Finite Element Glacier Dynamics Model Applied to Columbia Glacier, Alaska

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By W. G. SIKONIA

STUDIES OF COLUMBIA GLACIER, ALASKA

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*Description of a computer model indicating
that Columbia Glacier will begin
a rapid, catastrophic retreat in 1983*

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

	Page
Symbols and abbreviations	BIV
Abstract	1
Introduction	1
The finite element model	1
Calving law	3
Modeling Columbia Glacier	5
References cited	28

ILLUSTRATIONS

	Page
FIGURE 1. Index map of Columbia Glacier, Alaska	B2
2. Graph showing calving law	3
3. Contour map showing flow line used in modeling	7
4. Finite element grid	8
5. Flow-line profiles showing projected Columbia Glacier behavior	9
6-9. Graphs showing:	
6. Terminus position in time	23
7. Unsupported height at the terminus, in time	24
8. Surface horizontal speed at flow line	26
9. Rate of iceberg production	27

TABLES

	Page
TABLE 1. Calving law data	B4
2. Flow-line data	6

APPENDIXES

	Page
APPENDIX A. Mathematics	B29
Tangent stiffness matrix	29
Upper free-surface dynamics	30
Surface tractions and body forces	31
Updating the mesh	31
Future modification	31
B. User instructions for the computer program	32
Coordinate data	32
Material property data	32
Boundary restraint data	32
Nodal forced boundary data	32
Nodal temperature data	32
TANF macroinstruction	33
REST and SAVE macroinstructions	33
UPNO macroinstruction	33
PLOT macroinstruction	33
C. New subroutines	34
D. Modifications of the general purpose finite element program	47
E. Sample run	54

SYMBOLS AND ABBREVIATIONS

A _____	Ice flow law parameter	$\bar{K}$ _____	Coefficient matrix related to spatial variation of flow field
a _____	Year	K^* _____	Coefficient matrix related to rate of ice thickness change
α _____	Calving law parameter	K, K^* _____	Coefficient matrix describing effect of ice viscosity
a^* _____	Rate of ice-thickness-change vector	K^p _____	Coefficient matrix related to pressure distribution
a^p _____	Nodal pressure vector	km _____	Kilometer
a^u _____	Nodal velocity vector	Mg _____	Megagram
B _____	Constant in Budd sliding law	M _____	Mass matrix
B _____	Deformation rate shape function	m _____	Meter
b _____	Calving law parameter	μ _____	Viscosity
$\bar{b}$ _____	Annual ice balance	N _____	Shape function matrix
c _____	Calving law parameter	n _____	Ice flow law parameter
D _____	Discharge	Ω _____	Volume
D' _____	Constitutive matrix	p _____	Pressure; related quantities have this as superscript
DOF _____	Degree of freedom	r^2 _____	Coefficient of determination
d _____	Day	ρ_i _____	Density of ice
d _____	Effective shear deformation rate	ρ_w _____	Density of water
d_{ij} _____	Deformation rate tensor	s _____	Second
d _____	Deformation rate vector	s _____	Matrix used in determining emergence velocity
δ _____	Indicates variation of following variable	σ_{ij}' _____	Deviatoric stress tensor
∂ _____	Used in partial derivative	σ' _____	Deviatoric stress vector
E _____	$= (1/\mu) D'$	T _____	Denotes transpose matrix as superscript
$F(a)$ _____	Nonlinear ice-flow function of nodal variables a	τ_b _____	Shear stress at the bed
f _____	Force vector	UTM _____	Universal Transverse Mercator
G _____	Auxiliary matrix used in tangent matrix derivation	u _____	Denotes velocity; related quantities have this as superscript
γ _____	Angle of surface	u _____	Velocity vector
Γ_s _____	Ice surface	V_b _____	Sliding speed at the bed
h _____	Total ice thickness; related quantities have this as superscript	V_c _____	Calving speed
h_b _____	Altitude of bed	V_e _____	Emergence velocity
h_s _____	Altitude of surface	V_s _____	Surface ice speed
h_u _____	Height of the ice column unsupported by water pressure	$X(t)$ _____	Position of calving terminus at time t
h_w _____	Water depth		

STUDIES OF COLUMBIA GLACIER, ALASKA

FINITE ELEMENT GLACIER DYNAMICS MODEL APPLIED TO COLUMBIA GLACIER, ALASKA

By W. G. SIKONIA

ABSTRACT

A two-dimensional finite element computer model describes the dynamics of glacier flow and includes the flow of ice, sliding, calving, and surface balance. Surface profile and terminus position are followed in time. A calving law that relates calving speed to water discharge at the bed of the glacier and to the height of the ice column unsupported by water pressure is shown to fit observed calving at Columbia Glacier. Application of the flow model to Columbia Glacier indicates that catastrophic, rapid retreat from the terminal moraine will begin in 1983. This will produce an increase in the production of icebergs that can drift into oil tanker lanes to and from Valdez, Alaska.

INTRODUCTION

Columbia Glacier, Alaska (fig. 1), is in a state precariously close to catastrophic retreat (Post, 1975; Meier and others, 1978; Sikonia and Post, 1980; Meier and others, 1980a, b). A dynamic model of glacier behavior was sought that could adequately represent at least the lowest 14 km of the glacier; the model must be capable of dealing with a large amount of sliding, with flow up a terminal moraine, and with a moving calving face. Bindschadler applied a one-dimensional model (Bindschadler, 1978; Meier and others, 1980b), but it seems questionable whether the approximations of the model adequately represent reality near the calving face, especially with regard to surface-slope averaging schemes and longitudinal stresses.

THE FINITE ELEMENT MODEL

The two-dimensional finite element model described in this paper is an attempt to relate more adequately the motion of the ice mass to the physical processes involved. However, the two-dimensional nature of the model dictates that it also is an idealization of reality. The model represents a vertical cross section through a glacier along a central flow line, but no attempt has been made yet to include effects of lateral shear stresses or lateral deformation rates.

The ice flow law describing the deformational contribution to ice motion is

$$d_{ij} = A \tau^{n-1} \sigma'_{ij}, \quad (1)$$

where d_{ij} is the deformation rate tensor; σ'_{ij} , the deviatoric stress tensor; τ , the effective shear stress defined by

$$\tau = (1/2 \sigma'_{ij} \sigma'_{ij})^{1/2} \quad (2)$$

(summation convention on subscripts i, j); and A and n are constants, with approximate values of

$$A = 0.140 \text{ bar}^{-n} \text{a}^{-1} \text{ and } n = 3. \quad (3)$$

Sliding is modeled as a layer of very soft ice (large valued A) along the bed. In the Columbia Glacier application, the layer is assumed to be a constant 10 m thick, with $n=3$ and A ranging from 7 to 40 $\text{bar}^{-n} \text{a}^{-1}$, fitted along the bed so that the correct sliding is obtained to match measured surface velocities. This is approximately equivalent to use of a sliding law suggested by Budd and others (1979) in the form

$$V_b = B \tau_b^n / h_w. \quad (4)$$

Here V_b is the sliding speed on the bed; B , a constant perhaps approximately $1,800 \text{ m}^2 \text{a}^{-1} \text{bar}^{-n}$ for $n=3$; τ_b , the shear stress at the bed; and h_w , the ice-column height unsupported by water pressure

$$h_w = h - h_w \rho_w / \rho_i, \quad (5)$$

where h is total ice depth; h_w , water depth; and ρ_w , ρ_i , the densities of water and ice, respectively. Bindschadler (written commun., 1978) found that this sliding law fits Variegated Glacier, Alaska, data.

The solution proceeds in a sequence of time steps. At each step, equilibrium iterations using Newton's method are done first to produce consistent stress-velocity fields described by the nonlinear equation 1. By using the velocity field, the surface and calving front then are projected to new positions, and the process stepped in time.

FIGURE 1.—Index map of Columbia Glacier, Alaska. Arrows show direction of flow. Main ice stream is indicated by longer arrows and dots at 2-km intervals along the longitudinal coordinate system.

The finite element framework for the computer program is a general purpose program (Taylor, 1980; Zienkiewicz, 1977, p. 733). Velocity and pressure are chosen as the variables, and the treatment follows that of Zienkiewicz (1977, p. 612) except that, for ice, the viscosity, μ , is not constant but is rather a function of the effective shear stress,

$$\mu = 1/(2A\tau^{n-1}). \quad (6)$$

Also, kinetic effects can be ignored because of the slow creep of ice. Because the viscosity is nonconstant, the equations are nonlinear, and the tangent stiffness matrix for use in Newton-Raphson iteration takes the appropriate derivatives of viscosity into account. Other finite element programs with a similar approach are attributable to Schmidt (1977), Raymond (1978), and Hooke and others (1980), but these treat only geometrically static, purely creeping flow. The program described in this paper treats deformational motion, sliding, balance, and calving effects in a geometrically dynamic setting. It also starts with a good, readily available general purpose finite element framework; the advantage of this approach is that only the specific program modules directly concerned with the glacier dynamics need be considered, greatly simplifying programming, documentation, and orientation of new users.

To take into account the dynamics, the movement of the upper free surface must be followed. This surface is followed essentially as in Zienkiewicz (1977, p. 623); the free surface must be projected along the surface velocity vectors to its new position. The program makes this projection by defining an auxiliary variable—the vertical surface speed—decomposing the surface velocity into general nonorthogonal components along the surface and in the vertical direction. In addition to the movement of the upper free surface, the movement of the calving face is projected from one time step to the next by using the calving law described in the section on "Calving Law." Because of large changes in the configuration of the ice mass, the entire mesh must be reconstructed at each time step.

CALVING LAW

The position of the calving terminus, $X(t)$ (assumed vertical), in time is determined by the imbalance between the horizontal surface ice speed, V_h , at the terminus (positive downglacier) and the calving speed, V_c (positive upglacier),

$$X = V_h - V_c. \quad (7)$$

Alternatively, equation 7 defines calving speed, V_c , as the rate of retreat of the calving terminus in the moving ice stream. A calving law relating calving speed linearly

to water depth has been suggested (Meier and others, 1980b). The suggested water-depth law was restricted to yearly averaged data that was averaged also across the width of the glacier. It definitely does not apply for intervals of less than a year for calving at a single location on the terminus. When applied to the calving of Columbia Glacier at the head of the embayment, by using photogrammetrically determined terminus positions taken at approximately 2-month intervals from July 24, 1976, to September 2, 1980, the water-depth law yields a coefficient of determination, r^2 , of only 0.08. However, for Columbia Glacier, calving speed appears to be related to water discharge at the bed (Sikonia and Post, 1980). A law that does appear to fit the observed intra-yearly calving at Columbia Glacier is (see also fig. 2 and table 1)

$$V_c = aD^b h_u^c. \quad (8)$$

FIGURE 2.—Calving law $V_c = aD^b h_u^c$, where $a = 1.092 \times 10^3$ (km/a) ($\text{m}^3/\text{s})^{-b} \text{m}^{-c}$, $b = 0.5689$, and $c = -2.175$. V_c is speed of calving at the head of the embayment, D is the discharge of the Knik River, and h_u is the height of the unsupported ice column. The data points, as given in table 1, were determined from analysis of aerial photographs. Point 8 corresponds to a time interval during which Kadin Lake suddenly released a large volume of water into the subglacial flow; in this interval, the Knik River discharge would not correlate well with this flow. Points 8, 23, and 24 were not used in the regression that fitted the constants a , b , and c .

TABLE 1.—Calving law data

[N , data interval number. t_1 and t_2 , beginning and ending dates of interval. Δt , number of days in the interval. h_{s1} and h_{s2} , ice-cliff heights at head of embayment at times t_1 and t_2 , respectively. h_{w1} and h_{w2} , water depths at head of embayment at times t_1 and t_2 , respectively. D , average discharge of Knik River during interval. h_u , average unsupported height during interval. $(V_c)_o$ and $(V_c)_c$, observed and calculated calving speeds at head of embayment. ΔV_c , difference between calculated and observed calving speed. Calculated speed is based on the calving law $V_c = aD^b h_u^c$]

N	t_1	t_2	Δt (d)	h_{s1} (m)	h_{s2} (m)	h_{w1} (m)	h_{w2} (m)	D (m ³ /s)	h_u (m)	$(V_c)_o$ (m/a)	$(V_c)_c$ (m/a)	ΔV_c (m/a)
1	07/24/76	10/01/76	69	98	86	127	180	464.65	71.87	3,964	3,293	-671
2	10/01/76	11/17/76	47	86	86	180	175	119.82	62.73	2,008	2,047	39
3	11/17/76	01/19/77	63	86	88	163	146	59.96	66.74	1,190	1,207	17
4	01/19/77	03/07/77	47	85	89	155	142	63.45	67.53	1,697	1,215	-482
5	03/07/77	04/23/77	47	88	94	137	100	30.68	75.46	307	631	324
6	04/23/77	06/02/77	40	94	100	100	80	110.07	85.20	1,259	1,002	-257
7	06/02/77	07/07/77	35	99	95	80	109	486.96	84.61	2,256	2,371	115
8	07/07/77	08/29/77	53	93	99	102	278	765.94	71.09	7,059	4,481	-2,578
9	08/29/77	11/08/77	71	100	78	200	200	231.72	62.78	2,738	2,974	236
10	11/08/77	02/28/78	112	81	97	170	125	21.12	69.66	1,175	607	-568
11	02/28/77	04/19/78	50	96	84	125	112	30.90	74.46	712	652	-60
12	04/19/78	06/11/78	53	68	81	110	113	126.76	59.88	1,832	2,339	509
13	06/11/78	07/30/78	49	80	94	112	177	460.50	68.05	4,362	3,689	-673
14	07/30/78	08/26/78	27	90	90	160	182	684.48	67.58	4,588	4,692	104
15	08/26/78	11/08/78	74	92	77	185	210	230.27	58.61	3,150	3,442	292
16	11/08/78	01/06/79	59	72	76	215	182	22.46	47.97	1,657	1,415	-242
17	01/06/79	04/12/79	96	72	77	182	140	17.36	53.39	1,004	969	-35
18	04/12/79	08/18/79	128	93	111	85	135	412.75	87.58	2,318	2,002	-316
19	08/18/79	10/20/79	63	70	76	82	195	350.34	54.84	6,669	5,049	-1,620
20	10/20/79	02/29/80	132	77	75	195	167	44.71	52.27	1,478	1,737	259
21	02/29/80	05/12/80	73	74	90	167	130	35.61	62.53	683	1,034	351
22	05/12/80	07/22/80	71	80	101	110	137	390.94	74.31	1,748	2,775	1,027
23	07/22/80	09/02/80	42	92	89	90	118	587.54	76.86	2,880	3,252	372
24	09/02/80	10/30/80	58	91	85	110	133	207.33	72.07	2,205	2,068	-137

V_c is the calving speed at the head of the embayment, and h_u is the ice column height unsupported by water pressure, as defined in equation 5. The variable D would most appropriately be the actual discharge at the bed of the Columbia Glacier, but because actual discharge would be almost impossible to measure, a related discharge, that of nearby Knik River, was used instead (see Sikonia and Post, 1980). Constants a , b , and c have fitted values as follows:

$$\begin{aligned} a &= 1.092 \times 10^6 \text{ (m/a)(m}^3\text{/s)}^{-b}\text{m}^{-c}, \\ b &= 0.5689, \\ c &= -2.175, \end{aligned} \quad (9)$$

$$\begin{aligned} \rho_w &= 1.018 \text{ Mg/m}^3, \\ \rho_i &= 0.900 \text{ Mg/m}^3. \end{aligned} \quad (10)$$

The standard error for the Columbia data is 529 m/a (in calving speeds ranging from 307 to 4,588 m/a), with a coefficient of determination of the logarithmically derived corresponding linear regression problem of $r^2 = 0.83$. (Although 1.018 Mg/m³ is the measured density of seawater in front of Columbia Glacier, the modeling computer runs (see section entitled "Modeling Columbia Glacier") actually were made by using $\rho_w = 1.000 \text{ Mg/m}^3$ and $\rho_i = 0.900 \text{ Mg/m}^3$. In this case, $a = 1.798 \times 10^6 \text{ (m/a)(m}^3\text{/s)}^{-b}\text{m}^{-c}$, $b = 0.5510$, $c = -2.239$, $r^2 = 0.83$, and the standard error was 369 m/a, based on fewer data points than the constants in equation 9 because of limited data availability at the time. It was not considered worth re-running the program for these minor changes in constants.)

It is uncertain exactly what the relation between the discharge-unsupported height calving law and the water-depth law is, but there appear to be at least three possibilities:

1. One or the other law is wrong.
2. Some, as yet, not understood process averages the above law into the water-depth law for time periods of a year or longer.
3. The two laws are describing two, as yet, undistinguished distinct calving processes.

The discharge-unsupported height law is used in this study for reasons discussed in this section. This law also accommodates the observation that embayments form at the location of the main water discharge from the terminus and supports the physical idea that the closer the terminus is to floating, the more easily this discharge can bring about calving and ice removal from the face.

MODELING COLUMBIA GLACIER

The finite element model was applied to the lowest 14 km of Columbia Glacier to gain a better understanding of its possible future behavior (see also figs. 3 and 4 and table 2). The constant a in the calving law is too large for an idealized two-dimensional glacier; it produces an immediate catastrophic retreat, from the starting modeling date 1978.150, that has not occurred on the real glacier. This is understandable because embayments and related surface lowering are filled partly by flow from the sides, a factor which the two-dimensional model does not take into account. Also there is an "arch-bridging" stress effect within the ice around an embayment that could partly support the ice cliff at the head of the embayment, thus providing a larger unsupported height, h_u , and a smaller calving speed, V_c . This effect also is not taken into account in the two-dimensional model. An a corresponding to width-averaged calving is needed. Rather than trying to derive the averaging effect, the exponents b and c were fixed, and the a parameter adjusted for the two-dimensional glacier to produce future behavior that seems reasonable in view

of the actual configuration of the glacier from early 1978 to the present.

Future behavior is extremely sensitive to changes in the a parameter. For example, $a=1168750$ produced a collapse that could not be followed with a time step of 0.025 year by 1982.075; the terminus had retreated 2,285 m by 1982.025. Decreasing a by only 0.27 percent to $a=1165625$ extended extremely rapid collapse to 1984.600, the terminus retreating 3,031 m by 1984.525. Decreasing a by another 0.27 percent to $a=1162500$ produced a gradual advance to the crest of the terminal moraine by 1982.400 (see also figs. 5, 6, 7, 8, and 9). The modeling also showed that a collapse is preceded by thinning of the glacier to the point that the unsupported height factor, h_u , of the calving law is small enough to produce a large calving speed when applied in equation 8; for example, $h_u=7$ m at the terminus, time 1982.250 and $a=1168750$.

The sensitivity of the glacier's behavior to the a parameter may be overstated or at least compressed in time scale because of the two-dimensional idealization, but, nevertheless, the behavior of the real glacier is probably still quite dependent on relatively small changes in the calving. As indicated by the calving law, for the real glacier, decreased calving that would stall collapse could be brought about by low runoff or by outlet of the major discharge at a location having a relatively high ice cliff and shallow water depth. Reference to figure 7 shows that h_u was relatively large in 1980, and, as indicated on figure 6, the retreat was, indeed, slowed that year. However, heavy rains in July and August 1981, together with a partial outburst of Kadin Lake, produced a large discharge that caused a large embayment to form. The data presented in figure 6 show that the observed terminus position is following again the retreat predicted by the model using $a=1165625$ and that the indicated collapse of Columbia Glacier is imminent.

TABLE 2.—*Flow-line data*[Col., column number. Easting and Northing, UTM coordinates. h_s , ice surface altitude. h_b , bed altitude. b , annual balance. V_s , surface speed. $\dot{h}$, annual surface altitude change]

Col.	Easting (m)	Northing (m)	h_s (m)	h_b (m)	b (m/a)	V_s (m/a)	$\dot{h}$ (m/a)
1.00	496047.77	6776061.73	465	-278	-2.67	950	-2.6
2.00	496190.00	6775312.92	430	-247	-3.42	1,030	-3.8
3.00	496212.11	6774551.05	411	-262	-3.98	960	-4.0
4.00	496069.20	6773802.37	401	-238	-4.45	922	-4.7
5.00	495989.61	6773044.34	370	-204	-4.90	935	-3.2
6.00	496058.28	6772285.25	340	-191	-5.41	930	-2.8
7.00	496296.14	6771561.12	314	-224	-5.98	900	-1.9
8.00	496606.30	6770864.89	290	-320	-6.30	839	-6.3
9.00	496867.26	6770148.76	275	-382	-6.32	808	-8.6
10.00	497094.55	6769421.24	264	-395	-6.29	812	-6.0
11.00	497283.81	6768682.92	248	-384	-6.26	866	-6.9
12.00	497449.85	6767939.03	226	-383	-6.27	904	-7.3
13.00	497519.90	6767180.06	210	-402	-6.36	933	-6.9
14.00	497522.32	6766417.87	198	-401	-6.53	1,012	-8.5
15.00	497459.13	6765657.99	178	-402	-6.68	1,102	-9.6
15.50	497402.49	6765281.07	167	-402	-6.76	1,150	-9.5
16.00	497340.59	6764905.06	159	-382	-6.91	1,210	-9.0
16.50	497273.44	6764529.95	152	-355	-7.09	1,320	-8.4
17.00	497201.03	6764155.75	140	-320	-7.21	1,460	-8.2
17.50	497115.89	6763784.20	129	-286	-7.38		-7.3
18.00	497024.00	6763414.39	118	-260	-7.63		-3.0
18.25	496975.53	6763230.14	113	-242	-7.77		-0.7
18.50	496925.37	6763046.32	108	-221	-7.87		1.0
18.75	496873.53	6762862.94	100	-196	-7.93		1.1
19.00	496820.00	6762680.00	96	-162	-7.94		0.1
19.25	496759.80	6762499.20	96	-135	-7.94		-1.1
19.50	496699.05	6762318.60	96	-106	-7.94		-2.5
19.75	496637.76	6762138.18	96	-60	-7.94		
20.00	496575.92	6761957.94	96	-10	-7.94		
20.25	496513.54	6761777.91		-68			
20.50	496450.61	6761598.05		-132			
20.75	496387.14	6761418.37		-162			
21.00	496323.12	6761238.89		-168			
21.25	496257.12	6761060.15		-178			
21.50	496190.01	6760881.82		-182			
21.75	496121.77	6760703.90		-193			
22.00	496052.42	6760526.38		-202

FIGURE 3. - Flow line used in the modeling. The numbers along the flow line are the column numbers, and UTM locations and data correspond to those given in table 2. Bed contours are solid, surface contours are dashed, and the terminal moraine is dotted (column locations 21 and 22 are in Columbia Bay). Kadin Lake is at UTM coordinates 490000 m.E., 6774000 m.N.

