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SCIENTIFIC NOTEBOOK

by

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INTEGRATED PARALLEL TECHNOLOGY
Pleasanton, California

for

CENTER FOR NUCLEAR WASTE ANALYSES
San Antonio, Texas

Note: This is a hard copy of an electronic notebook. It is the continuation of Scientific notebook 136 and is separately bound. Scientific notebooks 136 and 136E describe a series of calculations to model the phenomenology associated the intersection of a vertically rising magma with a fault. The depth of intersection and dip angle of the fault are the variable parameters.

Electronic continuation of notebook 136

(This is a continuation
of a "MANUAL" scientific
Notebook. *Ben*
5/12/97)

- Oct. 5 Rpt. sent
- Oct. 9 Start scoping calculation for Alluvium fault- Alluv 1
- Oct. 11 Alluv 1 done. Material looks good
- Oct. 11 Start scoping calc. Alluv 2 to check zoning
- Oct. 13 Alluv 2 done. Zoning looks good
- Oct. 13 Start scoping calc. Alluv 3 to check range of strains for overlap
- Oct. 16 Alluv 3 done. No strain, only overburden stress. ???
- Oct. 16 Larry said to quit Alluv-Fault calculations.
- Oct. 17 Check Alluv 3 calc and impact on Dike-Fault calc.
Several unexplained phenomena with Dike-Fault calculations.
1. Movement direction of upper side of fault
2. Tensile fracture on 5 km calc.
- Oct. 17 Start ball in hole with overburden.
- Oct. 18 Ball calc done. Ball did not fall. No Gravity body force. ????
- Oct. 20 Gravity body force not in equation of motion. This explains
the unexplained phenomena with Dike-fault calc.
Gravity stress initialization (page 239 of Dyna3d manual) puts
the overburden stress of $\rho \cdot g \cdot \text{depth}$ into each zone based on its depth
but does not put the gravity coefficient into the equation of motion. That is
strange.
- Oct. 20 Try Dike calculation with prescribed base accelerations.
This is like taking the grid as a structure and placing it on a elevator,
pushing the up button for a 1 g acceleration. (page 283, Dyna3d manual).
This method requires a dynamic relaxation static analysis before the
calculation starts. (page 245, Dyna3d manual). The grid compresses
under the acceleration, giving each node a small velocity. The node
velocity is reduced by 1/2 of 1 percent each time step which is repeated
until the velocity of all the node is zero and equilibrium is established.
The overburden stress is lithostatic where the vertical stress is given by
the density* gravity*depth and the horizontal stress is $(\nu/(1-\nu)) \cdot$
vertical stress where ν = Poisson's ratio.
- Set up Ball2 calculation.
- Oct. 23 Ball 2 calc done. Ball falls like it should, Overburden looks good.
- Set up Dike2km1 with dike pressure = 0.016 GPa
- Oct. 25 Dike2km1 equilibrium done, Overburden stress looks good. Dike pressure
did not open up dike.

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Set up Dike2km2 with dike pressure = 0.06 GPa and course zones of 40 meters.

Oct. 27 Dike2km2 equilibrium done, Calc at 4 sec.
Result: Dike wall displacement = 2 meters.

Set up Dike2km3 with dike pressure = 0.0375 GPa

Oct. 30 Dike2km3 done.
Result: Dike wall displacement = 0.48 m.
Set up very course zone depth 2 km, dip 30 degrees
depth2km,dip30g40

Nov. 1 depth2km,dip30g40 in equilibrium in 2000 cycles.

Nov. 2 depth2km,dip30g40 done.
Result: Max disp = 0.438 m, Dike opened to depth -1820 m, Fault remained tightly closed. Results similar to old calculation.
Set up Dike5km1 with dike pressure = 0.05 GPa

Nov. 3 Dike5km1 done.
Result: Dike wall displacement = 0.01
Set up Dike5km2 with dike pressure = 0.1

Nov. 6 Dike5km2 done
Result: Dike wall displacement = 2.1 m
Set up Dike5km3 with dike pressure = 0.067

Nov. 7 Dike5km3 still running.
Set up Dike2km-dip70
zone size = 25 m
grid width = 5000 m
grid height = 3500 m
fault extended to 400 from dike on up side.
dike pressure = 0.4 GPa
zoned to surface

Nov. 8 to Nov. 14 Vacation.

