^k$ . The geomagnetic changes are calculated by subroutine PIEZ. This subroutine calls subroutine DIFCOEF which calculate the geomagnetic changes in the coordinate system ( $X'$ ,  $Y'$ ,  $Z$ ) (Fig. 2). These geomagnetic changes are transformed in the coordinate system ( $X$ ,  $Y$ ,  $Z$ ) in subroutine PIEZ. The subroutine DIFCOEF calls following subroutines ;

- DERIV Calculate constants which are needed to calculate geomagnetic changes.
- STRIKE\_0, DIP\_0, TENSILE\_0 Calculate geomagnetic changes produced by free-surface and fault plain due to strike, dip and tensile-opening faulting ( $S_0 + \Sigma$ ).
- STRIKE\_H0, DIP\_H0, TENSILE\_H0 Calculate geomagnetic changes produced by Curie surface due to strike, dip and tensile-opening faulting (H0).
- STRIKE\_H, DIP\_H, TENSILE\_H Calculate geomagnetic changes produced by Curie surface due to strike, dip and tensile-opening faulting (HI + HII).

3.2. *Process*

In our program, we can chose the calculation point : the grid point or arbitrary point. Prior to execution of this program, we have to make a parameter file. The format of the parameter file is as follows ;

Calculation at grid points ;	Calculation at arbitrary points ;
IFLG	IFLG
NDX NDY XX0 YY0	NUMB
DX DY	U1 U2 U3 FL FW DPT STR DIP
Z	POI AMU CMZ GMINC GMDEC HH
U1 U2 U3 FL FW DPT STR DIP	BETA
POI AMU CMZ GMINC GMDEC HH	X Y Z
BETA	

The meaning of these parameters are described in Table 1 and 2. When our program is executed, firstly we have to chose the calculation point :  
 "CALCULATE AT GRID POINTS OR ARBITRARY POINTS?"  
 "TYPE GRID POINTS=1 OR ARBITRARY POINTS=2"

Next, the parameter file name and output file name are requested :  
 "PARAMETER FILE NAME IS=?"  
 "OUTPUT FILE NAME IS=?"

Then the output file is made : geomagnetic field changes are output with the coordinate of calculation point. The parameter "IFLG" is prepared for choice of geomagnetic field components (eastward-, northward-, downward-component or total force) (see Table 1).

Table 1. The roles of input parameter IFLG.

IFLG	Designates output values.
=1	Output eastward component of geomagnetic field change.
=2	Output northward component of geomagnetic field change.
=3	Output downward component of geomagnetic field change.
=4	Output total force of geomagnetic field change.

Table 2. The meaning of input parameters.

In the case of the calculation at grid points :

NDX, NDY		Grid number.
DX, DY		Sample interval of X and Y axis.
XX0, YY0		Coordinate of start point of grid.
Z	(km)	Z-coordinate of observation points ( $Z \leq 0$ ).

In the case of the calculation at arbitrary points :

NUMB		Number of arbitrary points.
X, Y, Z	(km)	Coordinates of observation points.

Fault parameters and medium parameters :

U1, U2, U3	(m)	Components of the displacement vector ( $U_1, U_2, U_3$ ).
FL, FW	(km)	Fault length $L$ and width $W$ .
STR	(degree)	Strike angle of the fault $\theta$ .
DIP	(degree)	Dip angle of the fault $\delta$ ( $0 \leq \delta < \pi/2$ ).
DPT	(km)	Depth of the upper boundary of the fault $d$ .

POI		Poisson ratio.
AMU	(cgs)	Lamé constant $\mu$ .
CMZ	(A/m)	Initial magnetization of crustal rock $ \mathbf{J} $ .
GMDEC	(degree)	Magnetic declination.
GMINC	(degree)	Magnetic inclination.
HH	(km)	Depth of the Curie point isotherm $H$ .
BETA	( $\text{bar}^{-1}$ )	Stress sensitivity $\beta$ .

### Acknowledgement

I would like to express my thank to Prof. Y. Nishida, Prof. Y. Sasai and Mr. H. Oshima for their valuable comments.

### References

- Sasai Y., 1991. Tectonomagnetic modeling on the basis of the linear piezomagnetic effect. Bull. Earth. Res. Inst., Univ. Tokyo, **66**, 585-722.

