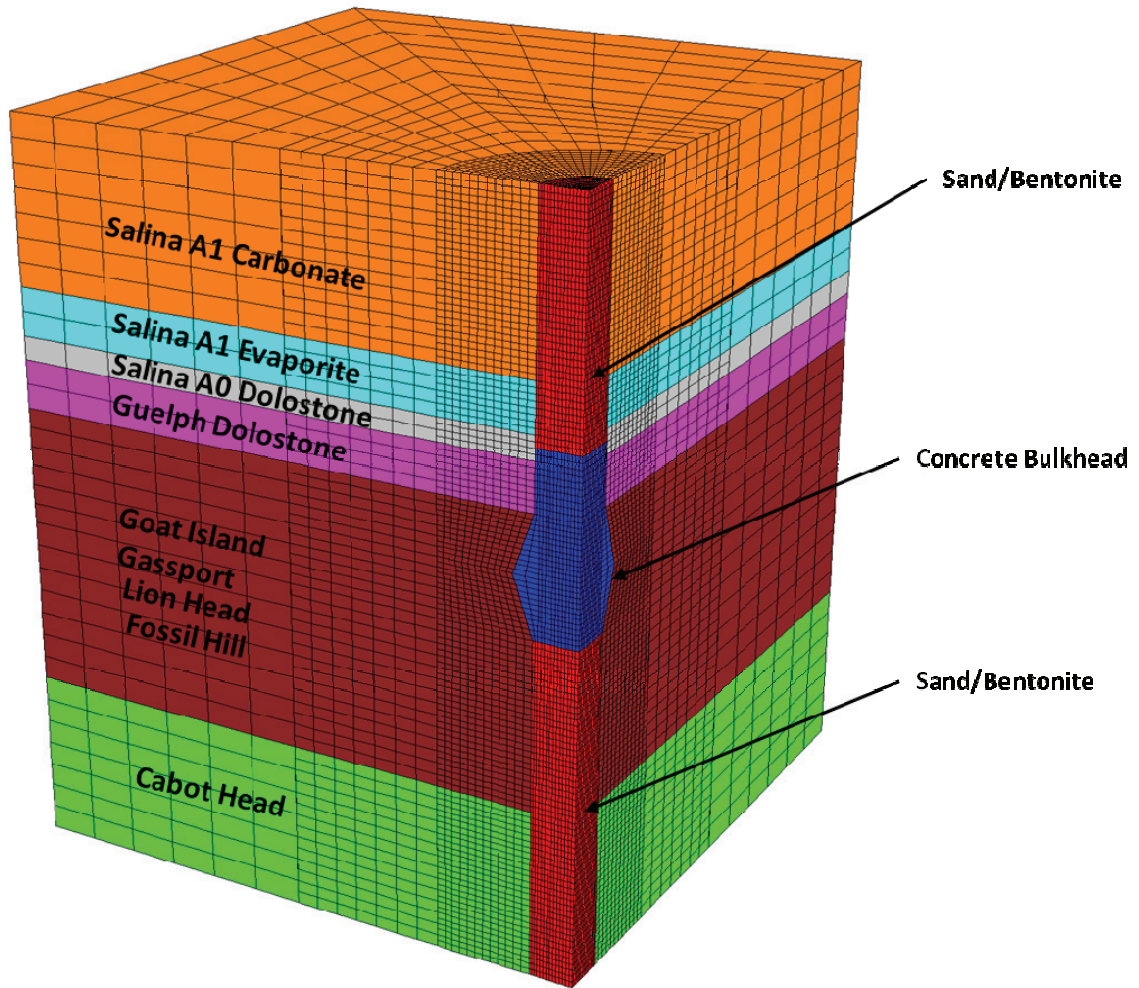


## **APPENDIX A. FLAC3D RESULTS FOR BULKHEAD B1**

This appendix includes the plots with the results for bulkhead B1. The summary plots show yielded zones in the model, contours of the shear and the volumetric strains in the isometric view but also in the horizontal cross-sections 22.4 m above the middle of the seal, in the middle of the seal and 22.4 m below the middle of the seal. The results are shown at the characteristic times, including: (1) time after shaft excavation, (2) 100 years (pre-closure), (3) 200 years (post-closure), (4) 100,000 years and (5) 1,000,000 years. The included results are for: (1) time-dependent strength degradation, (2) time-dependent strength degradation and glacial load, (3) time-dependent strength degradation, glacial load and pore pressure, and (4) time-dependent strength degradation, glacial load and seismic load applied at the peak of the first glacial event at 67,200 years.



**Figure A.1 : Layout of Quarter-symmetrical FLAC3D Model of Over-excavated and Backfilled Main Shaft for Bulkhead B1**

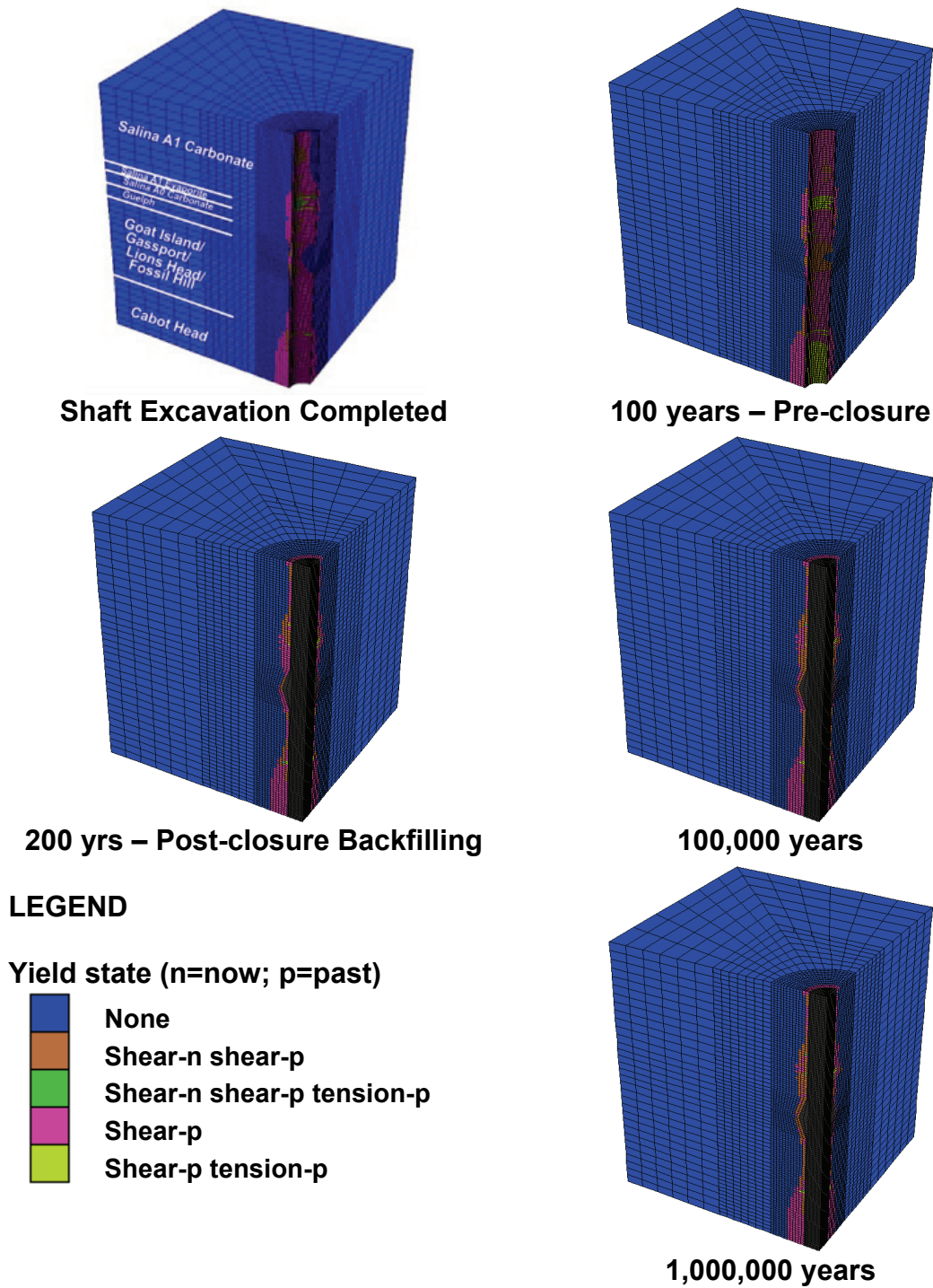


Figure A.2: Yield State – Concrete Bulkhead B1: Time-dependent Strength Degradation

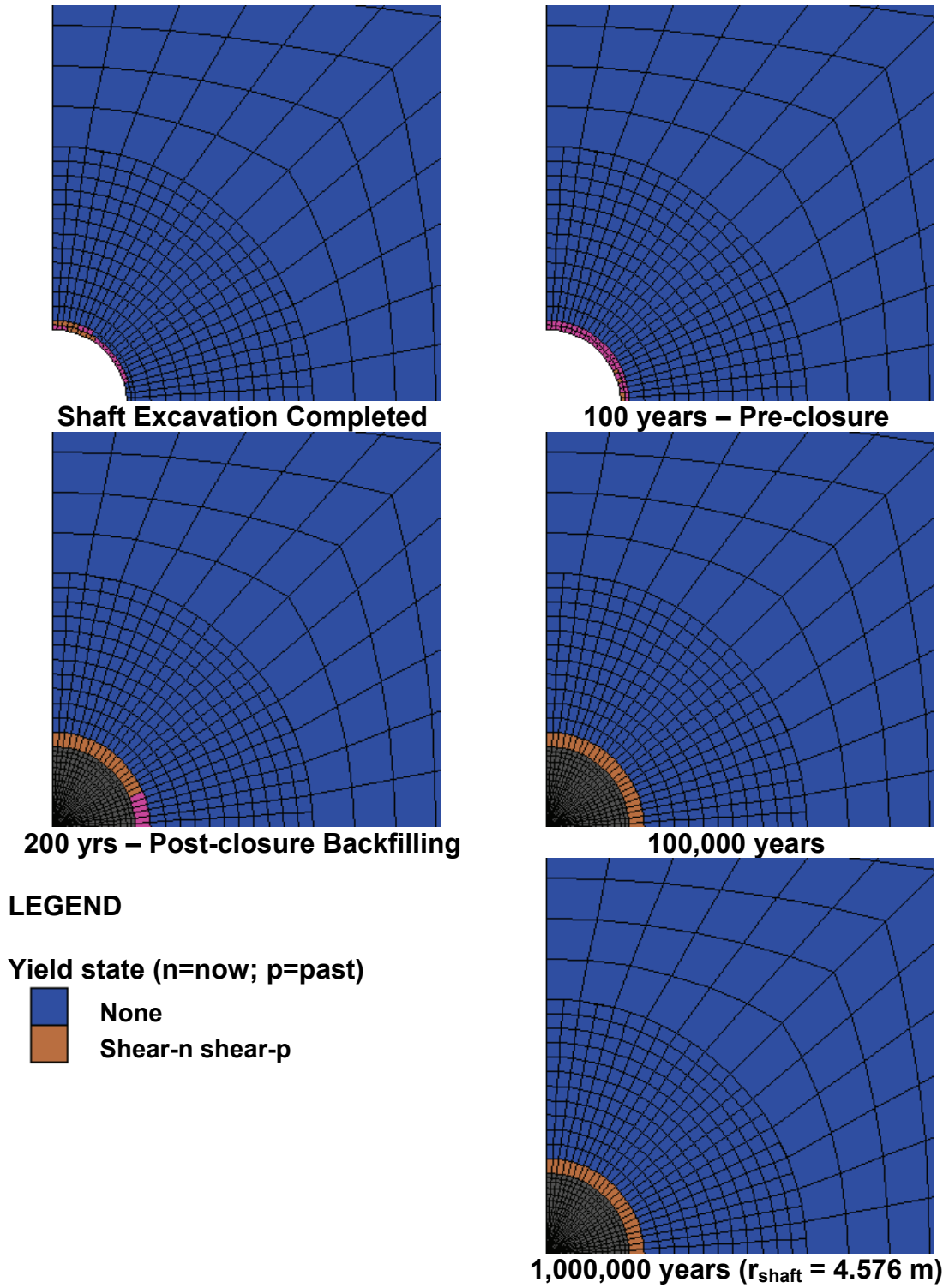


Figure A.3: Yield State – 22.4m Above Concrete Bulkhead B1: Time-dependent Strength Degradation