Nov. 15 Dike5km3 done.
Result: dike wall displacement = 0.37 to 0.78. Dike wall oscillated from 4 sec to 8 sec. Appears the pressure ramp is too steep.
Depth2km-dip70 done
Results: Initialization in 2500 cyc. 3538 elements
dt= 1.558 msec., cycle time per element = 9.316 msec
1 cyc requires 33 sec to complete
Time = 4 sec: Some tensile fracture on dike above intersection. fault opening up. Max displacement (-0.6m,+0.7 m)
Time = 8 sec: Every other zone between depths of -2000 m and -1650 m broke, Fault open path from dike. Distortion of grid at x=400 m, y=-2000 m, Maximum displacement (-1.18m,+1.75m)
Set up calculation for depth5km, dip 70 degrees
zone size = 25 m
grid width = 5000 m

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grid height = 6500 m
 fault extended to 400 m from dike on up side
 dike pressure = 0.067
 zoned to surface
 Number of elements = 4309, dt = 1.520 msec.
 cycle time per element = 8,995 msec
 1 cycle takes 39 sec to run
 Nov. 16 depth5km-dip70 still trying to achieve equilibrium.
 Nov. 17 depth5km-dip70 still trying to achieve equilibrium.
 kinetic energy = 31
 Nov. 20 depth5km-dip70 still trying to achieve equilibrium.
 kinetic energy = 1.4
 Nov. 21 depth5km-dip70 still trying to achieve equilibrium.
 kinetic energy = 11
 Nov. 22 depth5km-dip70 still trying to achieve equilibrium.
 kinetic energy = 1.4: not converging. took off
 Need to evaluate how to achieve equilibrium state.

 Set up depth2km-dip50g
 zone size = 20 m
 grid width = 5000 m
 grid height = 3500 m
 fault extended to 600 m from dike on up side
 dike pressure = 0.04 GPa
 zoned to surface.
 number elements = 4147, dt = 1.96 msec.
 1 cycle takes 38 seconds to run
 Nov. 23 Holiday
 Nov. 24 Depth2km-dip50g done
 Results: maximum displacement = ± 0.55 m
 dike bonds broke to depth of -1820 m but only every other zone broke.
 fault opened slightly on order 0.15 m and top surface remained
 stationary. Lower surface displace was -0.15 at 20 from dike .
 At 300m from dike upper/lower fault displacement was -0.031/-0.062.
 Fault closed beyond x=300 m from dike.

 Analysis: Alternating breaking bonds caused because on side of zone failed
 ahead of other side, thus relaxing tensile stress and other bond does not
 fail. solution is to reduce the thickness of grid so that both bonds break at
 same time.

 New Depth2km-dip50g1
 zone size = 20 m
 grid thickness = 8 m
 extended fault to 600 m
 grid width = 5000 m
 grid height = 3500 m

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zoned to surface

- Nov. 27 New Depth2km-dip50g1 done
Result: Equilibrium achieved in 20 hours. dike opened up clean to depth of -1700 m. Machine error caused sever distortion of grid such that much data was loss.

Re do Depth2km-dip50g1
- Nov. 30 Depth2km-dip50g1 done
Result: Equilibrium achieved in 20 hours.
Dike open above fault intersection to depth of -1700 m
Fault is closed.
Magma would definitely by pass the fault and continue up dike.
- Dec. 1 Set up Depth2km-dip30g
 zone size = 20 m
 grid thickness = 8 m
 extended fault to 1000 m
 grid width = 5000 m
 grid height = 3500 m
 zoned to surface
- Dec. 4 Depth2km-dip30g came to equilibrium in 40 hrs.
Calc now at time = 5 sec.
- Dec. 5 Depth 2 km-dip30g done.
Result: Maximum displacement = ± 0.056
Dike opened up to depth -1820 m.
Dike opening 0.5 m at intersection.
Fault completely closed.
- Dec. 6 Set up Dike2km-dip70g
 zone size = 20 m
 grid thickness = 6 m
 extended fault to 400 m
 grid width = 5000 m
 grid height = 3500 m
 zoned to surface
Convergence tolerance = $2e-4$ was $1e-4$
number elements = 3834, dt = 1.09 msec
1 cycle requires 37 sec to run.
- Dec. 7 Depth2km-dip70g still seeking equilibrium.
- Dec. 8 Vacation
- Dec. 11 Depth2km-dip70g lost due to loss of power over weekend from storm.
Machine down.
- Dec. 12 Machine still down
- Dec. 13 Restart Depth2km-dip70g

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Dec. 14 Depth2km-dip70g
Still seeking equilibrium
kinetic energy = 2.68 cycle = 2620

Dec. 15 Depth2km-dip70g
Still seeking equilibrium
kinetic energy = 2.08e-02 cycle = 5020

Dec. 16 Depth2km-dip70g
kinetic energy = 1.22e-02 cycle = 7640
Took off because not converging to equilibrium condition.

