Southwest Research Institute®
Surveillance Report

IDENTIFICATION		
Submitted By: Brient, Robert D.	**Date:** 09-APR-10	**Report Number:** 2010-SR-0097
Division: 20 - GEOSCIENCES & ENGINEERING 01.03: QA		**Project Number:** 14002.01.021
Quality Program: GED (20) QAM		
Associated Report: N/A		
Surveillance Scope: Review calculations conducted in support of the HLWRS licensing review and their verification.		
References: QAP-014, Documentation and Verification of Scientific and Engineering Calculations		
Starting Date: 09-APR-10		**Ending Date:** 09-APR-10
Person(s) Conducting Test/Exam/Procedure: R. Kazban, W. Patrick		
Satisfactory Findings: Calculations were performed to estimate phenomena relating to drift degradation in support of the Yucca Mountain license application review. Calculations are documented in Scientific Notebook 872 on pages 57-73. A QAP-014 calculation verification was requested by the MGFE manager and is documented on a Calculation Verification Worksheet and associated Comment Resolution Record Sheets. The verification identified a number of comments that required resolution and, in some cases, supplemental entries in Scientific Notebook 872. The calculation verification documentation is attached to the original copy of this surveillance report.		
Unsatisfactory Findings: None		
Recommendations/Actions: None		
Equipment Calibration: N/A		
SwRI cc: Chowdhury, Asadul H. (20), Kazban, Roman (20), Mohanty, Sitakanta (20), Ofoegbu, Goodluck I. (20), Patrick, Wesley C. (20), Sagar, Budhi (20)		

APPROVALS	
Management Approval: Brient, Robert D.	**Date:** 09-APR-10
QA Approval: Brient, Robert D.	**Date:** 09-APR-10

CALCULATION VERIFICATION WORKSHEET

Associated Document or Activity:		Project Number: 20.14002.01.~~191~~ 352
Assigned Verifier: W. Patrick	Manager: A. Chowdhury	Required Completion Date: 11/30/2009
Location of Calculation(s): Scientific Notebook #: 872	Page Number(s): 57-73	
Location of Corresponding Data In Document (Table or Page #, When Applicable):		

	Identify the Calculation Tools Used and Over Checks Needed.	Document the Calculation Verification: Which Calculations Were Checked; How They Were Checked, Software Used for the Original Calculation (When Applicable), and Conclusions.
X	Controlled Software: Check input for accuracy and output for reasonableness.	See attached sheets with details comments and observations.
	~~Uncontrolled Software: Check inputs, perform check calculations (copy of code shall be attached for QA records).~~ WCP 11/5/2009	
	~~Commercial Off-the-Shelf Software: Check inputs and outputs, check formulae.~~ WCP 11/5/2009	
	~~Other Calculation(s): Check inputs and perform check calculations.~~ WCP 11/5/2009	
	Verification By: [signature]	Date: 11/11/2009

REPORT REVIEW / COMMENT RESOLUTION RECORD		PAGE	OF	PAGES
PROJECT NUMBER 20.14002.01.352	**DOCUMENT DATE** Variable		**DOCUMENT NUMBER** Scientific Notebook (SN) 872; pages 57-73	

TITLE: Scientific Notebook 872

COMMENTS:	RESPONSES:
Note: The comments that follow were prepared in response to a request from MGFE manager Asad Chowdhury to verify certain calculations associated with the subject document. These comments are an attachment to the associated Calculation Verification Worksheet.	please, see attachment for responces
1. Page 57. The geometrical representation used in the calculations is appropriate. In particular, the drift dimension of 5.5 m diameter was revised from the octahedral cross-section used in previous calculations to be circular. This is seen as an improvement over previous calculations.	1. No response is required to these observations.
2. Page 57. The host rock above the drifts was zoned as a series of 10 circular arcs/layers of elements. This is a reasonable assumption for homogeneous rock masses with relatively symmetric loading conditions. The assumption about homogeneity of the rock mass needs to be explained further in the SN because of the known occurrence of fractures with dominant orientations, as well as variable lithophysal zones in some portions of the repository horizon. Information is needed about whether and if so the extent to which this assumption could influence the calculation results. The assumption about loading conditions is appropriate based on these and previous calculations and does not need to be addressed further.	2. same as above
3. Pages 57-58. The approach to remeshing/rezoning appears reasonable. Although it may help address the concern expressed in Comment 2 (it is being done because the analysts recognize that failures will not necessarily be along element interfaces), the rezoned areas nevertheless appear to remain essentially circular arcs.	3. same as above
4. Pages 57-73. Need to explain and document in the SN the basis for not rezoning the invert and lower right-hand side of the computational grid where the rock mass is overstressed. This comprises about 80 degrees of arc or nearly half of the modeled cross-section. Although gravity can be argued to keep the invert in place, this is not the case for the sidewall. Intuitively, if the sidewall slumps, the cross-section could become distorted. This, in turn, could modify the stress field around the opening.	4. same as above
5. Pages 60-68. Need to explain the apparent distortion (or rezoning?) that appears in the un-rezoned mesh (the tan area) beginning in year 101 (Fig. 4). The distortion increases progressively throughout the calculation (see Figs. 6, 8, 10, 12, 14, 16, 18, and 20).	5. same as above
6. Pages 60-69. A visual check (the area was not calculated) indicates that the amount of rubble that accumulates around the EBS is reasonable compared to the amount of rock in the overstressed zone of each preceding calculation. This important factor was checked throughout the calculation time frame.	6. No response is required to these observations.