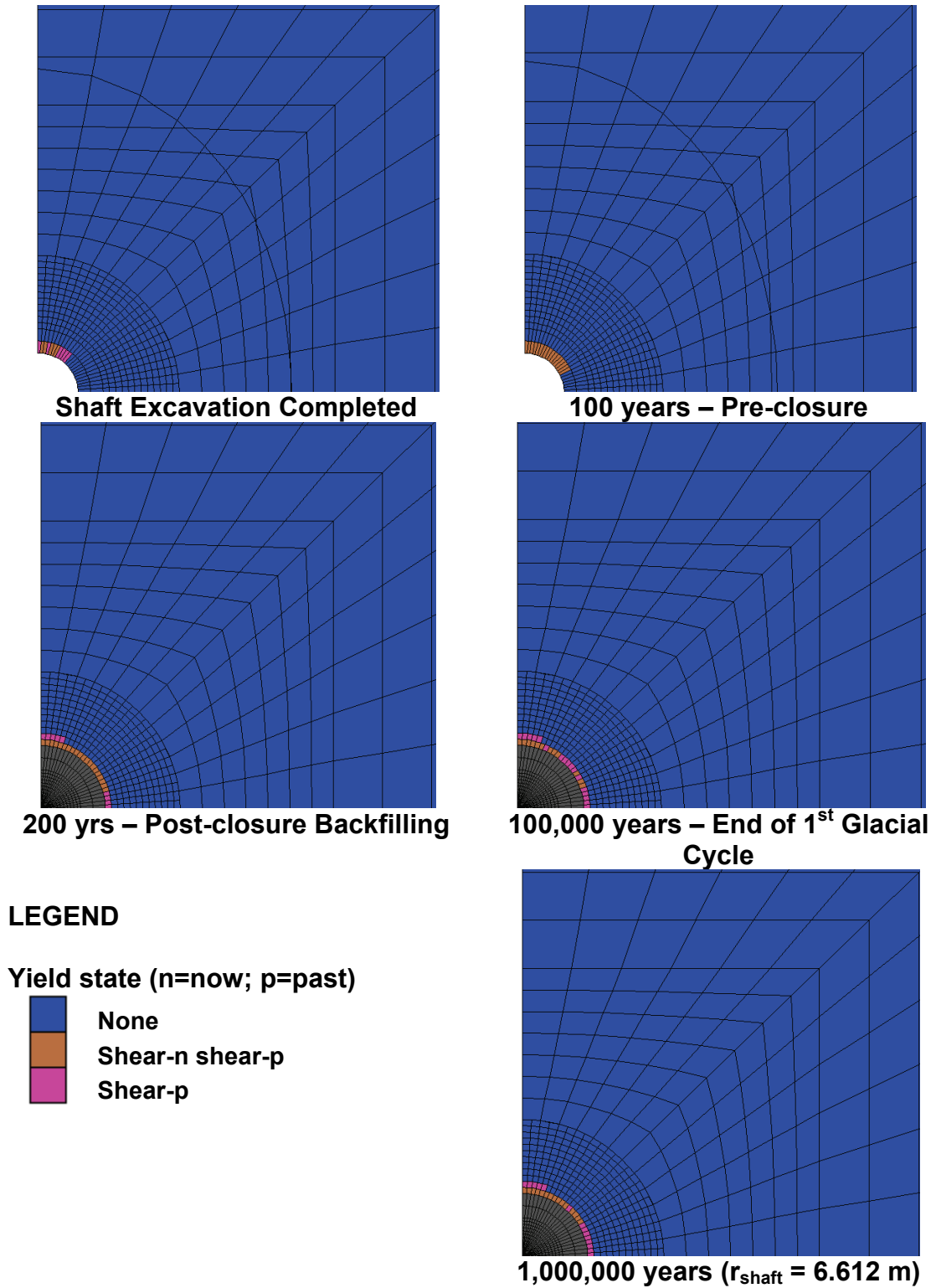


Figure A.4: Yield State – Middle of Concrete Bulkhead B1: Time-dependent Strength Degradation

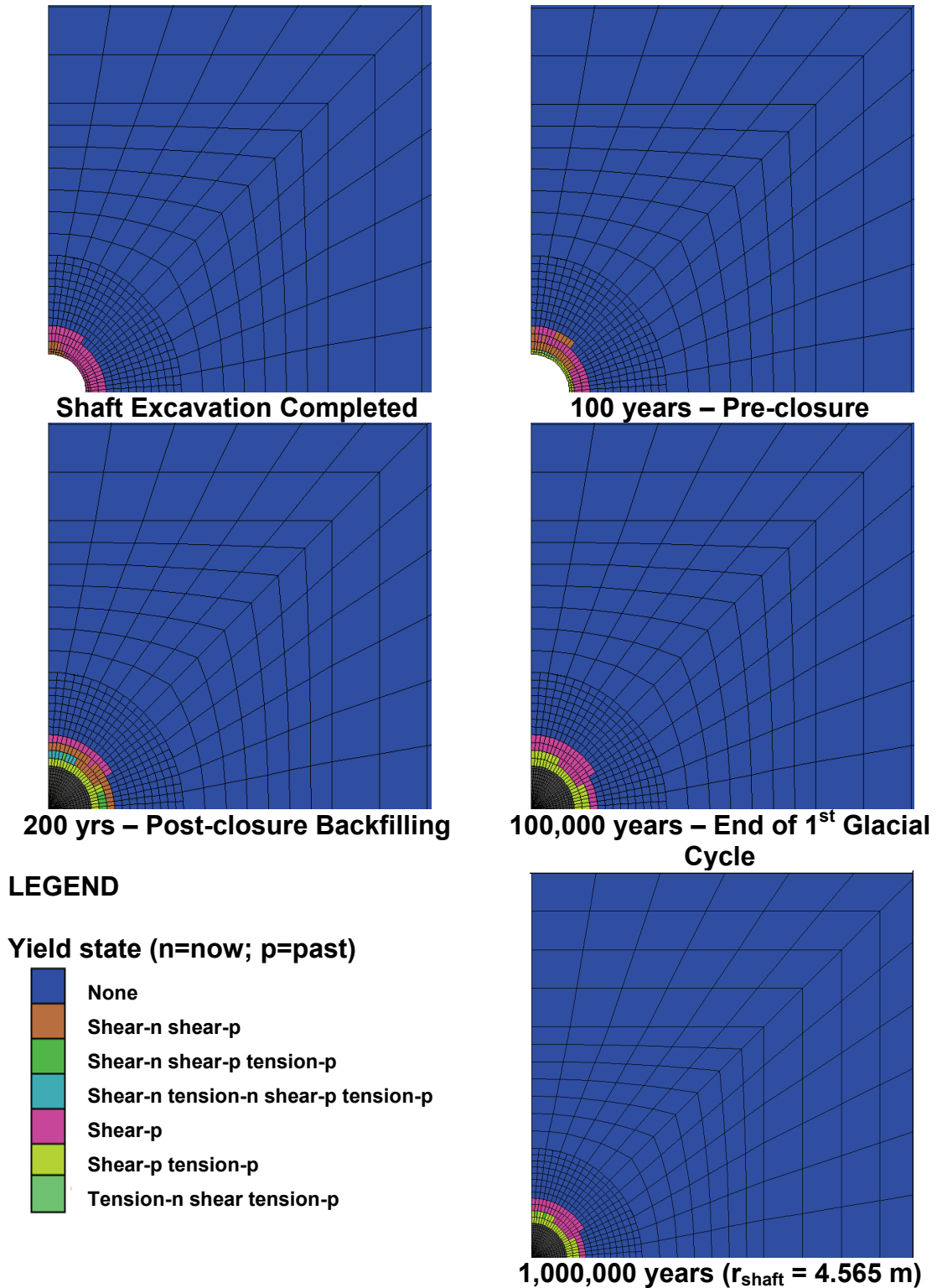


Figure A.5: Yield State – 22.4 m Below Concrete Bulkhead B1: Time-dependent Strength Degradation

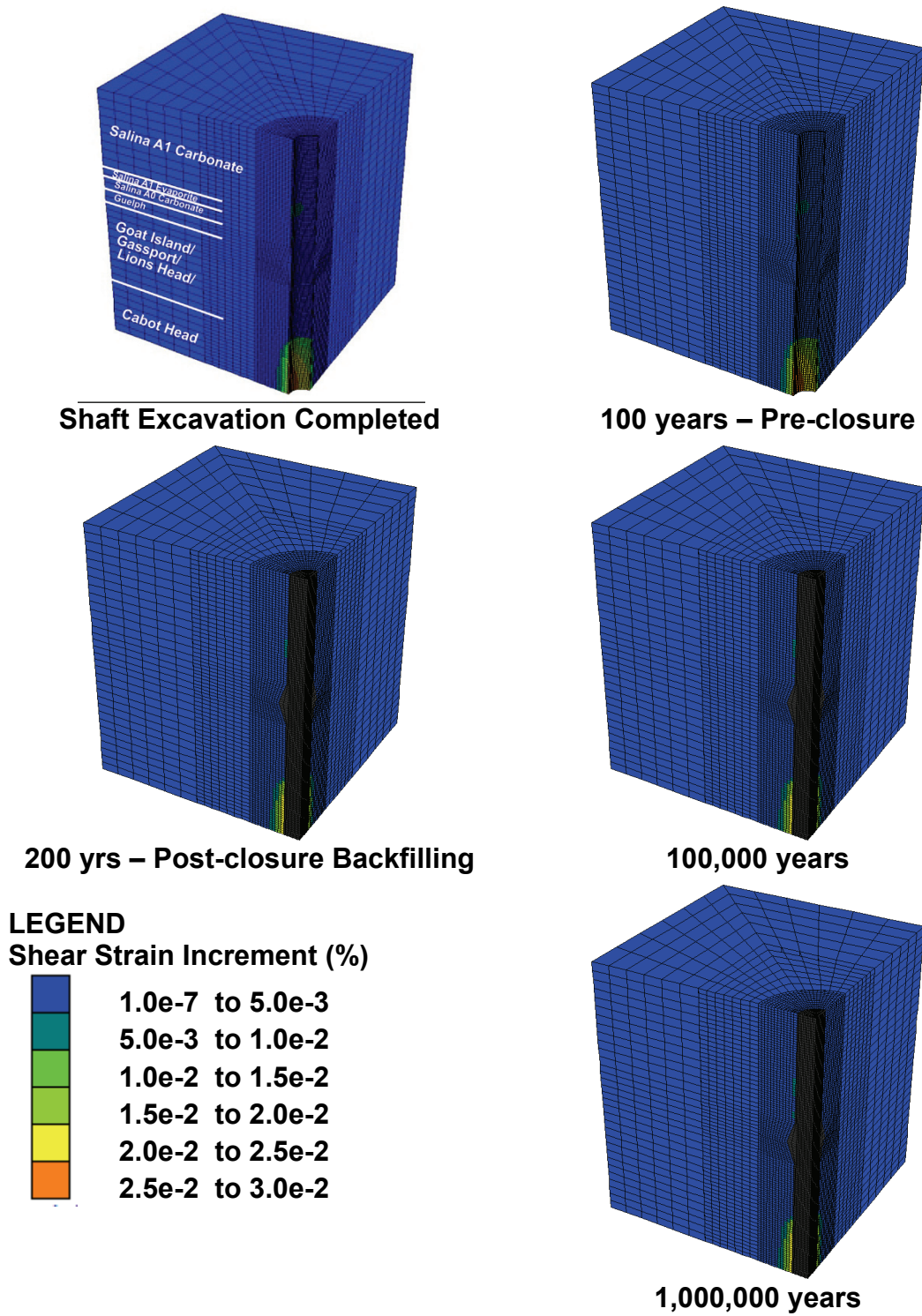


Figure A.6: Shear Strain – Concrete Bulkhead B1: Time-dependent Strength Degradation