Set up Depth5km-dike1a to calibrate dike pressure for 5 km
Set dike pressure = .07 GPa

Dec. 17 Dike1a came to equilibrium at 1600 cycles
relaxation tolerance = .001

Dec. 18 Dike1a at 5.2 seconds, Disp 3.8e-02 m, dt = 2.7 sec.

Dec. 19 Dike1a at 9.5 seconds,

Time(sec)	Disp(m)
5.0	.038
6.0	.239
7.0	.723
8.0	.672
9.0	.767

Bonds broke to depth of only -4950 but evenly.
Took off as displacement too large.

Set up Dike1b with relaxation tolerance = 5.0e-4
dike pressure = .065 at 7 sec.

Dec. 20 Dike1b reached equilibrium at cycle = 1600.

Dec. 21 Dike1b at time = 4.78 sec. No displacement on dike yet.

Dec. 22 Dike1b at time 9.78 sec. Took off as problem complete

Time (sec)	Disp (m)
6.0	0.0122
7.0	0.505
8.0	0.507
9.0	0.508
9.78	0.601

This is close enough to 0.5 m displacement of dike wall.

Set up dip70g1 depth 2 km with default tolerance of 0.001

Dec. 26 Dip70g1 depth2km at 6.0 seconds. Came to equilibrium in 3400 cycle at
a pseudo time of 4.3 seconds.
Max dike displacement = 0.5 m. crack tip at depth of -2050 m, full
pressure head at depth of -2250 m. Crack length to tip is 200 m.

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Dec. 27 Dip70g1 depth2km at 9.0 seconds. Dike open to fault. Fault beginning to open. Dike fractured above the fault to depth of -1500 m but not opening. Full pressure head at depth of -2175

Dec. 28 Dip70g1 depth2km at 11.7 seconds. Dike fractured above the fault to depth -1500 m and opening slightly. Full pressure head at depth of -2125. Fault still open.

Dec. 29 Dip70g1 depth2km at 14.3 seconds. Dike open to depth of -1500m. Fault closing up. Calculation terminated.

 Set up Dip70g depth5km.

Dec. 30 Dip70g depth5 km still running.

Dec. 31 Took Dip70g depth 5km off because the problem was not converging to a equilibrium solution. Modified the grid to extend the outer boundaries to \pm 5000 m. Problem back on

Jan. 1 Dip70g depth 5km on same convergence path as first calc. Took Dip70g off. Modified the grid so that thickness is 12 m instead of 6 m.

Jan. 2 Dip70g1 depth5km appears to be on track for convergence. Calculation at 1600 cycles.

Jan. 3. Dip70g1 depth 5km now at 3400 cycles. Still on convergence track.

Jan. 4 Dip70g1 depth 5km now at 4600 cycles. Drifting off convergence path.

Jan. 5 Dip70g1 depth 5km will not converge. Took off at 7000 cycles. Minimum tolerance reached was 0.0015 at 6200 cycles.

 Reset tolerance to 0.002 and started Dip70g1 depth 5km over

Jan. 8 Dip70g1 depth 5km at 5400 cycles.

Jan. 9 Dip70g1 depth 5km moving away from convergence. Took off
Need to rethink how to do Dip70

 Set up Dip50g depth 5km same as Dip50g depth2km

Jan. 10 Dip50g depth 5 km at cycle 1600 on convergence path.