7. Page 73; DVD titled Drift Degradation 2009, Run 01, 2-Element Degradation. Material properties were reviewed using print-outs provided by R. Kazban because the reviewer does not have software to read the files on this DVD. In discussions with Kazban 11/10/2009, he confirmed that none of the thermal or mechanical properties were changed relative to the analyses previously checked by this reviewer in November 2007. Spot checks were done on (i) global model thermal properties, (ii) global model mechanical properties, (iii) submodel thermal properties, (iv) submodel mechanical properties, (v) two-element thermal properties, and (vi) two-element mechanical properties. All selected and assigned properties appear to be appropriate based on these spot checks. Particular attention was given to the reassignment of properties associated with gradual degradation of the rock mass. The transition times and associated changes in properties were determined to be appropriate for both the failed rock and the resulting rubble.	7. same as above
8. Page 73. Figure 26 is incorrectly labeled Figure 25. This should be corrected and initialed in the SN.	8. same as above
9. Page 72. The overall approach to the 2-element degradation approach is reasonable. All material properties, stresses, and the like were kept the same. The calculation up to 100 years was the same as for the previous model, which supports the intended purpose of evaluating solely the effect(s) of removing only two of the overstressed elements rather than the entire area calculated to be overstressed.	9. No response is required to these observations.
10. Page 73, Figure 26. The reviewer noted that the stress scale for Figure 26(b) is different from that used in Figure 26(a) and all other figures in the preceding calculation sequence. Whereas all preceding figures use a range for the "overstressed" region (shown in gray color) to span 1.000 to 1.764 (average of 1.382), Figure 26(b) uses the range 1.000 to 3.038 (average of 2.019). As a result, the visual interpretation underestimates the magnitude of the stress increase for the 2-element degradation case relative to the previous models. Although this is technically acceptable, the reviewer suggests that the SN be annotated to indicate this is the case.	10. same as above
11. Page 73, Figure 26. Given the unusual shape of the stress contours—particularly the overstressed zone—and the higher average overstress calculated, it would be useful to extend the 2-element calculation to include additional steps. This would better address the request may by NRC staff members and may further resolution of this topic.	11. This can be addressed at the discretion of the principal investigator because it is a programmatic rather than a technical matter.
REVIEWER SIGNATURE: [signature] **DATE:** 11/11/2009	**RESPONDER SIGNATURE:** [signature] **DATE:** 11-17-09
RESPONSE ACCEPTED BY: [signature] **DATE:** 11/19/2009	**If resolution cannot be achieved, the matter shall be elevated to the next level of authority.**

REPORT REVIEW / COMMENT RESOLUTION RECORD		PAGE		OF		PAGES
PROJECT NUMBER 20.14002.01.352	DOCUMENT DATE Variable			DOCUMENT NUMBER Scientific Notebook (SN) 872; pages 57-73		

TITLE:	Scientific Notebook 872

COMMENTS:	RESPONSES:
Note: The comments that follow were prepared in response to a request from MGFE manager Asad Chowdhury to verify certain calculations associated with the subject document. These comments are an attachment to the associated Calculation Verification Worksheet.	Accepted.
1. Page 57. The geometrical representation used in the calculations is appropriate. In particular, the drift dimension of 5.5 m diameter was revised from the octahedral cross-section used in previous calculations to be circular. This is seen as an improvement over previous calculations.	1. No response is required to these observations.
2. Page 57. The host rock above the drifts was zoned as a series of 10 circular arcs/layers of elements. This is a reasonable assumption for homogeneous rock masses with relatively symmetric loading conditions. The assumption about homogeneity of the rock mass needs to be explained further in the SN because of the known occurrence of fractures with dominant orientations, as well as variable lithophysal zones in some portions of the repository horizon. Information is needed about whether and if so the extent to which this assumption could influence the calculation results. The assumption about loading conditions is appropriate based on these and previous calculations and does not need to be addressed further.	2. The intention of the analyses is to gain insight into a potential behavior on the emplacement drifts, and not, necessary, to obtain quantitative predictions of the drift performance. Therefore, although the rock mass around emplacement drifts may not be homogeneous in mechanical or thermal properties, the homogeneity assumption in the model allows investigation of rock behavior within the range of estimated properties. This particular model was not used to explore the effect of the uncertainties in the rock mass mechanical and thermal properties. Based on the previous studies, the mechanical properties of Category 5 lithophysal rock were chosen to investigation roof failure.
3. Pages 57-58. The approach to remeshing/rezoning appears reasonable. Although it may help address the concern expressed in Comment 2 (it is being done because the analysts recognize that failures will not necessarily be along element interfaces), the rezoned areas nevertheless appear to remain essentially circular arcs.	3. Accepted.
4. Pages 57-73. Need to explain and document in the SN the basis for not rezoning the invert and lower right-hand side of the computational grid where the rock mass is overstressed. This comprises about 80 degrees of arc or nearly half of the modeled cross-section. Although gravity can be argued to keep the invert in place, this is not the case for the sidewall. Intuitively, if the sidewall slumps, the cross-section could become distorted. This, in turn, could modify the stress field around the opening.	4. The area above the springline is remeshed as necessary because any broken rock in this area is likely to fall due to gravitational forces; whereas, broken rock below the springline is protected by underlying material and rubble accumulation. In other words, broken rock above the springline would require tensile resistance to remain in place; whereas, broken rock below the springline can still be restrained by frictional forces.
5. Pages 60-68. Need to explain the apparent distortion (or rezoning?) that appears in the un-rezoned mesh (the tan area) beginning in year 101 (Fig. 4). The distortion increases progressively throughout the calculation (see Figs. 6, 8, 10, 12, 14, 16, 18, and 20).	5. Figures 4, 6, 8, 10, 12, 14, 16, 18, and 20 depict finite element meshes used for a given analysis step. Changes in finite element mesh (seen in these figures) do not represent any material deformation, and were introduced to obtain appropriate mesh transitions.