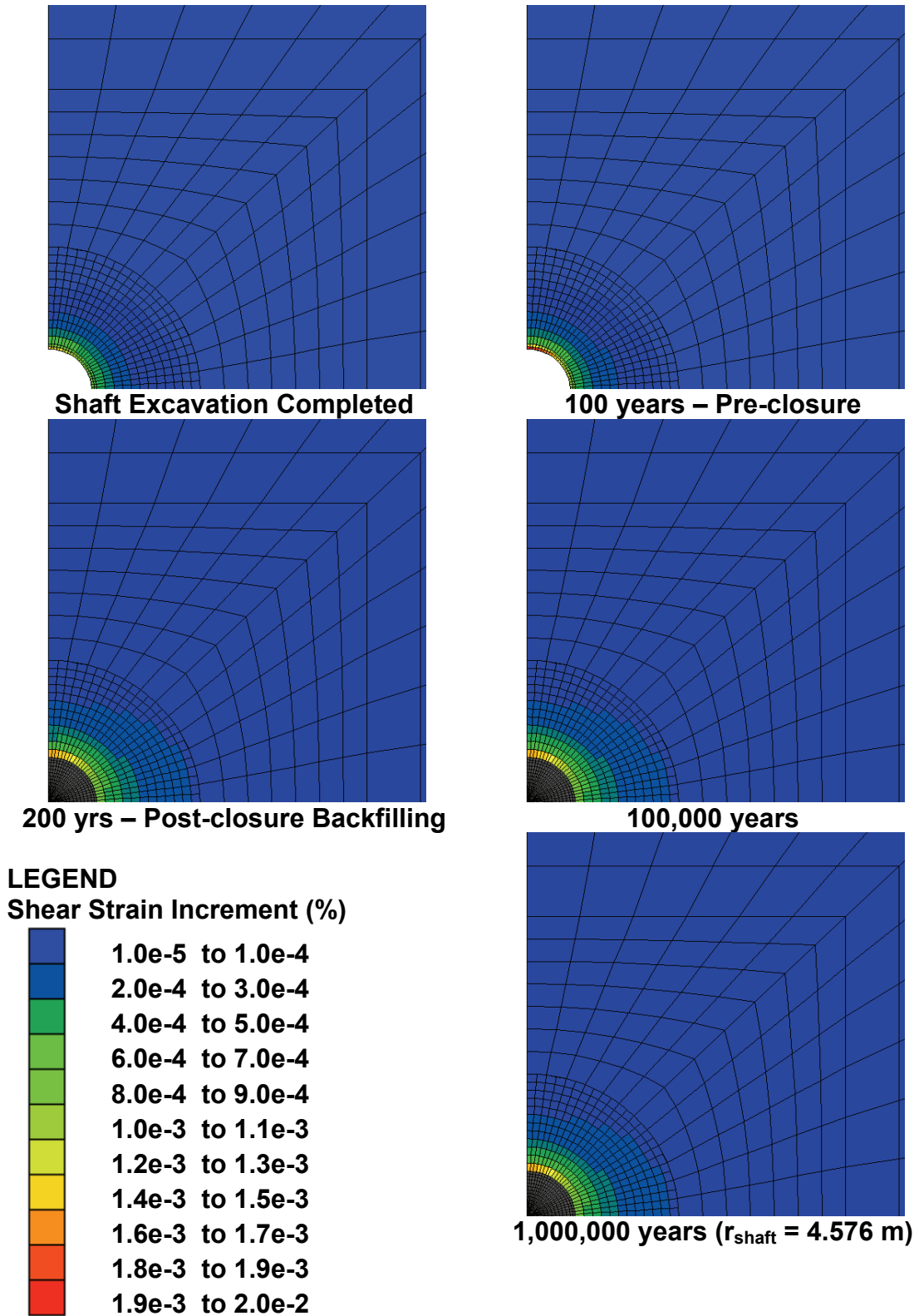


Figure A.7: Shear Strain – 22.4m Above Concrete Bulkhead B1: Time-dependent Strength Degradation



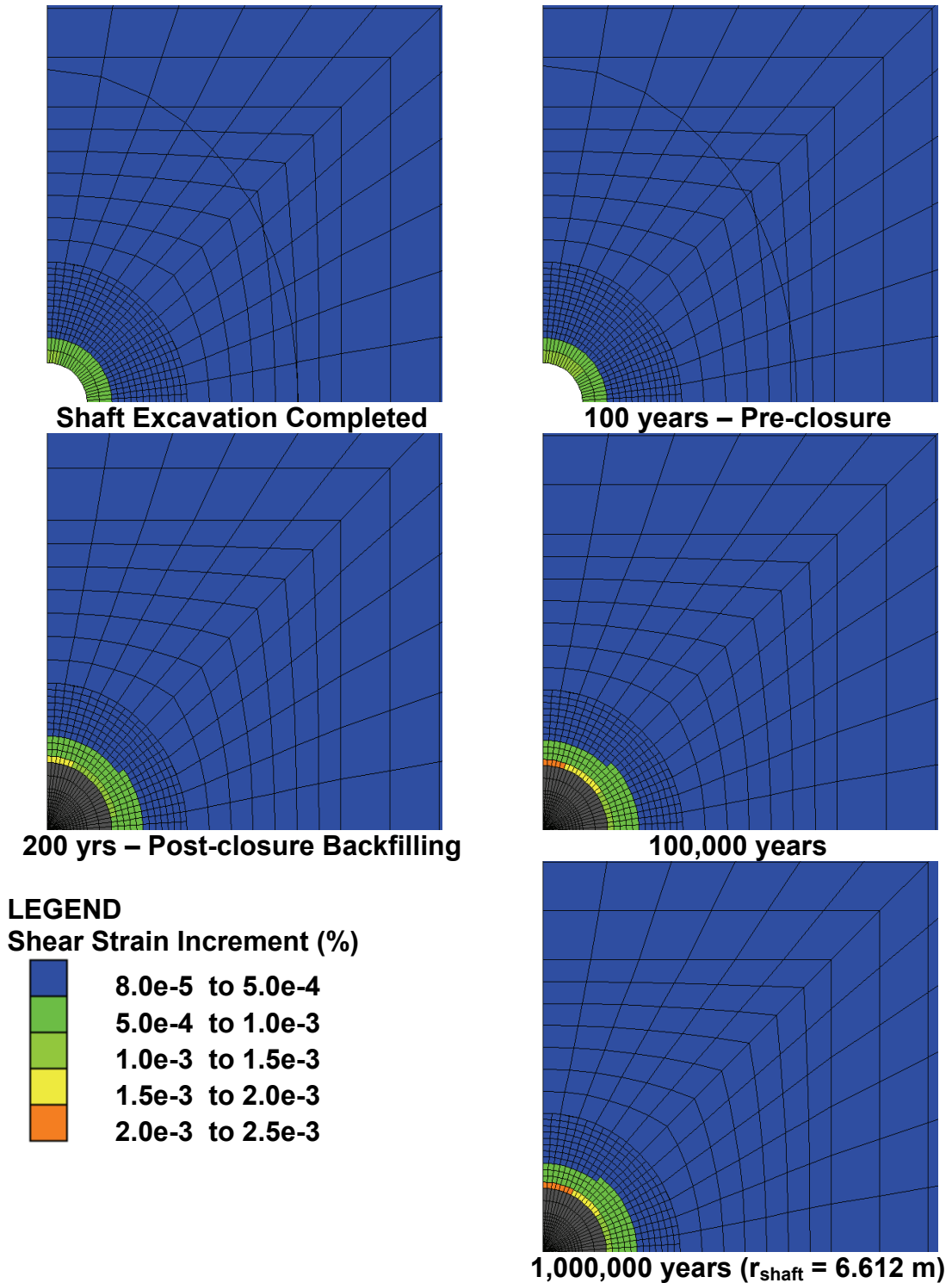


Figure A.8: Shear Strain – Middle of Concrete Bulkhead B1: Time-dependent Strength Degradation

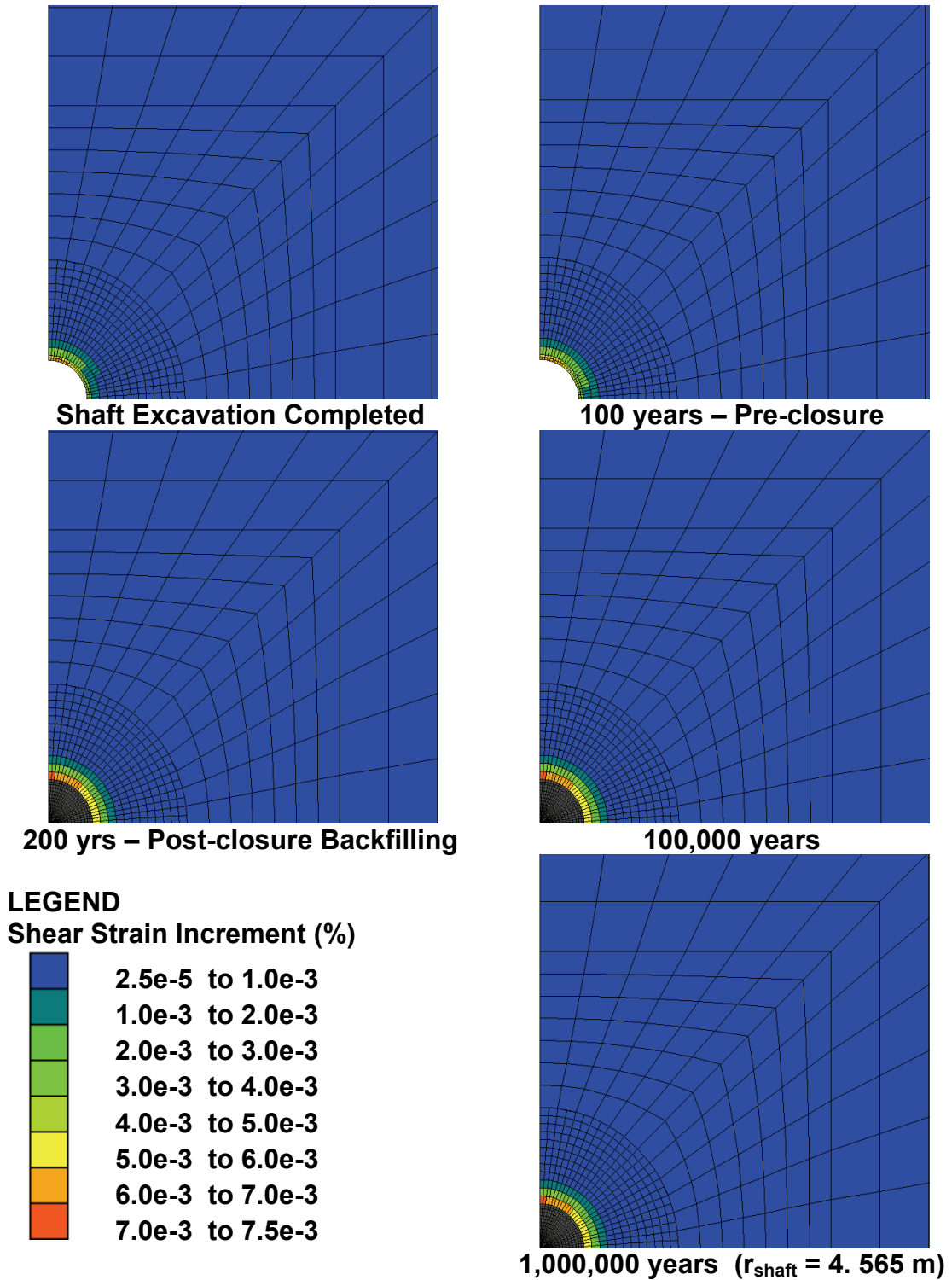


Figure A.9: Shear Strain – 22.4 m Below Concrete Bulkhead B1: Time-dependent Strength Degradation

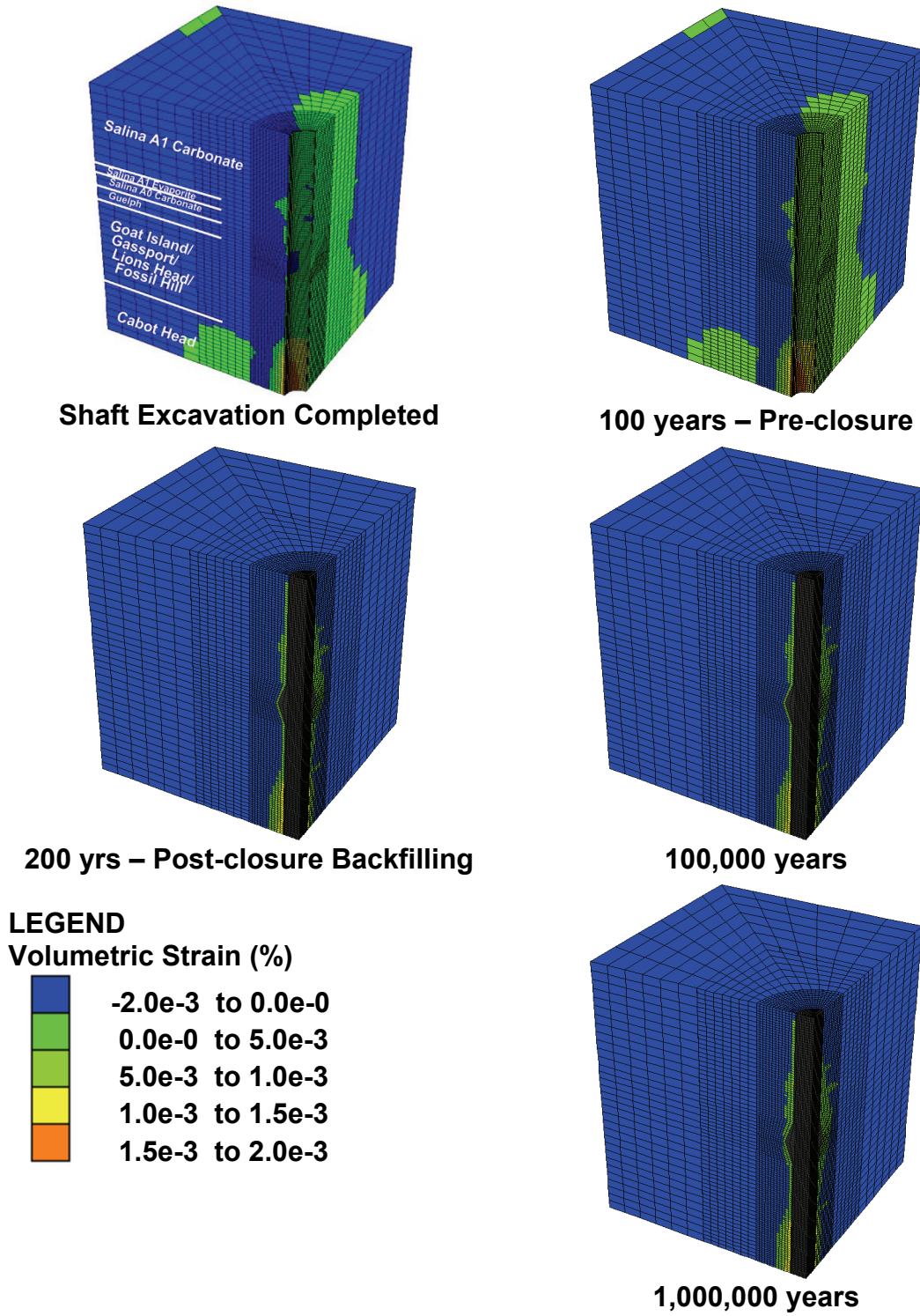


Figure A.10 : Volumetric Strain – Concrete Bulkhead B1: Time-dependent Strength Degradation