FIGURE 4.—Finite element grid. There are three elements through the thickness, with the bottom element a uniform 10 m in thickness. The ice velocity vectors are scaled to represent 0.05 year of displacement (if the ice continued beyond the velocity sampling points in straight lines, which, in general, it does not do).

FIGURE 5. - Future Columbia glacier behavior, projected by using modeling constant $a = 1165625$. The individual illustrations show the flow-line profile from column locations 11 through 20 as a function of time.

FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $a=1165625$. The individual illustrations show the flow-line profile from column locations 11 through 20 as a function of time.

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FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $\alpha=1165625$. The individual illustrations show the flow-line profile from column locations 11 through 20 as a function of time.

FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $a = 1165625$. The individual illustrations show the flow-line profile from column locations 10 through 18 as a function of time.

FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $\alpha=1165625$. The individual illustrations show the flow-line profile from column locations 1 through 10 as a function of time.

FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $\alpha=1165625$. The individual illustrations show the flow-line profile from column locations 1 through 10 as a function of time.

FIGURE 5 (Continued). - Future Columbia glacier behavior, projected by using modeling constant $\alpha = 1165625$. The individual illustrations show the flow-line profile from column locations 1 through 10 as a function of time.

FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $a=1165625$. The individual illustrations show the flow-line profile from column locations 1 through 10 as a function of time.

FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $a=1165625$. The individual illustrations show the flow-line profile from column locations 1 through 10 as a function of time.

FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $\alpha=1165625$. The individual illustrations show the flow-line profile from column locations 1 through 10 as a function of time.

FIGURE 5 (Continued).—Future Columbia glacier behavior, projected by using modeling constant $a=1165625$. The individual illustrations show the flow-line profile from column locations 1 through 10 as a function of time.

FIGURE 6. —Terminus position in time, for three values of the modeling constant a of the calving law. The observed position represents an average across the width of the terminus.

FIGURE 7. - Unsupported height, h_u , at the terminus, in time, for three values of the modeling constant a of the calving law. The observed is at the head of the embayment. The anomolous peak in this curve in early 1979 is due to a sudden, temporary switch of the location of the subglacial river discharge to a relatively undisturbed location on the terminus

with a higher ice cliff. The dotted curve represents approximately what would have resulted had this temporary shift in embayment location not occurred. The greater variability of the observed curve compared to that of the calculated curve probably is due also to the shifting of the subglacial discharge across the terminus.

FIGURE 8.—Surface horizontal speed at flow-line-column number 16.9, in time. A phase shift of unknown origin (a three-dimensional effect?) between computed speed and observed speed indicates computed speed leading the observed speed, $(V_c)_o$, by about $\frac{1}{8}$ year. Note the low speeds in 1980, when the retreat was interrupted.

FIGURE 9. - Rate of iceberg production, in volume, projected by using modeling constant $\alpha = 1165625$. This graph was derived by converting the two-dimensional flux of the model to three dimensions, using bed configuration and spatial velocity distributions for the real glacier.

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APPENDIX A: MATHEMATICS

The formulation used is that of Zienkiewicz (1977, p. 612, sec. 22.3.1). The $\mathbf{K}$ and $\mathbf{M}$ matrices can be omitted as they represent contributions from kinetic effects that can be ignored in the slow movement of glaciers. Quadratic Lagrange shape functions were used for velocities, and so each element is three nodes by three nodes. Pressure shape functions were chosen to be linear in the vertical direction and quadratic in the horizontal direction, and so pressure unknowns are associated with only the top and bottom nodes of each element; that is, with nodes number 4, 7, 3, 1, 5, and 2 in figure 24.25 of Zienkiewicz (1977, p. 748). Three-by-three Gaussian integration is used. The starting point for the element subroutine is Taylor's fluid element (Zienkiewicz, 1977, p. 755). The viscosity, μ , for ice is nonconstant, and so the resultant system of equations is solved iteratively and has a contribution to the tangent stiffness matrix (Zienkiewicz, p. 699, equation 24.2) arising from appropriate partial derivatives of μ .

TANGENT STIFFNESS MATRIX

Assume for simplicity that $\mathbf{a}^*$, $\mathbf{a}^p$ are partitioned within an element as in section 22.3.1 of Zienkiewicz (1977, p. 612). (Actually, in the program, the velocities and pressures alternate, grouped according to node number.) In Zienkiewicz' notation, the equation for ice is (see equation 22.17)

$$\mathbf{F}(\mathbf{a}) = \mathbf{K}\mathbf{a}^* + \mathbf{K}^p\mathbf{a}^p + \mathbf{f}^* = \mathbf{0}, \quad (\text{A1})$$

where

$$\mathbf{a}^T = ((\mathbf{a}^*)^T, (\mathbf{a}^p)^T). \quad (\text{A2})$$

This equation is nonlinear because μ (in $\mathbf{K}$) is a function of the effective shear stress, and so of $\mathbf{a}^*$. To solve iteratively by Newton's method, expand to the linear term in Taylor's series:

$$\mathbf{F}(\mathbf{a}) + \mathbf{F}'(\mathbf{a})\delta\mathbf{a} \cong \mathbf{0} \quad (\text{A3})$$

or

$$\left[\frac{\partial}{\partial \mathbf{a}^*} (\mathbf{K}\mathbf{a}^*) \right] \delta\mathbf{a}^* + \mathbf{K}^p\delta\mathbf{a}^p \cong -\mathbf{F}(\mathbf{a}). \quad (\text{A4})$$

Here $\mathbf{a}$ is the trial, or "current," approximation of the solution of equation A1, and $\delta\mathbf{a}$ represents a correction

to be applied to improve this approximation. Considering the first term in which

$$\mathbf{K}\mathbf{a}^* = \left[\int_{\Omega} \mathbf{B}^T \mathbf{D} \mathbf{B} d\Omega \right] \mathbf{a}^*, \quad (\text{A5})$$

define

$$\mathbf{G} = \frac{1}{\mu} \mathbf{B}^T \mathbf{D} \mathbf{B}. \quad (\text{A6})$$

Differentiating,

$$\left[\frac{\partial}{\partial \mathbf{a}^*} (\mu \mathbf{G} \mathbf{a}^*) \right] \delta\mathbf{a}^* = \left[\frac{\partial \mu}{\partial \mathbf{a}^*} \delta\mathbf{a}^* \right] \mathbf{G} \mathbf{a}^* + \mu \mathbf{G} \delta\mathbf{a}^*. \quad (\text{A7})$$

Note that $\frac{\partial \mu}{\partial \mathbf{a}^*}$ is a row matrix, while $\partial \mathbf{a}^*$ and $\mathbf{G} \mathbf{a}^*$ are column matrices. Because of the special nature of these matrices, the order of operations in the first term on the right can be rearranged to give

$$\left[\frac{\partial}{\partial \mathbf{a}^*} (\mu \mathbf{G} \mathbf{a}^*) \right] \delta\mathbf{a}^* = \left[\mathbf{G} \mathbf{a}^* \frac{\partial \mu}{\partial \mathbf{a}^*} + \mu \mathbf{G} \right] \delta\mathbf{a}^*. \quad (\text{A8})$$

Thus equation A4 becomes

$$\left[\int_{\Omega} \mathbf{G} \mathbf{a}^* \frac{\partial \mu}{\partial \mathbf{a}^*} d\Omega + \mathbf{K} \mathbf{a}^* \right] \delta\mathbf{a}^* + \mathbf{K}^p \delta\mathbf{a}^p \cong -\mathbf{F}(\mathbf{a}). \quad (\text{A9})$$

The integral represents the contribution due to the non-constant viscosity, μ . To express it in workable form, note that

$$\frac{\partial \mu}{\partial \mathbf{a}^*} = \frac{\partial \mu}{\partial d^2} \frac{\partial d^2}{\partial \mathbf{a}^*}, \quad (\text{A10})$$

where

$$d = (\frac{1}{2} d_{ij} d_{ij})^{1/2} \quad (\text{A11})$$

(summation convention on subscripts) is the effective shear deformation rate. Using the notation of Zienkiewicz, section 22.3.1, and writing column matrix $\mathbf{d}$ in place of d_{ij} ,

$$\mathbf{d} = \mathbf{B} \mathbf{a}^*, \quad (\text{A12})$$

we have

$$d^2 = \frac{1}{4} (\mathbf{B} \mathbf{a}^*)^T \mathbf{E} (\mathbf{B} \mathbf{a}^*), \quad (\text{A13})$$

where

$$\mathbf{E} = \frac{1}{\mu} \mathbf{D}. \quad (\text{A14})$$

Taking the derivative,

$$\frac{\partial d^2}{\partial \mathbf{a}^*} \delta \mathbf{a}^* = \frac{1}{4} [(\delta \mathbf{a}^*)^T \mathbf{B}^T \mathbf{E} \mathbf{B} \mathbf{a}^* + \mathbf{a}^{*T} \mathbf{B}^T \mathbf{E} \mathbf{B} \delta \mathbf{a}^*], \quad (\text{A15})$$

or rearranging,

$$\frac{\partial d^2}{\partial \mathbf{a}^*} \delta \mathbf{a}^* = [\frac{1}{2} \mathbf{a}^{*T} \mathbf{B}^T \mathbf{E} \mathbf{B}] \delta \mathbf{a}^*, \quad (\text{A16})$$

that is,

$$\frac{\partial d^2}{\partial \mathbf{a}^*} = \frac{1}{2} \mathbf{a}^{*T} \mathbf{B}^T \mathbf{E} \mathbf{B} = \frac{1}{2} (\mathbf{G} \mathbf{a}^*)^T. \quad (\text{A17})$$

From equations 1, 6, and A11, the ice viscosity, μ , can be written in terms of the effective deformation rate, d , as

$$\mu = \frac{(d^2)^{(1-n)/2n}}{2A^{1/n}}. \quad (\text{A18})$$

This yields

$$\frac{\partial \mu}{\partial d^2} = \frac{(1-n)d^{((1/n)-3)}}{4nA^{1/n}} \quad (\text{A19})$$

Thus, the integral term in equation A9 – the contribution in Newton's method due to nonconstant μ – is

$$\left[\int_{\Omega} \frac{1}{2} \frac{\partial \mu}{\partial d^2} (\mathbf{G} \mathbf{a}^*) (\mathbf{G} \mathbf{a}^*)^T d\Omega \right] \delta \mathbf{a}^*. \quad (\text{A20})$$

The column matrix

$$\mathbf{Q} = \mathbf{G} \mathbf{a}^* = \mathbf{B}^T \boldsymbol{\sigma}' \quad (\text{A21})$$

(defining $\mathbf{Q}$ as found in the element subroutine, not the $\mathbf{Q}$ of equation 24.10 of Zienkiewicz (1977, p. 710)) is evaluated by using the "current" velocities, $\mathbf{a}^*$, of the iterative Newton's method process. $\mathbf{Q}$ must be calculated as part of accounting for "current" internal forces (Zienkiewicz, equation 24.2, p. 699), so the dependence of the tangential matrix on μ can be obtained with little additional effort.

Some distribution of μ must be chosen initially to start the iterative process. In the program, this initial μ is assumed to be given by equation 6 with effective shear stress, τ , identically 1 bar throughout the ice mass.

UPPER FREE-SURFACE DYNAMICS

To follow the motion of the glacier surface in time, the ice velocity along the surface, Γ_s , is resolved into generally nonorthogonal components along the surface and in the vertical direction; this vertical component is called the emergence velocity, V_s . If γ is the angle between horizontal and an upward normal to the surface, define

$$\mathbf{s}^T = (\text{ctn } \gamma, 1), \quad (\text{A22})$$

then

$$V_s = \mathbf{s}^T \mathbf{u} = \mathbf{s}^T \mathbf{N}^* \mathbf{a}^*. \quad (\text{A23})$$

For V_s evaluated on the surface, the only nonzero elements in $\mathbf{N}^*$ are those which correspond to surface nodes. Let $\dot{h}$ represent the (unknown) rate of thickness change and suppose that

$$\dot{h} = \mathbf{N}^* \mathbf{a}^*, \quad (\text{A24})$$

where the scalar shape function elements in $\mathbf{N}^*$ correspond to scalar velocity shape function elements for the surface nodes, for evaluation on the surface only; that is, they correspond to the nonzero elements of $\mathbf{N}^*$ in equation A23. If $\dot{b}$ is the balance rate, then at any point on the surface,

$$\dot{h} - V_s - \dot{b} = 0. \quad (\text{A25})$$

To obtain a suitable numerical equation, use the Galerkin process and premultiply equation A25 by $(\delta \dot{h})^T$, then integrate over the surface:

$$(\delta \mathbf{a}^*)^T \int_{\Gamma_s} \mathbf{N}^{*T} (\dot{h} - V_s - \dot{b}) d\Gamma_s = 0. \quad (\text{A26})$$

Define

$$\mathbf{K}_{ij}^h = \alpha \int_{\Gamma_s} (\mathbf{N}_i^*)^T \mathbf{N}_j^* d\Gamma_s,$$

$$\mathbf{K}_{ij}^u = -\alpha \int_{\Gamma_s} (\mathbf{N}_i^*)^T \mathbf{s}^T \mathbf{N}_j^* d\Gamma_s, \quad (\text{A27})$$

$$\mathbf{f}_i^h = -\alpha \int_{\Gamma_s} (\mathbf{N}_i^*)^T \dot{b} d\Gamma_s,$$

where $\dot{b}$ is actually stored for the surface nodes and interpolated along the surface as $\dot{h}$ is in equation A24 and where α is a constant to be explained in the next paragraph. Thus, equation A26 is

$$\mathbf{K}^h \mathbf{a}^* + \mathbf{K}^u \mathbf{a}^* + \mathbf{f}^h = 0. \quad (\text{A28})$$

The equation which replaces equation 22.22 of Zienkiewicz (1977, p. 613) is as follows:

$$\begin{bmatrix} \mathbf{K}^h & \mathbf{K}^u & 0 \\ \mathbf{K}^{uT} & \mathbf{K} & \mathbf{K}^p \\ 0 & \mathbf{K}^{pT} & 0 \end{bmatrix} \begin{Bmatrix} \mathbf{a}^* \\ \mathbf{a}^* \\ \mathbf{a}^p \end{Bmatrix} + \begin{Bmatrix} \mathbf{f}^h \\ \mathbf{f} \\ 0 \end{Bmatrix} = 0. \quad (\text{A29})$$

$\mathbf{K}^{uT}$ was added to the stiffness matrix to preserve symmetry, and the value assigned to constant α of equations A27 was chosen to be a very small number (10^{-16}) so that the $\mathbf{K}^{uT}$ would not significantly alter the second (set of) rows of equation A29.

Here the unknowns $\mathbf{a}^h$, $\mathbf{a}^*$, and $\mathbf{a}^p$ have been partitioned into groups for simplicity, but, in the program,

they alternate, grouped by node number. The unknowns $\mathbf{a}^h$ occupy some of the third nodal degree of freedom (DOF) not needed for pressure unknowns $\mathbf{a}^p$ (since pressure is only linear in the vertical direction). The third DOF of the second node from the surface in a column, thus, is assigned the unknown $\mathbf{a}_i^h$, which then represents the rate of surface altitude change at the current column location.

The tangent stiffness matrix has $\mathbf{K}^h$, $\mathbf{K}^u$, and $\mathbf{K}^{ur}$ added in the same locations as in equation A29. The right side of the Newton's method equation must include the contribution arising from "current" $V_s, \dot{b}$, and $\dot{h}$,

$$\mathbf{P}_i^h = \alpha \int_{\Gamma_i} (\mathbf{N}_i^h)^T (V_s + \dot{b} - \dot{h}) d\Gamma. \quad (\text{A30})$$

(Caution: $\mathbf{P}$ as defined by Taylor in the element routines is the entire right side of the Newton's method equation; that is, it is $-\mathbf{f} - \mathbf{P}$ of equation 24.2 or equation 18.10 (Zienkiewicz, 1977, p. 699, 453).)

SURFACE TRACTIONS AND BODY FORCES

Water and atmospheric pressure (surface tractions) and gravity (a body force) are added to the equations, as in equation 22.16 of Zienkiewicz (1977, p. 612).

UPDATING THE MESH

If h_s denotes the ice surface altitude and h_b is the bed altitude and

$$h = h_s - h_b \text{ meters,} \quad (\text{A31})$$

the eight nodes within a vertical column have been chosen to be at locations $h_s, h_s - 0.4(h - 10), h_s - 0.8(h - 10), h_s - 0.9(h - 10), h_b + 10, h_b + 10, h_b + 5$ and h_b , with a greater concentration of nodes near the bed where deformation rates are higher. (In an infinitely wide slab glacier with $n=3$, deformational velocity varies through the thickness as a quartic; the program would approximate this quartic with two quadratics.)

The upper free surface and calving face are updated as in section 22.6 of Zienkiewicz (1977, p. 623), using $\mathbf{a}^h$ calculated as described in the section of Appendix A entitled "Upper Free-Surface Dynamics" and the calving speed from the calving law of equation 8. Because of large deformations, the entire mesh is updated at each step. The updating is done by calculating glacier length at each time step and then by requiring that each column of nodes be at the same fractional location within this new length as it was initially. Nodes are then distributed within each column as a fraction of the new thickness, as described in the preceding paragraph.

FUTURE MODIFICATION

The program was written to allow easy future modification to three space dimensions; a large part of this change can be done by simply replacing two-dimensional shape functions by three-dimensional ones.

APPENDIX B: USER INSTRUCTIONS FOR THE COMPUTER PROGRAM

The general purpose finite element program resembles closely that described by Taylor in chapter 24 of Zienkiewicz (1977); only relevant changes and specialized modules are described in this appendix. The program now (1980) available from Taylor contains a data preprocessor that converts free format input to fields always of length 10 – if an integer is expected, the field is I10; if a FORTRAN real is expected, the field is F10.0.

COORDINATE DATA

The program assumes that nodes are specified in vertical columns. Each column is, to some extent, considered a unit. The sample run of Appendix C (p. B34–B46) uses columns of 8 nodes (the user can select more elements per column if he chooses). The third and fourth nodes from the bottom in a column are at the same location on the column and have the velocity DOF tied together, allowing only a pressure discontinuity to accommodate the discontinuity in the A flow law parameter at that point. Extra “dummy” columns can be specified beyond the initial terminus position to accommodate an advancing glacier. The NUMNP on the control card should be the total number of nodes including these extras. The true terminus position is as specified on the material property data card.

MATERIAL PROPERTY DATA

Columns	Description	Variable
01 to 10	A of ice-flow law	D(1,1)
11 to 20	n of ice-flow law	D(2,1)
21 to 30	Uppermost element in terminal face	D(3,1)
31 to 40	Number of nodes in each column	D(4,1)

BOUNDARY RESTRAINT DATA

Boundary Condition Cards—FORMAT(8I10). – Use only 0, +1, and –1 for the constraint conditions that Taylor describes. A boundary code describing tying is the node number of a preceding like-numbered DOF. For example, to tie DOF 1 and DOF 2 of node 14 to DOF 1 and DOF 2 of node 13, specify the following boundary condition codes:

14	8	13	13
198	0	197	197

The tying uses the generation increment also to tie the first two degrees of freedom for node 22 to 21, node 30 to 29, . . . , node 198 to 197. When tying is specified, only the DOF of the node tied to is retained in the system of equations. Do not tie degrees of freedom that have specified displacements.

Unused degrees of freedom should have displacements specified. Thus, the middle row of nodes in each element, except for the surface elements, should have specified displacements for the third DOF, because pressure is only modeled linearly in the vertical direction. (The middle row of nodes of the surface elements have the $\dot{h}$ unknown as the third DOF.) Also, the extra “dummy” nodes beyond the initial terminus position should have all degrees of freedom with displacements specified.

NODAL FORCED BOUNDARY DATA

Boundary forces $F(3,*)$ corresponding to unused degrees of freedom in a column are used to store the balance rate, $\dot{b}$, and sliding flow law parameter, A_b . These are considered to be at the location of the column when dynamic modeling changes the column position. Within a column, storage is as follows:

“Current” parameters $F(3,*)$	Location in column
—	1 (surface)
—	2
—	3
$\dot{b}$	4
—	5
..	..
—	NDEEP–2
A_b	NDEEP–1
—	NDEEP (bed)

For example, if the second node from the bottom in a column is node number 55, the sliding flow law parameter, A_b , for the current position of the column is stored in $F(3,55)$.

NODAL TEMPERATURE DATA

In a manner similar to column storage of parameters in $F(3,*)$, nodal “temperatures,” $T(*)$, are used to store information corresponding to the initial configuration of the ice mass. Note the distinction that the $T(*)$ refer to fixed initial column coordinates, while the $F(3,*)$ refer to

current dynamic column coordinates. Within a column, storage is as follows:

<i>"Initial" parameters, T(')</i>	<i>Location in column</i>
X_b -----	1 (surface)
Y_b -----	2
Z_b (future use) -----	3
$\dot{b}$ -----	4
$\dot{h}$ (future use) -----	5
...-----	...
V_s -----	1 NDEEP-2
A_b -----	NDEEP-1
-----	NDEEP (bed)

Here X_b , Y_b , and Z_b are the bed coordinates; $\dot{b}$, the balance rate; $\dot{h}$, the rate of surface altitude change; V_s , the horizontal surface speed; and A_b , the sliding flow law parameter—all representing measured or estimated values for the initial column position. For example, if the second node from the surface in a column is node number 50, the y coordinate of the bed at the initial column position is stored in T(50).