6. Pages 60-69. A visual check (the area was not calculated) indicates that the amount of rubble that accumulates around the EBS is reasonable compared to the amount of rock in the overstressed zone of each preceding calculation. This important factor was checked throughout the calculation time frame.	6. No response is required to these observations.
7. Page 73; DVD titled Drift Degradation 2009, Run 01, 2-Element Degradation. Material properties were reviewed using print-outs provided by R. Kazban because the reviewer does not have software to read the files on this DVD. In discussions with Kazban 11/10/2009, he confirmed that none of the thermal or mechanical properties were changed relative to the analyses previously checked by this reviewer in November 2007. Spot checks were done on (i) global model thermal properties, (ii) global model mechanical properties, (iii) submodel thermal properties, (iv) submodel mechanical properties, (v) two-element thermal properties, and (vi) two-element mechanical properties. All selected and assigned properties appear to be appropriate based on these spot checks. Particular attention was given to the reassignment of properties associated with gradual degradation of the rock mass. The transition times and associated changes in properties were determined to be appropriate for both the failed rock and the resulting rubble.	7. Accepted.
8. Page 73. Figure 26 is incorrectly labeled Figure 25. This should be corrected and initialed in the SN.	8. Figure labeling was corrected and initialed.
9. Page 72. The overall approach to the 2-element degradation approach is reasonable. All material properties, stresses, and the like were kept the same. The calculation up to 100 years was the same as for the previous model, which supports the intended purpose of evaluating solely the effect(s) of removing only two of the overstressed elements rather than the entire area calculated to be overstressed.	9. No response is required to these observations.
10. Page 73, Figure 26. The reviewer noted that the stress scale for Figure 26(b) is different from that used in Figure 26(a) and all other figures in the preceding calculation sequence. Whereas all preceding figures use a range for the "overstressed" region (shown in gray color) to span 1.000 to 1.764 (average of 1.382), Figure 26(b) uses the range 1.000 to 3.038 (average of 2.019). As a result, the visual interpretation underestimates the magnitude of the stress increase for the 2-element degradation case relative to the previous models. Although this is technically acceptable, the reviewer suggests that the SN be annotated to indicate this is the case.	10. Accepted. A note was added as follows: "Note, that the stress scale for Figure 26(b) is different from that used in Figure 26(a). On Figure 26(a), a range for the "overstressed" region (shown in gray color) spans 1.000 to 1.764, whereas on Figure 26(b) it ranges between 1.000 and 3.038. As a result, the visual interpretation underestimates the magnitude of the stress increase for the 2-element degradation case relative to the model presented on Figure 26(a)."
11. Page 73, Figure 26. Given the unusual shape of the stress contours—particularly the overstressed zone—and the higher average overstress calculated, it would be useful to extend the 2-element calculation to include additional steps. This would better address the request may by NRC staff members and may further resolution of this topic.	11. This can be addressed at the discretion of the principal investigator because it is a programmatic rather than a technical matter.
REVIEWER SIGNATURE: [signature] **DATE:** 11/11/2009	**RESPONDER SIGNATURE:** [signature] **DATE:** 11-17-09
RESPONSE ACCEPTED BY: [signature] **DATE:** 11/19/2009	**If resolution cannot be achieved, the matter shall be elevated to the next level of authority.**