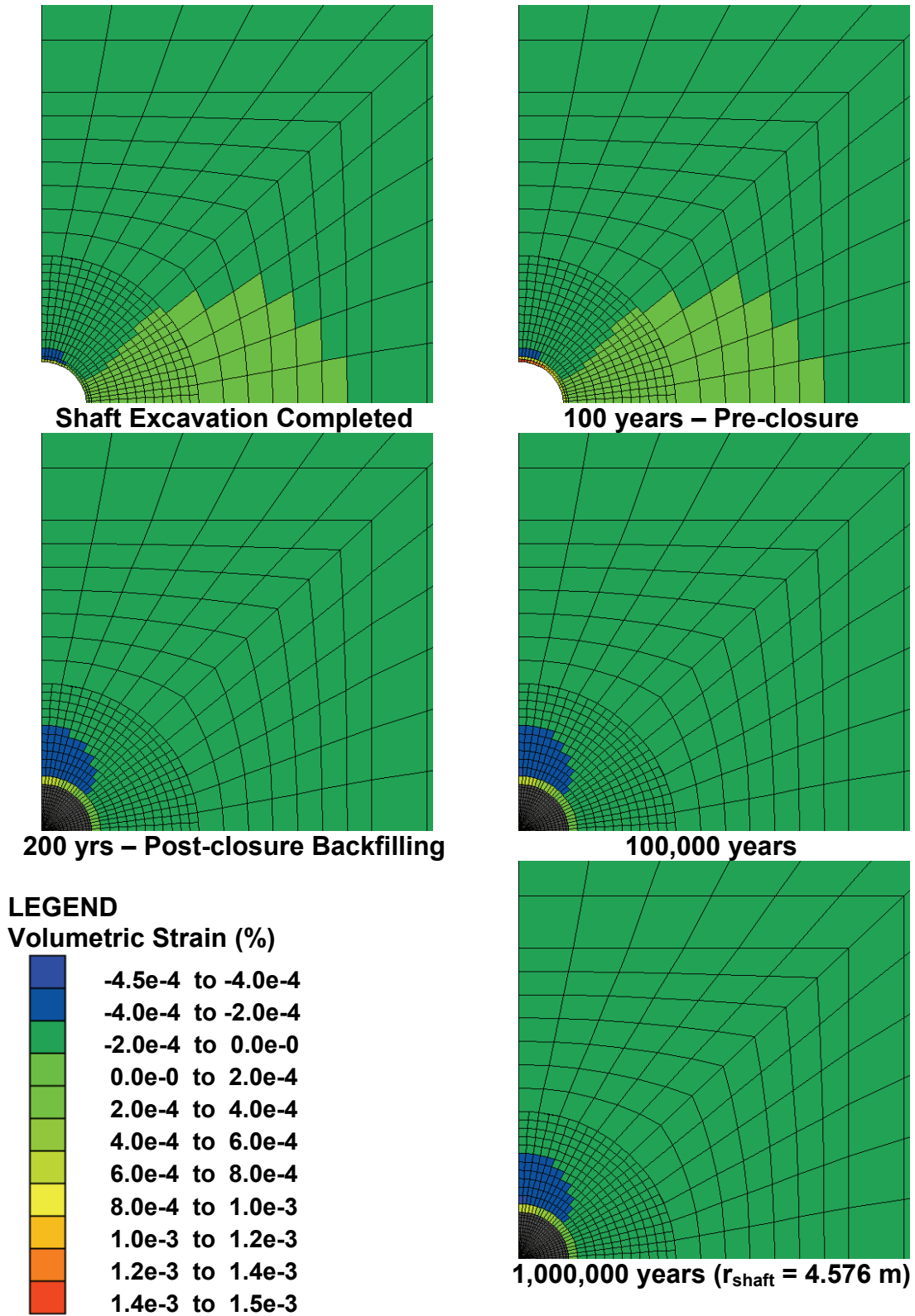


Figure A.11 : Volumetric Strain – 22.4m Above Concrete Bulkhead B1:  
 Time-dependent Strength Degradation

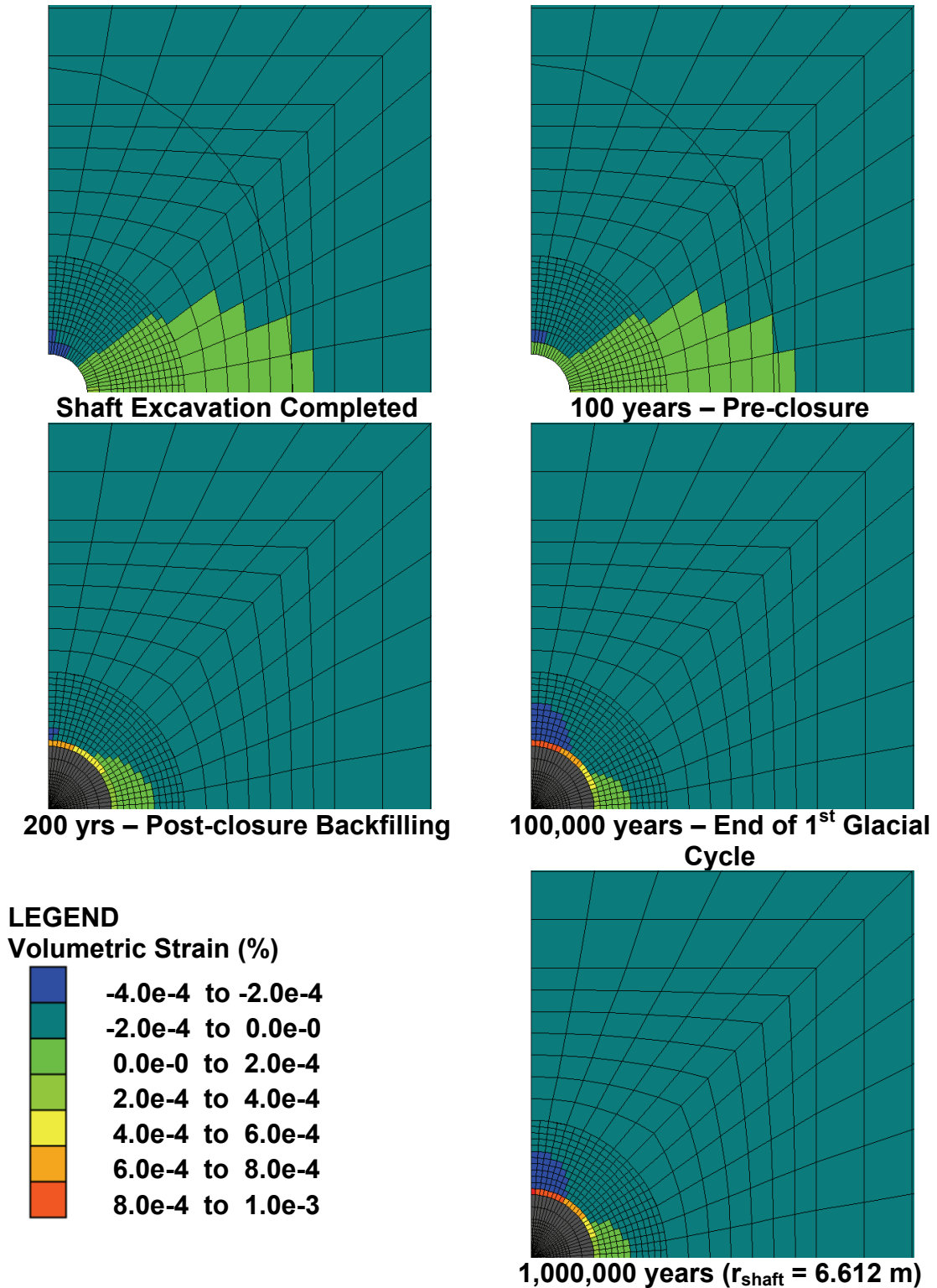


Figure A.12 : Volumetric Strain – Middle of Concrete Bulkhead B1: Time-dependent Strength Degradation

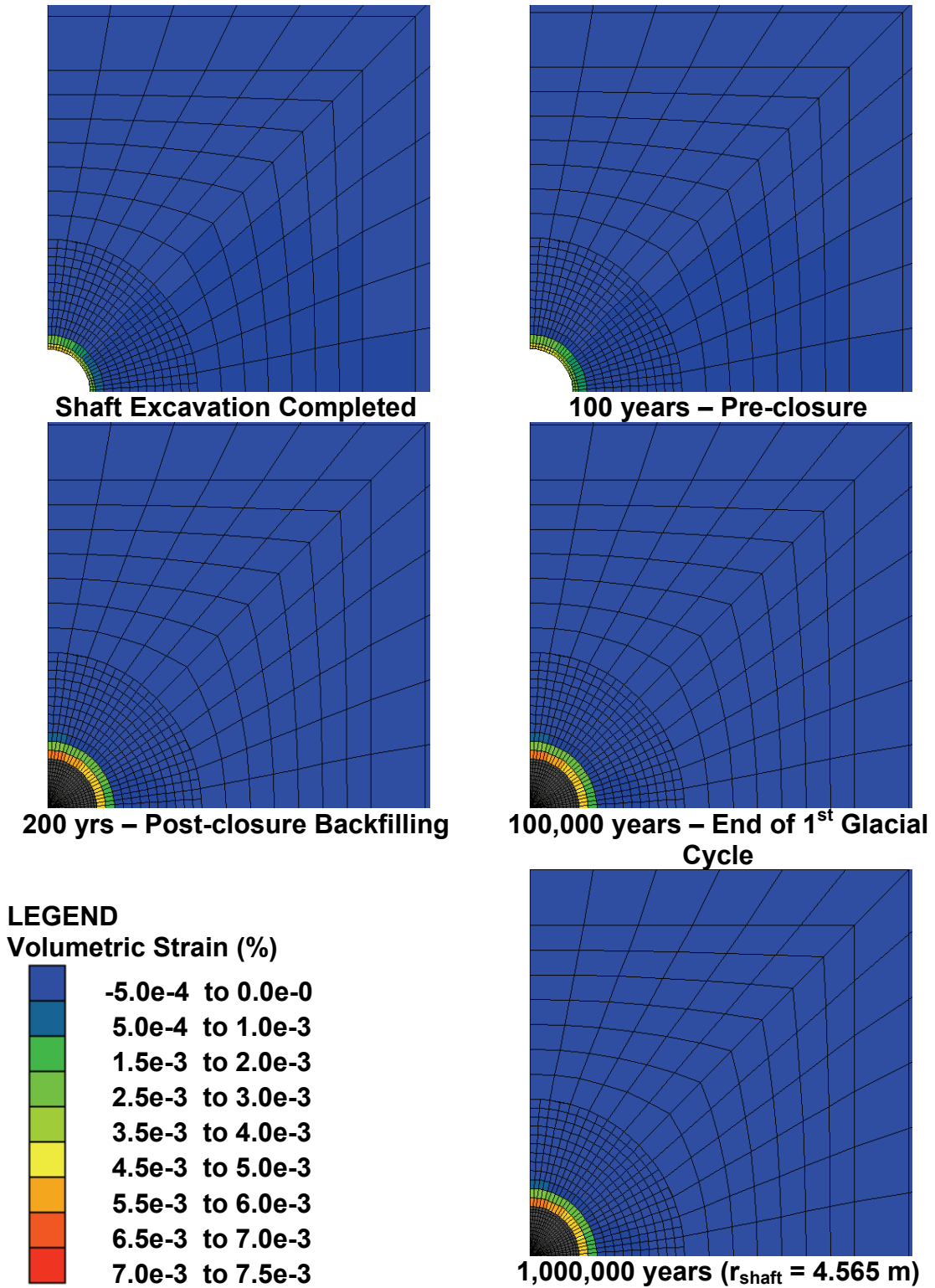


Figure A.13 : Volumetric Strain – 22.4 m Below Concrete Bulkhead B1:  
 Time-dependent Strength Degradation