TANF MACROINSTRUCTION

A few additional macroinstructions have been added to Taylor's set. TANF simply combines the functions of his TANG and FORM. Proceeding this way was more efficient for the case at hand and is, in fact, now required by the element subroutine ELMT04 for ice flow rather than the TANG and FORM routines.

REST AND SAVE MACROINSTRUCTIONS

Program restart capability is provided through REST and SAVE macroinstructions. SAVE writes the node number, nodal coordinates, and nodal degrees of freedom to FORTRAN file 15 with

```
FORMAT(I16,4(1PE16.9))
```

or

```
FORMAT(I16,4(1PE16.9)/5(1PE16.9))
```

depending on the number of coordinates and degrees of freedom. Macro REST reads this file as FORTRAN file 16. If

```
REST      1.
```

is specified, where the 1. is in columns 21 to 30, the coordinates, $\dot{b}$, A_b , and the degrees of freedom are updated from the restart file. If 0. is given in place of the 1., the coordinates, $\dot{b}$ and A_b are left as on the initial input data, and only the degrees of freedom are updated.

UPNO MACROINSTRUCTION

The mesh is updated as in section 22.6 of Zienkiewicz (1977, p. 623) by using the macroinstruction (UPNO (mnemonically, "update nodes"). The upper surface is adjusted according to ice velocity vectors and balance rate, and the calving face is adjusted according to the calving law of equation 7.

PLOT MACROINSTRUCTION

The PLOT macroinstruction produces a plot giving surface, bed, and calving face outlines and velocity vectors. The plot routine expects scaling information immediately following a SCAL macro card that is placed after the END macro that terminates MACR processing. The scaling parameters are as follows:

<i>Columns</i>	<i>Description</i>	<i>Variable</i>
01 to 10 ___	Minimum x -coordinate in plot	XMIN
11 to 20 ___	Maximum x -coordinate in plot	XMAX
21 to 30 ___	Minimum y -coordinate in plot	YMIN
31 to 40 ___	Maximum y -coordinate in plot	YMAX
41 to 50 ___	Scale factor in units per inch	SCALE
51 to 60 ___	Vector scale factor in speed units per inch	VSCALE
61 to 70 ___	Arrowhead length in inches	AHLEN
71 to 80 ___	Plot rotation, 0 or 90 degrees (only)	ROT

This scaling parameter card is followed by an END macro; that is, the plot routine reads the SCAL card, the parameter card, and an END card.

APPENDIX C: NEW SUBROUTINES

The following subroutines were written by the author specifically to treat the modeling of glaciers.

SUBROUTINE ELMT04(D,UL,XL,IX,TL,S,P,NDF,NDM,NST,ISW)	ELM 001
C	ELM 002
C.... TWO DIMENSIONAL ELEMENT FOR ICE FLOW	ELM 003
C	ELM 004
COMMON /CDATA/ O,HEAD(20),NUMNP,NUMEL,NUMMAT,NEN,NEQ,IPR	ELM 005
COMMON /ELDATA/ DM,N,MA,MCT,IEL,NEL	ELM 006
COMMON /RSTART/ ISTART	ELM 007
COMMON /JACOBI/ XS(2,2),SX(2,2)	ELM 008
COMMON M(1)	ELM 009
COMMON /POINTR/ N0,N1,N2,N3,N4,N5,N6,N7,N8,N9,N10,N11,N12,N13,	ELM 010
* N14,NE	ELM 011
LOGICAL SFLAG	ELM 012
DIMENSION XL(NDM,1),UL(NDF,1),P(NDF,1),S(NST,1),D(1),V(3),DV(2,2)	ELM 013
1,SHP(3,9),IX(1),SG(9),TG(9),WG(9),SHPP(3,9),TL(1)	ELM 014
DIMENSION SGLD(3),TGLD(3),WGLD(3),IANODE(9),IXP(9),INTERP(9)	ELM 015
DIMENSION ITOP(3),MID(3),Q(27),ANODE(3)	ELM 016
C.... IANODE GIVES VISCOSITY "A" INTERPOLATION (REDEFINITION OF NODES).	ELM 017
C.... INTERP YIELDS PRESSURE INTERPOLATION (1=NODE USED, 0=NOT).	ELM 018
DATA IANODE/1,2,2,1,3,2,3,1,3/,INTERP/1,1,1,1,1,0,1,0,0/	ELM 019
DATA ITOP/3,4,7/,MID/6,8,9/,Q/27*0./	ELM 020
GO TO (1,2,3,4,5,3),ISW	ELM 021
C.... INPUT/OUTPUT FLUID PROPERTIES	ELM 022
C.... LINTID IS THE NUMBER OF INTEGRATION POINTS IN EACH DIRECTION	ELM 023
C.... D(1) = A (ICE), D(2) = N	ELM 024
C.... D(3) IS THE LOWEST NUMBERED NODE IN THE CALVING FACE -	ELM 025
C.... ALL NODES FROM D(3) TO NUMNP ARE ASSUMED TO BE IN THE FACE.	ELM 026
C.... D(4) IS THE NUMBER OF NODES IN A VERTICAL COLUMN THROUGH DEPTH.	ELM 027
1 READ(5,1000) (D(I),I=1,4)	ELM 028
WRITE(6,2000) (D(I),I=1,4)	ELM 029
LINTID = 3	ELM 030
LINT = 0	ELM 031
ISTART = 0	ELM 032
FLEPS = 1./D(2)	ELM 033
F2EPS = 1./D(2) - 1.	ELM 034
RHOG = 0.0882	ELM 035
RHOGW = 0.0980	ELM 036
ATMOSP = 1.013	ELM 037
ALPHA = 1.E-16	ELM 038
NFACE = D(3) + 0.1	ELM 039
NDEEP = D(4) + 0.1	ELM 040

DO 20 I=1,9	ELM 041
IXP(I) = 0	ELM 042
IF(INTERP(I).EQ.1)NELPC=I	ELM 043
20 SHPP(3,I) = 0.	ELM 044
RETURN	ELM 045
2 RETURN	ELM 046
C.... COMPUTE SYMMETRIC TANGENT STIFFNESS AND OUT OF BALANCE FORCES.	ELM 047
C.... USE TANF, NOT TANG AND FORM -- ONLY ONE PASS PER ELEMENT.	ELM 048
3 ISTART = ISTART + 1	ELM 049
C.... REDEFINE NUMNP TO EXCLUDE "EXTRA" NODES BEYOND CALVING FACE.	ELM 050
NUMNP = NFACE + NDEEP - 1	ELM 051
L = LINTld	ELM 052
IF(L*L.NE.LINT) CALL PGAUSS(L,LINT,SG,TG,WG)	ELM 053
DO 65 L=1,LINT	ELM 054
CALL SHAPE(SG(L),TG(L),XL,SHP,XSJ,NDM,NEL,IX,.FALSE.)	ELM 055
XSJWG = XSJ*WG(L)	ELM 056
C.... CALL PRESSURE SHAPE FUNCTIONS -- .TRUE. BECAUSE PRESSURE	ELM 057
C.... GRADIENT NOT NEEDED, AND WOULD NOT BE CORRECT ANYWAY	ELM 058
C.... BECAUSE NOT ISOPARAMETRIC.	ELM 059
NELP = MIN0(NELPC,NEL)	ELM 060
DO 25 I=1,NELPC	ELM 061
25 IXP(I) = IX(I)*INTERP(I)	ELM 062
CALL SHAPE(SG(L),TG(L),XL,SHPP,XSJP,NDM,NELP,IXP,.TRUE.)	ELM 063
C.... COMPUTE VELOCITIES, VELOCITY GRADIENTS, PRESSURES = V(3),	ELM 064
C.... AND FLOW LAW PARAMETER A (ENTERED AS NODAL "TEMPERATURE").	ELM 065
C.... USE ONLY LOWER NODES TO ALLOW VISCOSITY DISCONTINUITY IN DEPTH,	ELM 066
C.... BUT STILL RETAIN CONTINUITY ALONG FLOW DIRECTION.	ELM 067
DO 32 I = 1,2	ELM 068
V(I) = 0.	ELM 069
DO 31 K = 1,NEL	ELM 070
31 V(I) = V(I) + SHP(3,K)*UL(I,K)	ELM 071
DO 32 J = 1,2	ELM 072
DV(I,J) = 0.0	ELM 073
DO 32 K = 1,NEL	ELM 074
32 DV(I,J) = DV(I,J) + SHP(J,K)*UL(I,K)	ELM 075
V(3) = 0.	ELM 076
DO 280 K=1,NELP	ELM 077
280 V(3) = V(3) + SHPP(3,K)*UL(3,K)	ELM 078
A = 0.	ELM 079
C.... CHECK IF AT BED.	ELM 080
IF(MOD(IX(1),NDEEP).NE.0)GO TO 283	ELM 081
C.... COMPUTE "A" FLOW LAW COEFFICIENT ALONG BED TO SIMULATE SLIDING.	ELM 082
DO 281 K=1,3	ELM 083
281 CALL VALUES(ANODE(K),M(Nl0),3,IX(MID(K)),NDF)	ELM 084
DO 282 K=1,NEL	ELM 085
282 A = A + SHP(3,K)*ANODE(IANODE(K))	ELM 086
283 A = AMAX1(D(1),A)	ELM 087
C.... COMPUTE EFFECTIVE STRAIN RATE EPSEFF	ELM 088
EPSEFF = 0.	ELM 089
DO 290 I=1,2	ELM 090

DO 290 J=1,2	ELM 091
290 EPSEFF = EPSEFF + (DV(I,J) + DV(J,I))**2	ELM 092
EPSEFF = SQRT(EPSEFF/8.)	ELM 093
C.... NOW COMPUTE VISCOSITY AMU -- USE AMUCON IF	ELM 094
C.... FIRST PASS (ALL ELEMENTS) THROUGH TANF -- INDICATED	ELM 095
C.... BY FLAG ISTART.LE.NUMEL.	ELM 096
C.... FOR FIRST PASS USE VISCOSITY AT BED WITH TAUBED = 1.	ELM 097
C.... DMU IS DERIVATIVE OF VISCOSITY MU W.R.T. EPSEFF SQUARED --	ELM 098
C.... USED IN NEWTON'S METHOD -- DMU = 0. FOR FIRST PASS.	ELM 099
AMU = 0.5/A	ELM 100
DMU = 0.	ELM 101
IF(ISTART.LE.NUMEL)GO TO 291	ELM 102
AMU = (0.5/A**F1EPS)*EPSEFF**F2EPS	ELM 103
DMU = (0.25*F2EPS/A**F1EPS)*EPSEFF**(F2EPS-2.)	ELM 104
291 XMU = AMU*XSJWG	ELM 105
XDMU2 = DMU/2.*XSJWG	ELM 106
C.... COMPUTE DIVERGENCE TERM	ELM 107
DIV = DV(1,1) + DV(2,2)	ELM 108
GAMXY = DV(1,2) + DV(2,1)	ELM 109
C.... COMPUTE INTERNAL FORCES	ELM 110
C.... Q RELATES TO NEWTON'S METHOD ACCOUNTING OF THE DERIVATIVE OF	ELM 111
C.... VISCOSITY.	ELM 112
J1 = 1	ELM 113
DO 64 J=1,NEL	ELM 114
Q(J1) = 2.*DV(1,1)*SHP(1,J) + GAMXY*SHP(2,J)	ELM 115
P(1,J) = P(1,J) + SHP(1,J)*V(3)*XSJWG - Q(J1)*XMU	ELM 116
Q(J1+1) = 2.*DV(2,2)*SHP(2,J) + GAMXY*SHP(1,J)	ELM 117
P(2,J) = P(2,J) + SHP(2,J)*V(3)*XSJWG - Q(J1+1)*XMU	ELM 118
* - XSJWG*RHOG*SHP(3,J)	ELM 119
C.... THE LAST TERM ABOVE IS GRAVITY LOADING	ELM 120
P(3,J) = P(3,J) + SHPP(3,J)*DIV*XSJWG	ELM 121
J1 = J1 + NDF	ELM 122
64 CONTINUE	ELM 123
C.... COMPUTE TANGENT, LOOP OVER COLUMNS OF S	ELM 124
K1 = 1	ELM 125
DO 34 K = 1,NEL	ELM 126
A1 = XMU*SHP(1,K)	ELM 127
A2 = XMU*SHP(2,K)	ELM 128
QK1 = Q(K1)*XDMU2	ELM 129
QK1P1 = Q(K1+1)*XDMU2	ELM 130
C.... LOOP OVER ROWS OF S	ELM 131
J1 = 1	ELM 132
DO 33 J = 1,K	ELM 133
S(J1 ,K1) = S(J1 ,K1) + SHP(1,J)*(A1+A1)+SHP(2,J)*A2	ELM 134
* + Q(J1)*QK1	ELM 135
S(J1 ,K1+1) = S(J1 ,K1+1) + SHP(2,J)*A1 + Q(J1)*QK1P1	ELM 136
S(J1 ,K1+2) = S(J1 ,K1+2) - SHP(1,J)*SHPP(3,K)*XSJWG	ELM 137
S(J1+1,K1) = S(J1+1,K1) + SHP(1,J)*A2 + Q(J1+1)*QK1	ELM 138
S(J1+1,K1+1) = S(J1+1,K1+1) + SHP(1,J)*A1+SHP(2,J)*(A2+A2)	ELM 139
* + Q(J1+1)*QK1P1	ELM 140

	S(J1+1,K1+2) = S(J1+1,K1+2) - SHP(2,J)*SHPP(3,K)*XSJWG	ELM 141
	S(J1+2,K1) = S(J1+2,K1) - SHPP(3,J)*SHP(1,K)*XSJWG	ELM 142
	S(J1+2,K1+1) = S(J1+2,K1+1) - SHPP(3,J)*SHP(2,K)*XSJWG	ELM 143
33	J1 = J1 + NDF	ELM 144
34	K1 = K1 + NDF	ELM 145
65	CONTINUE	ELM 146
C....	CHECK IF AT CALVING FACE WHERE ICOLUM=2.	ELM 147
	IF(IX(3).LT.NFACE)GO TO 302	ELM 148
C....	COMPUTE 1-D GAUSS POINTS AND WEIGHTS FROM 2-D FOR CALVING FACE.	ELM 149
	DO 301 L1D=1,LINT1D	ELM 150
	L2D = L1D	ELM 151
	IF(L1D.EQ.3)L2D=9	ELM 152
	SG1D(L1D) = 1.	ELM 153
	TG1D(L1D) = SG(L2D)	ELM 154
301	WG1D(L1D) = SQRT(WG(L2D))	ELM 155
	ICOLUM = 2	ELM 156
	DELTA = -2.*ATAN(1.)	ELM 157
	GO TO 304	ELM 158
302	CONTINUE	ELM 159
C....	CHECK IF AT FREE SURFACE WHERE ICOLUM=1.	ELM 160
	IF(MOD(IX(3),NDEEP).NE.1)GO TO 66	ELM 161
C....	COMPUTE 1-D GAUSS POINTS AND WEIGHTS FROM 2-D FOR FREE SURFACE.	ELM 162
	DO 303 L1D=1,LINT1D	ELM 163
	L2D = L1D	ELM 164
	IF(L1D.EQ.3)L2D = 9	ELM 165
	SG1D(L1D) = SG(L2D)	ELM 166
	TG1D(L1D) = 1.	ELM 167
303	WG1D(L1D) = SQRT(WG(L2D))	ELM 168
	ICOLUM = 1	ELM 169
	DELTA = 2.*ATAN(1.)	ELM 170
C....	COMPUTE WATER + ATMOSPHERIC FORCE AT INTEGRATION POINT ON FACE.	ELM 171
304	DO 330 L1D=1,LINT1D	ELM 172
C....	CALL 2-D SHAPE FUNCTION WITH LAST ARGUMENT .TRUE.; THIS RETURNS	ELM 173
C....	NATURAL (NOT GLOBAL) DERIVATIVES.	ELM 174
	CALL SHAPE(SG1D(L1D),TG1D(L1D),XL,SHP,XSJ,NDM,NEL,IX,.TRUE.)	ELM 175
C....	COMPUTE GLOBAL COORDINATES CORRESPONDING TO INTEGRATION POINTS.	ELM 176
C....	NATURAL DERIVATIVES FROM COMMON /JACOBI/ ARE	ELM 177
C....	XS(2,ICOLUM)=DY, XS(1,ICOLUM)=DX.	ELM 178
C....	NOTE THAT XS IS THE TRANSPOSE OF THE JACOBIAN.	ELM 179
	YCOORD = 0.	ELM 180
	DO 305 K=1,NEL	ELM 181
305	YCOORD = YCOORD + XL(2,K)*SHP(3,K)	ELM 182
C....	COMPUTE JACOBIAN = LINE LENGTH TRANSFORMATION	ELM 183
	XSJ = SQRT(XS(1,ICOLUM)**2 + XS(2,ICOLUM)**2)	ELM 184
C....	COMPUTE ANGLE OF FACE, +X TO +NORMAL COORD. ALONG FACE (DY/DX).	ELM 185
	BETA = ATAN2(XS(2,ICOLUM),XS(1,ICOLUM))	ELM 186
C....	COMPUTE ANGLE TO OUTWARD NORMAL TO FACE.	ELM 187
	GAMMA = BETA + DELTA	ELM 188
C....	ADD TO INTERNAL FORCES	ELM 189
	DO 310 J=1,NEL	ELM 190

WFORCE = (AMAX1(-YCOORD,0.)*RHOGW+ATMOSP)*XSJ*WG1D(L1D)*SHP(3,J)	ELM 191
P(1,J) = P(1,J) - WFORCE*COS(GAMMA)	ELM 192
310 P(2,J) = P(2,J) - WFORCE*SIN(GAMMA)	ELM 193
C.... CHECK IF AT UPPER FREE SURFACE, WHERE ICOLUM=1.	ELM 194
IF(ICOLUM.NE.1)GO TO 330	ELM 195
C.... ADD HDOT SUBMATRIX TO TANGENT STIFFNESS.	ELM 196
C.... TERMS INVOLVING J2, K2, INCLUDE EMERGENCE CHANGE DUE TO VELOCITY	ELM 197
C.... CHANGE CALCULATED IN THIS ITERATION. HDOT TERMS ARE MULTIPLIED	ELM 198
C.... BY VERY SMALL ALPHA SO SYMMETRY CAN BE PRESERVED WITHOUT CHANGING	ELM 199
C.... VELOCITY CALCULATION.	ELM 200
CTNGAM = COS(GAMMA)/SIN(GAMMA)	ELM 201
DO 315 K=1,3	ELM 202
K1 = MID(K)*NDF	ELM 203
K2 = ITOP(K)*NDF	ELM 204
SHK = ALPHA*SHP(3,ITOP(K))*XSJ*WG1D(L1D)	ELM 205
DO 315 J=1,3	ELM 206
J1 = MID(J)*NDF	ELM 207
J2 = ITOP(J)*NDF	ELM 208
SHJSHK = SHP(3,ITOP(J))*SHK	ELM 209
S(J2-2,K1) = S(J2-2,K1) - CTNGAM*SHJSHK	ELM 210
S(J2-1,K1) = S(J2-1,K1) - SHJSHK	ELM 211
S(J1,K2-1) = S(J1,K2-1) - SHJSHK	ELM 212
S(J1,K2-2) = S(J1,K2-2) - CTNGAM*SHJSHK	ELM 213
315 S(J1,K1) = S(J1,K1) + SHJSHK	ELM 214
C.... COMPUTE BALANCE AND OLD HDOT (SO ITERATION YIELDS DELTA HDOT)	ELM 215
C.... AT INTEGRATION POINT.	ELM 216
BALANC = 0.	ELM 217
HDOT = 0.	ELM 218
DO 316 J=1,3	ELM 219
HDOT = HDOT + UL(3,MID(J))*SHP(3,ITOP(J))	ELM 220
CALL VALUES(BALNOD,M(N10),3,IX(MID(J))+2,NDF)	ELM 221
316 BALANC = BALANC + BALNOD*SHP(3,ITOP(J))	ELM 222
C.... COMPUTE SURFACE VELOCITY AT INTEGRATION POINT	ELM 223
DO 320 I=1,2	ELM 224
V(I) = 0.	ELM 225
DO 320 J=1,3	ELM 226
320 V(I) = V(I) + SHP(3,ITOP(J))*UL(I,ITOP(J))	ELM 227
C.... COMPUTE EMERGENCE	ELM 228
EMERG = (V(1)*COS(GAMMA) + V(2)*SIN(GAMMA))/SIN(GAMMA)	ELM 229
C.... ADD TO RIGHT HAND SIDE	ELM 230
DO 325 J=1,3	ELM 231
325 P(3,MID(J)) = P(3,MID(J))	ELM 232
* + ALPHA*(EMERG + BALANC - HDOT)*SHP(3,ITOP(J))*XSJ*WG1D(L1D)	ELM 233
330 CONTINUE	ELM 234
IF(ICOLUM.EQ.2)GO TO 302	ELM 235
C.... FORM LOWER PART OF TANGENT STIFFNESS MATRIX BY SYMMETRY.	ELM 236
66 NL = NDF*NEL	ELM 237
DO 68 J=2,NL	ELM 238
DO 68 K=1,J	ELM 239
68 S(J,K) = S(K,J)	ELM 240