Global model thermal material properties

```
C:\Documents and Settings\rkazban\Desktop\Drift Degradation\DD_AfterReview\m2Globalmodel\tMaterials.def
***
*** Thermal Material Definitions
*** To be expanded as rock layers fail
***
*** Thermal conductivity          J/(yr-m-K)
*** Density                       kg/m^3
*** Specific heat                 J/(kg-K)
***
*Material, name=rockMat
*Conductivity
5.869695E7,
*Density
2325.
*Specific Heat
 969.0,   0.0
 969.0,  92.0
4741.0,  96.0
4741.0, 112.0
 988.0, 116.0
 988.0, 150.0
***
*Material, name=metalMat
*Conductivity
3.502894E8,
*Density
8690.
*Specific Heat
423.,
***
*Material, name=airMat
*Conductivity
3.155760E8,
*Density
1.2
*Specific heat
1000.0,
```

Spot checked thermal & mechanical properties.
[signature]
11/10/2009

Global model mechanical material properties

```
C:\Documents and Settings\rkazban\Desktop\Drift Degradation\DD_AfterReview\m2Globalmodel\mMaterials.def
***
*** Mechnical Material Definitions
***
**
** Linear-elastic model
** Parameters from high-grade lithophysal-rock data
**          Mean strength properties
** Stress distributions post-processed to calculate
**   stress/strength ratio distributions
**
** Young's modulus:   2.0E4 MPa
** Friction angle:    40 degrees
** Cohesion:          7.06 MPa
**
*Material, name=rockMat
*Elastic
20000., 0.20
*Expansion
  7.14e-06,  0.
  7.14e-06, 50.
  7.47e-06, 75.
  7.46e-06,100.
  9.07e-06,125.
  9.07e-06,225.
*User Output Variables
      1,
```