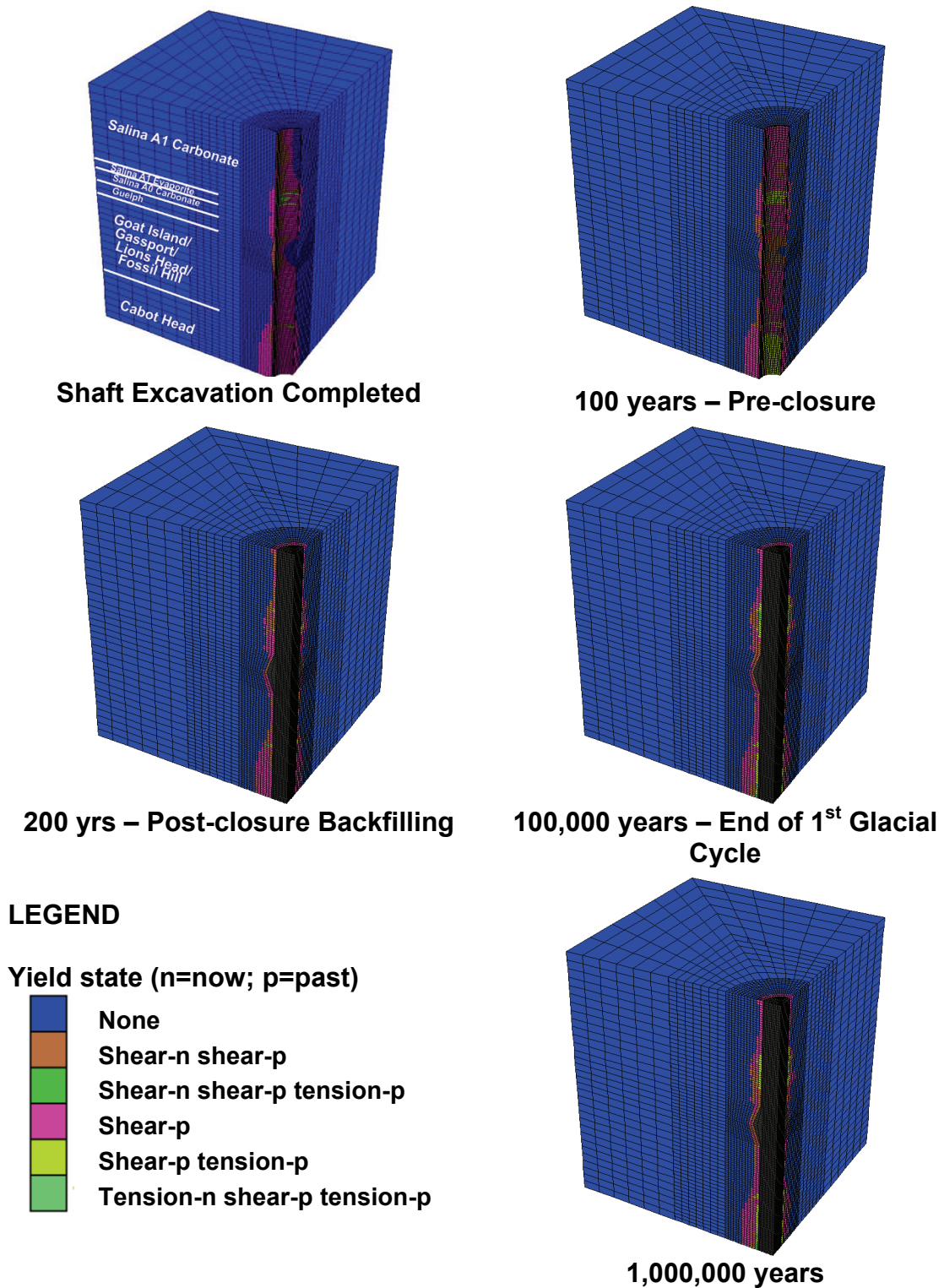


Figure A.14 : Yield State – Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load

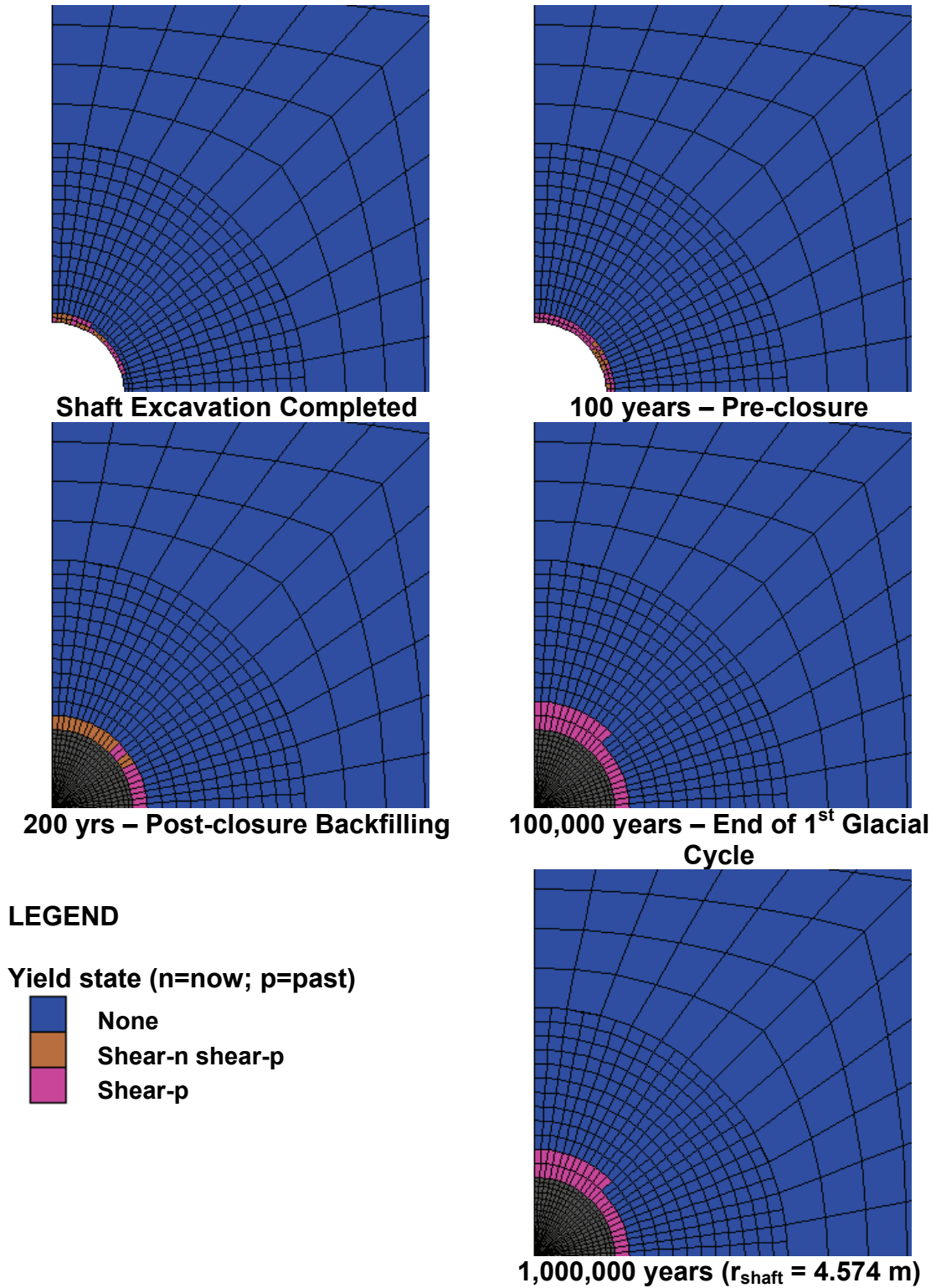
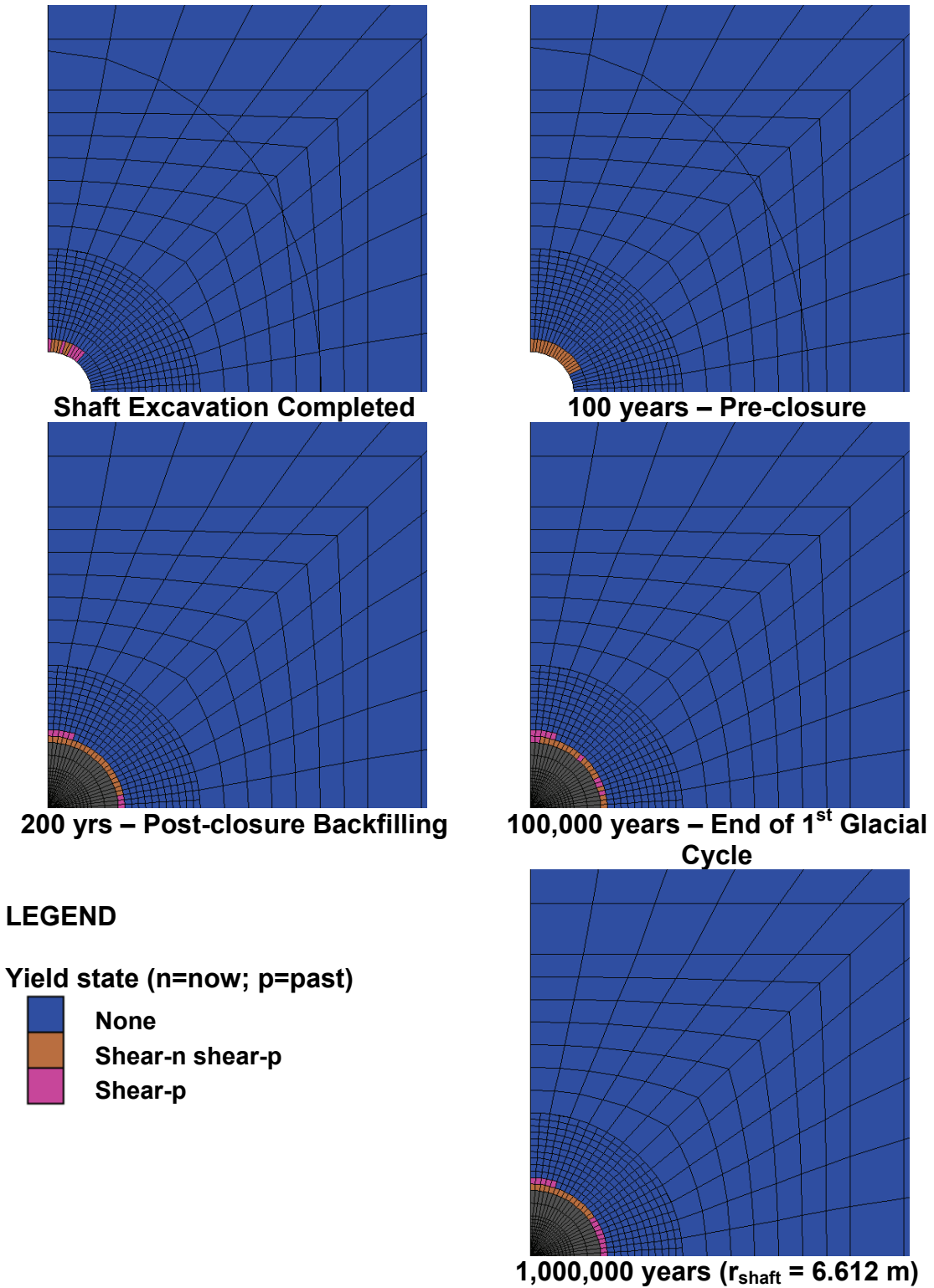


Figure A.15 : Yield State - 22.4m Above Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load