RETURN	ELM 241
C.... COMPUTE STRESSES AND VELOCITY GRADIENTS	ELM 242
4 RETURN	ELM 243
C.... COMPUTE MASS MATRIX	ELM 244
5 RETURN	ELM 245
C.... FORMATS	ELM 246
1000 FORMAT(10F10.0)	ELM 247
2000 FORMAT(5X,32HTWO DIMENSIONAL ICE FLOW ELEMENT//	ELM 248
1 10X,12HVISCOS. A =,E12.5/	ELM 249
2 10X,12HVISCOS. N =,E12.5/	ELM 250
3 10X,12HCALVE NODE =,E12.5/	ELM 251
4 10X,12HNODES DEEP =,E12.5/)	ELM 252
END	ELM 253
SUBROUTINE PLT(ID,X,B,F,T,D,TIME,NDM,NDF)	PLT 001
C	PLT 002
C.... PLOT DISPLACEMENT VECTORS B AT NODAL COORDINATES X	PLT 003
C	PLT 004
LOGICAL PCOMP	PLT 005
COMMON /PRLOD/PROP	PLT 006
COMMON /CDATA/ O,HEAD(20),NUMNP,NUMEL,NUMMAT,NEN,NEQ,IPR	PLT 007
COMMON /NORIG/ NUMEXT	PLT 008
DIMENSION X(NDM,1),B(1),UL(6),ID(NDF,1),F(NDF,1),WD(2),D(1),T(1)	PLT 009
DATA BL/4HBLAN/,DOTFAC/0.3/,TICFAC/2./,NWD/2/	PLT 010
DATA WD/4HSCAL,4HEND /,FIRST/0./	PLT 011
C.... FUNCTIONS TO APPLY ORIGIN SHIFT, SCALE, AND ROTATION	PLT 012
X2(XP,YP) = (SHIFT + COSINE*(XP-XMIN) - SINE*(YP-YMIN))/SCALE	PLT 013
Y2(XP,YP) = (SINE*(XP-XMIN) + COSINE*(YP-YMIN))/SCALE	PLT 014
C.... FIRST=0 MEANS READ IN NEW SCALES AS THIS IS THE FIRST	PLT 015
C.... TIME THROUGH THIS PLOT MACRO	PLT 016
IF(ABS(FIRST).GT..5)GO TO 2	PLT 017
FIRST = 1.	PLT 018
10 READ(5,5000)CC	PLT 019
DO 20 J=1,NWD	PLT 020
20 IF(PCOMP(CC,WD(J)))GO TO 30	PLT 021
GO TO 10	PLT 022
30 GO TO (1,2),J	PLT 023
C.... READ SCALE INFORMATION	PLT 024
1 READ(5,5001)XMIN,XMAX,YMIN,YMAX,SCALE,VSCALE,AHLEN,ROT	PLT 025
DOTLEN = DOTFAC*AHLEN	PLT 026
BLOWUP = SCALE/VSCALE	PLT 027
ANGLE = 0.	PLT 028
COSINE = 1.	PLT 029
SINE = 0.	PLT 030
SHIFT = 0.	PLT 031
IF(ABS(ROT-90.).GT..5)GO TO 15	PLT 032
COSINE = 0.	PLT 033
SINE = 1.	PLT 034
ANGLE = 90.	PLT 035
SHIFT = YMAX - YMIN	PLT 036
15 CONTINUE	PLT 037

CALL PLOTS(0,0,99)	PLT 038
GO TO 10	PLT 039
C.... PLOT DISPLACEMENT VECTORS	PLT 040
2 CALL NEWPEN(2)	PLT 041
DO 202 N=1,NUMNP	PLT 042
IF(PCOMP(X(1,N),BL))GO TO 202	PLT 043
DO 200 I=1,NDF	PLT 044
UL(I) = F(I,N)*PROP*BLOWUP	PLT 045
K = IABS(ID(I,N))	PLT 046
200 IF(K.GT.0)UL(I)=B(K)*BLOWUP	PLT 047
XTAIL = X(1,N)	PLT 048
YTAIL = X(2,N)	PLT 049
IF(XTAIL.LT.XMIN.OR.XTAIL.GT.XMAX.OR.YTAIL.LT.YMIN.OR.	PLT 050
* YTAIL.GT.YMAX)GO TO 202	PLT 051
CALL SYMBOL(X2(XTAIL,YTAIL),Y2(XTAIL,YTAIL),DOTLEN,1,ANGLE,-1)	PLT 052
DV = SQRT(UL(1)**2 + UL(2)**2)/SCALE	PLT 053
IF(DV.LT.DOTLEN)GO TO 202	PLT 054
AHLEN2 = AMIN1(AHLEN,DV)	PLT 055
XTIP = XTAIL + UL(1)	PLT 056
YTIP = YTAIL + UL(2)	PLT 057
IF(XTIP.LT.XMIN.OR.XTIP.GT.XMAX.OR.YTIP.LT.YMIN.OR.	PLT 058
* YTIP.GT.YMAX)GO TO 202	PLT 059
CALL AROHD(X2(XTAIL,YTAIL),Y2(XTAIL,YTAIL),X2(XTIP,YTIP),	PLT 060
1 Y2(XTIP,YTIP),AHLEN2,0.,14)	PLT 061
202 CONTINUE	PLT 062
NDEEP = D(4) + 0.1	PLT 063
CALL NEWPEN(1)	PLT 064
C.... PLOT BED, SMOOTHED.	PLT 065
TICK = TICFAC*AHLEN*SCALE	PLT 066
XR = X2(T(1),T(2))	PLT 067
YR = Y2(T(1),T(2))	PLT 068
CALL PLOT(XR,YR,3)	PLT 069
CALL SMOOT(XR,YR,0)	PLT 070
NDEEP1 = NDEEP + 1	PLT 071
NUMEXM = NUMEXT - NDEEP	PLT 072
NUMNPM = NUMNP - NDEEP	PLT 073
DO 330 I=NDEEP1,NUMEXM,NDEEP	PLT 074
XR = X2(T(I),T(I+1))	PLT 075
YR = Y2(T(I),T(I+1))	PLT 076
CALL SMOOT(XR,YR,-2)	PLT 077
XP = T(I-NDEEP)	PLT 078
YP = T(I-NDEEP+1) - TICK	PLT 079
XR = X2(XP,YP)	PLT 080
YR = Y2(XP,YP)	PLT 081
CALL SMOOT(XR,YR,2)	PLT 082
YP = YP + TICK	PLT 083
XR = X2(XP,YP)	PLT 084
YR = Y2(XP,YP)	PLT 085
330 CALL SMOOT(XR,YR,2)	PLT 086
XP = T(NUMEXM+1)	PLT 087

YP = T(NUMEXM+2)	PLT 088
XR = X2(XP,YP)	PLT 089
YR = Y2(XP,YP)	PLT 090
CALL SMOOT(XR,YR,-24)	PLT 091
YP = YP - TICK	PLT 092
XR = X2(XP,YP)	PLT 093
YR = Y2(XP,YP)	PLT 094
CALL PLOT(XR,YR,2)	PLT 095
YP = YP + TICK	PLT 096
XR = X2(XP,YP)	PLT 097
YR = Y2(XP,YP)	PLT 098
CALL PLOT(XR,YR,2)	PLT 099
K = NUMEXM - NDEEP + 1	PLT 100
XP = T(K)	PLT 101
YP = T(K+1)	PLT 102
XR = X2(XP,YP)	PLT 103
YR = Y2(XP,YP)	PLT 104
CALL PLOT(XR,YR,3)	PLT 105
YP = YP - TICK	PLT 106
XR = X2(XP,YP)	PLT 107
YR = Y2(XP,YP)	PLT 108
CALL PLOT(XR,YR,2)	PLT 109
YP = YP + TICK	PLT 110
XR = X2(XP,YP)	PLT 111
YR = Y2(XP,YP)	PLT 112
CALL PLOT(XR,YR,2)	PLT 113
C.... PLOT SURFACE, SMOOTHED.	PLT 114
XR = X2(X(1,1),X(2,1))	PLT 115
YR = Y2(X(1,1),X(2,1))	PLT 116
CALL PLOT(XR,YR,3)	PLT 117
CALL SMOOT(XR,YR,0)	PLT 118
DO 340 I=NDEEP1,NUMNPM,NDEEP	PLT 119
XR = X2(X(1,I),X(2,I))	PLT 120
YR = Y2(X(1,I),X(2,I))	PLT 121
340 CALL SMOOT (XR,YR,-2)	PLT 122
XR = X2(X(1,NUMNPM+1),X(2,NUMNPM+1))	PLT 123
YR = Y2(X(1,NUMNPM+1),X(2,NUMNPM+1))	PLT 124
CALL SMOOT(XR,YR,-24)	PLT 125
C.... PLOT CALVING FACE	PLT 126
XP = X(1,NUMNPM+1)	PLT 127
YP = X(2,NUMNPM+1)	PLT 128
XR = X2(XP,YP)	PLT 129
YR = Y2(XP,YP)	PLT 130
CALL PLOT(XR,YR,3)	PLT 131
XP = X(1,NUMNP)	PLT 132
YP = X(2,NUMNP)	PLT 133
XR = X2(XP,YP)	PLT 134
YR = Y2(XP,YP)	PLT 135
CALL PLOT(XR,YR,2)	PLT 136
C.... PLOT SEALEVEL.	PLT 137

XP = X(1,NUMEXT)	PLT 138
YP = 0.	PLT 139
XR = X2(XP,YP)	PLT 140
YR = Y2(XP,YP)	PLT 141
CALL PLOT(XR,YR,3)	PLT 142
XP = X(1,1)	PLT 143
YP = 0.	PLT 144
XR = X2(XP,YP)	PLT 145
YR = Y2(XP,YP)	PLT 146
CALL PLOT(XR,YR,2)	PLT 147
C.... PLOT TIME.	PLT 148
K = NUMNPM/2 - NDEEP + 1	PLT 149
XP = T(K)	PLT 150
YP = T(K+1) - TICK*3.	PLT 151
XR = X2(XP,YP)	PLT 152
YR = Y2(XP,YP)	PLT 153
CALL NUMBER(XR,YR,3.*AHLEN,TIME+1900.,ANGLE,3)	PLT 154
CALL PLOT(X2(XMAX,YMIN),0.,-3)	PLT 155
RETURN	PLT 156
5000 FORMAT(A4)	PLT 157
5001 FORMAT(8F10.0)	PLT 158
END	PLT 159
SUBROUTINE REST(ID,X,B,F,T,D,NDM,NDF,V1)	RES 01
C	RES 02
C.... READ NODE NUMBER N, COORDINATES X, AND DISPLACEMENTS B	RES 03
C.... FROM RESTART TAPE15	RES 04
C	RES 05
COMMON /CDATA/ O,HEAD(20),NUMNP,NUMEL,NUMMAT,NEN,NEQ,IPR	RES 06
COMMON /RSTART/ ISTART	RES 07
COMMON /NORIG/ NUMEXT	RES 08
DIMENSION X(NDM,1),B(1),UL(6),ID(NDF,1),XR(3),T(1),F(NDF,1),D(1)	RES 09
REWIND 15	RES 10
C.... SHIFT "FIXED" BED COORDINATES, BDOT, AND "A" TO TEMPERATURE ARRAY	RES 11
NDEEP = D(4) + 0.1	RES 12
DO 5 N=NDEEP,NUMNP,NDEEP	RES 13
DO 4 I=1,NDM	RES 14
4 T(N-NDEEP+I) = X(I,N)	RES 15
T(N-NDEEP+4) = F(3,N-NDEEP+4)	RES 16
5 T(N-1) = F(3,N-1)	RES 17
C.... SET TOTAL NUMBER OF NODES IN EXTENDED GRID, BEFORE	RES 18
C.... NUMNP IS REDUCED IN SUBROUTINE ELMT04.	RES 19
NUMEXT = NUMNP	RES 20
NVBLS = NDM + NDF	RES 21
10 IF(NVBLS.LE.4) READ(15,15000)N,(XR(I),I=1,NDM),(UL(I),I=1,NDF)	RES 22
IF(NVBLS.GT.4) READ(15,15001)N,(XR(I),I=1,NDM),(UL(I),I=1,NDF)	RES 23
C.... CHECK FOR BLANK EOF INDICATOR	RES 24
IF(N.LE.0.OR.N.GT.NUMNP)GO TO 103	RES 25
C.... SKIP REDEFINITION OF CURRENT COORDINATES, BDOT, ABED UNLESS	RES 26
C.... V1 IS POSITIVE.	RES 27
IF(V1.LE.0.)GO TO 95	RES 28

DO 90 I=1,NDM	RES 29
90 X(I,N) = XR(I)	RES 30
IF(MOD(N,NDEEP).EQ.4.OR.MOD(N,NDEEP).EQ.NDEEP-1)F(3,N) = UL(3)	RES 31
95 DO 100 I=1,NDF	RES 32
K = IABS(ID(I,N))	RES 33
100 IF(K.GT.0)B(K)=UL(I)	RES 34
GO TO 10	RES 35
103 REWIND 15	RES 36
C.... SET FLAG SO STRAIN-DEPENDENT VISCOSITY USED	RES 37
ISTART = NUMEL + 1	RES 38
RETURN	RES 39
15000 FORMAT(I16,4(1PE16.9))	RES 40
15001 FORMAT(I16,4(1PE16.9)/5(1PE16.9))	RES 41
END	RES 42
SUBROUTINE SAVE(ID,X,B,F,NDM,NDF)	SAV 01
C	SAV 02
C.... SAVE NODE NUMBER N, COORDINATES X, AND DISPLACEMENTS B	SAV 03
C.... ON TAPE16.	SAV 04
C	SAV 05
LOGICAL PCOMP	SAV 06
COMMON /PRLOD/PROP	SAV 07
COMMON /CDATA/ O,HEAD(20),NUMNP,NUMEL,NUMMAT,NEN,NEQ,IPR	SAV 08
DIMENSION X(NDM,1),B(1),UL(6),ID(NDF,1),F(NDF,1)	SAV 09
DATA BL/4HBLAN/	SAV 10
REWIND 16	SAV 11
NVBLS = NDM + NDF	SAV 12
DO 102 N=1,NUMNP	SAV 13
IF(PCOMP(X(1,N),BL))GO TO 102	SAV 14
DO 100 I=1,NDF	SAV 15
UL(I) = F(I,N)*PROP	SAV 16
K = IABS(ID(I,N))	SAV 17
100 IF(K.GT.0)UL(I) = B(K)	SAV 18
IF(NVBLS.LE.4)WRITE(16,16000)N,(X(I,N),I=1,NDM),(UL(I),I=1,NDF)	SAV 19
IF(NVBLS.GT.4)WRITE(16,16002)N,(X(I,N),I=1,NDM),(UL(I),I=1,NDF)	SAV 20
102 CONTINUE	SAV 21
C.... WRITE END OF DATA INDICATOR -- BLANK CARD	SAV 22
WRITE(16,16001)	SAV 23
IF(NVBLS.GT.4)WRITE(16,16001)	SAV 24
16001 FORMAT(1H)	SAV 25
END FILE 16	SAV 26
REWIND 16	SAV 27
RETURN	SAV 28
16000 FORMAT(I16,4(1PE16.9))	SAV 29
16002 FORMAT(I16,4(1PE16.9)/5(1PE16.9))	SAV 30
END	SAV 31
SUBROUTINE UPNODE(D,X,B,DT,F,T,TIME,ID,NDM,NDF)	UPN 001
C.... UPDATE MESH FOR 2-D DYNAMIC GLACIER PROBLEM	UPN 002
COMMON /CDATA/O,HEAD(20),NUMNP,NUMEL,NUMMAT,NEN,NEQ,IPR	UPN 003
COMMON /NORIG/ NUMEXT	UPN 004
DIMENSION D(1),X(NDM,1),B(1),ID(NDF,1),FACT(3),T(1),F(NDF,1)	UPN 005

DIMENSION DKNIK(40),IXS(3),IXB(3),IX(9),XDUM(1,5),SHP(3,9)	UPN 006
DIMENSION ISURF(3)	UPN 007
DATA FACT/0.4,0.8,0.9/	UPN 008
DATA RHOI/1./,RHOI/0.9/,ACONST/1165625./,BCONST/0.550989/	UPN 009
DATA CCONST/-2.23920/,IX/1,1,0,0,1,0,0,0,0/,TT/-1./	UPN 010
DATA XDUM/5*0./,ISURF/1,2,5/,SHP/27*0./	UPN 011
DATA DKNIK/24.27, 23.69, 25.38, 28.15, 29.78, 29.36, 27.44,	UPN 012
* 21.51, 22.95, 23.86, 25.43, 26.12, 44.59, 84.95, 99.69, 143.10,	UPN 013
* 220.03, 317.97, 426.72, 479.86, 542.15, 607.59, 656.56, 720.51,	UPN 014
* 805.18, 705.21, 476.12, 356.48, 372.13, 257.24, 157.36, 135.86,	UPN 015
* 83.29, 61.79, 62.53, 44.41, 32.71, 30.47, 27.13, 25.63/	UPN 016
NDEEP = D(4) + 0.1	UPN 017
NDEEP1 = NDEEP + 1	UPN 018
NDPM4 = NDEEP - 4	UPN 019
NDPM5 = NDEEP - 5	UPN 020
C.... FIRST DETERMINE UNSUPPORTED HEIGHT HU.	UPN 021
C.... DO BEFORE PROJECTING SURFACE TO (TIME+DT).	UPN 022
HG = X(2,NUMNP-NDEEP+1)	UPN 023
HW = AMAX1(0.,-X(2,NUMNP))	UPN 024
HU = HG - (RHOI/RHOI - 1.)*HW	UPN 025
C.... LOCATE ADJUSTED SURFACE ALTITUDE.	UPN 026
DO 10 I=NDEEP1,NUMNP,NDEEP	UPN 027
K = IABS(ID(3,I+1))	UPN 028
10 X(2,I) = X(2,I) + B(K)*DT	UPN 029
C.... DETERMINE DELX.	UPN 030
C.... FIRST DETERMINE V.	UPN 031
K = IABS(ID(1,NUMNP-NDEEP+1))	UPN 032
V = B(K)	UPN 033
C.... NEXT DETERMINE DISCHARGE "DISCH" FOR THE TIME INTERVAL "TIME" TO	UPN 034
C.... "TIME + DT".	UPN 035
C.... NEXT DETERMINE DISCHARGE FROM THE SAME INTERVAL.	UPN 036
I = AMOD(TIME,1.0)/DT + 1.1	UPN 037
DISCH = DKNIK(I)	UPN 038
C.... DETERMINE CALVING SPEED USING CALVING LAW.	UPN 039
VC = ACONST*DISCH**BCONST*HU**CCONST	UPN 040
C.... DETERMINE DELX	UPN 041
DELX = (V - VC)*DT	UPN 042
C.... FIND ORIGINAL TOTAL GLACIER LENGTH.	UPN 043
XTORIG = T(NUMNP-NDEEP+1)	UPN 044
XOORIG = T(1)	UPN 045
ORIGL = XTORIG - XOORIG	UPN 046
C.... FIND THE BED LENGTH.	UPN 047
XBED = T(NUMEXT-NDEEP+1)	UPN 048
BEDLEN = XBED - XOORIG	UPN 049
C.... FIND NEW CURRENT TOTAL LENGTH.	UPN 050
CURRL = X(1,NUMNP-NDEEP+1) + DELX	UPN 051
C.... INSURE THAT TERMINUS REMAINS WITHIN THE BED LENGTH.	UPN 052
CURRL = AMIN1(BEDLEN,CURRL)	UPN 053
CURRL = AMAX1(CURRL,0.)	UPN 054
C.... FIND NEW COLUMN X-COORDINATES -- PROPORTIONED	UPN 055

C.... AS IN ORIGINAL MESH.	UPN 056
C.... THE FIRST COLUMN REMAINS FIXED -- START WITH THE SECOND.	UPN 057
IXS(1) = 1	UPN 058
IXS(3) = 1 + NDEEP	UPN 059
IXS(2) = 1 + 2*NDEEP	UPN 060
IXB(1) = 1	UPN 061
IXB(3) = 1 + NDEEP	UPN 062
IXB(2) = 1 + 2*NDEEP	UPN 063
DO 300 I=NDEEP1,NUMNP,NDEEP	UPN 064
C.... FIND ORIGINAL X-COORDINATE OF COLUMN.	UPN 065
XIORIG = T(I)	UPN 066
C.... FIND PROPORTIONATE NEW X-COORDINATE.	UPN 067
XSURF = (XIORIG - X0ORIG)/ORIGL*CURRL + X0ORIG	UPN 068
C.... REPLACE X-COORDINATE OF ALL NODES IN THIS COLUMN EXCEPT	UPN 069
C.... THE SURFACE NODE.	UPN 070
DO 40 J=2,NDEEP	UPN 071
40 X(1,I+J-1) = XSURF	UPN 072
C.... DETERMINE CORRECT ELEMENT FOR SURFACE ALTITUDE INTERPOLATION.	UPN 073
50 IF(IXS(2).GE.NUMNP-NDEEP+1)GO TO 60	UPN 074
IF(XSURF.LE.X(1,IXS(2)))GO TO 60	UPN 075
DO 55 K=1,3	UPN 076
55 IXS(K) = IXS(K) + NDEEP	UPN 077
GO TO 50	UPN 078
60 CONTINUE	UPN 079
C.... INTERPOLATE SURFACE.	UPN 080
C.... FIRST FIND CORRESPONDING NATURAL COORDINATES.	UPN 081
IF(XSURF.GE.X(1,IXS(3)))	UPN 082
* SS = (XSURF - X(1,IXS(3))) / (X(1,IXS(2)) - X(1,IXS(3)))	UPN 083
IF(XSURF.LT.X(1,IXS(3)))	UPN 084
* SS = (XSURF - X(1,IXS(3))) / (X(1,IXS(3)) - X(1,IXS(1)))	UPN 085
CALL SHAPE(SS,TT,XDUM,SHP,XSJ,1,5,IX,.TRUE.)	UPN 086
YSURF = 0.	UPN 087
DO 70 K=1,3	UPN 088
70 YSURF = YSURF + SHP(3,ISURF(K))*X(2,IXS(K))	UPN 089
C.... STORE INTERPOLATED NEW CURRENT Y-COORDINATE OF THE SURFACE NODE	UPN 090
C.... IN PLACE OF THE Y-COORDINATE OF THE SECOND NODE OF THE COLUMN,	UPN 091
C.... TEMPORARILY.	UPN 092
X(2,I+1) = YSURF	UPN 093
C.... DETERMINE CORRECT ELEMENT FOR BED INTERPOLATION.	UPN 094
250 IF(IXB(2).GE.NUMEXT-NDEEP+1)GO TO 260	UPN 095
IF(XSURF.LE.T(IXB(2)))GO TO 260	UPN 096
DO 255 K=1,3	UPN 097
255 IXB(K) = IXB(K) + NDEEP	UPN 098
GO TO 250	UPN 099
260 CONTINUE	UPN 100
C.... INTERPOLATE BED.	UPN 101
C.... FIRST FIND CORRESPONDING NATURAL COORDINATES.	UPN 102
IF(XSURF.GE.T(IXB(3)))	UPN 103
* SS = (XSURF - T(IXB(3))) / (T(IXB(2)) - T(IXB(3)))	UPN 104
IF(XSURF.LT.T(IXB(3)))	UPN 105