Submodel thermal material properties

```
C:\Documents and Settings\rkazban\Desktop\Drift Degradation\DD_AfterReview\m2Submodel\tMaterials.def
***
*** Thermal Material Definitions
*** To be expanded as rock layers fail
***
*** Thermal conductivity         J/(yr-m-K)
*** Density                      kg/m^3
*** Specific heat                J/(kg-K)
***
*Material, name=rockMat
*Conductivity
5.869695E7,
*Density
2325.
*Specific Heat
 969.0,   0.0
 969.0,  92.0
4741.0,  96.0
4741.0, 112.0
 988.0, 116.0
 988.0, 150.0
***
*Material, name=metalMat
*Conductivity
3.502894E8,
*Density
8690.
*Specific Heat
423.,
***
*Material, name=airMat
*Conductivity
3.155760E8,
*Density
1.2
*Specific heat
1000.0,
***                           Layer b001, rock to air at 100-101 yr
*Material, name=b001Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 100.0   ✓ transition time correct
3.155760E8, 25.0, 101.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 100.0   ✓
1.2,    25.0, 101.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 100.0
 969.0,  92.0, 100.0
4741.0,  96.0, 100.0
```

```
4741.0, 112.0, 100.0
 988.0, 116.0, 100.0
 988.0, 150.0, 100.0
1000.0,   0.0, 101.0
1000.0, 150.0, 101.0
***                        Layer b002, rock to air at 101-102 yr
*Material, name=b002Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 101.0
3.155760E8, 25.0, 102.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 101.0
1.2,    25.0, 102.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 101.0
 969.0,  92.0, 101.0
4741.0,  96.0, 101.0
4741.0, 112.0, 101.0
 988.0, 116.0, 101.0
 988.0, 150.0, 101.0
1000.0,   0.0, 102.0
1000.0, 150.0, 102.0
***                        Layer b003, rock to air at 102-103 yr
*Material, name=b003Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 102.0
3.155760E8, 25.0, 103.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 102.0
1.2,    25.0, 103.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 102.0
 969.0,  92.0, 102.0
4741.0,  96.0, 102.0
4741.0, 112.0, 102.0
 988.0, 116.0, 102.0
 988.0, 150.0, 102.0
1000.0,   0.0, 103.0
1000.0, 150.0, 103.0
***                        Layer b004, rock to air at 103-104 yr
*Material, name=b004Mat
```

```
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 103.0
3.155760E8, 25.0, 104.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 103.0
1.2,    25.0, 104.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 103.0
 969.0,  92.0, 103.0
4741.0,  96.0, 103.0
4741.0, 112.0, 103.0
 988.0, 116.0, 103.0
 988.0, 150.0, 103.0
1000.0,   0.0, 104.0
1000.0, 150.0, 104.0
***                         Layer b005, rock to air at 104-105 yr
*Material, name=b005Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 104.0
3.155760E8, 25.0, 105.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 104.0
1.2,    25.0, 105.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 104.0
 969.0,  92.0, 104.0
4741.0,  96.0, 104.0
4741.0, 112.0, 104.0
 988.0, 116.0, 104.0
 988.0, 150.0, 104.0
1000.0,   0.0, 105.0
1000.0, 150.0, 105.0
***                         Layer b006, rock to air at 105-106 yr
*Material, name=b006Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 105.0
3.155760E8, 25.0, 106.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 105.0
```

```
1.2,    25.0, 106.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 105.0
 969.0,  92.0, 105.0
4741.0,  96.0, 105.0
4741.0, 112.0, 105.0
 988.0, 116.0, 105.0
 988.0, 150.0, 105.0
1000.0,   0.0, 106.0
1000.0, 150.0, 106.0
***                         Layer b007, rock to air at 106-107 yr
*Material, name=b007Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 106.0
3.155760E8, 25.0, 107.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 106.0
1.2,    25.0, 107.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 106.0
 969.0,  92.0, 106.0
4741.0,  96.0, 106.0
4741.0, 112.0, 106.0
 988.0, 116.0, 106.0
 988.0, 150.0, 106.0
1000.0,   0.0, 107.0
1000.0, 150.0, 107.0
***                         Layer b008, rock to air at 107-108 yr
*Material, name=b008Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 107.0
3.155760E8, 25.0, 108.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 107.0
1.2,    25.0, 108.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
```

```
 988.0, 150.0,   0.0
 969.0,   0.0, 107.0
 969.0,  92.0, 107.0
4741.0,  96.0, 107.0
4741.0, 112.0, 107.0
 988.0, 116.0, 107.0
 988.0, 150.0, 107.0
1000.0,   0.0, 108.0
1000.0, 150.0, 108.0
***                      Layer b009, rock to air at 108-109 yr
*Material, name=b009Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 108.0
3.155760E8, 25.0, 109.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 108.0
1.2,    25.0, 109.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 108.0
 969.0,  92.0, 108.0
4741.0,  96.0, 108.0
4741.0, 112.0, 108.0
 988.0, 116.0, 108.0
 988.0, 150.0, 108.0
1000.0,   0.0, 109.0
1000.0, 150.0, 109.0
***                      Layer b010, rock to air at 109-110 yr
*Material, name=b010Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 109.0
3.155760E8, 25.0, 110.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 109.0
1.2,    25.0, 110.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 109.0
 969.0,  92.0, 109.0
4741.0,  96.0, 109.0