**Figure A.16 : Yield State – Middle of Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load**

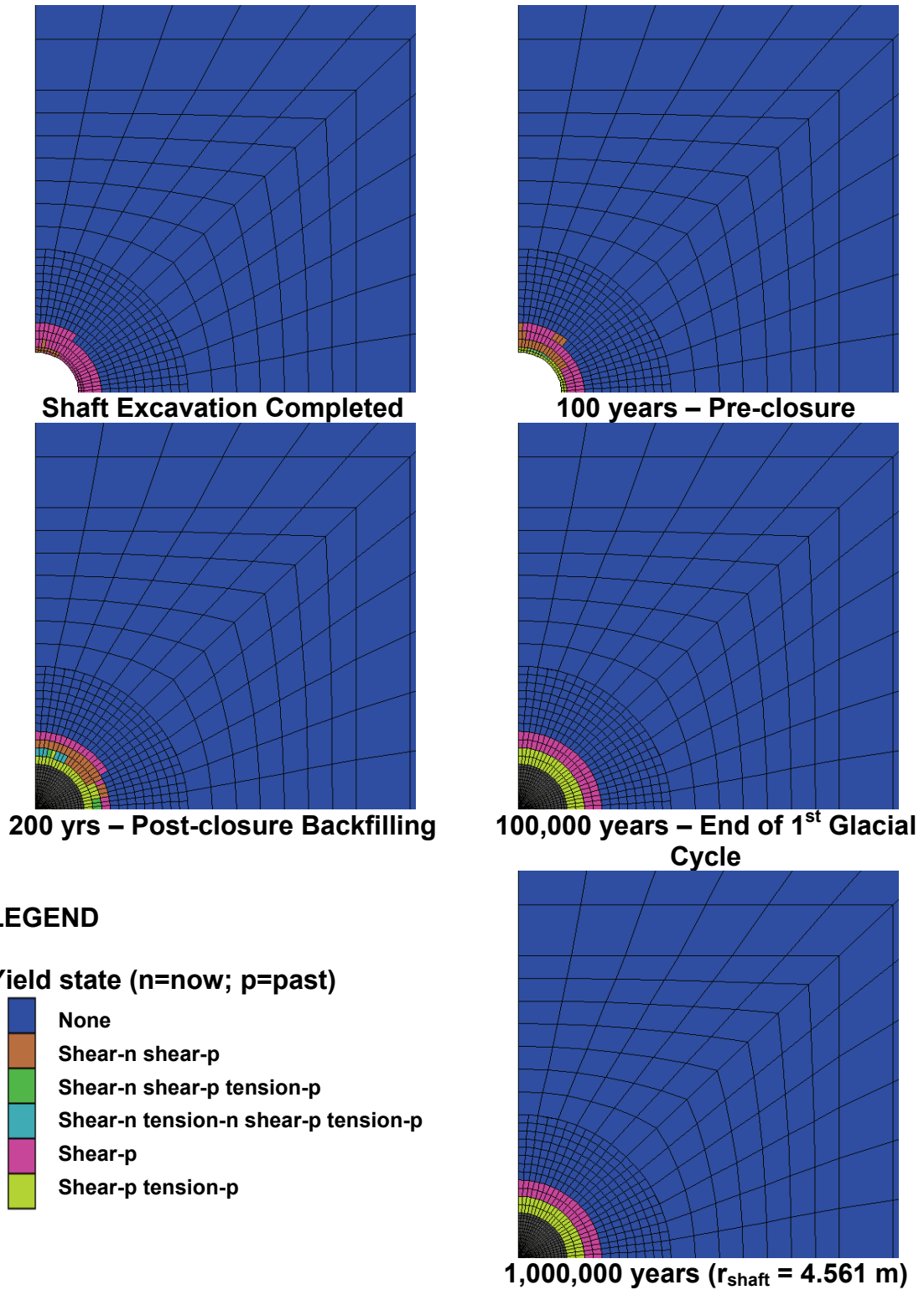


Figure A.17 : Yield State - 22.4m Below Concrete Bulkhead B1 (Lions Head Fm.): Time-dependent Strength Degradation + Glacial Load

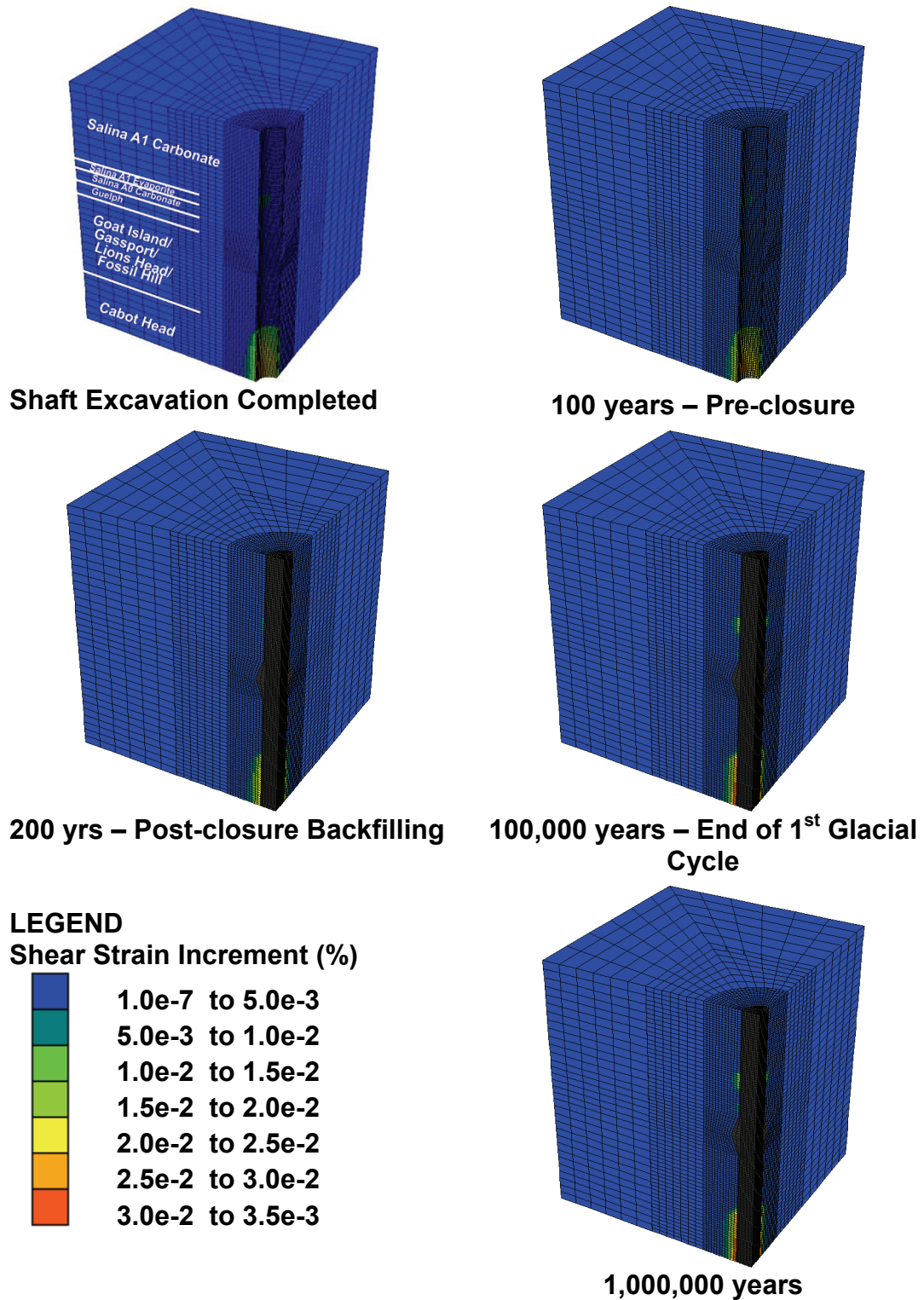


Figure A.18 : Shear Strain – Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load

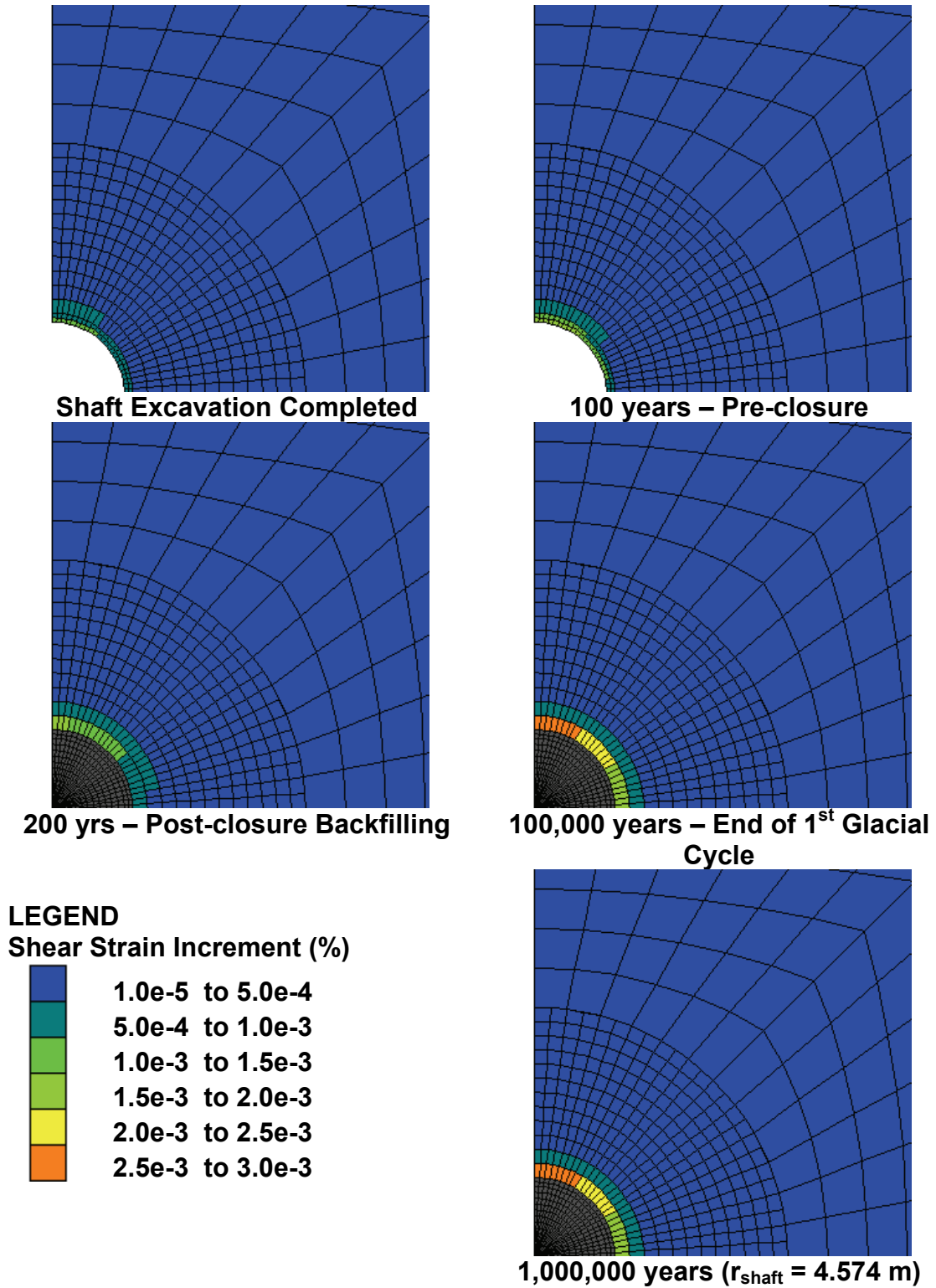
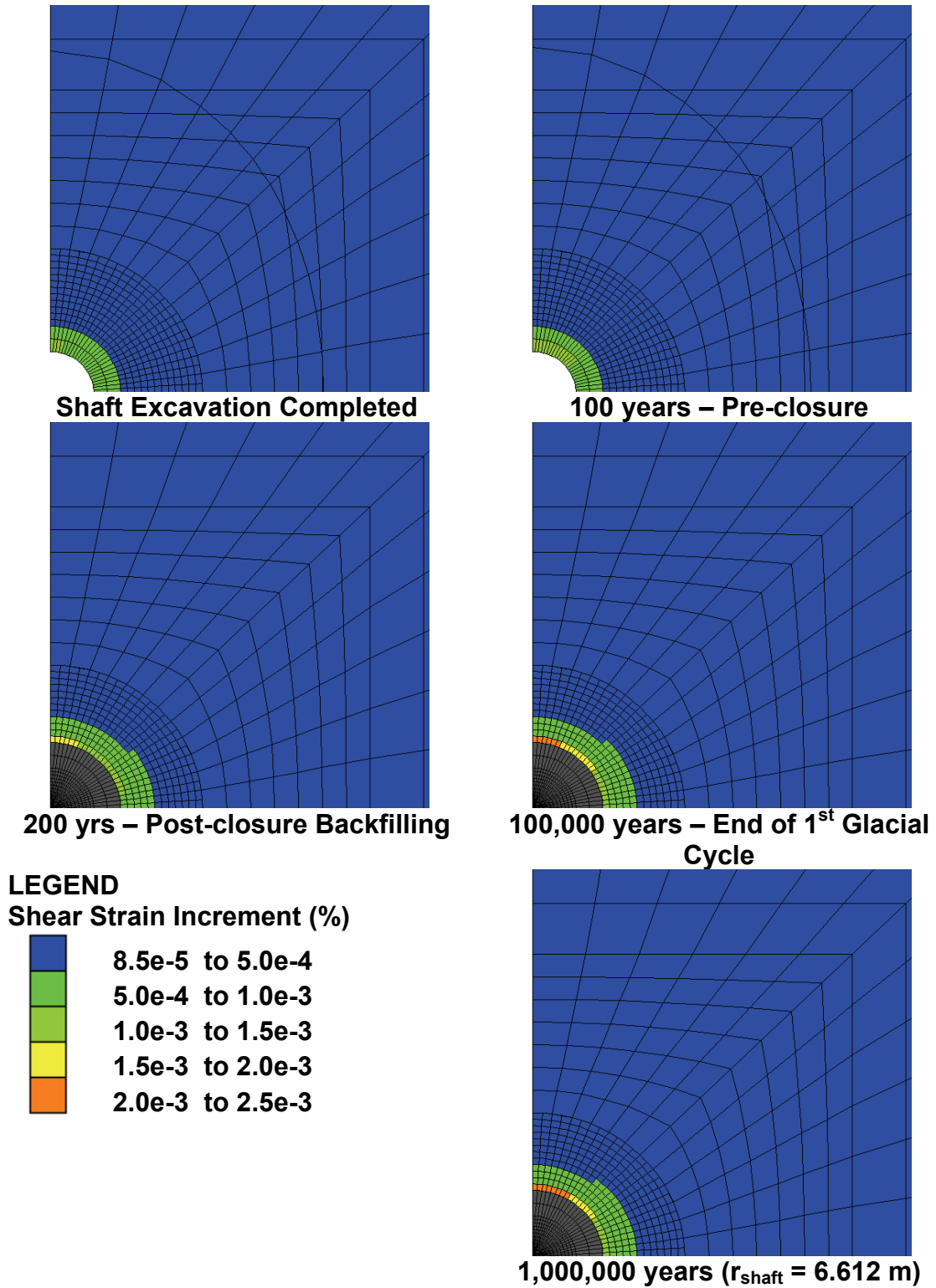