* SS = (XSURF - T(IXB(3))) / (T(IXB(3)) - T(IXB(1)))	UPN 106
CALL SHAPE(SS,TT,XDUM,SHP,XSJ,1,5,IX,.TRUE.)	UPN 107
YBED = 0.	UPN 108
BCURR = 0.	UPN 109
ACURR = 0.	UPN 110
DO 270 K=1,3	UPN 111
YBED = YBED + SHP(3,ISURF(K))*T(IXB(K)+1)	UPN 112
BCURR = BCURR + SHP(3,ISURF(K))*T(IXB(K)+3)	UPN 113
270 ACURR = ACURR + SHP(3,ISURF(K))*T(IXB(K)+NDEEP-2)	UPN 114
C.... REPLACE OLD "CURRENT" BED ALTITUDE, BDOT, AND ABED WITH	UPN 115
C.... NEW ONES (CORRESPONDING TO XSURF NOW).	UPN 116
X(2,I+NDEEP-1) = YBED	UPN 117
X(2,I+NDEEP-2) = YBED + 5.	UPN 118
X(2,I+NDEEP-3) = YBED + 10.	UPN 119
X(2,I+NDEEP-4) = YBED + 10.	UPN 120
F(3,I+3) = BCURR	UPN 121
F(3,I+NDEEP-2) = ACURR	UPN 122
300 CONTINUE	UPN 123
C.... REPLACE COLUMN COORDINATES WITH NEW INTERPOLATED ONES.	UPN 124
DO 310 I=NDEEP1,NUMNP,NDEEP	UPN 125
X(1,I) = X(1,I+1)	UPN 126
X(2,I) = X(2,I+1)	UPN 127
DELTA = X(2,I) - X(2,I+NDPM4)	UPN 128
DO 310 K=1,NDPM5	UPN 129
310 X(2,I+K) = X(2,I) - DELTA*FACT(K)	UPN 130
RETURN	UPN 131
END	UPN 132
SUBROUTINE VALUES(VALUE,F,I,J,NDF)	VAL 1
C.....LOCATE BOUNDARY VALUES FOR SUBROUTINE ELMT04 IN COMMON M.	VAL 2
DIMENSION F(NDF,1)	VAL 3
VALUE = F(I,J)	VAL 4
RETURN	VAL 5
END	VAL 6

APPENDIX D: MODIFICATIONS OF THE GENERAL PURPOSE FINITE ELEMENT PROGRAM

Included below are modifications to the general purpose finite element program as it is listed in Zienkiewicz (1977). The subroutine FREEFM is from R. L. Taylor (written commun., 1980), as received from him in the card deck of the general purpose program. It is included here for completeness, so that the reader may refer to the program listed in Zienkiewicz. Some single line modifications listed below are also from Taylor; these are indicated either by explicit statement to that effect or by identification of the form CR 4/80C in columns 73

through 80 of the card. Changes with blanks in these columns are attributable to the author. Enough lines of the general purpose subroutines of Zienkiewicz (1977) are given so that the reader can locate the changes. The inclusion of modifications by Taylor is meant only to specify the exact form of the program used in the modeling. It is strongly recommended that the interested reader obtain the latest version of the program directly from Taylor.

```

C**** COMMENT OUT CDC PROGRAM CARD NOT REQUIRED ON IBM.
C    PROGRAM FEAPB(INPUT=101,OUTPUT=101,TAPE4=INPUT,TAPE5=101,
C    1          TAPE6=OUTPUT)
C    MASTER MINIFEM                                IFEM  1C
C.... SET PROGRAM CAPACITY * MAX MUST AGREE WITH DIMENSION OF M    IFEM  2C
C**** CHANGE PROGRAM CAPACITY FOR PROBLEM AT HAND.
COMMON M(20000)
COMMON/PSIZE/ MAX                                IFEM  4C
C**** CHANGE MAX TO AGREE WITH DIMENSION OF M.
MAX = 20000
CALL FREEFM(M,M(11),M(21),M(31),M(111))          CR 4/80C
CALL PCONTR                                      IFEM  6C
STOP                                              IFEM  7C
END                                              IFEM  8C
SUBROUTINE FREEFM(IS,IE,IT,IN,IWD)              FRE  01
C.... FREE FORMATED READ * * CONVERTED TO FIELD WIDTHS OF TEN (10)  FRE  02
C.... CARDS WHICH BEGIN WITH A STAR (*) ARE ALPHANUMERIC           FRE  03
C.... A CARD WHICH BEGINS WITH TWO STARS (**) WILL TERMINATE INPUT  FRE  04
LOGICAL BL,FL                                     FRE  05
DIMENSION IS(10),IE(10),IT(10),IN(80),IWD(80)   FRE  06
C**** CHANGE 10H TO 01H TO ACCOMMODATE IBM (STILL OK ON CDC) .
C    DATA NDIG,IBL/10,10H          //,ISL/1H//
DATA NDIG,IBL/10,01H          //,ISL/1H//
DATA IA,IC,IR,IZ/1HA,1H,,1HR,1HZ//,IST/1H*/
REWIND 5
WRITE(6,2000)
FL = .TRUE.
10  READ(4,1000) IN
    ILM = 1
    DO 20 I = 1,80
        IF(IN(I).NE.IBL) ILM = I +1
20  CONTINUE
    IL = 1

```

30	JL = IL + 1	FRE 18
	DO 35 I = 1,80	FRE 19
35	IWD(I) = IBL	FRE 20
	IF(IN(IL).NE.IST) GO TO 50	FRE 21
	IF(IN(JL).EQ.IST) GO TO 160	FRE 22
	DO 40 I = JL,ILM	FRE 23
	IF(IN(I).EQ.ISL) GO TO 45	FRE 24
40	IWD(I-IL) = IN(I)	FRE 25
	IL = ILM + 1	FRE 26
	GO TO 150	FRE 27
45	IL = I + 1	FRE 28
	GO TO 150	FRE 29
50	DO 100 I = 1,10	FRE 30
	IS(I) = 0	FRE 31
100	IT(I) = IR	FRE 32
	BL = .TRUE.	FRE 33
	K = 1	FRE 34
105	J = IN(IL)	FRE 35
	IF(J.EQ.IBL.AND.BL) GO TO 120	FRE 36
	IF(J.EQ.IBL.OR.J.EQ.IC.OR.J.EQ.ISL) GO TO 110	FRE 37
	IF(.NOT.BL) GO TO 120	FRE 38
	BL = .FALSE.	FRE 39
	IS(K) = IL	FRE 40
	IF(J.GE.IA.AND.J.LE.IZ) IT(K) = IA	FRE 41
	GO TO 120	FRE 42
110	BL = .TRUE.	FRE 43
	IE(K) = IL - 1	FRE 44
	K = K + 1	FRE 45
120	IL = IL + 1	FRE 46
	IF(K.GT.8.OR.J.EQ.ISL) GO TO 125	FRE 47
	IF(IL.LE.ILM) GO TO 105	FRE 48
125	K = K - 1	FRE 49
	IF(K.EQ.0) GO TO 150	FRE 50
	KL = 1	FRE 51
	KR = NDIG	FRE 52
	DO 145 I = 1,K	FRE 53
	JL = IS(I)	FRE 54
	IF(JL.EQ.0) GO TO 144	FRE 55
	JR = IE(I)	FRE 56
	IF(JR-JL.GT.9) GO TO 200	FRE 57
	II = KR - JR	FRE 58
	IF(IT(I).EQ.IA) II = KL - JL	FRE 59
	DO 140 J = JL,JR	FRE 60
140	IWD(J+II) = IN(J)	FRE 61
144	KL = KR + 1	FRE 62
145	KR = KR + NDIG	FRE 63
150	WRITE(6,2001) IWD	FRE 64
	WRITE(5,1000) IWD	FRE 65
	IF(IL.LE.ILM.OR.IN(IL-1).EQ.ISL) GO TO 30	FRE 66
	GO TO 10	FRE 67
160	REWIND 5	FRE 68
	WRITE(6,2002)	FRE 69
	IF(FL) RETURN	FRE 70
	STOP	FRE 71

200	WRITE(6,3000) IN	FRE	72
	FL = .FALSE.	FRE	73
	GO TO 10	FRE	74
1000	FORMAT(80A1)	FRE	75
2000	FORMAT(1H1,54HFIXED FORMAT FORM OF DATA CARDS FROM FREE FORMAT INP	FRE	76
	1UT ///1X)	FRE	77
2001	FORMAT(5X,80A1)	FRE	78
2002	FORMAT(1H0,17HEND OF DATA INPUT ///1X)	FRE	79
3000	FORMAT(5X,48HMORE THAN TEN CHARACTERS/DIGITS ON THE DATA CARD//	FRE	80
	1 10X,80A1)	FRE	81
	END	FRE	82
	SUBROUTINE PCONTR	PCO	1C
	.		
	.		
	.		
	COMMON M(1)	PCO	14C
C****	ADD THE FOLLOWING COMMON SO VARIABLES IN M CAN BE FOUND.		
	COMMON /POINTR/ N0,N1,N2,N3,N4,N5,N6,N7,N8,N9,N10,N11,N12,N13,		
	* N14,NE		
	DIMENSION TITL(20),WD(3)	PCO	15C
	.		
	.		
	.		
	CALL SETMEM(NE)	PCO	59C
	CALL PZERO(M(N13),NEQ)	CR10/77C	
	GO TO 1	PCO	60C
	.		
	.		
	.		
C****	FROM R.L. TAYLOR -- NEW INPUT FORMAT.		
1001	FORMAT(8I10)	PCO	68C
	.		
	.		
	.		
	END	PCO	74C
	BLOCK DATA		1C
	.		
	.		
	.		
C****	SINGLE PRECISION IS SUFFICIENT.		
	DATA O/1H0/,IPR/1/		
	END		9C
	SUBROUTINE GENVEC(NDM,X,CD,PRT,ERR)	GEN	1C
	.		
	.		
	.		
C****	FROM R.L. TAYLOR -- NEW INPUT FORMAT.		
1000	FORMAT(2I10,6F10.0)	GEN	38C
	.		
	.		
	.		
	END	GEN	44C

```

SUBROUTINE PMESH(IDL,IE,D,ID,X,IX,F,T,NDF,NDM,NEN1,III)
.
.
.
C**** REMOVE DATA SPECIFICATION FOR UNUSED VARIABLE VA.
DATA WD/4HCOOR,4HELEM,4HMATE,4HBOUN,4HFORC,4HTEMP,4HEND ,4HPRIN,
C 1 4HNOPR,4HPAGE/,BL/4HBLAN/,VA/4H VAL,2HUE/,LIST/10/,PRT/.TRUE./
1 4HNOPR,4HPAGE/,BL/4HBLAN/, LIST/10/,PRT/.TRUE./
C.... INITIALIZE ARRAYS
.
.
.
ID(I,N) = 0
X(1,N) = BL
100 F(I,N) = 0.0
.
.
.
C**** FROM R.L. TAYLOR -- OMIT XHED FROM VARIABLES READ.
READ(5,1002) MA,IEL
C**** FROM R.L. TAYLOR -- OMIT XHED FROM VARIABLES WRITTEN.
WRITE(6,2003)MA,IEL
IE(MA) = IEL
300 CALL ELMLIB(D(1,MA),IDL,X,IX,IDL,IDL,IDL,NDF,NDM,NDF,1)
GO TO 10
.
.
.
DO 53 I = 1,NDF
C**** GENERATION FOR TIED DEGREES OF FREEDOM.
IF(ID(I,L-LG).GT.1) ID(I,L)=ID(I,L-LG) + LG
53 IF(ID(I,L-LG).LT.0) ID(I,L) = -1
.
.
.
C**** FROM R.L. TAYLOR -- NEW INPUT FORMAT.
1001 FORMAT(8I10)
C**** FROM R.L. TAYLOR -- NEW INPUT FORMAT.
1002 FORMAT(2I10)
.
.
.
END
SUBROUTINE PMACR (UL,XL,TL,LD,P,S,IE,D,ID,X,IX,F,T,JDIAG,B,DR,CT
1,NDF,NDM,NEN1,NST,NEND)
.
.
.
COMMON /TDATA/ TIME,DT,C1,C2,C3,C4,C5
C**** INCREASE THE NUMBER OF MACROS.
DIMENSION WD(27),CT(4,1),CTL(4),LVS(9),LVE(9),JDIAG(1),
1 UL(1),XL(1),TL(1),LD(1),P(1),S(1),IE(1),D(1),ID(1),X(1),
2 IX(1),F(1),T(1),B(1),DR(1)

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C**** INCREASE THE NUMBER OF MACROS.
DATA WD/4HTOL ,4HDT ,4HSTRE,4HDISP,4HTANG,4HFORM,4HLOOP,4HNEXT, PMA 18C
1      4HPROP,4HDATA,4HTIME,4HCONV,4HSOLV,4HLMAS,4HCMAS,4HMESH, PMA 19C
2      4HEIGE,4HEXCD,4HUTAN,4HREAC,4HCHEC,4HSAVE,4HREST,4HPLOT,
3      4HUTAF,4HTANF,4HUPNO/
DATA NWD/27/,ENDM/4HEND /,NV,NC/1,1/
C.... SET INITIAL VALUES OF PARAMETERS PMA 22C
.
.
.
IF(L.NE.1.AND.L.NE.LL) PMA 85C
1WRITE(6,2010) I,(CT(K,L),K = 1,4) PMA 86C
C**** INCREASE THE NUMBER OF MACROS.
GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,
* 22,23,24,25,26,27),J
C.... SET SOLUTION TOLERANCE PMA 88C
.
.
.
CALL PFORM(UL,XL,TL,LD,P,S,IE,D,ID,X,IX,F,T,JDIAG,DR,DR,DR, PMA121C
2 NDF,NDM,NEN1,NST,6,B,M(NV),.FALSE.,.TRUE.,.FALSE.,.FALSE.) PMA122C

C**** ADD STATEMENT NUMBER 60.
60 BFR = .TRUE.
RN = 0. PMA124C
.
.
.
21 CALL PFORM(UL,XL,TL,LD,P,S,IE,D,ID,X,IX,F,T,JDIAG,DR,DR,DR, PMA229C
1 NDF,NDM,NEN1,NST,2,B,F,.FALSE.,.FALSE.,.FALSE.,.FALSE.) PMA230C
C**** ADD MACROS.
GO TO 330
C.... SAVE NODE NUMBER N, COORDINATES X, AND DISPLACEMENTS B
C.... ON TAPE16.
22 CALL SAVE(ID,X,B,F,NDM,NDF)
GO TO 330
C.... READ NODE NUMBER N, COORDINATES X (IF CT(3,L) = 1.),
C.... AND DISPLACEMENTS B FROM RESTART TAPE15.
C.... IF CT(3,L) = 0., READ ONLY DISPLACEMENTS.
23 CALL REST(ID,X,B,F,T,D,NDM,NDF,CT(3,L))
GO TO 330
C.... PLOT
24 CALL PLT(ID,X,B,F,T,D,TIME,NDM,NDF)
GO TO 330
C.... FORM TANGENT STIFFNESS AND OUT OF BALANCE FORCES, ONE CALL
C.... PER ELEMENT.
25 IF(CFL)CALL PSETM(NC,NE,JDIAG(NEQ)*IPR,CFL)
CALL PZERO(M(NC),JDIAG(NEQ))
CFR = .TRUE.
26 IF(J.EQ.26)CFR = .FALSE.
IF(GFL)CALL PSETM(NA,NE,JDIAG(NEQ)*IPR,GFL)
IF(NPLD.GT.0)PROP = PROPLD(TIME,0)
CALL PZERO(M(NA),JDIAG(NEQ))
CALL PLOAD(ID,F,DR,NNEQ,PROP)

```

```

      CALL PFORM(UL,XL,TL,LD,P,S,IE,D,ID,X,IX,F,T,JDIAG,DR,M(NA),M(NC),
2      NDF,NDM,NEN1,NST,3,B,M(NV),.TRUE.,.TRUE.,CFR,.FALSE.)
      AFR = .TRUE.
      GO TO 60
C.... UPDATE MESH
27 CALL UPNODE(D,X,B,DT,F,T,TIME,ID,NDM,NDF)
330  L = L + 1
                                     .
                                     .
                                     .
C**** FROM R.L. TAYLOR -- NEW INPUT FORMAT.
1000  FORMAT(A4,6X,A4,6X,2F10.0)
                                     .
                                     .
                                     .
      END
                                     .
      SUBROUTINE ACTCOL(A,B,JDIAG,NEQ,AFAC,BACK)
                                     .
                                     .
                                     .
      ID = JDIAG(K+I)
C**** GIVE ERROR MESSAGE FOR DIVISION BY 0.
      IF(A(ID).NE.0.0) GO TO 310
      INDEX = K + I
      GO TO 1100
310  D = A(I)
      A(I) = A(I)/A(ID)
                                     .
                                     .
                                     .
      ID = JDIAG(I)
C**** GIVE ERROR MESSAGE FOR DIVISION BY 0.
      IF(A(ID).NE.0.0)GO TO 610
      INDEX = I
      GO TO 1100
610  B(I) = B(I)/A(ID)
700  AENGY = AENGY + B(I)*B(I)*A(ID)
                                     .
                                     .
                                     .
      GO TO 800
C**** ERROR MESSAGE AND STOP FOR SINGULAR SYSTEM.
1100 WRITE(6,6000)INDEX
6000 FORMAT(46H0ZERO DIAGONAL IN PARTIALLY REDUCED SYSTEM AT ,
*16HDIAGONAL NUMBER ,I6)
      STOP
      END
      SUBROUTINE PROFIL (JDIAG,ID,IX,NDF,NEN1,NAD)
                                     .
                                     .
                                     .
      GO TO 40
C**** RESTRAINED (J.LE.1) OR TIED(J.GT.1) NODES

```

PMA231C

PMA243C

PMA264C

ACT 1C

ACT 33C

ACT 36C

ACT 45C

ACT 47C

ACT 61C

ACT 62C

PRO 1C

PRO 16C

```

30  IF(J.LE.1) ID(I,N) = 0
    IF(J.GT.1) ID(I,N)=ID(I,MOD(J-1,NUMNP)+1)
40  CONTINUE
                                     .
                                     .
                                     .
    END
    SUBROUTINE PRDIS(ID,X,B,F,NDM,NDF)
                                     .
                                     .
                                     .
    RETURN
    C**** CHANGE TIME FORMAT FROM E13.5 TO E16.8.
2000 FORMAT(A1,20A4//5X,19HNODAL DISPLACEMENTS,5X,4HTIME,E16.8//
1    6X,4HNODE,9(I7,A4,A2))
    END
    SUBROUTINE SHAP2(S,T,SHP,IX,NEL)
                                     .
                                     .
                                     .
    T2 = (1.-T*T)/2.
    DO 100 I=5,9
    DO 100 J = 1,3
                                     .
                                     .
                                     .
    IF(IX(9).EQ.0) GO TO 107
    C**** FROM R.L. TAYLOR -- MULTIPLY BY 4.
    SHP(1,9) = -4.*S*T2
    SHP(2,9) = -4.*T*S2
    SHP(3,9) = 4.*S2*T2
                                     .
                                     .
                                     .
    END

```

PRO 18C

PRO 49C

PRT 1C

PRT 25C

PRT 27C

PRT 28C

SHA 1C

SHA 7C

CR 3/78C

SHA 9C

SHA 33C

SHA 34C

SHA 35C

SHA 36C

SHA 51C

APPENDIX E: SAMPLE RUN

The following sample run demonstrates input and output associated with going from time 1981.150 to time 1981.275 by using calving law constant $\alpha = 1165625$. The corresponding plots can be found in figure 4. During the actual modeling runs, 3 years were run at a time; the only modification necessary for such a multiple run is to change the macroinstruction LOOP*1 to LOOP*24. The asterisks appearing in some of the macros are merely spacers so that the subroutine FREEFM will place the constants that follow them in the proper card position. The input data contained in data set \$\$\$\$\$\$.COLDATA is simply the freeform version of the data as listed at the beginning of the output, with single spaces between data items and an appended card with ** in columns 1 and 2. In addition, the title card has an asterisk

in column 1 to indicate alphanumeric data. The general purpose program is contained in subroutine library \$\$\$\$\$\$.LOADLIB, with the element subroutine ELMT04 for glacier flow in element ICE2 of that library. The data sets \$\$\$\$\$\$.OLDSTART and \$\$\$\$\$\$.RESTART are restart files read by macro REST and written by macro SAVE, respectively. Data set \$\$\$\$\$\$.COLPLOT is the plot file. SYS1.RS232.DATA100.CALCOMP is a library of Calcomp¹ software designed to drive a local Calcomp drum plotter. Step COPYPLOT copies the plot file to the appropriate output class K for local plotting.