4741.0, 112.0, 109.0
 988.0, 116.0, 109.0
 988.0, 150.0, 109.0
```

```
1000.0,   0.0, 110.0
1000.0, 150.0, 110.0
***                        Layer a001, air to rubble at 100-101 yr
*Material, name=a001Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 100.0
6.311520E6, 25.0, 101.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 100.0
2325,  25.0, 101.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  100.0
 969.0,   0.0, 101.0
 969.0,  92.0, 101.0
4741.0,  96.0, 101.0
4741.0, 112.0, 101.0
 988.0, 116.0, 101.0
 988.0, 150.0, 101.0
***                        Layer a002, air to rubble at 101-102 yr
*Material, name=a002Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 101.0
6.311520E6, 25.0, 102.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 101.0
2325,  25.0, 102.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  101.0
 969.0,   0.0, 102.0
 969.0,  92.0, 102.0
4741.0,  96.0, 102.0
4741.0, 112.0, 102.0
 988.0, 116.0, 102.0
 988.0, 150.0, 102.0
***                        Layer a003, air to rubble at 102-103 yr
*Material, name=a003Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 102.0
6.311520E6, 25.0, 103.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 102.0
2325,  25.0, 103.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  102.0
 969.0,   0.0, 103.0
 969.0,  92.0, 103.0
4741.0,  96.0, 103.0
4741.0, 112.0, 103.0
```

```
 988.0, 116.0, 103.0
 988.0, 150.0, 103.0
***                        Layer a004, air to rubble at 103-104 yr
*Material, name=a004Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 103.0
6.311520E6, 25.0, 104.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 103.0
2325,  25.0, 104.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  103.0
 969.0,   0.0, 104.0
 969.0,  92.0, 104.0
4741.0,  96.0, 104.0
4741.0, 112.0, 104.0
 988.0, 116.0, 104.0
 988.0, 150.0, 104.0
***                        Layer a005, air to rubble at 104-105 yr
*Material, name=a005Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 104.0
6.311520E6, 25.0, 105.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 104.0
2325,  25.0, 105.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  104.0
 969.0,   0.0, 105.0
 969.0,  92.0, 105.0
4741.0,  96.0, 105.0
4741.0, 112.0, 105.0
 988.0, 116.0, 105.0
 988.0, 150.0, 105.0
***                        Layer a006, air to rubble at 105-106 yr
*Material, name=a006Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 105.0
6.311520E6, 25.0, 106.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 105.0
2325,  25.0, 106.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  105.0
 969.0,   0.0, 106.0
 969.0,  92.0, 106.0
4741.0,  96.0, 106.0
4741.0, 112.0, 106.0
```

```
 988.0, 116.0, 106.0
 988.0, 150.0, 106.0
***                      Layer a007, air to rubble at 106-107 yr
*Material, name=a007Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 106.0
6.311520E6, 25.0, 107.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 106.0
2325,  25.0, 107.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  106.0
 969.0,   0.0, 107.0
 969.0,  92.0, 107.0
4741.0,  96.0, 107.0
4741.0, 112.0, 107.0
 988.0, 116.0, 107.0
 988.0, 150.0, 107.0
***                      Layer a008, air to rubble at 107-108 yr
*Material, name=a008Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 107.0
6.311520E6, 25.0, 108.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 107.0
2325,  25.0, 108.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  107.0
 969.0,   0.0, 108.0
 969.0,  92.0, 108.0
4741.0,  96.0, 108.0
4741.0, 112.0, 108.0
 988.0, 116.0, 108.0
 988.0, 150.0, 108.0
***                      Layer a009, air to rubble at 108-109 yr
*Material, name=a009Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 108.0
6.311520E6, 25.0, 109.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 108.0
2325,  25.0, 109.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  108.0
 969.0,   0.0, 109.0
 969.0,  92.0, 109.0
4741.0,  96.0, 109.0
4741.0, 112.0, 109.0
```

```
 988.0, 116.0, 109.0
 988.0, 150.0, 109.0
***                      Layer a010, air to rubble at 109-110 yr
*Material, name=a010Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 109.0
6.311520E6, 25.0, 110.0
*Density, dependencies=1
1.2,    25.0,   0.0
1.2,    25.0, 109.0
2325,   25.0, 110.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  109.0
 969.0,   0.0, 110.0
 969.0,  92.0, 110.0
4741.0,  96.0, 110.0
4741.0, 112.0, 110.0
 988.0, 116.0, 110.0
 988.0, 150.0, 110.0
***                      Layer b001-a010, rock to air at 100-101 yr
***                                 and air to rubble at 109-110 yr
*Material, name=b001-a010Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 100.0
3.155760E8, 25.0, 101.0
3.155760E8, 25.0, 109.0
6.311520E6, 25.0, 110.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 100.0
1.2,    25.0, 101.0
1.2,    25.0, 109.0
2325,   25.0, 110.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 100.0
 969.0,  92.0, 100.0
4741.0,  96.0, 100.0
4741.0, 112.0, 100.0
 988.0, 116.0, 100.0
 988.0, 150.0, 100.0
1000.0,   0.0, 101.0
1000.0, 150.0, 101.0
1000.0,   0.0, 109.0
1000.0, 150.0, 109.0
969.0,    0.0, 110.0
 969.0,  92.0, 110.0
4741.0,  96.0, 110.0
4741.0, 112.0, 110.0
```