## Appendix

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1 C
2 PROGRAM MGAL
3 C*****
4 C
5 C GEOMAGNETIC FIELD CHANGE AT OUTSIDE THE MEDIUM
6 C DUE TO AN INCLINED RECTANGULAR FAULT
7 C IN A SEMIINFINITE MEDIUM
8 C CODED BY M. UTSUGI...DEC 1996
9 C
10 C*****
11 C**** INPUT PARAMETERS
12 C NDX,NDY : GRID NUMBER (X,Y)
13 C DX,DY : SAMPLE INTERVAL (X,Y)
14 C NUMB : NUMBER OF ARBITRARY POINTS
15 C Z : Z-COORDINATE OF OBS. POINT
16 C
17 C IFLG =1..OUTPUT EASTWARD 2..NORTHWARD 3..DOWNWARD COMPONENT
18 C 4..TOTAL FORCE OF GEOMAGNETIC FIELD CHANGE
19 C U1,U2,U3 : DISLOCATION VECTOR(M)
20 C U1..STRIKE-SLIP
21 C U2..DIP-SLIP
22 C U3..TENSILE-OPENING
23 C DIP_STR : FAULT DIP AND STRIKE ANGLE (DEGREE)
24 C FL,FW,DPT : FAULT LENGTH, WIDTH AND DEPTH(KM)
25 C POI,AMU : POISSON RATIO AND LAME CONSTANT MU(CGS)
26 C BETA : STRESS SENSITIVITY
27 C HH : CURIE DEPTH(KM)
28 C CMZ : CRUSTAL MAGNETIZATION(A/M)
29 C GMINC,GMDEC : GEOMAGNETIC INCLINATION AND DECRINATION(DEG.)
30 C***** OUTPUT VALUES
31 C DMX,DMY,DMZ,DMF : EAST, NORTH, DOWNWARD COMPONENTS
32 C AND TOTAL FORCE OF GEOMAGNETIC
33 C FIELD CHANGE (NT)
34 C
35 INTEGER I,J,K,INDX,NDX,NDY,NUMB,IFLG
36 IMPLICIT REAL*8 (A-H,O-Z)
37 DIMENSION SITX(50),SITY(50),SITZ(50)
38 CHARACTER*20 INFILE1,INFILE2
39 C
40 WRITE(6,*) 'CALCULATE AT GRID POINTS OR ARBITRARY POINTS'
41 WRITE(6,*) 'TYPE GRID POINTS=1 OR ARBITRARY POINTS=2'
42 READ(5,*) INDX
43 WRITE(6,*) 'PARAMETER FILE NAME=?'
44 READ(5,*) INFILE1
45 WRITE(6,*) 'OUTPUT FILE NAME=?'
46 READ(5,*) INFILE2
47 C
48 OPEN(10,FILE=INFILE1,STATUS='OLD')
49 OPEN(20,FILE=INFILE2,STATUS='NEW')
50 IF(INDX.EQ.1) GOTO 100
51 IF(INDX.EQ.2) GOTO 200
52 C
53 100 READ(10,*) IFLG
54 READ(10,*) NDX,NDY
55 READ(10,*) Z
56 READ(10,*) DX,DY,XX0,YY0
57 READ(10,*) U1,U2,U3,FL,FW,DPT,STR,DIP
58 READ(10,*) POI,AMU,CMZ,GMINC,GMDEC,HH,BETA
59 CLOSE(10)
60 IF(Z.GT.0.D0) THEN
61 WRITE(6,*) 'POSITIV Z CANNOT BE ACCEPTED IN THIS PROGRAM'
62 GOTO 400
63 ENDF
64 IF(DIP.EQ.90.D0) THEN
65 WRITE(6,*) 'DIP=90 CANNOT BE ACCEPTED IN THIS PROGRAM'
66 GOTO 400
67 ENDF
68 STR=90.D0-STR
69 CALL CALCON1(POI,AMU,BETA,CMZ,DIP,STR,GMINC,GMDEC)
70 C
71 X=XX0
72 DO 120 J=1,NDX+1
73 Y=YY0
74 DO 110 J=1,NDY+1
75 CALL PIEZ(X,Y,Z,U1,U2,U3,DIP_STR,FL,FW,DPT,POI,
76 & AMU,BETA,HH,CMZ,GMINC,GMDEC,DMX,DMY,DMZ,DMF)
77 IF(IFLG.EQ.1) WRITE(20,310) X,Y,DMX
78 IF(IFLG.EQ.2) WRITE(20,310) X,Y,DMY
79 IF(IFLG.EQ.3) WRITE(20,310) X,Y,DMZ
80 IF(IFLG.EQ.4) WRITE(20,310) X,Y,DMF
81 Y=Y+DY
82 110 CONTINUE
83 X=X+DX
84 120 CONTINUE
85 GOTO 300
86 C
87 200 READ(10,*) IFLG
88 READ(10,*) NUMB
89 READ(10,*) U1,U2,U3,FL,FW,DPT,STR,DIP
90 READ(10,*) POI,AMU,CMZ,GMINC,GMDEC,HH,BETA
91 DO 210 K=1,NUMB

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92      READ(10,*) SITX(K),SITY(K),SITZ(K)
93      IF(SITZ(K).GT.0.D0) THEN
94          WRITE(6,*) 'POSITIV Z CANNOT BE ACCEPTED IN THIS PROGRAM'
95          GOTO 400
96      ENDDIF
97  210 CONTINUE
98      CLOSE(10)
99      IF(DIP.EQ.90.D0) THEN
100         WRITE(6,*) 'DIP=90 CANNOT BE ACCEPTED IN THIS PROGRAM'
101         GOTO 400
102     ENDDIF
103     STR=90.D0-STR
104     CALL CALCON1(POI,AMU,BETA,CMZ,DIP,STR,GMINC,GMDEC)
105 C
106     DO 220 K=1,NUMB
107         X=SITX(K)
108         Y=SITY(K)
109         Z=SITZ(K)
110         CALL PIEZ(X,Y,Z,U1,U2,U3,DIP,STR,FL,FW,DPT,POI,
111             & AMU,BETA,HH,CMZ,GMINC,GMDEC,DMX,DMY,DMZ,DMF)
112         IF(IFLG.EQ.1) WRITE(20,310) X,Y,DMX
113         IF(IFLG.EQ.2) WRITE(20,310) X,Y,DMY
114         IF(IFLG.EQ.3) WRITE(20,310) X,Y,DMZ
115         IF(IFLG.EQ.4) WRITE(20,310) X,Y,DMF
116     220 CONTINUE
117     300 CLOSE(20)
118     310 FORMAT(' ',F10.3,F10.3,F15.5)
119     400 STOP
120     END
121 C
122 C
123 C
124     SUBROUTINE PIEZ(X,Y,Z,U1,U2,U3,DIP,STR,FL,FW,DPT,POI,
125         & AMU,BETA,HH,CMZ,GMINC,GMDEC,DMX,DMY,DMZ,DMF)
126     INTEGER I
127     IMPLICIT REAL*8 (A-H,O-Z)
128 C
129 C*****
130 C CALCULATE EACH COMPONENT OF GEOMAGNETIC FIELD CHANGE
131 C*****
132 C***** INPUT *****
133 C X,Y,Z : COORDINATE OF OBS. POINT
134 C U1,U2,U3 : DISLOCATION VECTOR
135 C DIP,STR : FAULT DIP AND STRIKE ANGLE
136 C FL,FW,DPT : FAULT LENGTH, WIDTH AND DEPTH OF BURIAL
137 C POI,AMU : POISSON RATIO AND LAME CONSTANT MU
138 C BETA : STRESS SENSITIVITY
139 C HH : CURIE DEPTH
140 C CMZ : CRUSTAL MAGNETIZATION
141 C GMINC,GMDEC : GEOMAGNETIC INCLINATION AND DECRINATION
142 C***** OUTPUT *****
143 C DMX,DMY,DMZ,DMF : EAST, NORTH, DOWNWARD COMPONENTS
144 C AND TOTAL FORCE OF GEOMAGNETIC
145 C FIELD CHANGE
146 C
147     COMMON /C0/ SD,CD,TD,SED
148     DIMENSION DM0(3)
149     DATA PI/3.141592653589793D0/
150     P18=PI/180.D0
151 C-----
152 C COORDINATE TRANSFORM
153 C-----
154     XT=X*DCOS(STR*P18)+Y*DSIN(STR*P18)
155     YT=X*DSIN(STR*P18)-Y*DCOS(STR*P18)
156     ZT=Z
157 C-----
158     DD1=DPT-ZT
159     DD2=DPT-2.D0*HH+ZT
160     DD3=DPT+2.D0*HH-ZT
161 C
162     P1=YT*CD-DD1*SD
163     P2=YT*CD-DD2*SD
164     P3=YT*CD-DD3*SD
165     Q1=YT*SD+DD1*CD
166     Q2=YT*SD+DD2*CD
167     Q3=YT*SD+DD3*CD
168     QD=YT*SD+(DPT-HH)*CD
169 C
170     FW2=(HH-DPT)/SD
171     BDPT=DPT-FW*SD
172     ZH=ZT-HH
173 C
174     DO 100 I=1,3
175         JDRV=I
176         CALL DIFCOEF(XT,ZT,P1,P2,P3,Q1,Q2,Q3,QD,U1,U2,U3,
177             & FL,FW,DPT,FW2,BDPT,HH,JDRV,DM)
178         DM0(I)=DM
179  100 CONTINUE
180     DMX0=DM0(1)
181     DMY0=DM0(2)
182     DMZ0=DM0(3)