¹The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

H A S P J O B L O G

\$21.50.22 JOB 8770 -- \$\$\$\$\$\$ -- BEGINNING EXEC - INIT 7 - CLASS F

\$21.51.25 JOB 8770 ENDED 001105L

---- HASP-II REL STATISTICS ----

40 CARDS READ

1,116 SYSOUT PRINT RECORDS

335 SYSOUT PUNCH RECORDS

1.06MINUTES ELAPSED TIME

//\$\$\$\$\$\$ JOB (\$\$\$\$\$\$, \$\$\$\$\$\$, \$\$\$\$\$\$, 10, 1000, , , N), 'SIKONIA*R*',

J8770

// CLASS=F,MSGLEVEL=(2,0)

***ROUTE PRINT REMOTE241 REL

***ROUTE PUNCH REMOTE21 REL

//FEAPRUN EXEC FORTXCG,TIME=5,COND=(0,LT),

// PARM.FORT='NOMAP,NAME(FEAP),OPTIMIZE(2),',

// ULIB='\$\$\$\$\$\$\$.LOADLIB',PARM.GO='NOMAP,EP=FEAP,SIZE=210K',

// REGION.GO=236K

//FORT.SYSPRINT DD SYSOUT=A

//FORT.SYSIN DD *

IEF142I - STEP WAS EXECUTED - COND CODE 0000

IEF373I STEP /FORT / START 81037.2150

IEF374I STEP /FORT / STOP 81037.2150 CPU 0MIN 00.17SEC MAIN 248K LCS OK

CCD006I STEP /FORT / I/O IN DD SEQ; 4A4:2 563:1 155:0

CCD006I STEP /FORT / I/O IN DD SEQ; 563:0 4D1:1

CCD001I STEP /FORT / MEMORY RESERVED 250K; ACCESSES: DISK 4/ TAPE 0

//GO.SYSLIB DD

// DD DSN=SYS1.RS232.DATA100.CALCOMP,DISP=SHR

// DD DSN=SYS1.FORTGLIB,DISP=SHR

// DD DSN=XTENT.LIB,DISP=SHR

//GO.SYSLINB DD DSN=\$\$\$\$\$\$.LOADLIB(ICE2),DISP=SHR

//GO.FT06F001 DD SYSOUT=A

//GO.SYSIN DD UNIT=SYSDK,SPACE=(TRK,(34,34)),

// DCB=(RECFM=FB,LRECL=80,BLKSIZE=640)

```
//GO.FT04F001 DD DSN=$$$$$$.COLDATA,DISP=SHR
//GO.FT99F001 DD DSN=$$$$$$.COLPLOT,DISP=OLD
//GO.FT15F001 DD DSN=$$$$$$.OLDSTART,DISP=SHR
//GO.FT16F001 DD DSN=$$$$$$.RESTART,DISP=(OLD,KEEP,KEEP)
IEF142I - STEP WAS EXECUTED - COND CODE 0000
```

```
IEF373I STEP /GO      / START 81037.2150
IEF374I STEP /GO      / STOP  81037.2151 CPU    OMIN 12.14SEC MAIN 234K LCS    OK
CCD006I STEP /GO      / I/O IN DD SEQ; 4A3:1      634:260      314:232
CCD006I STEP /GO      / I/O IN DD SEQ; 314:0      314:0        563:3
CCD006I STEP /GO      / I/O IN DD SEQ; 634:10     155:89         4A4:46
CCD006I STEP /GO      / I/O IN DD SEQ; 4B0:0      4A5:0         746:42
CCD006I STEP /GO      / I/O IN DD SEQ; 740:42     741:4         746:102
CCD001I STEP /GO      / MEMORY RESERVED 236K; ACCESSES: DISK      831/ TAPE      0
//COPYPLOT EXEC PGM=IEBGGENER,TIME=1,COND=(0,LT),REGION=104K
//SYSPRINT DD SYSOUT=A
//SYSIN DD DUMMY
//SYSUT1 DD DSN=$$$$$$.COLPLOT,DISP=SHR
//SYSUT2 DD SYSOUT=(K,,WS81),DCB=(RECFM=U,BLKSIZE=80)
IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF373I STEP /COPYPLOT/ START 81037.2151
IEF374I STEP /COPYPLOT/ STOP  81037.2151 CPU    OMIN 00.22SEC MAIN  34K LCS    OK
CCD006I STEP /COPYPLOT/ I/O IN DD SEQ; 4A2:1      000:0         740:43
CCD006I STEP /COPYPLOT/ I/O IN DD SEQ; 4B0:19
CCD001I STEP /COPYPLOT/ MEMORY RESERVED 104K; ACCESSES: DISK      63/ TAPE      0
IEF375I JOB /$$$$$$$/ START 81037.2150
IEF376I JOB /$$$$$$$/ STOP  81037.2151 CPU    OMIN 12.53SEC
CCD007A JOB /$$$$$$$/ BASIC CHR: FIXED CPU DSK-IO TPE-IO KBYTE-HR TOTAL
                        .41  2.79   .80           .54   4.54
CCD007D JOB /$$$$$$$/ LOCAL CHR: FORMS PRINTING CRDS-RD CRDS-PU TOTAL
                        .00           .00           .00
CCD002I JOB /$$$$$$$/ TOTAL CHARGE RECORDED = $4.54
CCD003I JOB /$$$$$$$/ US GEOLOGICAL SURVEY REL OS REL 218 TIME = 21.51.25 DATE =
                        02/06/81
```

LEVEL 2.3.0 (JUNE 78) OS/360 FORTRAN H EXTENDED DATE 81.037/21.50.27

REQUESTED OPTIONS: NOMAP,NAME(FEAP),OPTIMIZE(2),

OPTIONS IN EFFECT: NAME(FEAP) OPTIMIZE(2) LINECOUNT(54) SIZE(MAX) AUTODBL(NONE)

SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF

NOALC NOANSF NOTERM IBM

C PROGRAM FEAPB(INPUT=101,OUTPUT=101,TAPE4=INPUT,TAPE5=101,

C 1 TAPE6=OUTPUT)

C MASTER MINIFEM

IFEM 1C

C.... SET PROGRAM CAPACITY * MAX MUST AGREE WITH

DIMENSION OF M

IFEM 2C

ISN 0002 COMMON M(20000)

ISN 0003 COMMON/PSIZE/ MAX

IFEM 4C

ISN 0004 MAX = 20000

ISN 0005 CALL FREEFM(M,M(11),M(21),M(31),M(111))

ISN 0006 CALL PCONTR

IFEM 6C

ISN 0007 STOP

IFEM 7C

ISN 0008 END

IFEM 8C

*OPTIONS IN EFFECT*NAME(FEAP) OPTIMIZE(2) LINECOUNT(54) SIZE(MAX) AUTODBL(NONE)
 *OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF
 NOALC NOANSF NOTERM IBM
 STATISTICS SOURCE STATEMENTS = 7, PROGRAM SIZE = 318,
 SUBPROGRAM NAME = FEAP
 STATISTICS NO DIAGNOSTICS GENERATED
 ***** END OF COMPILATION ***** 58K BYTES OF CORE NOT USED
 OS/360 LOADER
 OPTIONS USED - PRINT,NOMAP,NOLET,CALL,RES,NOTERM,SIZE=215040,NAME=**GO
 EP=FEAP
 TOTAL LENGTH 2EC28
 ENTRY ADDRESS 4BA810

FIXED FORMAT FORM OF DATA CARDS FROM FREE FORMAT INPUT

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****
 232 36 1 2 3 9 0

NOPR
 COOR

1	1	0.0	465.00
3	1	0.0	-121.40
5	0	0.0	-268.00
6	1	0.0	-268.00
8	0	0.0	-278.00
9	1	762.50	430.00
11	1	762.50	-103.60
13	0	762.50	-237.00
14	1	762.50	-237.00
16	0	762.50	-247.00
17	1	1525.00	411.00
19	1	1525.00	-119.40
21	0	1525.00	-252.00
22	1	1525.00	-252.00
24	0	1525.00	-262.00
25	1	2287.50	401.00
27	1	2287.50	-102.20
29	0	2287.50	-228.00
30	1	2287.50	-228.00
32	0	2287.50	-238.00
33	1	3050.00	370.00
35	1	3050.00	-81.20
37	0	3050.00	-194.00
38	1	3050.00	-194.00
40	0	3050.00	-204.00
41	1	3812.50	340.00
43	1	3812.50	-76.80
45	0	3812.50	-181.00
46	1	3812.50	-181.00
48	0	3812.50	-191.00
49	1	4575.00	314.00
51	1	4575.00	-108.40

53	0	4575.00	-214.00
54	1	4575.00	-214.00
56	0	4575.00	-224.00
57	1	5337.50	290.00
59	1	5337.50	-190.00
61	0	5337.50	-310.00
62	1	5337.50	-310.00
64	0	5337.50	-320.00
65	1	6100.00	275.00
67	1	6100.00	-242.60
69	0	6100.00	-372.00
70	1	6100.00	-372.00
72	0	6100.00	-382.00
73	1	6862.50	264.00
75	1	6862.50	-255.20
77	0	6862.50	-385.00
78	1	6862.50	-385.00
80	0	6862.50	-395.00
81	1	7625.00	248.00
83	1	7625.00	-249.60
85	0	7625.00	-374.00
86	1	7625.00	-374.00
88	0	7625.00	-384.00
89	1	8387.50	226.00
91	1	8387.50	-253.20
93	0	8387.50	-373.00
94	1	8387.50	-373.00
96	0	8387.50	-383.00
97	1	9150.00	210.00
99	1	9150.00	-271.60
101	0	9150.00	-392.00
102	1	9150.00	-392.00
104	0	9150.00	-402.00
105	1	9912.50	198.00
107	1	9912.50	-273.20
109	0	9912.50	-391.00
110	1	9912.50	-391.00
112	0	9912.50	-401.00
113	1	10675.00	178.00
115	1	10675.00	-278.00
117	0	10675.00	-392.00
118	1	10675.00	-392.00
120	0	10675.00	-402.00
121	1	11056.25	167.00
123	1	11056.25	-280.20
125	0	11056.25	-392.00
126	1	11056.25	-392.00
128	0	11056.25	-402.00
129	1	11437.50	159.00
131	1	11437.50	-265.80
133	0	11437.50	-372.00
134	1	11437.50	-372.00
136	0	11437.50	-382.00
137	1	11818.75	152.00

139	1	11818.75	-245.60
141	0	11818.75	-345.00
142	1	11818.75	-345.00
144	0	11818.75	-355.00
145	1	12200.00	140.00
147	1	12200.00	-220.00
149	0	12200.00	-310.00
150	1	12200.00	-310.00
152	0	12200.00	-320.00
153	1	12581.25	129.00
155	1	12581.25	-195.00
157	0	12581.25	-276.00
158	1	12581.25	-276.00
160	0	12581.25	-286.00
161	1	12962.50	118.00
163	1	12962.50	-176.40
165	0	12962.50	-250.00
166	1	12962.50	-250.00
168	0	12962.50	-260.00
169	1	13153.12	113.00
171	1	13153.12	-163.00
173	0	13153.12	-232.00
174	1	13153.12	-232.00
176	0	13153.12	-242.00
177	1	13343.75	108.00
179	1	13343.75	-147.20
181	0	13343.75	-211.00
182	1	13343.75	-211.00
184	0	13343.75	-221.00
185	1	13534.37	100.00
187	1	13534.37	-128.80
189	0	13534.37	-186.00
190	1	13534.37	-186.00
192	0	13534.37	-196.00
193	1	13725.00	96.00
195	1	13725.00	-102.40
197	0	13725.00	-152.00
198	1	13725.00	-152.00
200	0	13725.00	-162.00
201	1	13915.62	96.00
203	1	13915.62	-80.80
205	0	13915.62	-125.00
206	1	13915.62	-125.00
208	0	13915.62	-135.00
209	1	14106.25	96.00
211	1	14106.25	-57.60
213	0	14106.25	-96.00
214	1	14106.25	-96.00
216	0	14106.25	-106.00
217	1	14296.87	96.00
219	1	14296.87	-20.80
221	0	14296.87	-50.00
222	1	14296.87	-50.00
224	0	14296.87	-60.00

225	1	14487.50	96.00
227	1	14487.50	19.20
229	0	14487.50	0.0
230	1	14487.50	0.0
232	0	14487.50	-10.00

ELEM

01	1	3	19	17	1	11	18
9	2	10	2				
03	1	8	24	22	6	16	23
14	7	15	0				
04	1	19	35	33	17	27	34
25	18	26	2				
06	1	24	40	38	22	32	39
30	23	31	0				
07	1	35	51	49	33	43	50
41	34	42	2				
09	1	40	56	54	38	48	55
46	39	47	0				
10	1	51	67	65	49	59	66
57	50	58	2				
12	1	56	72	70	54	64	71
62	55	63	0				
13	1	67	83	81	65	75	82
73	66	74	2				
15	1	72	88	86	70	80	87
78	71	79	0				
16	1	83	99	97	81	91	98
89	82	90	2				
18	1	88	104	102	86	96	103
94	87	95	0				
19	1	99	115	113	97	107	114
105	98	106	2				
21	1	104	120	118	102	112	119
110	103	111	0				
22	1	115	131	129	113	123	130
121	114	122	2				
24	1	120	136	134	118	128	135
126	119	127	0				
25	1	131	147	145	129	139	146
137	130	138	2				
27	1	136	152	150	134	144	151
142	135	143	0				
28	1	147	163	161	145	155	162
153	146	154	2				
30	1	152	168	166	150	160	167
158	151	159	0				
31	1	163	179	177	161	171	178
169	162	170	2				
33	1	168	184	182	166	176	183
174	167	175	0				
34	1	179	195	193	177	187	194
185	178	186	2				
36	1	184	200	198	182	192	199
190	183	191	0				

B60

STUDIES OF COLUMBIA GLACIER, ALASKA

MATE

	1	4			
	.140	3.00	193.	8.	
BOUN					
8	8	-1	-1		
200	0	1	1		
1	0	1			
2	0	1			
3	0	1			
5	0	1			
6	0	1	5		
4	8	1	0	-1	
196	0	0	0	1	
7	8	1	0	-1	
199	0	0	0	1	
14	8	13	13		
198	0	197	197		
201	1	-1	-1	-1	
232	0	1	1	1	

FORC

1	0	950.00		
2	0	943.56		
3	0	846.88		
4	0	784.83	0	-2.67
5	0	698.25		
6	0	698.25		
7	0	349.13	0	40.
12	0	0	0	-3.42
20	0	0	0	-3.98
28	0	0	0	-4.45
36	0	0	0	-4.90
44	0	0	0	-5.41
52	0	0	0	-5.98
60	0	0	0	-6.30
68	0	0	0	-6.32
76	0	0	0	-6.29
84	0	0	0	-6.26
92	0	0	0	-6.27
100	0	0	0	-6.36
108	0	0	0	-6.53
116	0	0	0	-6.68
124	0	0	0	-6.76
132	0	0	0	-6.91
140	0	0	0	-7.09
148	0	0	0	-7.21
156	0	0	0	-7.38
164	0	0	0	-7.63
172	0	0	0	-7.77
180	0	0	0	-7.87
188	0	0	0	-7.93
196	0	0	0	-7.94
204	0	0	0	-7.94
212	0	0	0	-7.94
220	0	0	0	-7.94

APPENDIX E: SAMPLE RUN

B61

228	0	0	0	-7.94
15	0	0	0	37.
23	0	0	0	25.14
31	0	0	0	8.99
39	0	0	0	8.38
47	0	0	0	6.91
55	0	0	0	8.63
63	0	0	0	11.24
71	0	0	0	7.51
79	0	0	0	7.36
87	0	0	0	15.91
95	0	0	0	21.35
103	0	0	0	22.58
111	0	0	0	18.01
119	0	0	0	20.84
127	0	0	0	28.
135	0	0	0	33.
143	0	0	0	37.76
151	0	0	0	40.25
159	0	0	0	40.25
167	0	0	0	40.25
175	0	0	0	40.25
183	0	0	0	40.25
191	0	0	0	40.25
199	0	0	0	40.25
207	0	0	0	40.25
215	0	0	0	40.25
223	0	0	0	40.25
231	0	0	0	40.25

TEMP

6	0	950
14	0	1030
22	0	960
30	0	922
38	0	935
46	0	930
54	0	900
62	0	839
70	0	808
78	0	812
86	0	866
94	0	904
102	0	933
110	0	1012
118	0	1102
126	0	1150
134	0	1210
142	0	1320
150	0	1460

END
MACR
TOL
DT
TIME

* 1.E-2
* 81.15

```

REST          *          1.
LOOP          *          10.
TANF
SOLV
CONV
DT            *          0.
TIME
NEXT
PLOT
DISP
SAVE
LOOP          *          1
LOOP          *          5
DT            *          .025
UPNO
TIME
LOOP          *          10
TANF
SOLV
CONV
DT            *          0.
TIME
NEXT
NEXT
PLOT
DISP
SAVE
NEXT
END
SCAL
-500.    16000.    -1000.    1000.    635.    12700.    .08    90.
END
STOP

```

END OF DATA INPUT

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

```

NUMBER OF NODAL POINTS    =    232
NUMBER OF ELEMENTS        =    36
NUMBER OF MATERIAL SETS   =    1
DIMENSION OF COORDINATE SPACE=    2
DEGREE OF FREEDOMS/NODE   =    3
NODES PER ELEMENT (MAXIMUM) =    9
EXTRA D.O.F. TO ELEMENT   =    0