Jan. 11 Dip50g depth 5km at cycle 3200 on convergence path

Jan. 12 Dip50 g depth 5 km converged at cycle 3400. tolerance = .001 Calc now at 2.4 seconds.
high pressure developed in zone at $x = -200$ $y = -5200$
Don't know why.
Dip50g depth 5km terminated due to corrupted files

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- Set up Dip30g depth 5 km same as Dip30g depth 2 km.
- Jan. 14 Problem at 800 cycles and came off with corrupted files some time Friday night. Complete shutdown and reboot of Sun.
Restart Dip30g depth 5km.
- Jan. 15 Dip30g Depth 5km at 1200 cycles.
- Jan. 16 Dip30g Depth 5km at 3400 cycles. Ratio reduced by half every six hundred cycles. Ratio now at 0.048.
- Jan. 17 Dip30g Depth 5km at 4800 cycles. on track. Ratio still reduced by half every six hundred cycles. Equilibrium expected some time Friday. Ratio now at 0.0095
New grid completed for Depth 5 km Dip70g2.
- Jan. 18 Dip30g Depth 5km at 6800 cycles. on track. Ratio now reduced by half every 1000 cycles. Ratio now at .00165.
- Jan. 19 Dip30g Depth 5km at 0400 cycles of run. Initialization complete at 7800 cycles. Grid distorted and section missing. Calculation came off with Bus error 2.
Trying whole new type grid.
Dip50g2 Depth 5km started.
5571 elements. Equilibrium tolerance = .001
cycle time = 48 seconds.
200 cycles takes 2 hr 40 min.
5000 cycles takes 67 hrs.
- Jan. 21 Power outage. Machine down.
Restart Dip50g2 Depth 5km
- Jan. 22 Dip50g2 Depth 5km at 1400 cycles. Ratio = 0.5199.
Equilibrium path almost identical to Dip30g Depth 5km.
- Jan. 23 Dip50g2 Depth 5km at 3000 cycles. Ratio .0752. Equilibrium path just slightly ahead of Dip30g Depth 5km where ratio at 3000 cycles was .0770.
- Jan. 24 Dip50g2 Depth 5km at 4600 cycles. Ratio 0.0109. Equilibrium path still ahead of Dip30g Depth 5km (ratio 0.012). Some breakage of dike bonds is occurring during relaxation process.
- Jan. 25 Dip50g2 Depth 5km at 6200 cycles. Ratio 0.00185. Equilibrium path still ahead of Dip30g Depth 5km (ratio 0.00273). Expect equilibrium to occur at cycle 6800.
- Jan. 26 Dip50g2 Depth 5km came to equilibrium at 7000 cycles. Ratio was 0.00092. Checked pressure at time 0.0 sec. High tensile stresses in some of the zones. Will deform grid as problem continues. High stresses in

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regions of grid away from fault intersection with dike. Let it run over the weekend.

- Jan. 28 Machine down some time Sat from power loss. Dip50g2 Depth 5km abandoned. Started calibration calc for dike pressure for depth of 1 km.
- Jan. 29 Machine must have rebooted sometime Sunday. Power loss damaged Disk2 on which calculations have been running. In fact Disk2 may have already been damaged due to previous power outages. That could explain some of the strange stresses in isolated zones that we have seen. Also consistent with large sections of the grid missing on other calculations. Restarted Dike25 Depth 1 km on Disk1.
- Jan. 30 Machine rebooted sometime Mon. nite. The code resides on Disk2 while the calculation is on Disk1. Moved codes over to Disk1. This makes disk space on Disk1 tight. Re designed source deck for Dike25 calculation. Restarted on Disk1.
- Jan. 31 Dike25 depth 1km came to equilibrium in 1200 cycles. Ratio = 0.00048. Problem ran 2000+ cycles when machine went down and rebooted. Something still wrong with computer disks. Codes are still assessing files from Disk2. Transferring all files from Disk2 and shut down Disk2.
- Dike25 Depth1km at 2000 cycles. Time 5.5 seconds Displacement for dike pressure 0.0285 averages 0.48 m to 5 seconds but varied from 0.31 to 0.645 m. The pressure was ramped from zero to 0.0285 in 3 seconds.
- Changed ramp time to 6 seconds and put Dike25 Depth1km back on
- Feb. 1 Calculation Dike25 Depth1km came to equilibrium and at 1.9 seconds. Plot of stress state at equilibrium looks good. Displacement = 0.051 meters.
- Feb. 2 Computer died some time during the nite. Screen is blank. Uncoupled disk2 from primary disk.
- Set up Depth 1km dip30 same as depth 2 km dip30g.
- Feb. 3 Depth 1km dip 30 came to equilibrium at 1800 cycles
- Feb. 5 Depth 1km dip30 completed. Displacement varied from 0.49 to 0.51 after full displacement. Dike cracked propagated to depth 566 m.
- Set up Depth 1km Dip50 same as Dip 50 Depth 2 km.
- Feb. 6 Depth 1km Dip50 came to equilibrium in 1800 cycles. Now at calculation time of 0.3 seconds.
- Feb. 7 Computer down due to power outage. Depth 1km, Dip50 at 2 seconds. Had to reformat disks and get problem back on
- Feb. 8 Computer down due to power outage. Depth 1km, Dip50 at 4 seconds. Had to reformat disks and get problem back on.