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183 C-----
184 C      CALCULATE EACH COMPONENT OF
185 C      GEOMAGNETIC FIELD CHANGE
186 C-----
187      DMX=-DMX0*DCOS(STR*P18)-DMY0*DSIN(STR*P18)
188      DMY=-DMX0*DSIN(STR*P18)+DMY0*DCOS(STR*P18)
189      DMZ=-DMZ0
190      DMF=DMX*DCOS(GMINC*P18)*DSIN(GMDEC*P18)
191      &      +DMY*DCOS(GMINC*P18)*DCOS(GMDEC*P18)
192      &      +DMZ*DSIN(GMINC*P18)
193      RETURN
194      END
195 C
196 C
197 C
198      SUBROUTINE DIFCOEF(XT,ZT,P1,P2,P3,Q1,Q2,Q3,QD,U1,U2,U3,
199      &      FL,FW,DPT,FW2,BDPT,HH,JDRV,DM)
200      INTEGER I,J,K,JDRV
201      IMPLICIT REAL*8 (A-H,O-Z)
202 C
203 C*****
204 C      CALCULATE DIFFERENTIAL COEFFICIENT
205 C      OF PIEZOMAGNETIC POTENTIAL
206 C*****
207 C***** INPUT *****
208 C      XT,ZT : TRANSFORMED COORDINATE OF OBS. POINT
209 C      P1,P2,P3 : Y-COORDINATE OF OBS. POINT IN FAULT SYSTEM
210 C      Q1,Q2,Q3 : Z-COORDINATE OF OBS. POINT IN FAULT SYSTEM
211 C      U1,U2,U3 : DISLOCATION VECTOR
212 C      FL,FW,DPT : FAULT LENGTH, WIDTH AND FAULT DEPTH
213 C      BDPT : DEPTH OF BOTTOM OF FAULT
214 C      HH : CURIE DEPTH
215 C      JDRV =1..OUTPUT XT-DERIVATION
216 C           =2.. YZ-DERIVATION
217 C           =3.. ZT-DERIVATION OF PIEZOMAGNETIC POTENTIAL
218 C***** OUTPUT *****
219 C      DM : DIFFERENTIAL COEFFICIENT OF PIEZOMAGNETIC POTENTIAL
220 C
221      COMMON /C0/ SD,CD,TD,SED
222      DIMENSION DIF0(4),DIFH0(4),DIFH(4)
223      DATA F0/0.D0/
224 C
225      K=1
226      ZH=ZT-HH
227      DO 200 I=1,2
228      IF(I.EQ.1) XI=XT
229      IF(I.EQ.2) XI=XT-FL
230      DO 100 J=1,2
231      IF(J.EQ.1) THEN
232      ET1=P1
233      ET3=P3
234      ELSEIF(J.EQ.2) THEN
235      ET1=P1-FW
236      ET3=P3-FW
237      ENDIF
238 C
239      SGN=1.D0
240      CALL DERIV(XI,ET3,Q3,QD,ZH,HH,SGN,JDRV)
241      IF(U1.NE.F0) CALL STRIKE_H0(HH,SH0)
242      IF(U2.NE.F0) CALL DIP_H0(HH,DH0)
243      IF(U3.NE.F0) CALL TENSILE_H0(HH,TH0)
244      DIFH0(K)=U1*SH0+U2*DH0+U3*TH0
245      CALL DERIV(XI,ET1,Q1,QD,ZH,HH,SGN,JDRV)
246      IF(U1.NE.F0) CALL STRIKE_0(HH,S0)
247      IF(U2.NE.F0) CALL DIP_0(HH,D0)
248      IF(U3.NE.F0) CALL TENSILE_0(HH,T0)
249      DIF0(K)=U1*S0+U2*D0+U3*T0
250 C
251      IF(DPT.GT.HH) THEN
252      IF(U1.NE.F0) CALL STRIKE_H(SGN,HH,SH)
253      IF(U2.NE.F0) CALL DIP_H(SGN,HH,DH)
254      IF(U3.NE.F0) CALL TENSILE_H(SGN,HH,TH)
255      DIFH(K)=U1*SH+U2*DH+U3*TH
256      GOTO 30
257      ENDIF
258      IF(DPT.LT.HH.AND.BDPT.LT.HH) GOTO 10
259      IF(DPT.LT.HH.AND.BDPT.GT.HH) GOTO 20
260 C
261 10      IF(J.EQ.1) ET2=P2
262      IF(J.EQ.2) ET2=P2-FW
263      SGN=-1.D0
264      CALL DERIV(XI,ET2,Q2,QD,ZH,HH,SGN,JDRV)
265      IF(U1.NE.F0) CALL STRIKE_H(SGN,HH,SH)
266      IF(U2.NE.F0) CALL DIP_H(SGN,HH,DH)
267      IF(U3.NE.F0) CALL TENSILE_H(SGN,HH,TH)
268      DIFH(K)=U1*SH+U2*DH+U3*TH
269      GOTO 30
270 C
271 20      IF(J.EQ.1) THEN
272      ET1=P1-FW2
273      ET2=P2