```

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

MATERIAL PROPERTIES

MATERIAL SET 1 FOR ELEMENT TYPE 4

TWO DIMENSIONAL ICE FLOW ELEMENT

```

VISCOS. A = 0.14000E+00
VISCOS. N = 0.30000E+01
CALVE NODE = 0.19300E+03
NODES DEEP = 0.80000E+01

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FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

MACRO INSTRUCTIONS

MACRO STATEMENT	VARIABLE 1	VARIABLE 2
TOL	.10000E-01	.0
DT	81.150	.0
TIME	.0	.0
REST	1.0000	.0
LOOP	10.000	.0
TANF	.0	.0
SOLV	.0	.0
CONV	.0	.0
DT	.0	.0
TIME	.0	.0
NEXT	.0	.0
PLOT	.0	.0
DISP	.0	.0
SAVE	.0	.0
LOOP	1.0000	.0
LOOP	5.0000	.0
DT	.25000E-01	.0
UPNO	.0	.0
TIME	.0	.0
LOOP	10.000	.0
TANF	.0	.0
SOLV	.0	.0
CONV	.0	.0
DT	.0	.0
TIME	.0	.0
NEXT	.0	.0
NEXT	.0	.0
PLOT	.0	.0
DISP	.0	.0
SAVE	.0	.0
NEXT	.0	.0
END	.0	.0

MACRO INSTRUCTION	1 EXECUTED**	TOL	V1 =	.1000E-01	, V2 =	.0
MACRO INSTRUCTION	2 EXECUTED**	DT	V1 =	81.15	, V2 =	.0
MACRO INSTRUCTION	3 EXECUTED**	TIME	V1 =	.0	, V2 =	.0
MACRO INSTRUCTION	4 EXECUTED**	REST	V1 =	1.000	, V2 =	.0
MACRO INSTRUCTION	5 EXECUTED**	LOOP	V1 =	10.00	, V2 =	12.00
MACRO INSTRUCTION	6 EXECUTED**	TANF	V1 =	.0	, V2 =	.0

FORCE CONVERGENCE TEST

RNMAX =	.39112	RN =	.39112	TOL =	.10000E-01
MACRO INSTRUCTION	7 EXECUTED**	SOLV	V1 =	.0	, V2 = .0
MACRO INSTRUCTION	8 EXECUTED**	CONV	V1 =	.0	, V2 = .0

DISPLACEMENT CONVERGENCE TEST

UNMAX =	13151.	UN =	.26771E-01	TOL =	.10000E-01
MACRO INSTRUCTION	9 EXECUTED**	DT	V1 =	.0	, V2 = .0
MACRO INSTRUCTION	10 EXECUTED**	TIME	V1 =	.0	, V2 = .0
MACRO INSTRUCTION	11 EXECUTED**	NEXT	V1 =	10.00	, V2 = 6.000
MACRO INSTRUCTION	12 EXECUTED**	PLOT	V1 =	.0	, V2 = .0
MACRO INSTRUCTION	13 EXECUTED**	DISP	V1 =	.0	, V2 = .0

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE ***** TIME 81.150
 PROPORTIONAL LOAD 1.0000

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

NODAL DISPLACEMENTS TIME 0.81149994E+02

NODE	1 COORD	2 COORD	1 DISPL	2 DISPL	3 DISPL	3 Explanation
1	0.0	465.0000	0.9500E+03	0.2658E+02	0.1454E+01	pressure
2	0.0	171.8000	0.9436E+03	0.3344E+02	0.1315E+02	hdot
3	0.0	-121.4000	0.8469E+03	0.4342E+02	0.5157E+02	pressure
4	0.0	-194.7000	0.7848E+03	0.4757E+02	-0.2670E+01	bdot
5	0.0	-268.0000	0.6982E+03	0.6042E+02	0.6282E+02	pressure
6	0.0	-268.0000	0.6982E+03	0.6042E+02	0.6363E+02	pressure
7	0.0	-273.0000	0.3491E+03	0.3069E+02	0.4000E+02	Abcd
8	0.0	-278.0000	0.0	0.0	0.6445E+02	pressure
9	768.9395	456.6458	0.9785E+03	-0.2287E+02	0.3865E+00	
10	768.9395	179.2141	0.9582E+03	-0.1728E+02	0.8934E+00	
11	768.9395	-98.2178	0.9041E+03	-0.7195E+01	0.4951E+02	
12	768.9395	-167.5757	0.8807E+03	-0.2426E+01	-0.3426E+01	
13	768.9395	-236.9341	0.8561E+03	0.3056E+01	0.6186E+02	
14	768.9395	-236.9341	0.8561E+03	0.3056E+01	0.6235E+02	
15	768.9395	-241.9341	0.4316E+03	0.1645E+01	0.3694E+02	
16	768.9395	-246.9341	0.0	0.0	0.6325E+02	
17	1537.8792	429.7080	0.9810E+03	-0.1349E+02	0.6445E+00	
18	1537.8792	157.0576	0.9806E+03	-0.6178E+01	0.4564E+00	
19	1537.8792	-115.5928	0.9235E+03	-0.7839E+00	0.4921E+02	
20	1537.8792	-183.7554	0.8882E+03	-0.3930E+01	-0.3989E+01	
21	1537.8792	-251.9182	0.8384E+03	-0.1038E+02	0.6127E+02	
22	1537.8792	-251.9182	0.8384E+03	-0.1038E+02	0.6072E+02	
23	1537.8792	-256.9182	0.4251E+03	-0.5466E+01	0.2490E+02	
24	1537.8792	-261.9182	0.0	0.0	0.6156E+02	
25	2306.8184	422.9641	0.1045E+04	-0.1377E+02	-0.6725E-01	
26	2306.8184	162.8738	0.1024E+04	0.1247E+02	0.2698E+01	
27	2306.8184	-97.2166	0.9461E+03	0.3053E+02	0.4666E+02	
28	2306.8184	-162.2393	0.8948E+03	0.3436E+02	-0.4462E+01	
29	2306.8184	-227.2621	0.8223E+03	0.3676E+02	0.5836E+02	
30	2306.8184	-227.2621	0.8223E+03	0.3676E+02	0.5858E+02	
31	2306.8184	-232.2621	0.4134E+03	0.1864E+02	0.8783E+01	
32	2306.8184	-237.2621	0.0	0.0	0.5948E+02	
33	3075.7583	397.1182	0.1138E+04	-0.3268E+02	0.9516E-01	
34	3075.7583	160.9837	0.1114E+04	-0.3918E+01	0.2955E+01	
35	3075.7583	-75.1506	0.1025E+04	0.2363E+02	0.4208E+02	
36	3075.7583	-134.1843	0.9871E+03	0.2973E+02	-0.4916E+01	
37	3075.7583	-193.2181	0.9433E+03	0.3318E+02	0.5281E+02	
38	3075.7583	-193.2181	0.9433E+03	0.3318E+02	0.5299E+02	
39	3075.7583	-198.2181	0.4804E+03	0.1690E+02	0.8344E+01	
40	3075.7583	-203.2181	0.0	0.0	0.5386E+02	
41	3844.6975	369.8826	0.1206E+04	-0.5064E+02	0.2668E+00	
42	3844.6975	149.3443	0.1182E+04	-0.3620E+02	0.2964E+01	
43	3844.6975	-71.1938	0.1100E+04	-0.1966E+02	0.3966E+02	
44	3844.6975	-126.3284	0.1039E+04	-0.1402E+02	-0.5433E+01	
45	3844.6975	-181.4632	0.9477E+03	-0.9526E+01	0.4966E+02	
46	3844.6975	-181.4632	0.9477E+03	-0.9526E+01	0.4974E+02	
47	3844.6975	-186.4632	0.4826E+03	-0.4756E+01	0.6918E+01	
48	3844.6975	-191.4632	0.0	0.0	0.5063E+02	
49	4613.6367	319.5710	0.1219E+04	-0.8927E+02	0.2130E+01	
50	4613.6367	104.8030	0.1196E+04	-0.1060E+03	-0.3566E+00	

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

NODAL DISPLACEMENTS		TIME 0.81149994E+02			
NODE	1 COORD	2 COORD	1 DISPL	2 DISPL	3 DISPL
51	4613.6367	-109.9651	0.1124E+04	-0.1178E+03	0.3881E+02
52	4613.6367	-163.6570	0.1078E+04	-0.1176E+03	-0.6002E+01
53	4613.6367	-217.3492	0.1009E+04	-0.1131E+03	0.4791E+02
54	4613.6367	-217.3492	0.1009E+04	-0.1131E+03	0.4783E+02
55	4613.6367	-222.3492	0.5209E+03	-0.5836E+02	0.8741E+01
56	4613.6367	-227.3492	0.0	0.0	0.4870E+02
57	5382.5742	281.2563	0.1089E+04	-0.1921E+02	0.2112E+01
58	5382.5742	42.9097	0.1076E+04	-0.5648E+02	0.6542E+01
59	5382.5742	-195.4370	0.9849E+03	-0.8647E+02	0.4367E+02
60	5382.5742	-255.0234	0.9346E+03	-0.9266E+02	-0.6310E+01
61	5382.5742	-314.6104	0.8710E+03	-0.9498E+02	0.5376E+02
62	5382.5742	-314.6104	0.8710E+03	-0.9498E+02	0.5342E+02
63	5382.5742	-319.6104	0.4392E+03	-0.4815E+02	0.1120E+02
64	5382.5742	-324.6104	0.0	0.0	0.5429E+02
65	6151.5156	270.0581	0.1001E+04	0.3958E+01	0.2001E+01
66	6151.5156	12.2664	0.9778E+03	-0.8922E+01	0.5873E+01
67	6151.5156	-245.5256	0.8962E+03	-0.2281E+02	0.4647E+02
68	6151.5156	-309.9736	0.8555E+03	-0.2435E+02	-0.6320E+01
69	6151.5156	-374.4216	0.8090E+03	-0.2707E+02	0.5796E+02
70	6151.5156	-374.4216	0.8090E+03	-0.2707E+02	0.5769E+02
71	6151.5156	-379.4216	0.4065E+03	-0.1364E+02	0.7387E+01
72	6151.5156	-384.4216	0.0	0.0	0.5858E+02
73	6920.4570	256.9724	0.9923E+03	-0.7751E+01	0.6951E+00
74	6920.4570	0.1812	0.9711E+03	-0.5736E+01	0.6039E+01
75	6920.4570	-256.6106	0.8839E+03	-0.1563E+00	0.4632E+02
76	6920.4570	-320.8083	0.8274E+03	0.8642E+00	-0.6288E+01
77	6920.4570	-385.0063	0.7512E+03	0.1675E+01	0.5767E+02
78	6920.4570	-385.0063	0.7512E+03	0.1675E+01	0.5769E+02
79	6920.4570	-390.0063	0.3774E+03	0.8385E+00	0.7704E+01
80	6920.4570	-395.0063	0.0	0.0	0.5857E+02
81	7689.3945	239.8603	0.1001E+04	-0.1462E+02	0.7923E+00
82	7689.3945	-5.4953	0.9865E+03	-0.1085E+02	0.5455E+01
83	7689.3945	-250.8506	0.9322E+03	0.1088E+01	0.4402E+02
84	7689.3945	-312.1895	0.8920E+03	0.8432E+01	-0.6259E+01
85	7689.3945	-373.5288	0.8343E+03	0.1788E+02	0.5492E+02
86	7689.3945	-373.5288	0.8343E+03	0.1788E+02	0.5547E+02
87	7689.3945	-378.5288	0.4222E+03	0.9346E+01	0.1649E+02
88	7689.3945	-383.5288	0.0	0.0	0.5638E+02
89	8458.3359	216.2448	0.1006E+04	-0.2367E+02	0.7183E+00
90	8458.3359	-19.8220	0.9992E+03	-0.2227E+02	0.1431E+01
91	8458.3359	-255.8888	0.9684E+03	-0.1869E+02	0.4247E+02
92	8458.3359	-314.9053	0.9475E+03	-0.1722E+02	-0.6275E+01
93	8458.3359	-373.9224	0.9187E+03	-0.1509E+02	0.5284E+02
94	8458.3359	-373.9224	0.9187E+03	-0.1509E+02	0.5299E+02
95	8458.3359	-378.9224	0.4685E+03	-0.7634E+01	0.2164E+02
96	8458.3359	-383.9224	0.0	0.0	0.5387E+02
97	9227.2734	193.8667	0.1005E+04	-0.1446E+02	0.8011E+00
98	9227.2734	-40.8036	0.1001E+04	-0.1389E+02	0.2497E+01
99	9227.2734	-275.4739	0.9639E+03	-0.1330E+02	0.4242E+02
100	9227.2734	-334.1414	0.9376E+03	-0.1393E+02	-0.6374E+01

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

NODAL DISPLACEMENTS		TIME 0.81149994E+02			
NODE	1 COORD	2 COORD	1 DISPL	2 DISPL	3 DISPL
101	9227.2734	-392.8093	0.9023E+03	-0.1475E+02	0.5275E+02
102	9227.2734	-392.8093	0.9023E+03	-0.1475E+02	0.5262E+02
103	9227.2734	-397.8093	0.4529E+03	-0.7455E+01	0.2238E+02
104	9227.2734	-402.8093	0.0	0.0	0.5350E+02
105	9996.2148	177.0835	0.1014E+04	-0.6122E+01	0.6530E+00
106	9996.2148	-50.1546	0.1008E+04	-0.3719E+01	0.1126E+02
107	9996.2148	-277.3923	0.9791E+03	0.1995E+00	0.4115E+02
108	9996.2148	-334.2019	0.9559E+03	0.1658E+01	-0.6547E+01
109	9996.2148	-391.0117	0.9225E+03	0.3707E+01	0.5117E+02
110	9996.2148	-391.0117	0.9225E+03	0.3707E+01	0.5135E+02
111	9996.2148	-396.0117	0.4677E+03	0.1906E+01	0.1796E+02
112	9996.2148	-401.0117	0.0	0.0	0.5223E+02
113	10765.1523	156.6192	0.1020E+04	-0.1305E+02	0.7924E+00
114	10765.1523	-62.8644	0.1015E+04	-0.1277E+02	0.1112E+02
115	10765.1523	-282.3479	0.9908E+03	-0.1292E+02	0.3919E+02
116	10765.1523	-337.2187	0.9737E+03	-0.1291E+02	-0.6705E+01
117	10765.1523	-392.0901	0.9501E+03	-0.1263E+02	0.4880E+02
118	10765.1523	-392.0901	0.9501E+03	-0.1263E+02	0.4882E+02
119	10765.1523	-397.0901	0.4841E+03	-0.6267E+01	0.2214E+02
120	10765.1523	-402.0901	0.0	0.0	0.4971E+02
121	11149.6211	149.5192	0.1024E+04	0.6732E+01	0.3306E+00
122	11149.6211	-65.8687	0.1026E+04	0.1787E+02	0.9019E+01
123	11149.6211	-281.2566	0.9940E+03	0.2880E+02	0.3899E+02
124	11149.6211	-335.1035	0.9772E+03	0.3101E+02	-0.6790E+01
125	11149.6211	-388.9509	0.9582E+03	0.3309E+02	0.4855E+02
126	11149.6211	-388.9509	0.9582E+03	0.3309E+02	0.4881E+02
127	11149.6211	-393.9509	0.4736E+03	0.1643E+02	0.2942E+02
128	11149.6211	-398.9509	0.0	0.0	0.4968E+02
129	11534.0937	148.0525	0.1061E+04	0.2465E+02	-0.7999E-01
130	11534.0937	-57.4969	0.1056E+04	0.4870E+02	0.2809E+02
131	11534.0937	-263.0461	0.1029E+04	0.6691E+02	0.3699E+02
132	11534.0937	-314.4336	0.1013E+04	0.7144E+02	-0.6953E+01
133	11534.0937	-365.8213	0.9896E+03	0.7523E+02	0.4636E+02
134	11534.0937	-365.8213	0.9896E+03	0.7523E+02	0.4682E+02
135	11534.0937	-370.8213	0.5074E+03	0.3856E+02	0.3423E+02
136	11534.0937	-375.8213	0.0	0.0	0.4772E+02
137	11918.5625	140.1805	0.1124E+04	0.1301E+02	-0.1882E+00
138	11918.5625	-50.5356	0.1108E+04	0.4891E+02	0.3065E+02
139	11918.5625	-241.2516	0.1066E+04	0.7625E+02	0.3374E+02
140	11918.5625	-288.9304	0.1050E+04	0.8179E+02	-0.7127E+01
141	11918.5625	-336.6099	0.1030E+04	0.8593E+02	0.4247E+02
142	11918.5625	-336.6099	0.1030E+04	0.8593E+02	0.4300E+02
143	11918.5625	-341.6099	0.5193E+03	0.4347E+02	0.3863E+02
144	11918.5625	-346.6099	0.0	0.0	0.4388E+02
145	12303.0312	131.3288	0.1210E+04	0.6849E+01	-0.2639E+00
146	12303.0312	-41.4878	0.1192E+04	0.5015E+02	0.3638E+02
147	12303.0312	-214.3042	0.1136E+04	0.9043E+02	0.3090E+02
148	12303.0312	-257.5083	0.1114E+04	0.9956E+02	-0.7251E+01
149	12303.0312	-300.7129	0.1088E+04	0.1066E+03	0.3895E+02
150	12303.0312	-300.7129	0.1088E+04	0.1066E+03	0.3971E+02

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

NODAL DISPLACEMENTS		TIME 0.81149994E+02			
NODE	1 COORD	2 COORD	1 DISPL	2 DISPL	3 DISPL
151	12303.0312	-305.7129	0.5562E+03	0.5478E+02	0.4050E+02
152	12303.0312	-310.7129	0.0	0.0	0.4061E+02
153	12687.5039	116.6096	0.1298E+04	-0.1562E+01	-0.2111E+00
154	12687.5039	-37.2140	0.1287E+04	0.3523E+02	0.4183E+02
155	12687.5039	-191.0374	0.1237E+04	0.7301E+02	0.2695E+02
156	12687.5039	-229.4932	0.1215E+04	0.8263E+02	-0.7442E+01
157	12687.5039	-267.9495	0.1189E+04	0.9161E+02	0.3394E+02
158	12687.5039	-267.9495	0.1189E+04	0.9161E+02	0.3488E+02
159	12687.5039	-272.9495	0.6078E+03	0.4715E+02	0.4025E+02
160	12687.5039	-277.9495	0.0	0.0	0.3576E+02
161	13071.9727	101.4698	0.1391E+04	0.1581E+02	-0.3078E+00
162	13071.9727	-34.5920	0.1386E+04	0.5316E+02	0.6919E+02
163	13071.9727	-170.6537	0.1342E+04	0.8741E+02	0.2428E+02
164	13071.9727	-204.6691	0.1325E+04	0.9566E+02	-0.7724E+01
165	13071.9727	-238.6848	0.1304E+04	0.1033E+03	0.3045E+02
166	13071.9727	-238.6848	0.1304E+04	0.1033E+03	0.3135E+02
167	13071.9727	-243.6848	0.6799E+03	0.5462E+02	0.4025E+02
168	13071.9727	-248.6848	0.0	0.0	0.3225E+02
169	13264.2031	94.3128	0.1473E+04	0.9351E+01	-0.5730E+00
170	13264.2031	-31.4634	0.1454E+04	0.7239E+02	0.3975E+02
171	13264.2031	-157.2396	0.1403E+04	0.1234E+03	0.2189E+02
172	13264.2031	-188.6836	0.1385E+04	0.1339E+03	-0.7833E+01
173	13264.2031	-220.1277	0.1363E+04	0.1437E+03	0.2756E+02
174	13264.2031	-220.1277	0.1363E+04	0.1437E+03	0.2865E+02
175	13264.2031	-225.1277	0.6702E+03	0.7095E+02	0.4025E+02
176	13264.2031	-230.1277	0.0	0.0	0.2952E+02
177	13456.4414	89.8647	0.1602E+04	-0.7009E+01	-0.1291E+01
178	13456.4414	-24.7626	0.1576E+04	0.1070E+03	0.6118E+02
179	13456.4414	-139.3900	0.1492E+04	0.1856E+03	0.2025E+02
180	13456.4414	-168.0467	0.1469E+04	0.2002E+03	-0.7910E+01
181	13456.4414	-196.7039	0.1450E+04	0.2093E+03	0.2610E+02
182	13456.4414	-196.7039	0.1450E+04	0.2093E+03	0.2713E+02
183	13456.4414	-201.7039	0.8329E+03	0.1207E+03	0.4025E+02
184	13456.4414	-206.7039	0.0	0.0	0.2811E+02
185	13648.6719	76.2207	0.1824E+04	-0.4276E+02	-0.8349E+00
186	13648.6719	-20.9452	0.1795E+04	0.6911E+02	0.6717E+02
187	13648.6719	-118.1111	0.1689E+04	0.1934E+03	0.1660E+02
188	13648.6719	-142.4025	0.1643E+04	0.2221E+03	-0.7942E+01
189	13648.6719	-166.6940	0.1591E+04	0.2464E+03	0.2117E+02
190	13648.6719	-166.6940	0.1591E+04	0.2464E+03	0.2295E+02
191	13648.6719	-171.6940	0.7263E+03	0.1141E+03	0.4025E+02
192	13648.6719	-176.6940	0.0	0.0	0.2379E+02
193	13840.9141	66.9960	0.1955E+04	-0.2757E+02	-0.1211E+01
194	13840.9141	-13.7014	0.2063E+04	0.4808E+02	0.1659E+02
195	13840.9141	-94.3988	0.2034E+04	0.1827E+03	0.1231E+02
196	13840.9141	-114.5732	0.2000E+04	0.2339E+03	-0.7941E+01
197	13840.9141	-134.7476	0.1959E+04	0.2749E+03	0.1806E+02
198	13840.9141	-134.7476	0.1959E+04	0.2749E+03	0.2018E+02
199	13840.9141	-139.7476	0.1570E+04	0.2394E+03	0.4025E+02
200	13840.9141	-144.7476	0.0	0.0	0.2173E+02

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**MACRO INSTRUCTION 14 EXECUTED** SAVE          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 15 EXECUTED** LOOP          V1 =      1.000    , V2 =      32.00
**MACRO INSTRUCTION 16 EXECUTED** LOOP          V1 =      5.000    , V2 =      28.00
**MACRO INSTRUCTION 17 EXECUTED** DT            V1 =     .2500E-01 , V2 =      .0
**MACRO INSTRUCTION 18 EXECUTED** UPNO          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 19 EXECUTED** TIME          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 20 EXECUTED** LOOP          V1 =     10.00    , V2 =     27.00
**MACRO INSTRUCTION 21 EXECUTED** TANF          V1 =      .0      , V2 =      .0

  FORCE CONVERGENCE TEST
    RNMAX =    1985.6      RN =    1985.6      TOL =    .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 23 EXECUTED** CONV          V1 =      .0      , V2 =      .0

  DISPLACEMENT CONVERGENCE TEST
    UNMAX =    13008.      UN =    166.76      TOL =    .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT            V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 25 EXECUTED** TIME          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT          V1 =      1.000    , V2 =     21.00
**MACRO INSTRUCTION 21 EXECUTED** TANF          V1 =      .0      , V2 =      .0

  FORCE CONVERGENCE TEST
    RNMAX =    15.457      RN =    15.457      TOL =    .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 23 EXECUTED** CONV          V1 =      .0      , V2 =      .0

  DISPLACEMENT CONVERGENCE TEST
    UNMAX =    13010.      UN =    2.4093      TOL =    .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT            V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 25 EXECUTED** TIME          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT          V1 =     10.00    , V2 =     21.00
**MACRO INSTRUCTION 27 EXECUTED** NEXT          V1 =      1.000    , V2 =     17.00
**MACRO INSTRUCTION 17 EXECUTED** DT            V1 =     .2500E-01 , V2 =      .0
**MACRO INSTRUCTION 18 EXECUTED** UPNO          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 19 EXECUTED** TIME          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 20 EXECUTED** LOOP          V1 =     10.00    , V2 =     27.00
**MACRO INSTRUCTION 21 EXECUTED** TANF          V1 =      .0      , V2 =      .0

  FORCE CONVERGENCE TEST
    RNMAX =    2440.2      RN =    2440.2      TOL =    .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 23 EXECUTED** CONV          V1 =      .0      , V2 =      .0

  DISPLACEMENT CONVERGENCE TEST
    UNMAX =    12846.      UN =    195.34      TOL =    .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT            V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 25 EXECUTED** TIME          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT          V1 =      1.000    , V2 =     21.00
**MACRO INSTRUCTION 21 EXECUTED** TANF          V1 =      .0      , V2 =      .0

  FORCE CONVERGENCE TEST
    RNMAX =    19.483      RN =    19.483      TOL =    .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 23 EXECUTED** CONV          V1 =      .0      , V2 =      .0

  DISPLACEMENT CONVERGENCE TEST