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- Feb. 9 Computer down due to power outage. Depth 1km, Dip50 at 7 seconds. Restarted computers, disks ok. Checked calculation and found grid distortion. Still don't know if this is the result of file damage due to the power outage or the way the problem is set up. Looks like the fault is opening up but the dike is partially fracturing above the intersection. Looks like most of this fracturing is caused by the grid distortion at $x=240$, $y=-1000$. Smoothed out the zoning in parts 6,8,13 and 14 to make it similar to the zoning in Dip50g1 Depth2km which ran successfully. Called it Dip50g1a Depth 1km and restarted calculation.
- Feb. 10 Checked dip50g1a Depth 1km. Calculation came to equilibrium at 1800 cycles. Stress state at equilibrium clean with no high or low regions.
- Feb. 12 Calculation Dip50g1a Depth 1km completed. Dike displacement = 0.5 m. Displacement at intersection of dike and fault is -0.3 on left and 0.3 on right side. Fault is open. and dike did not propagate past the fault. No bond failure occurred above the fault.
- Set up dike Depth 2 km.
- Feb. 13 Dike Depth 2 km came to equilibrium at 1400 cycles. Calculation at time of 4.3 seconds. Error in grid.
- Set up dike Depth 3km.
- Feb. 14 Dike depth 3 km came to equilibrium in 1600 cycles. Tolerance ratio of 0.001
- Feb. 15 Storm caused power failure caused distortion in grid. Will recheck source to ensure distortion not from other cause.
- Set up Dike Depth 2 km.
- Feb. 16 Dike Depth 2 km came to equilibrium at 1600 cycles.. Tolerance ratio of 0.001. Calculation now at 1 sec.
- Feb. 19 Dike Depth 2 km at 6.4 seconds. Crack tip at -1780.
- Feb. 20 Dike Depth 2 km at 8.0 seconds. Crack width 0.49 m, tip at -1780 m depth. Tip length 220 m. Calculation complete.
- Dike Depth 3km started again.
- Feb. 21 Dike Depth 3km at 2.3 seconds.
- Feb. 22 Dike Depth 3km at 5.2 seconds.
- Feb. 23 Dike Depth 3km at 8.5 seconds. Took off as complete.
- Set up Depth2km Dip70
- Feb. 26 Depth2km Dip 70 came to equilibrium at cycle 2800. Now at time of 6.5 seconds

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Feb. 27	Depth2km Dip 70 complete.
Feb. 28	Set up Dike5km. zone size 25 m.
Feb. 29	Dike5km running. attempting to achieve equilibrium.
Mar. 1	Dike5km equilibrium at cycle 3200.
Mar. 4.	Dike5km complete. Dike open to 50 m above pressure head.
Mar. 5	Set up Dike5kma with zone size of 20 m
Mar. 6	Dike5kma running.
Mar. 7	Dike5kma at equilibrium.
Mar. 8	Dike5kma running.
Mar. 11	Dike5kma complete. Dike open to 60 m above pressure.
Mar. 12	Set up Depth5km, Dip 70 degrees.
Mar. 13	Depth5km, Dip 70 degrees still running
Mar. 14	Depth5km,Dip 70 degrees still running
Mar. 15	Depth5km,Dip 70 degrees still running
Mar. 17	Depth5km,Dip 70 degrees achieved equilibrium
Mar. 18	Depth5km,Dip 70 degrees still running
Mar. 19	Depth5km,Dip 70 degrees still running
Mar. 20	Depth5km,Dip 70 degrees still running
Mar. 21	Depth5km,Dip 70 degrees complete
Mar. 22	Analysis of Depth5km,Dip 70 degrees. Complete writting of report.
Mar. 25	Checking report. Draft sent to Larry.

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