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274         ELSEIF(J.EQ.2) THEN
275             ET1=P1-FW
276             ET2=P2-FW2
277         ENDIF
278         SGN=1.D0
279         CALL DERIV(XI,ET1,Q1,QD,ZH,HH,SGN,JDRV)
280         IF(U1.NE.F0) CALL STRIKE_H(SGN,HH,SH1)
281         IF(U2.NE.F0) CALL DIP_H(SGN,HH,DH1)
282         IF(U3.NE.F0) CALL TENSILE_H(SGN,HH,TH1)
283         SGN=-1.D0
284         CALL DERIV(XI,ET2,Q2,QD,ZH,HH,SGN,JDRV)
285         IF(U1.NE.F0) CALL STRIKE_H(SGN,HH,SH2)
286         IF(U2.NE.F0) CALL DIP_H(SGN,HH,DH2)
287         IF(U3.NE.F0) CALL TENSILE_H(SGN,HH,TH2)
288         DIF(K)=U1*(SH1+SH2)+U2*(DH1+DH2)+U3*(TH1+TH2)
289         K=K+1
290     100 CONTINUE
291     200 CONTINUE
292     DM0=DIF0(1)-DIF0(2)-DIF0(3)+DIF0(4)
293     DMH0=DIFH0(1)-DIFH0(2)-DIFH0(3)+DIFH0(4)
294     DMH=DIFH(1)-DIFH(2)-DIFH(3)+DIFH(4)
295     DM=DM0+DMH0+DMH
296     RETURN DM
297     END
298 C
299 C
300 C
301 SUBROUTINE CALCON1(POI,AMU,BETA,CMZ,DIP,STR,GMINC,GMDEC)
302 IMPLICIT REAL*8 (A-H,O-Z)
303 C
304 C*****
305 C     CALCULATE MEDIUM CONSTANTS, FALUT-DIP CONSTANTS
306 C     AND SEISMOMAGNETIC MOMENT
307 C*****
308 C***** INPUT *****
309 C     POI,AMU : POISSON RATIO AND LAME CONSTANT MU
310 C     BETA : STRESS SENSITIVITY
311 C     CMZ : CRUSTAL MAGNETIZATION
312 C     DIP,STR : FAULT DIP AND STRIKE ANGLE
313 C     GMINC,GMDEC : GEOMAGNETIC INCLINATION AND DECLINATION
314 C
315 COMMON /C0/ SD,CD,TD,SED
316 & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
317 DATA PI/3.141592653589793D0/
318 C
319 P18=PI/180.D0
320 SD=DSIN(DIP*P18)
321 CD=DCOS(DIP*P18)
322 TD=DTAN(DIP*P18)
323 SED=1.D0/CD
324 C----- AL : MEDIUM CONSTANT ALPHA -----
325 C----- =(LAMBDA+MU)/(LAMBDA+2MU) -----
326 AL=1.D0/(2.D0*(1.D0-POI))
327 ALL=4.D0*AL-1.D0
328 AL1=3.D0*AL/ALL
329 AL2=12.D0*AL/ALL
330 AL3=AL*(2.D0*AL-1.D0)/ALL
331 AL4=AL*(2.D0*AL-5.D0)/ALL
332 AL5=2.D0*AL*(1.D0-AL)/ALL
333 AL6=6.D0*(AL*AL)/ALL
334 C----- SMM : SEISMOMAGNETIC MOMENT -----
335 SMM=CMZ*BETA*AMU*(1.D0+POI)
336 C0=0.5D0*SMM*1.D-7
337 CX=C0*DCOS(GMINC*P18)*DSIN((STR+GMDEC)*P18)
338 CY=-C0*DCOS(GMINC*P18)*DCOS((STR+GMDEC)*P18)
339 CZ=C0*DSIN(GMINC*P18)
340 RETURN
341 END
342 C
343 C
344 C
345 SUBROUTINE CALCON2(XI,ET,QQ,CC)
346 IMPLICIT REAL*8 (A-H,O-Z)
347 C
348 C*****
349 C     CALCULATE STATION GEOMETRY CONSTANTS
350 C*****
351 C***** INPUT *****
352 C     XI,ET,QQ : COORDINATES OF OBS. POINT IN FAULT SYSTEM
353 C     CC : SGN*(QQ*COS(DIP)-ET*SIN(DIP))
354 C
355 COMMON /PRM/ R,R3,RX,RE,RC,RRX,RRE,RRC,RX2,RE2,RC2,
356 & TRX,TRE,TRC,R3X2,R3E2,R3C2
357 R=DSQRT(XI*XI+ET*ET+QQ*QQ)
358 R3=R*R*R
359 C
360 RX=R+XI
361 RE=R+ET
362 RC=R+CC
363 C
364 RRX=R*RX