Figure A.19 : Shear Strain – 22.4 m Above Concrete Bulkhead: Time-dependent Strength Degradation + Glacial Load



**Figure A.20 : Shear Strain – Middle of Concrete Bulkhead: Time-dependent Strength Degradation + Glacial Load**

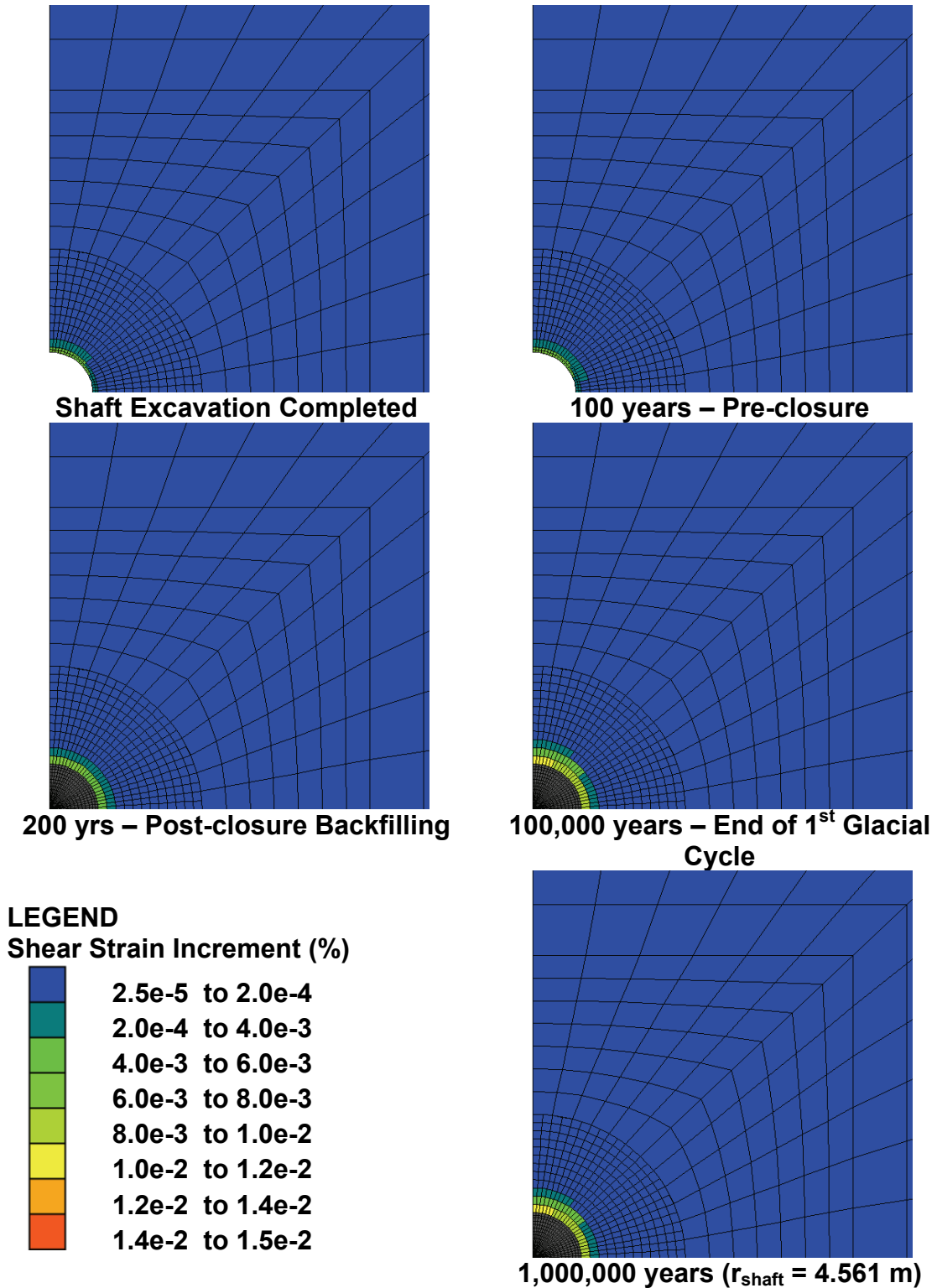


Figure A.21 : Shear Strain – 22.4 m Below Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load

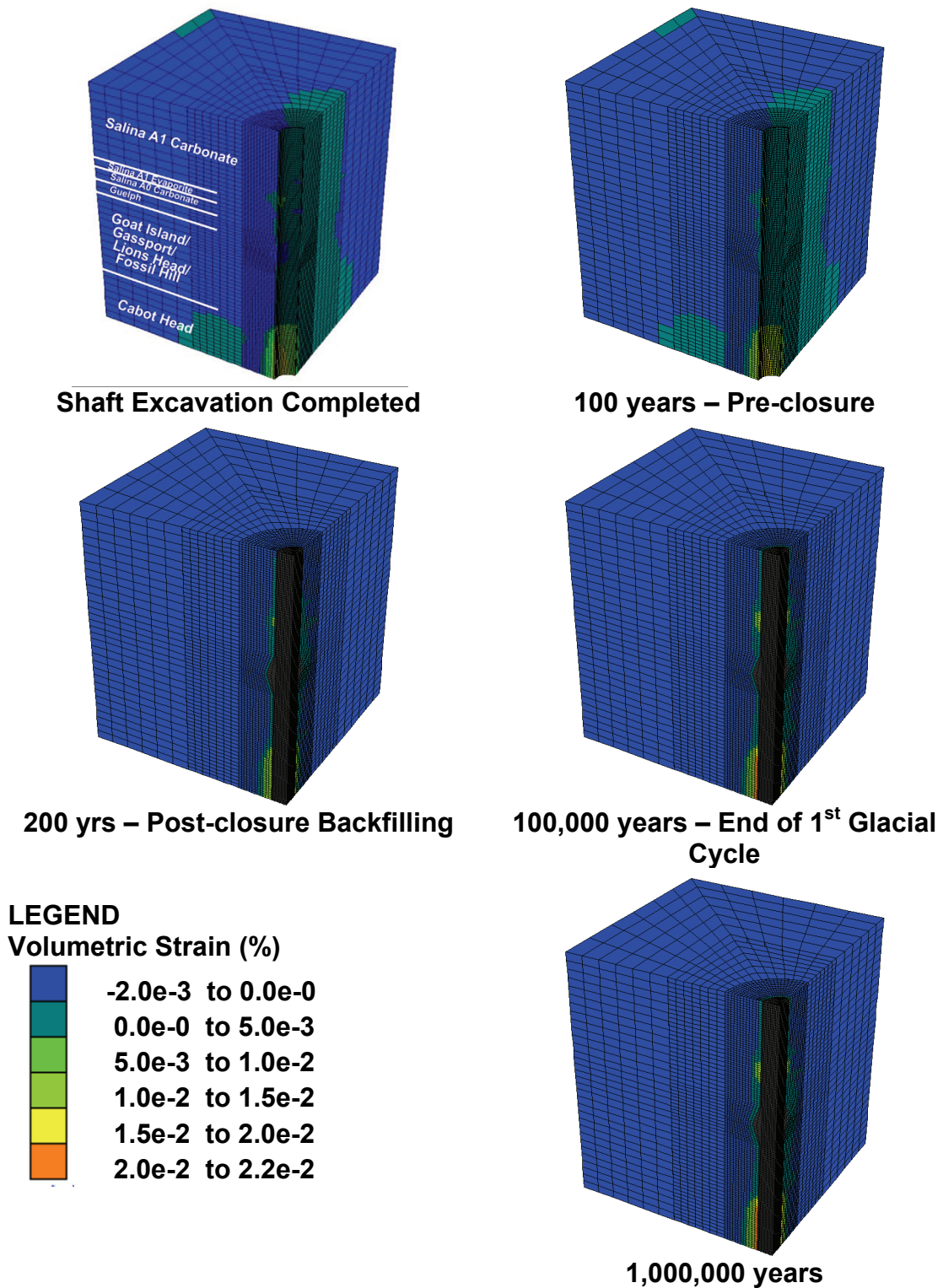
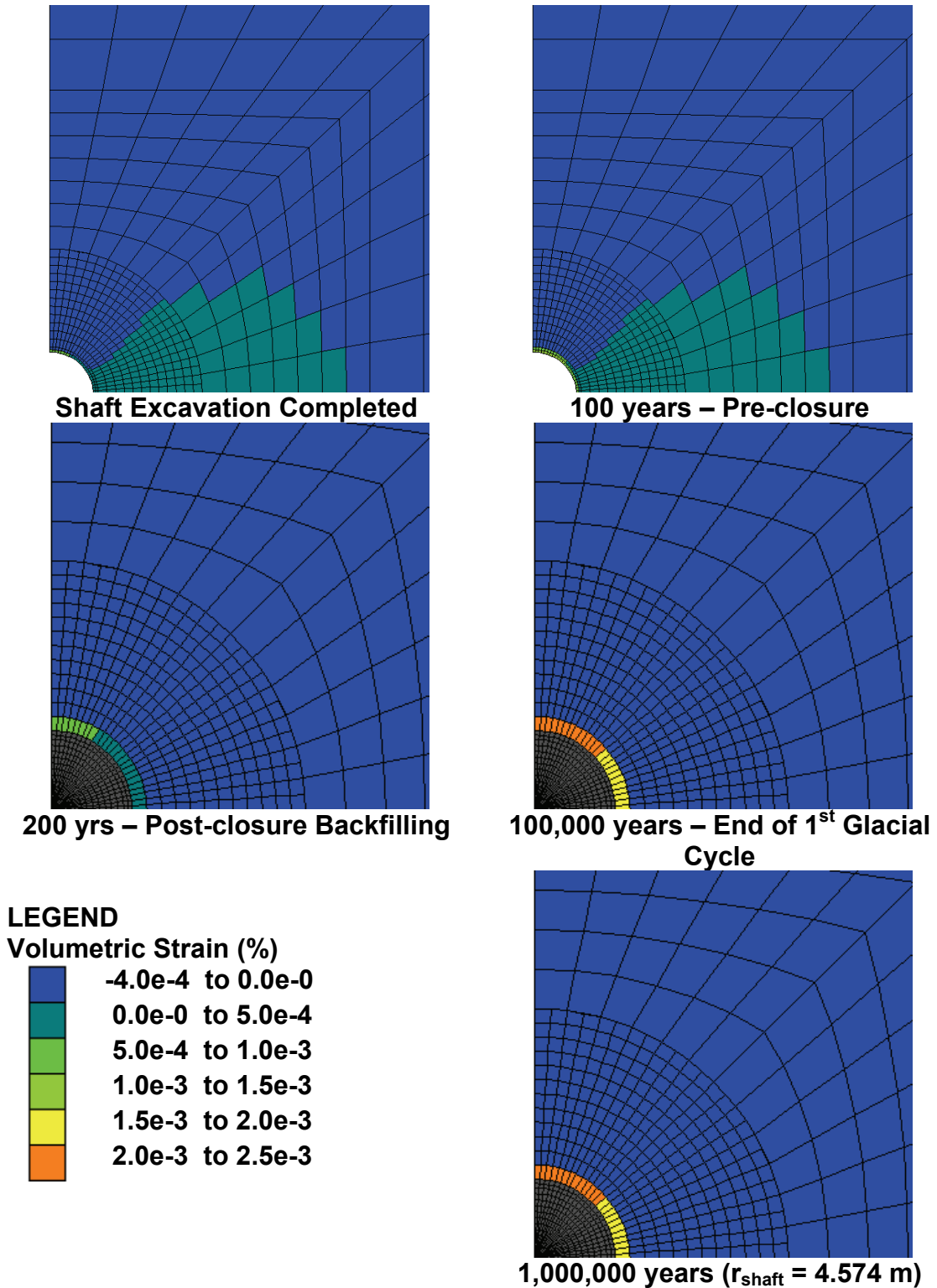