    UNMAX =    12848.      UN =    3.0509      TOL =    .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT            V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 25 EXECUTED** TIME          V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT          V1 =     10.00    , V2 =     21.00

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**MACRO INSTRUCTION 27 EXECUTED** NEXT          V1 = 2.000 , V2 = 17.00
**MACRO INSTRUCTION 17 EXECUTED** DT            V1 = .2500E-01 , V2 = .0
**MACRO INSTRUCTION 18 EXECUTED** UPNO          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 19 EXECUTED** TIME          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 20 EXECUTED** LOOP          V1 = 10.00 , V2 = 27.00
**MACRO INSTRUCTION 21 EXECUTED** TANF          V1 = .0 , V2 = .0
  FORCE CONVERGENCE TEST
    RNMAX = 2394.2      RN = 2394.2      TOL = .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 23 EXECUTED** CONV          V1 = .0 , V2 = .0
  DISPLACEMENT CONVERGENCE TEST
    UNMAX = 12704.      UN = 175.48      TOL = .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT            V1 = .0 , V2 = .0
**MACRO INSTRUCTION 25 EXECUTED** TIME          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT          V1 = 1.000 , V2 = 21.00
**MACRO INSTRUCTION 21 EXECUTED** TANF          V1 = .0 , V2 = .0
  FORCE CONVERGENCE TEST
    RNMAX = 27.012      RN = 27.012      TOL = .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 23 EXECUTED** CONV          V1 = .0 , V2 = .0
  DISPLACEMENT CONVERGENCE TEST
    UNMAX = 12706.      UN = 2.7596      TOL = .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT            V1 = .0 , V2 = .0
**MACRO INSTRUCTION 25 EXECUTED** TIME          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT          V1 = 10.00 , V2 = 21.00
**MACRO INSTRUCTION 27 EXECUTED** NEXT          V1 = 3.000 , V2 = 17.00
**MACRO INSTRUCTION 17 EXECUTED** DT            V1 = .2500E-01 , V2 = .0
**MACRO INSTRUCTION 18 EXECUTED** UPNO          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 19 EXECUTED** TIME          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 20 EXECUTED** LOOP          V1 = 10.00 , V2 = 27.00
**MACRO INSTRUCTION 21 EXECUTED** TANF          V1 = .0 , V2 = .0
  FORCE CONVERGENCE TEST
    RNMAX = 1750.1      RN = 1750.1      TOL = .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 23 EXECUTED** CONV          V1 = .0 , V2 = .0
  DISPLACEMENT CONVERGENCE TEST
    UNMAX = 12572.      UN = 152.09      TOL = .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT            V1 = .0 , V2 = .0
**MACRO INSTRUCTION 25 EXECUTED** TIME          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT          V1 = 1.000 , V2 = 21.00
**MACRO INSTRUCTION 21 EXECUTED** TANF          V1 = .0 , V2 = .0
  FORCE CONVERGENCE TEST
    RNMAX = 127.53      RN = 127.53      TOL = .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 23 EXECUTED** CONV          V1 = .0 , V2 = .0
  DISPLACEMENT CONVERGENCE TEST
    UNMAX = 12574.      UN = 2.6256      TOL = .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT            V1 = .0 , V2 = .0
**MACRO INSTRUCTION 25 EXECUTED** TIME          V1 = .0 , V2 = .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT          V1 = 10.00 , V2 = 21.00
**MACRO INSTRUCTION 27 EXECUTED** NEXT          V1 = 4.000 , V2 = 17.00
**MACRO INSTRUCTION 17 EXECUTED** DT            V1 = .2500E-01 , V2 = .0

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**MACRO INSTRUCTION 18 EXECUTED** UPNO      V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 19 EXECUTED** TIME      V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 20 EXECUTED** LOOP      V1 =     10.00    , V2 =     27.00
**MACRO INSTRUCTION 21 EXECUTED** TANF      V1 =      .0      , V2 =      .0

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FORCE CONVERGENCE TEST

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      RNMAX =     1291.0      RN      =     1291.0      TOL      =     .10000E-01
**MACRO INSTRUCTION 22 EXECUTED** SOLV      V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 23 EXECUTED** CONV      V1 =      .0      , V2 =      .0

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DISPLACEMENT CONVERGENCE TEST

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      UNMAX =     1246.6      UN      =     123.86      TOL      =     .10000E-01
**MACRO INSTRUCTION 24 EXECUTED** DT        V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 25 EXECUTED** TIME      V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 26 EXECUTED** NEXT      V1 =     10.00    , V2 =     21.00
**MACRO INSTRUCTION 27 EXECUTED** NEXT      V1 =      5.000    , V2 =     17.00
**MACRO INSTRUCTION 28 EXECUTED** PLOT      V1 =      .0      , V2 =      .0
**MACRO INSTRUCTION 29 EXECUTED** DISP      V1 =      .0      , V2 =      .0

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FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE ***** TIME 81.275

PROPORTIONAL LOAD 1.0000

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

NODAL DISPLACEMENTS TIME 0.81274963E+02

NODE	1 COORD	2 COORD	1 DISPL	2 DISPL	3 DISPL
1	0.0	465.0000	0.9500E+03	0.2882E+02	0.1535E+01
2	0.0	171.8000	0.9436E+03	0.3435E+02	0.1517E+02
3	0.0	-121.4000	0.8469E+03	0.4353E+02	0.5159E+02
4	0.0	-194.7000	0.7848E+03	0.4749E+02	-0.2670E+01
5	0.0	-268.0000	0.6982E+03	0.6017E+02	0.6284E+02
6	0.0	-268.0000	0.6982E+03	0.6017E+02	0.6365E+02
7	0.0	-273.0000	0.3491E+03	0.3056E+02	0.4000E+02
8	0.0	-278.0000	0.0	0.0	0.6447E+02
9	774.9919	456.7146	0.9753E+03	-0.2072E+02	0.4242E+00
10	774.9919	179.2788	0.9557E+03	-0.1599E+02	0.2853E+01
11	774.9919	-98.1570	0.9024E+03	-0.6765E+01	0.4952E+02
12	774.9919	-167.5159	0.8791E+03	-0.2233E+01	-0.3431E+01
13	774.9919	-236.8751	0.8548E+03	0.3018E+01	0.6187E+02
14	774.9919	-236.8751	0.8548E+03	0.3018E+01	0.6234E+02
15	774.9919	-241.8751	0.4309E+03	0.1622E+01	0.3688E+02
16	774.9919	-246.8751	0.0	0.0	0.6324E+02
17	1549.9841	429.6428	0.9762E+03	-0.1030E+02	0.6830E+00
18	1549.9841	157.0532	0.9760E+03	-0.3824E+01	0.3248E+01
19	1549.9841	-115.5364	0.9192E+03	0.5947E+00	0.4924E+02
20	1549.9841	-183.6838	0.8838E+03	-0.2891E+01	-0.3997E+01
21	1549.9841	-251.8313	0.8338E+03	-0.9678E+01	0.6130E+02
22	1549.9841	-251.8313	0.8338E+03	-0.9678E+01	0.6073E+02
23	1549.9841	-256.8313	0.4227E+03	-0.5113E+01	0.2468E+02
24	1549.9841	-261.8313	0.0	0.0	0.6157E+02
25	2324.9758	423.0266	0.1037E+04	-0.1124E+02	-0.5320E-01
26	2324.9758	163.1912	0.1017E+04	0.1365E+02	0.5053E+01
27	2324.9758	-96.6445	0.9395E+03	0.3074E+02	0.4662E+02
28	2324.9758	-161.6035	0.8878E+03	0.3431E+02	-0.4473E+01
29	2324.9758	-226.5626	0.8145E+03	0.3651E+02	0.5830E+02
30	2324.9758	-226.5626	0.8145E+03	0.3651E+02	0.5852E+02
31	2324.9758	-231.5626	0.4095E+03	0.1851E+02	0.8597E+01
32	2324.9758	-236.5626	0.0	0.0	0.5942E+02
33	3099.9685	396.8281	0.1126E+04	-0.2900E+02	0.1372E+00

34	3099.9685	161.0949	0.1103E+04	-0.2955E+01	0.6358E+01
35	3099.9685	-74.6382	0.1017E+04	0.2284E+02	0.4203E+02
36	3099.9685	-133.5715	0.9795E+03	0.2885E+02	-0.4932E+01
37	3099.9685	-192.5051	0.9362E+03	0.3245E+02	0.5274E+02
38	3099.9685	-192.5051	0.9362E+03	0.3245E+02	0.5293E+02
39	3099.9685	-197.5051	0.4769E+03	0.1656E+02	0.8310E+01
40	3099.9685	-202.5051	0.0	0.0	0.5380E+02
41	3874.9602	368.8999	0.1185E+04	-0.4704E+02	0.3037E+00
42	3874.9602	148.5506	0.1162E+04	-0.3464E+02	0.6679E+01
43	3874.9602	-71.7986	0.1084E+04	-0.2039E+02	0.3967E+02
44	3874.9602	-126.8860	0.1026E+04	-0.1568E+02	-0.5454E+01
45	3874.9602	-181.9735	0.9358E+03	-0.1186E+02	0.4961E+02
46	3874.9602	-181.9735	0.9358E+03	-0.1186E+02	0.4968E+02
47	3874.9602	-186.9735	0.4768E+03	-0.5977E+01	0.6931E+01
48	3874.9602	-191.9735	0.0	0.0	0.5056E+02
49	4649.9492	317.6731	0.1192E+04	-0.8114E+02	0.2195E+01
50	4649.9492	102.3462	0.1170E+04	-0.1003E+03	0.3837E+01

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

NODAL DISPLACEMENTS		TIME 0.81274963E+02			
NODE	1 COORD	2 COORD	1 DISPL	2 DISPL	3 DISPL
51	4649.9492	-112.9807	0.1094E+04	-0.1151E+03	0.3902E+02
52	4649.9492	-166.8125	0.1048E+04	-0.1162E+03	-0.6023E+01
53	4649.9492	-220.6443	0.9791E+03	-0.1126E+03	0.4809E+02
54	4649.9492	-220.6443	0.9791E+03	-0.1126E+03	0.4797E+02
55	4649.9492	-225.6443	0.5050E+03	-0.5810E+02	0.8847E+01
56	4649.9492	-230.6443	0.0	0.0	0.4884E+02
57	5424.9414	281.0791	0.1054E+04	-0.9754E+01	0.2136E+01
58	5424.9414	41.1132	0.1039E+04	-0.4953E+02	0.1298E+02
59	5424.9414	-198.8525	0.9476E+03	-0.8097E+02	0.4398E+02
60	5424.9414	-258.8440	0.8986E+03	-0.8734E+02	-0.6318E+01
61	5424.9414	-318.8357	0.8368E+03	-0.8974E+02	0.5414E+02
62	5424.9414	-318.8357	0.8368E+03	-0.8974E+02	0.5380E+02
63	5424.9414	-323.8357	0.4217E+03	-0.4547E+02	0.1113E+02
64	5424.9414	-328.8357	0.0	0.0	0.5467E+02
65	6199.9336	270.1453	0.9592E+03	0.5920E+01	0.2010E+01
66	6199.9336	11.4897	0.9382E+03	-0.6883E+01	0.8312E+01
67	6199.9336	-247.1658	0.8640E+03	-0.1952E+02	0.4661E+02
68	6199.9336	-311.8296	0.8260E+03	-0.2080E+02	-0.6319E+01
69	6199.9336	-376.4937	0.7824E+03	-0.2302E+02	0.5812E+02
70	6199.9336	-376.4937	0.7824E+03	-0.2302E+02	0.5789E+02
71	6199.9336	-381.4937	0.3934E+03	-0.1161E+02	0.7286E+01
72	6199.9336	-386.4937	0.0	0.0	0.5878E+02
73	6974.9297	256.8132	0.9498E+03	-0.3999E+01	0.8032E+00
74	6974.9297	0.1335	0.9307E+03	-0.2694E+01	0.9165E+01
75	6974.9297	-256.5461	0.8516E+03	0.1483E+01	0.4629E+02
76	6974.9297	-320.7161	0.7993E+03	0.2469E+01	-0.6286E+01
77	6974.9297	-384.8862	0.7284E+03	0.2891E+01	0.5766E+02
78	6974.9297	-384.8862	0.7284E+03	0.2891E+01	0.5767E+02
79	6974.9297	-389.8862	0.3661E+03	0.1450E+01	0.8074E+01
80	6974.9297	-394.8862	0.0	0.0	0.5855E+02
81	7749.9180	239.0933	0.9555E+03	-0.1150E+02	0.1017E+01
82	7749.9180	-5.8043	0.9420E+03	-0.9521E+01	0.8511E+01
83	7749.9180	-250.7019	0.8951E+03	0.1285E+00	0.4395E+02
84	7749.9180	-311.9260	0.8576E+03	0.7086E+01	-0.6259E+01

85	7749.9180	-373.1509	0.8030E+03	0.1561E+02	0.5488E+02
86	7749.9180	-373.1509	0.8030E+03	0.1561E+02	0.5538E+02
87	7749.9180	-378.1509	0.4069E+03	0.8168E+01	0.1701E+02
88	7749.9180	-383.1509	0.0	0.0	0.5629E+02
89	8524.9102	214.6174	0.9552E+03	-0.1915E+02	0.9557E+00
90	8524.9102	-21.2081	0.9497E+03	-0.1881E+02	0.4678E+01
91	8524.9102	-257.0334	0.9224E+03	-0.1738E+02	0.4242E+02
92	8524.9102	-315.9897	0.9030E+03	-0.1636E+02	-0.6280E+01
93	8524.9102	-374.9465	0.8762E+03	-0.1495E+02	0.5280E+02
94	8524.9102	-374.9465	0.8762E+03	-0.1495E+02	0.5290E+02
95	8524.9102	-379.9465	0.4469E+03	-0.7574E+01	0.2188E+02
96	8524.9102	-384.9465	0.0	0.0	0.5378E+02
97	9299.9023	192.5049	0.9525E+03	-0.8651E+01	0.1247E+01
98	9299.9023	-41.8501	0.9479E+03	-0.9233E+01	0.4868E+01
99	9299.9023	-276.2048	0.9116E+03	-0.1030E+02	0.4240E+02
100	9299.9023	-334.7937	0.8873E+03	-0.1063E+02	-0.6387E+01

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

NODAL DISPLACEMENTS		TIME 0.81274963E+02			
NODE	1 COORD	2 COORD	1 DISPL	2 DISPL	3 DISPL
101	9299.9023	-393.3828	0.8549E+03	-0.1176E+02	0.5282E+02
102	9299.9023	-393.3828	0.8549E+03	-0.1176E+02	0.5264E+02
103	9299.9023	-398.3828	0.4285E+03	-0.5936E+01	0.2214E+02
104	9299.9023	-403.3828	0.0	0.0	0.5353E+02
105	10074.8945	176.7471	0.9544E+03	-0.2155E+01	0.8901E+00
106	10074.8945	-50.3697	0.9492E+03	-0.1550E+01	0.1362E+02
107	10074.8945	-277.4863	0.9231E+03	0.6115E+00	0.4112E+02
108	10074.8945	-334.2656	0.9017E+03	0.1667E+01	-0.6564E+01
109	10074.8945	-391.0452	0.8706E+03	0.3158E+01	0.5113E+02
110	10074.8945	-391.0452	0.8706E+03	0.3158E+01	0.5127E+02
111	10074.8945	-396.0452	0.4419E+03	0.1616E+01	0.1799E+02
112	10074.8945	-401.0452	0.0	0.0	0.5215E+02
113	10849.8867	155.4968	0.9552E+03	-0.3793E+01	0.1113E+01
114	10849.8867	-63.5514	0.9507E+03	-0.4707E+01	0.1871E+02
115	10849.8867	-282.5994	0.9269E+03	-0.6922E+01	0.3919E+02
116	10849.8867	-337.3613	0.9104E+03	-0.7465E+01	-0.6725E+01
117	10849.8867	-392.1238	0.8885E+03	-0.7910E+01	0.4878E+02
118	10849.8867	-392.1238	0.8885E+03	-0.7910E+01	0.4873E+02
119	10849.8867	-397.1238	0.4510E+03	-0.3895E+01	0.2359E+02
120	10849.8867	-402.1238	0.0	0.0	0.4963E+02
121	11237.3828	150.2279	0.9566E+03	0.1928E+02	0.4064E+00
122	11237.3828	-63.8597	0.9571E+03	0.2765E+02	0.1498E+02
123	11237.3828	-277.9473	0.9271E+03	0.3572E+02	0.3892E+02
124	11237.3828	-331.4692	0.9118E+03	0.3718E+02	-0.6823E+01
125	11237.3828	-384.9915	0.8948E+03	0.3876E+02	0.4837E+02
126	11237.3828	-384.9915	0.8948E+03	0.3876E+02	0.4863E+02
127	11237.3828	-389.9915	0.4419E+03	0.1922E+02	0.3064E+02
128	11237.3828	-394.9915	0.0	0.0	0.4951E+02
129	11624.8789	150.7312	0.9885E+03	0.2897E+02	-0.4567E-01
130	11624.8789	-53.4030	0.9822E+03	0.5029E+02	0.3111E+02
131	11624.8789	-257.5371	0.9575E+03	0.6617E+02	0.3661E+02
132	11624.8789	-308.5706	0.9423E+03	0.7013E+02	-0.6995E+01
133	11624.8789	-359.6042	0.9215E+03	0.7316E+02	0.4593E+02
134	11624.8789	-359.6042	0.9215E+03	0.7316E+02	0.4634E+02
135	11624.8789	-364.6042	0.4721E+03	0.3746E+02	0.3537E+02

136	11624.8789	-369.6042	0.0	0.0	0.4724E+02
137	12012.3750	142.2204	0.1045E+04	0.1843E+02	-0.1379E+00
138	12012.3750	-45.9574	0.1031E+04	0.4992E+02	0.3542E+02
139	12012.3750	-234.1351	0.9915E+03	0.7445E+02	0.3338E+02
140	12012.3750	-281.1792	0.9765E+03	0.7946E+02	-0.7158E+01
141	12012.3750	-328.2241	0.9587E+03	0.8321E+02	0.4200E+02
142	12012.3750	-328.2241	0.9587E+03	0.8321E+02	0.4252E+02
143	12012.3750	-333.2241	0.4834E+03	0.4212E+02	0.3931E+02
144	12012.3750	-338.2241	0.0	0.0	0.4341E+02
145	12399.8711	133.1550	0.1119E+04	0.1276E+02	-0.1695E+00
146	12399.8711	-36.9271	0.1104E+04	0.4695E+02	0.4065E+02
147	12399.8711	-207.0090	0.1056E+04	0.7955E+02	0.3036E+02
148	12399.8711	-249.5296	0.1036E+04	0.8724E+02	-0.7293E+01
149	12399.8711	-292.0505	0.1012E+04	0.9337E+02	0.3825E+02
150	12399.8711	-292.0505	0.1012E+04	0.9337E+02	0.3897E+02

FEAP COLUMBIA GLACIER VERTICAL CENTERLINE PROFILE *****

NODAL DISPLACEMENTS		TIME 0.81274963E+02			
NODE	1 COORD	2 COORD	1 DISPL	2 DISPL	3 DISPL
151	12399.8711	-297.0505	0.5201E+03	0.4817E+02	0.4056E+02
152	12399.8711	-302.0505	0.0	0.0	0.3987E+02
153	12787.3672	118.2029	0.1189E+04	0.6555E+01	-0.1346E+00
154	12787.3672	-33.4582	0.1181E+04	0.3665E+02	0.4326E+02
155	12787.3672	-185.1193	0.1139E+04	0.6797E+02	0.2667E+02
156	12787.3672	-223.0344	0.1121E+04	0.7596E+02	-0.7505E+01
157	12787.3672	-260.9500	0.1099E+04	0.8338E+02	0.3354E+02
158	12787.3672	-260.9500	0.1099E+04	0.8338E+02	0.3440E+02
159	12787.3672	-265.9500	0.5602E+03	0.4281E+02	0.4025E+02
160	12787.3672	-270.9500	0.0	0.0	0.3529E+02
161	13174.8633	104.6301	0.1271E+04	0.2728E+02	-0.3111E+00
162	13174.8633	-29.1245	0.1270E+04	0.6326E+02	0.6827E+02
163	13174.8633	-162.8789	0.1233E+04	0.9604E+02	0.2384E+02
164	13174.8633	-196.3176	0.1218E+04	0.1039E+03	-0.7783E+01
165	13174.8633	-229.7564	0.1199E+04	0.1111E+03	0.2995E+02
166	13174.8633	-229.7564	0.1199E+04	0.1111E+03	0.3087E+02
167	13174.8633	-234.7564	0.6223E+03	0.5801E+02	0.4025E+02
168	13174.8633	-239.7564	0.0	0.0	0.3177E+02
169	13368.6094	97.0733	0.1357E+04	0.2381E+02	-0.5945E+00
170	13368.6094	-24.9426	0.1339E+04	0.8648E+02	0.5714E+02
171	13368.6094	-146.9585	0.1291E+04	0.1334E+03	0.2130E+02
172	13368.6094	-177.4623	0.1274E+04	0.1423E+03	-0.7880E+01
173	13368.6094	-207.9665	0.1257E+04	0.1504E+03	0.2677E+02
174	13368.6094	-207.9665	0.1257E+04	0.1504E+03	0.2781E+02
175	13368.6094	-212.9665	0.6225E+03	0.7506E+02	0.4025E+02
176	13368.6094	-217.9665	0.0	0.0	0.2869E+02
177	13562.3594	92.0420	0.1496E+04	-0.5806E-01	-0.1345E+01
178	13562.3594	-17.4035	0.1464E+04	0.1197E+03	0.5321E+02
179	13562.3594	-126.8490	0.1375E+04	0.2031E+03	0.1920E+02
180	13562.3594	-154.2104	0.1351E+04	0.2184E+03	-0.7935E+01
181	13562.3594	-181.5718	0.1331E+04	0.2276E+03	0.2491E+02
182	13562.3594	-181.5718	0.1331E+04	0.2276E+03	0.2601E+02
183	13562.3594	-186.5718	0.7400E+03	0.1243E+03	0.4025E+02
184	13562.3594	-191.5718	0.0	0.0	0.2697E+02
185	13756.1055	78.2083	0.1743E+04	-0.4757E+02	-0.9306E+00
186	13756.1055	-11.9215	0.1707E+04	0.6358E+02	0.8268E+02

187	13756.1055	-102.0513	0.1595E+04	0.1812E+03	0.1544E+02
188	13756.1055	-124.5837	0.1548E+04	0.2081E+03	-0.7941E+01
189	13756.1055	-147.1162	0.1495E+04	0.2310E+03	0.1974E+02
190	13756.1055	-147.1162	0.1495E+04	0.2310E+03	0.2155E+02
191	13756.1055	-152.1162	0.7126E+03	0.1115E+03	0.4025E+02
192	13756.1055	-157.1162	0.0	0.0	0.2240E+02
193	13949.8594	62.7661	0.1895E+04	-0.7402E+02	-0.1078E+01
194	13949.8594	-10.3158	0.1965E+04	-0.1467E+02	0.6399E+02
195	13949.8594	-83.3978	0.1922E+04	0.9215E+02	0.1077E+02
196	13949.8594	-101.6682	0.1889E+04	0.1333E+03	-0.7940E+01
197	13949.8594	-119.9387	0.1850E+04	0.1682E+03	0.1576E+02
198	13949.8594	-119.9387	0.1850E+04	0.1682E+03	0.1780E+02
199	13949.8594	-124.9387	0.1454E+04	0.1565E+03	0.4025E+02
200	13949.8594	-129.9387	0.0	0.0	0.1928E+02

MACRO INSTRUCTION 30 EXECUTED

SAVE

V1 = .0 , V2 = .0

MACRO INSTRUCTION 31 EXECUTED

NEXT

V1 = 1.000 , V2 = 16.00

DATA SET UTILITY - GENERATE

PAGE 0001

PROCESSING ENDED AT EOD