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365 RRE=R*RE
366 RRC=R*RC
367 C
368 RX2=RX*RX
369 RE2=RE*RE
370 RC2=RC*RC
371 C
372 TRX=2.D0*R+XI
373 TRE=2.D0*R+ET
374 TRC=2.D0*R+CC
375 R3X2=R3*RX2
376 R3E2=R3*RE2
377 R3C2=R3*RC2
378 RETURN
379 END
380 C
381 C
382 C
383 SUBROUTINE DERIV(XI,ET,QQ,QD,ZH,HH,SGN,JDRV)
384 INTEGER LT,JDRV
385 IMPLICIT REAL*8 (A-H,O-Z)
386 C
387 C*****
388 C CALCULATE DIFFERENTIAL COEFFICIENT OF
389 C ELEMENTARY FUNCTIONS
390 C*****
391 C***** INPUT *****
392 C XI,ET,QQ : COORDINATES OF OBS. POINT IN FAULT SYSTEM
393 C GD : YT*SIN(DIP)+(DPT-HH)*COS(DIP)
394 C ZH : ZT-HH
395 C HH : CURIE DEPTH
396 C JDRV =1..CALCULATE XT-DERIVATE
397 C =2.. YT-DERIVATE
398 C =3.. ZT-DERIVATE OF ELEMENTARY FUNCTIONS
399 C
400 COMMON /C0/ SD,CD,TD,SED
401 & /PRM/ R,R3,RX,RE,RC,RRX,RRE,RRC,RX2,RE2,RC2,
402 & TRX,TRE,TRC,R3X2,R3E2,R3C2
403 & /MAIN/ W(9)
404 & /ELM1/ FLX,FILE,FLC,TAN,G(2)
405 & /ELM2/ A(3),B(3),D(3),E(3),F(3)
406 & /ELM3/ SX1,SY1,SZ1,DX1,DY1,DZ1,TX1,TY1,TZ1
407 DATA F0,F1,EPS/0.D0,1.00,1.D-6/
408 C
409 YY=ET*CD+QQ*SD
410 CC=SGN*(QQ*CD-ET*SD)
411 CALL CALCON2(XI,ET,QQ,CC)
412 IF(ABS(RE).GT.EPS) LT=1
413 IF(ABS(RE).LE.EPS) LT=0
414 C
415 AI0=F1/RRC
416 IF(LT.EQ.1) AI0=AI0+SGN*SD/RRE
417 C-----
418 C X-DERIVATIVE
419 C-----
420 IF(JDRV.NE.1) GOTO 100
421 C-----
422 C ELEMENTARY FUNCTIONS
423 C DIPOLES
424 C-----
425 TAN=F0
426 FLE=F0
427 FLX=F1/R
428 FLC=XI/RRC
429 G(1)=SGN*YY/RRC
430 IF(LT.EQ.1) THEN
431 TAN=TAN-QQ/RRE
432 FLE=FLE+XI/RRE
433 G(1)=G(1)+QQ/RRE
434 ENDF
435 G(2)=FLC+SGN*SD*FLE
436 C
437 W(1)=TD*(F1/RC-(XI*XI)/(R*RC2))+TD*TD*G(1)
438 W(2)=-TD*XI*YY/(R*RC2)-SGN*TD*TD*G(2)
439 W(3)=TD*G(2)
440 W(4)=CD*(W(2)-SD*FLE)
441 W(5)=CD*W(1)
442 W(6)=-SD*G(1)
443 W(7)=-SD*(W(2)-SD*FLE)
444 W(8)=-SD*W(1)
445 W(9)=-SD*TD*G(1)
446 C-----
447 C ELEMENTARY FUNCTIONS
448 C QUADRA AND OCTA POLES
449 C-----
450 IF(LT.EQ.1) THEN
451 A(1)=F1/RRE-(XI*XI)*TRE/R3E2
452 A(2)=-XI*CD/(R*RE2)-XI*YY*TRE/R3E2
453 A(3)=SGN*XI*SD/(R*RE2)-XI*CC*TRE/R3E2
454 ELSE
455 DO 10 I=1,3

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456         A(I)=F0
457 10      CONTINUE
458         ENDIF
459 C
460         B(1)=F1/RR-(XI*XI)*TRC/R3C2
461         B(2)=-XI*YY*TRC/R3C2
462 C
463         D(1)=-XI/R3
464         D(2)=-YY/R3
465         D(3)=-CC/R3
466 C
467         E(1)=F0
468         E(2)=SGN*CC/R3
469         E(3)=-SGN*YY/R3
470         AI1=-XI*TRC/R3C2
471         F(2)=F0
472         IF(LT.EQ.1) THEN
473             E(1)=E(1)+XI*QQ*TRE/R3E2
474             E(2)=E(2)+SD/RRE-(XI*XI)*SD*TRE/R3E2
475             E(3)=E(3)+SGN*(CD/RRE-(XI*XI)*CD*TRE/R3E2)
476             AI1=AI1-SGN*XI*SD*TRE/R3E2
477             F(2)=F(2)-SGN*XI*SD/(R*RE2)
478         ENDIF
479         F(1)=XI*AI1+A10
480         F(2)=F(2)+YY*SED*AI1
481         F(3)=B(1)+D(3)
482 C
483         SX1=QD*A(1)+ZH*F(1)*TD
484         SY1=QD*A(2)+ZH*F(2)*SD
485         SZ1=QD*A(3)+ZH*A(2)*SD
486         DX1=QD*D(1)+ZH*B(2)*SD
487         DY1=QD*D(2)+ZH*F(3)*SD
488         DZ1=QD*D(3)+ZH*D(2)*SD
489         TX1=QD*E(1)-ZH*(A(2)+SD*B(2))*TD
490         TY1=QD*(D(3)-SD*A(1))+ZH*(D(2)-TD*F(1))*SD
491         TZ1=QD*E(3)+ZH*E(2)*SD
492 C-----
493 C      Y-DERIVATIVE
494 C-----
495 100    IF(JDRV.NE.2) GOTO 200
496 C-----
497 C      ELEMENTARY FUNCTIONS
498 C      DIPOLES
499 C-----
500         TAN=SGN*CC/RRX
501         FLE=F0
502         FLX=YY/RRX
503         FLC=YY/RRC
504         G(1)=-SGN*XI/RRC
505         IF(LT.EQ.1) THEN
506             TAN=TAN+XI*SD/RRE
507             FLE=FLE+CD/RE+YY/RRE
508             G(1)=G(1)-XI*SD/RRE
509         ENDIF
510         G(2)=FLC+SGN*FLE
511 C
512         W(1)=-TD*XI*YY/(R*RC2)+TD*TD*G(1)
513         W(2)=-TD*(F1/RC-(YY*YY)/(R*RC2))-SGN*TD*TD*G(2)
514         W(3)=-TD*G(2)
515         W(4)=CD*(W(2)-SD*FLE)
516         W(5)=CD*W(1)
517         W(6)=-SD*G(1)
518         W(7)=-SD*(W(2)-SD*FLE)
519         W(8)=-SD*W(1)
520         W(9)=-SD*TD*G(1)
521 C-----
522 C      ELEMENTARY FUNCTIONS
523 C      QUADRA AND OCTA POLES
524 C-----
525         IF(LT.EQ.1) THEN
526             A(1)=-XI*CD/(R*RE2)-XI*YY*TRE/R3E2
527             A(2)=-SD*SD/RE2-(YY*CD+SGN*CC*SD)/(R*RE2)
528             & A(3)=-YY*YY*TRE/R3E2
529             & A(3)=-SGN*SD*CD/RE2-(CC*CD-SGN*YY*SD)/(R*RE2)
530             & A(3)=-YY*CC*TRE/R3E2
531         ELSE
532             DO 110 I=1,3
533                 A(I)=F0
534 110      CONTINUE
535         ENDIF
536 C
537         B(1)=-XI*YY*TRC/R3C2
538         B(2)=F1/RR-(YY*YY)*TRC/R3C2
539 C
540         D(1)=-YY/R3
541         D(2)=F1/RR-(YY*YY)*TRX/R3X2
542         D(3)=-YY*CC*TRX/R3X2
543 C
544         E(1)=F0
545         E(2)=-SGN*YY*CC*TRX/R3X2
546         E(3)=-SGN*(F1/RR-(YY*YY)*TRX/R3X2)