988.0, 116.0, 110.0
988.0, 150.0, 110.0

Submodel mechanical material properties

```
C:\Documents and Settings\rkazban\Desktop\Drift Degradation\DD_AfterReview\m2Submodel\mMaterials.def
***
*** Mechnical Material Definitions
***
**
** Linear-elastic model
** Parameters from high-grade lithophysal-rock data
**          Mean strength properties
** Stress distributions post-processed to calculate
**   stress/strength ratio distributions
**
** Young's modulus:   2.0E4 MPa
** Friction angle:    40 degrees
** Cohesion:          7.06 MPa
**
*Material, name=rockMat
*Elastic
20000., 0.20
*Expansion
  7.14e-06,  0.
  7.14e-06, 50.
  7.47e-06, 75.
  7.46e-06,100.
  9.07e-06,125.
  9.07e-06,225.
*User Output Variables
      1,
```

2-element model: Submodel thermal material prop.

```
C:\Documents and Settings\rkazban\Desktop\Drift Degradation\DD_2009Run01\Submodel\tMaterials.def
***
*** Thermal Material Definitions
*** To be expanded as rock layers fail
***
*** Thermal conductivity          J/(yr-m-K)
*** Density                       kg/m^3
*** Specific heat                 J/(kg-K)
***
*Material, name=rockMat
*Conductivity
5.869695E7,
*Density
2325.
*Specific Heat
 969.0,   0.0
 969.0,  92.0
4741.0,  96.0
4741.0, 112.0
 988.0, 116.0
 988.0, 150.0
***
*Material, name=metalMat
*Conductivity
3.502894E8,
*Density
8690.
*Specific Heat
423.,
***
*Material, name=airMat
*Conductivity
3.155760E8,
*Density
1.2
*Specific heat
1000.0,
***                        Layer b001, rock to air at 100-101 yr
*Material, name=b001Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 100.0
3.155760E8, 25.0, 101.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 100.0
1.2,    25.0, 101.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 100.0
 969.0,  92.0, 100.0
4741.0,  96.0, 100.0
```

```
4741.0, 112.0, 100.0
 988.0, 116.0, 100.0
 988.0, 150.0, 100.0
1000.0,   0.0, 101.0
1000.0, 150.0, 101.0
***                     Layer b002, rock to air at 101-102 yr
*Material, name=b002Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 101.0
3.155760E8, 25.0, 102.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 101.0
1.2,    25.0, 102.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 101.0
 969.0,  92.0, 101.0
4741.0,  96.0, 101.0
4741.0, 112.0, 101.0
 988.0, 116.0, 101.0
 988.0, 150.0, 101.0
1000.0,   0.0, 102.0
1000.0, 150.0, 102.0
***                     Layer b003, rock to air at 102-103 yr
*Material, name=b003Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 102.0
3.155760E8, 25.0, 103.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 102.0
1.2,    25.0, 103.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 102.0
 969.0,  92.0, 102.0
4741.0,  96.0, 102.0
4741.0, 112.0, 102.0
 988.0, 116.0, 102.0
 988.0, 150.0, 102.0
1000.0,   0.0, 103.0
1000.0, 150.0, 103.0
***                     Layer b004, rock to air at 103-104 yr
*Material, name=b004Mat
```

```
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 103.0
3.155760E8, 25.0, 104.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 103.0
1.2,    25.0, 104.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 103.0
 969.0,  92.0, 103.0
4741.0,  96.0, 103.0
4741.0, 112.0, 103.0
 988.0, 116.0, 103.0
 988.0, 150.0, 103.0
1000.0,   0.0, 104.0
1000.0, 150.0, 104.0
***                       Layer b005, rock to air at 104-105 yr
*Material, name=b005Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 104.0
3.155760E8, 25.0, 105.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 104.0
1.2,    25.0, 105.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 104.0
 969.0,  92.0, 104.0
4741.0,  96.0, 104.0
4741.0, 112.0, 104.0
 988.0, 116.0, 104.0
 988.0, 150.0, 104.0
1000.0,   0.0, 105.0
1000.0, 150.0, 105.0
***                       Layer b006, rock to air at 105-106 yr
*Material, name=b006Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 105.0
3.155760E8, 25.0, 106.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 105.0
```

```
1.2,    25.0, 106.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 105.0
 969.0,  92.0, 105.0
4741.0,  96.0, 105.0
4741.0, 112.0, 105.0
 988.0, 116.0, 105.0
 988.0, 150.0, 105.0
1000.0,   0.0, 106.0
1000.0, 150.0, 106.0
***                         Layer b007, rock to air at 106-107 yr
*Material, name=b007Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 106.0
3.155760E8, 25.0, 107.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 106.0
1.2,    25.0, 107.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 106.0
 969.0,  92.0, 106.0
4741.0,  96.0, 106.0
4741.0, 112.0, 106.0
 988.0, 116.0, 106.0
 988.0, 150.0, 106.0
1000.0,   0.0, 107.0
1000.0, 150.0, 107.0
***                         Layer b008, rock to air at 107-108 yr
*Material, name=b008Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 107.0
3.155760E8, 25.0, 108.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 107.0
1.2,    25.0, 108.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
```

```
 988.0, 150.0,   0.0
 969.0,   0.0, 107.0
 969.0,  92.0, 107.0
4741.0,  96.0, 107.0
4741.0, 112.0, 107.0
 988.0, 116.0, 107.0
 988.0, 150.0, 107.0
1000.0,   0.0, 108.0
1000.0, 150.0, 108.0
***                      Layer b009, rock to air at 108-109 yr
*Material, name=b009Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 108.0
3.155760E8, 25.0, 109.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 108.0
1.2,    25.0, 109.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 108.0
 969.0,  92.0, 108.0
4741.0,  96.0, 108.0
4741.0, 112.0, 108.0
 988.0, 116.0, 108.0
 988.0, 150.0, 108.0
1000.0,   0.0, 109.0
1000.0, 150.0, 109.0
***                      Layer b010, rock to air at 109-110 yr
*Material, name=b010Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 109.0
3.155760E8, 25.0, 110.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 109.0
1.2,    25.0, 110.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 109.0
 969.0,  92.0, 109.0
4741.0,  96.0, 109.0
4741.0, 112.0, 109.0
 988.0, 116.0, 109.0