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547 AI1=-YY*TRC/R3C2
548 F(2)=-SED*AI0
549 IF(LT.EQ.1) THEN
550 E(1)=E(1)-SD/RE2+SGN*CC/(R*RE2)+YY*QQ*TRC/R3E2
551 E(2)=E(2) -SD*(XI*CD/(R*RE2)+XI*YY*TRC/R3E2)
552 E(3)=E(3)-SGN*CD*(XI*CD/(R*RE2)+XI*YY*TRC/R3E2)
553 AI1=AI1-SGN*SD*(CD/(R*RE2)+YY*TRC/R3E2)
554 F(2)=F(2)-SGN*SD*(CD/RE2+YY/(R*RE2))
555 ENDIF
556 F(1)=-XI*AI1
557 F(2)=-F(2)+YY*SED*AI1
558 F(3)=-B(1)+D(3)
559 C
560 SX1=QD*A(1)+ZH*F(1)*TD
561 SY1=QD*A(2)+ZH*F(2)*SD
562 SZ1=QD*A(3)+ZH*A(2)*SD
563 DX1=QD*D(1)+ZH*B(2)*SD+SD/R
564 DY1=QD*D(2)-ZH*F(3)*SD+SD*YY/RRX
565 DZ1=QD*D(3)+ZH*D(2)*SD+SD*CC/RRX
566 TX1=QD*E(1)-ZH*(A(2)+SD*B(2))*TD
567 TY1=QD*E(1)-ZH*(A(2)+SD*B(2))-TD*F(1))*SD
568 & +SD*CC/RRX
569 TZ1=QD*E(3)+ZH*E(2)*SD+SD*SGN*YY/RRX
570 IF(LT.EQ.1) THEN
571 SX1=SD*X1/RRR
572 SY1=SD*Y1/RRR
573 SZ1=SD*Z1/RRR
574 TX1=SD*TX1/RRR
575 TY1=SD*TY1/RRR
576 TZ1=SD*TZ1/RRR
577 ENDIF
578 C -----
579 C Z-DERIVATIVE
580 C -----
581 200 IF(JDRV.NE.3) GOTO 300
582 C -----
583 C ELEMENTARY FUNCTIONS
584 C DIPOLES
585 C -----
586 TAN=-SGN*YY/RRX
587 FLE=F0
588 FLX=-CC/RRX
589 FLC=-F1/R
590 G(1)=F0
591 G(2)=F0
592 IF(LT.EQ.1) THEN
593 TAN=TAN-SGN*X1*CD/RRR
594 FLE=FLE+SGN*SD/RE-CC/RRR
595 G(1)=G(1)+SGN*X1*CD/RRR
596 ENDIF
597 G(2)=FLC+SGN*FLE
598 C -----
599 W(1)=TD*X1/RRR+TD*TD*G(1)
600 W(2)=TD*YY/RRR-SGN*TD*TD*G(2)
601 W(3)=TD*G(2)
602 W(4)=CD*(W(2)-SD*FLE)
603 W(5)=CD*W(1)
604 W(6)=-SD*G(1)
605 W(7)=-SD*(W(2)-SD*FLE)
606 W(8)=-SD*W(1)
607 W(9)=SD*TD*G(1)
608 C -----
609 C ELEMENTARY FUNCTIONS
610 C QUADRA AND OCTA POLES
611 C -----
612 IF(LT.EQ.1) THEN
613 A(1)=-XI*CD/(R*RE2)-XI*YY*TRC/R3E2
614 A(2)=-SD*SD/RE2-(YY*CD+SGN*CC*SD)/(R*RE2)
615 & -YY*YY*TRC/R3E2
616 A(3)=-SGN*SD*CD/RE2-(CC*CD-SGN*YY*SD)/(R*RE2)
617 & -YY*CC*TRC/R3E2
618 ELSE
619 DO 210 I=1,3
620 A(I)=F0
621 210 CONTINUE
622 ENDIF
623 C -----
624 B(1)=XI/R3
625 B(2)=YY/R3
626 C -----
627 D(1)=CC/R3
628 D(2)=-YY*CC*TRX/R3X2
629 D(3)=-F1/RRX+(CC*CC)*TRX/R3X2
630 C -----
631 E(1)=F0
632 E(2)=-SGN*(F1/RRX-(CC*CC)*TRX/R3X2)
633 E(3)=-SGN*YY*CC*TRX/R3X2
634 AI1=F1/R3
635 F(2)=F0
636 IF(LT.EQ.1) THEN
637 E(1)=E(1)+SGN*(CD/RE2+YY/(R*RE2))-QQ*CC*TRC/R3E2

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638      E(2)=E(2)+SD*(-SGN*XI*SD/(R*RE2))+XI*CC*TR/R3E2)
639      E(3)=E(3)+CD*(-XI*SD/(R*RE2)+SGN*XI*CC*TR/R3E2)
640      AI1=AI1-SD*(SD/(R*RE2)-SGN*CC*TR/R3E2)
641      F(2)=F(2)+SD*(-SD/RE2+SGN*CC/(R*RE2))
642      ENDIF
643      F(1)=XI*AI1
644      F(2)=F(2)+SED*YY*AI1
645      F(3)=B(1)+D(3)
646 C
647      SX1=QD*A(1)+ZH*F(1)*TD+XI*AI0*TD
648      SY1=QD*A(2)+ZH*F(2)*SD+YY*AI0*TD
649      SZ1=QD*A(3)+ZH*A(2)*SD
650      DX1=QD*D(1)+ZH*B(2)*SD-SD*YY/RR
651      DY1=QD*D(2)-ZH*F(3)*SD-SD*(XI/RR+CC/RRX)
652      DZ1=QD*D(3)+ZH*D(2)*SD+SD*YY/RRX
653      TX1=QD*E(1)-ZH*A(2)+SD*B(2))*TD
654      &
655      TY1=QD*(D(3)-SD*A(1))+ZH*(D(2)-TD*F(1))*SD
656      &
657      TZ1=QD*E(3)+ZH*E(2)*SD-SD*SGN*CC/RRX
658      IF(L1.EQ.1) THEN
659          SY1=SY1-SGN*SD*SD/RE
660          SZ1=SZ1+SD*(CD/RE+YY/RRE)
661          TX1=TX1-TD*(CD/RE+YY/RRE)
662          TZ1=TZ1+SD*SD*XI/RRE
663      ENDIF
664 C
665 300 RETURN
666 END
667 C
668 C
669 C
670      SUBROUTINE STRIKE_0(HH,S0)
671      IMPLICIT REAL*8 (A-H,O-Z)
672      COMMON /MAIN/ W(9)
673      &
674      & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
675      SX=2.D0*W(1)
676      SY=2.D0*W(2)
677      SZ=2.D0*W(3)
678      S0=CX*SX+CY*SY+CZ*SZ
679      RETURN S0
680      END
681 C
682 C
683 C
684      SUBROUTINE STRIKE_H0(HH,SH0)
685      IMPLICIT REAL*8 (A-H,O-Z)
686      COMMON /C0/ SD,CD,TD,SED
687      &
688      & /MAIN/ W(9)
689      & /ELM1/ FLX,FLE,FLC,TAN,G(2)
690      & /ELM2/ A(3),B(3),D(3),E(3),F(3)
691      & /ELM3/ SX1,SY1,SZ1,DX1,DY1,DZ1,TX1,TY1,TZ1
692 C
693      SH0X=(-2.D0+AL3)*W(3)-AL1*TAN-AL5*G(1)
694      &
695      & -2.D0*AL3*HH*(A(1)*CD-F(1)*TD)
696      &
697      & -AL2*HH*F(1)*TD-AL5*SX1
698 C
699      SH0Y=(-2.D0+AL3)*W(2)+AL3*FLE*SD+AL5*G(2)
700      &
701      & -2.D0*AL3*HH*(A(2)*CD-F(2)*SD)
702      &
703      & -AL2*HH*F(2)*SD-AL5*SY1
704 C
705      SH0Z=(-2.D0+AL4)*W(3)-AL1*FLE*CD
706      &
707      & -2.D0*AL*HH*(A(3)*CD-A(2)*SD)
708      &
709      & -AL2*HH*(A(2)*SD+AL5*SZ1
710 C
711      SH0=CX*SH0X+CY*SH0Y+CZ*SH0Z
712      RETURN SH0
713      END
714 C
715 C
716 C
717      SUBROUTINE STRIKE_H(SGN,HH,SH)
718      IMPLICIT REAL*8 (A-H,O-Z)
719      COMMON /C0/ SD,CD,TD,SED
720      &
721      & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
722      & /MAIN/ W(9)
723      & /ELM1/ FLX,FLE,FLC,TAN,G(2)
724      & /ELM2/ A(3),B(3),D(3),E(3),F(3)
725      & /ELM3/ SX1,SY1,SZ1,DX1,DY1,DZ1,TX1,TY1,TZ1
726 C
727      SHX1=-SGN*(AL3*W(2)+AL1*TAN+AL5*G(1))
728      SHY1=-SGN*AL3*W(2)-AL5*G(2)
729      SHZ1=AL4*W(3)-AL1*FLE*CD
730      IF(SGN.EQ.1.D0) THEN
731          SHX2=AL5*SX1
732          SHY2=AL5*SY1-AL3*SD*FLE
733          SHZ2=-AL5*SZ1
734      ELSEIF(SGN.EQ.-1.D0) THEN
735          SHX2=-AL6*SX1