 988.0, 150.0, 109.0
```

```
1000.0,   0.0, 110.0
1000.0, 150.0, 110.0
***                        Layer a001, air to rubble at 100-101 yr
*Material, name=a001Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 100.0
6.311520E6, 25.0, 101.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 100.0
2325,  25.0, 101.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  100.0
 969.0,   0.0, 101.0
 969.0,  92.0, 101.0
4741.0,  96.0, 101.0
4741.0, 112.0, 101.0
 988.0, 116.0, 101.0
 988.0, 150.0, 101.0
***                        Layer a002, air to rubble at 101-102 yr
*Material, name=a002Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 101.0
6.311520E6, 25.0, 102.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 101.0
2325,  25.0, 102.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  101.0
 969.0,   0.0, 102.0
 969.0,  92.0, 102.0
4741.0,  96.0, 102.0
4741.0, 112.0, 102.0
 988.0, 116.0, 102.0
 988.0, 150.0, 102.0
***                        Layer a003, air to rubble at 102-103 yr
*Material, name=a003Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 102.0
6.311520E6, 25.0, 103.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 102.0
2325,  25.0, 103.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  102.0
 969.0,   0.0, 103.0
 969.0,  92.0, 103.0
4741.0,  96.0, 103.0
4741.0, 112.0, 103.0
```

```
 988.0, 116.0, 103.0
 988.0, 150.0, 103.0
***                      Layer a004, air to rubble at 103-104 yr
*Material, name=a004Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 103.0
6.311520E6, 25.0, 104.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 103.0
2325,  25.0, 104.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  103.0
 969.0,   0.0, 104.0
 969.0,  92.0, 104.0
4741.0,  96.0, 104.0
4741.0, 112.0, 104.0
 988.0, 116.0, 104.0
 988.0, 150.0, 104.0
***                      Layer a005, air to rubble at 104-105 yr
*Material, name=a005Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 104.0
6.311520E6, 25.0, 105.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 104.0
2325,  25.0, 105.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  104.0
 969.0,   0.0, 105.0
 969.0,  92.0, 105.0
4741.0,  96.0, 105.0
4741.0, 112.0, 105.0
 988.0, 116.0, 105.0
 988.0, 150.0, 105.0
***                      Layer a006, air to rubble at 105-106 yr
*Material, name=a006Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 105.0
6.311520E6, 25.0, 106.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 105.0
2325,  25.0, 106.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  105.0
 969.0,   0.0, 106.0
 969.0,  92.0, 106.0
4741.0,  96.0, 106.0
4741.0, 112.0, 106.0
```

```
 988.0, 116.0, 106.0
 988.0, 150.0, 106.0
***                         Layer a007, air to rubble at 106-107 yr
*Material, name=a007Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 106.0
6.311520E6, 25.0, 107.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 106.0
2325,  25.0, 107.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  106.0
 969.0,   0.0, 107.0
 969.0,  92.0, 107.0
4741.0,  96.0, 107.0
4741.0, 112.0, 107.0
 988.0, 116.0, 107.0
 988.0, 150.0, 107.0
***                         Layer a008, air to rubble at 107-108 yr
*Material, name=a008Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 107.0
6.311520E6, 25.0, 108.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 107.0
2325,  25.0, 108.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  107.0
 969.0,   0.0, 108.0
 969.0,  92.0, 108.0
4741.0,  96.0, 108.0
4741.0, 112.0, 108.0
 988.0, 116.0, 108.0
 988.0, 150.0, 108.0
***                         Layer a009, air to rubble at 108-109 yr
*Material, name=a009Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 108.0
6.311520E6, 25.0, 109.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 108.0
2325,  25.0, 109.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  108.0
 969.0,   0.0, 109.0
 969.0,  92.0, 109.0
4741.0,  96.0, 109.0
4741.0, 112.0, 109.0
```

```
 988.0, 116.0, 109.0
 988.0, 150.0, 109.0
***                         Layer a010, air to rubble at 109-110 yr
*Material, name=a010Mat
*Conductivity, dependencies=1
3.155760E8, 25.0,   0.0
3.155760E8, 25.0, 109.0
6.311520E6, 25.0, 110.0
*Density, dependencies=1
1.2,   25.0,   0.0
1.2,   25.0, 109.0
2325,  25.0, 110.0
*Specific heat, dependencies=1
1000.0, 25.0,    0.0
1000.0, 25.0,  109.0
 969.0,   0.0, 110.0
 969.0,  92.0, 110.0
4741.0,  96.0, 110.0
4741.0, 112.0, 110.0
 988.0, 116.0, 110.0
 988.0, 150.0, 110.0
***                         Layer b001-a010, rock to air at 100-101 yr
***                                    and air to rubble at 109-110 yr
***   material definition for b001-a010 was chanaged to b002mat
***   for 0901Model which does not go beyond 101 year
*Material, name=b001-a010Mat
*Conductivity, dependencies=1
5.869695E7, 25.0,   0.0
5.869695E7, 25.0, 101.0
3.155760E8, 25.0, 102.0
*Density, dependencies=1
2325.0, 25.0,   0.0
2325.0, 25.0, 101.0
1.2,    25.0, 102.0
*Specific Heat, dependencies=1
 969.0,   0.0,   0.0
 969.0,  92.0,   0.0
4741.0,  96.0,   0.0
4741.0, 112.0,   0.0
 988.0, 116.0,   0.0
 988.0, 150.0,   0.0
 969.0,   0.0, 101.0
 969.0,  92.0, 101.0
4741.0,  96.0, 101.0
4741.0, 112.0, 101.0
 988.0, 116.0, 101.0
 988.0, 150.0, 101.0
1000.0,   0.0, 102.0
1000.0, 150.0, 102.0
```

2-element model: Submodel mechanical material prop.

```
C:\Documents and Settings\rkazban\Desktop\Drift Degradation\DD_2009Run01\Submodel\mMaterials.def
***
*** Mechnical Material Definitions
***
**
** Linear-elastic model
** Parameters from high-grade lithophysal-rock data
**          Mean strength properties
** Stress distributions post-processed to calculate
**   stress/strength ratio distributions
**
** Young's modulus:   2.0E4 MPa
** Friction angle:    40 degrees
** Cohesion:          7.06 MPa
**
*Material, name=rockMat
*Elastic
20000., 0.20
*Expansion
  7.14e-06,  0.
  7.14e-06, 50.
  7.47e-06, 75.
  7.46e-06,100.
  9.07e-06,125.
  9.07e-06,225.
*User Output Variables
      1,
```