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729      SHY2=-AL6*SY1+(AL1-AL6)*FLE
730      SHZ2=-AL6*SZ1
731      ENDIF
732      SHX=SHX1+SHX2
733      SHY=SHY1+SHY2
734      SHZ=SHZ1+SHZ2
735 C
736      SH=CX*SHX+CY*SHY+CZ*SHZ
737      RETURN SH
738      END
739 C
740 C
741 C
742      SUBROUTINE DIP_0(CHH,D0)
743      IMPLICIT REAL*8 (A-H,O-Z)
744      COMMON /MAIN/ W(9)
745      & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
746 C
747      DX=-2.D0*W(4)
748      DY=2.D0*W(5)
749      DZ=2.D0*W(6)
750      D0=CX*DX+CY*DY+CZ*DZ
751      RETURN D0
752      END
753 C
754 C
755 C
756      SUBROUTINE DIP_H0(HH,DH0)
757      IMPLICIT REAL*8 (A-H,O-Z)
758      COMMON /C0/ SD,CD,TD,SED
759      & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
760      & /MAIN/ W(9)
761      & /ELM1/ FLX,FLE,FLC,TAN,G(2)
762      & /ELM2/ A(3),B(3),D(3),E(3),F(3)
763      & /ELM3/ SX1,SY1,SZ1,DX1,DY1,DZ1,TX1,TY1,TZ1
764 C
765      DH0X=(2.D0-AL3)*W(4)
766      & +AL5*(2.D0*SD*CD*FLE-(CD-SD*TD)*G(2))
767      & +2.D0*AL4*HH*(D(1)*CD-B(2)*SD)-AL2*HH*A(2)
768      & +AL5*DZ1
769 C
770      DH0Y=(2.D0-AL3)*W(5)-AL*SD*FLX+AL3*CD*TAN
771      & -AL5*(CD-SD*TD)*G(1)
772      & +2.D0*AL3*HH*(D(2)*CD+F(3)*SD)+AL2*HH*F(1)*SD
773      & +AL5*DY1
774 C
775      DH0Z=(2.D0+AL4)*W(6)+AL*CD*FLX+AL3*TAN
776      & +2.D0*AL*HH*(D(3)*CD-D(2)*SD)-AL2*HH*A(1)*SD*CD
777      & -AL5*DZ1
778 C
779      DH0=CX*DH0X+CY*DH0Y+CZ*DH0Z
780      RETURN DH0
781      END
782 C
783 C
784 C
785      SUBROUTINE DIP_H(SGN,HH,DH)
786      IMPLICIT REAL*8 (A-H,O-Z)
787      COMMON /C0/ SD,CD,TD,SED
788      & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
789      & /MAIN/ W(9)
790      & /ELM1/ FLX,FLE,FLC,TAN,G(2)
791      & /ELM2/ A(3),B(3),D(3),E(3),F(3)
792      & /ELM3/ SX1,SY1,SZ1,DX1,DY1,DZ1,TX1,TY1,TZ1
793 C
794      DHX1=SGN*AL3*W(4)
795      & -AL5*(2.D0*SD*CD*FLE-(CD-SD*TD)*G(2))
796      DHY1=-SGN*AL3*W(5)+AL*FLX-SGN*AL3*CD*TAN
797      & +SGN*AL5*(CD-SD*TD)*G(1)
798      DHZ1=SGN*AL4*W(6)-AL*CD*FLX-SGN*AL3*SD*TAN
799      IF(SGN.EQ.1.D0) THEN
800          DHX2=-AL5*DX1
801          DHY2=-AL5*DY1
802          DHZ2=-AL5*DZ1
803      ELSEIF(SGN.EQ.-1.D0) THEN
804          DHX2=AL6*DX1
805          DHY2=AL6*DY1
806          DHZ2=AL6*DZ1
807      ENDIF
808      DHX=DHX1+DHX2
809      DHY=DHY1+DHY2
810      DHZ=DHZ1+DHZ2
811 C
812      DH=CX*DHX+CY*DHY+CZ*DHZ
813      RETURN DH
814      END
815 C
816 C
817 C
818      SUBROUTINE TENSILE_0(CHH,T0)
819      IMPLICIT REAL*8 (A-H,O-Z)

```

```

820 COMMON /MAIN/ W(9)
821 & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
822 C
823 TX=-2.D0*W(7)
824 TY=-2.D0*W(8)
825 TZ=-2.D0*W(9)
826 T0=CX*TX+CY*TY+CZ*TZ
827 RETURN T0
828 END
829 C
830 C
831 C
832 SUBROUTINE TENSILE_H0(HH,TH0)
833 IMPLICIT REAL*8 (A-H,O-Z)
834 COMMON /C0/ SD,CD,TD,SED
835 & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
836 & /MAIN/ W(9)
837 & /ELM1/ FLX,FLE,FLC,TAN,G(2)
838 & /ELM2/ A(3),B(3),D(3),E(3),F(3)
839 & /ELM3/ SX1,SY1,SZ1,DX1,DY1,DZ1,TX1,TY1,TZ1
840 C
841 TH0X=(2.D0-AL3)*W(7)
842 & +2.D0*AL5*SD*FLC-AL*FLE
843 & +2.D0*AL4*HH*(E(1)*CD+(A(2)+SD*B(2))*TD)
844 & -(AL2-2.D0*AL6)*HH*A(3)+AL5*TX1
845 C
846 TH0Y=(-2.D0+AL3)*W(8)
847 & -AL3*SD*TAN-AL*CD*FLX+2.D0*AL5*SD*G(1)
848 & -2.D0*AL*HH*(D(3)-A(1)*SD)*CD
849 & -(D(2)-F(1)*TD)*SD)
850 & +(AL2-2.D0*AL6)*HH*F(1)*SD*TD-AL5*TY1
851 C
852 TH0Z=(-2.D0+AL4)*W(9)
853 & +AL3*CD*TAN-AL*SD*FLX
854 & -AL3*HH*(E(3)*CD-E(2)*SD)+AL2*HH*A(1)*SD*SD
855 & -AL5*TZ1
856 C
857 TH0=CX*TH0X+CY*TH0Y+CZ*TH0Z
858 RETURN TH0
859 END
860 C
861 C
862 C
863 SUBROUTINE TENSILE_H(SGN,HH,TH)
864 IMPLICIT REAL*8 (A-H,O-Z)
865 COMMON /C0/ SD,CD,TD,SED
866 & /C1/ AL,AL1,AL2,AL3,AL4,AL5,AL6,CX,CY,CZ
867 & /MAIN/ W(9)
868 & /ELM1/ FLX,FLE,FLC,TAN,G(2)
869 & /ELM2/ A(3),B(3),D(3),E(3),F(3)
870 & /ELM3/ SX1,SY1,SZ1,DX1,DY1,DZ1,TX1,TY1,TZ1
871 C
872 THX1=SGN*AL3*W(7)+SGN*AL*FLE-SGN*2.D0*AL5*SD*FLC
873 THY1=SGN*AL3*W(8)+AL*CD*FLX-SGN*AL4*TAN
874 & -SGN*2.D0*AL5*G(1)
875 THZ1=SGN*AL4*W(9)+AL*SD*FLX-SGN*AL3*CD*TAN
876 C
877 IF(SGN.EQ.1) THEN
878 THX2=-AL5*TX1
879 THY2=-AL5*TY2
880 THZ2=-AL5*TZ1
881 ELSE
882 THX2=AL6*TX1
883 THY2=AL6*TY2
884 THZ2=AL6*TZ1
885 ENDIF
886 THZ=THZ1+THZ2
887 TH=CZ*THZ
888 RETURN TH
889 END
890
891
892
893
894
895

```