Figure A.22 : Volumetric Strain – Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load



**Figure A.23 : Volumetric Strain – 22.4m Above Concrete Bulkhead B1:  
 Time-dependent Strength Degradation + Glacial Load**



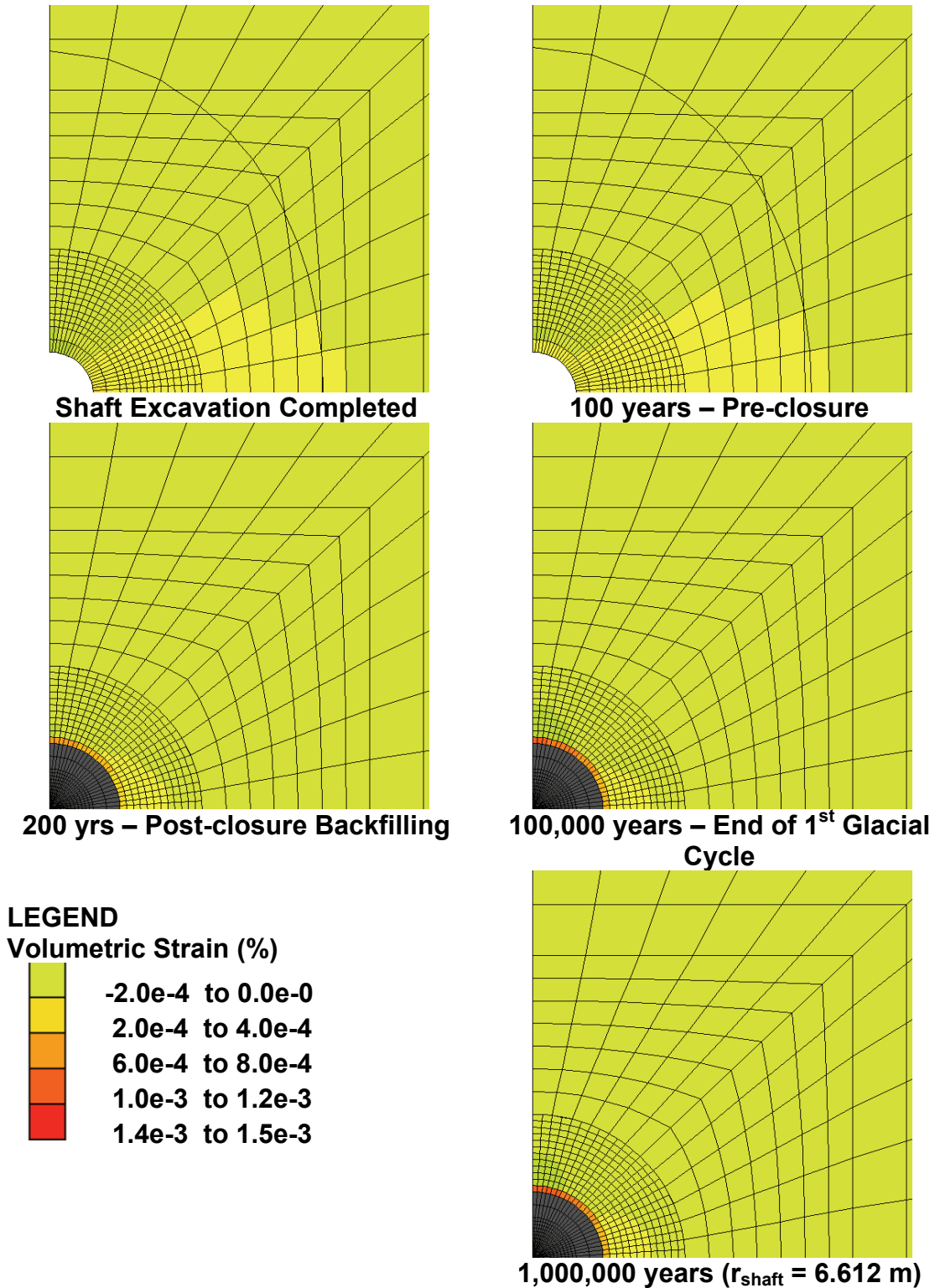
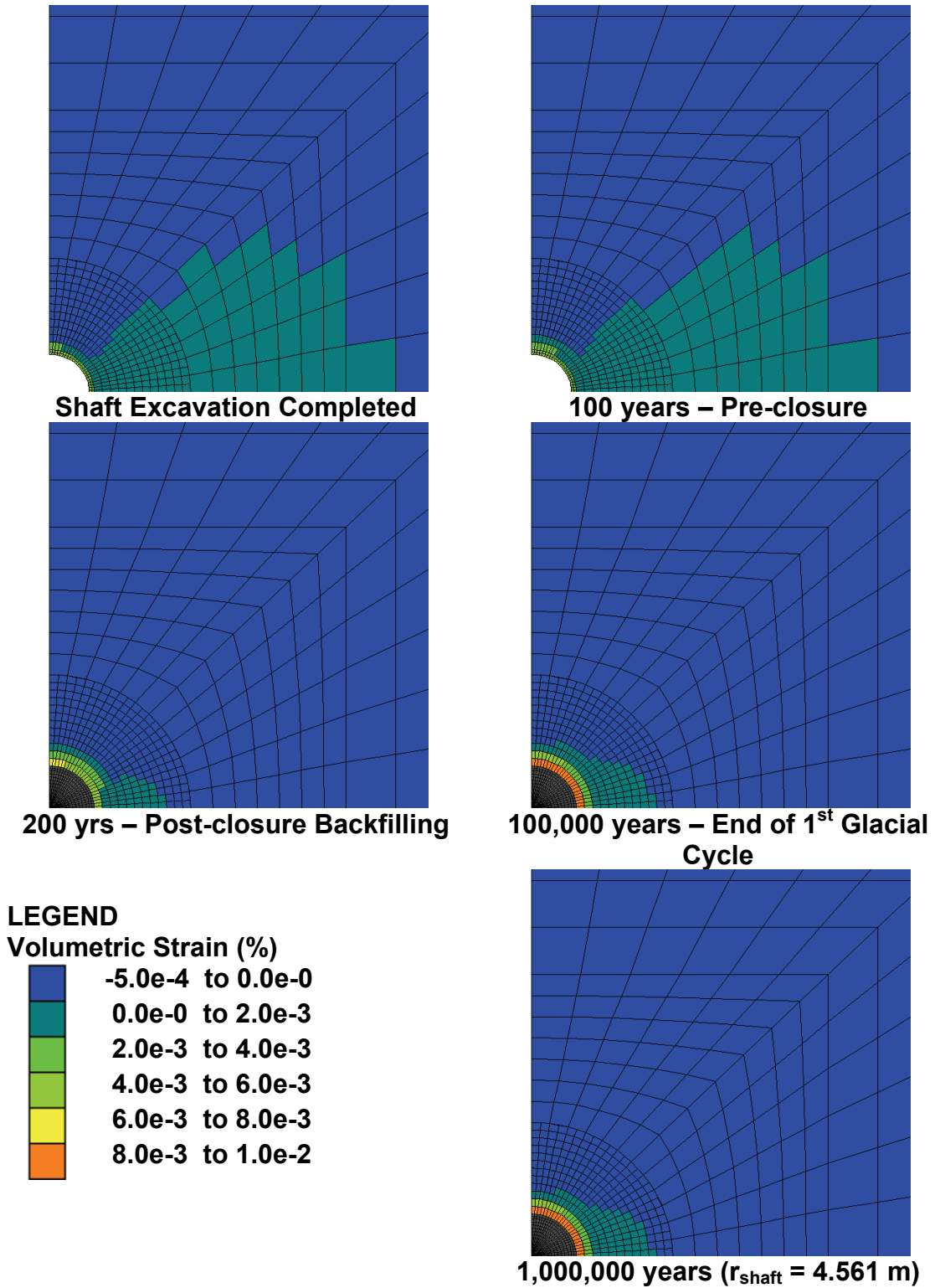


Figure A.24 : Volumetric Strain – Middle of Concrete Bulkhead B1 (Goat Island Fm.): Time-dependent Strength Degradation + Glacial Load



**Figure A.25 : Volumetric Strain – 22.4 m Below Concrete Bulkhead B1:  
 Time-dependent Strength Degradation + Glacial Load**

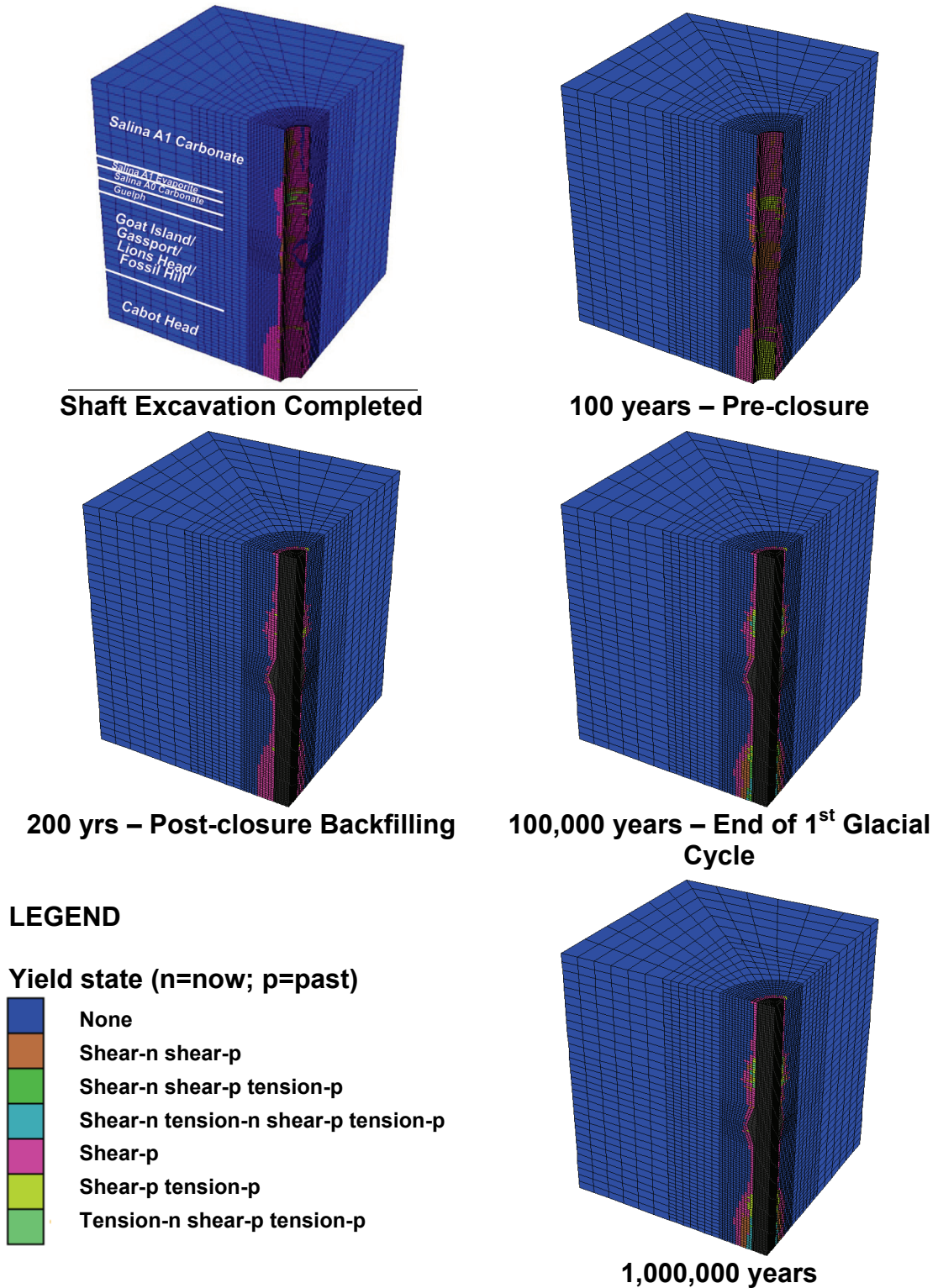


Figure A.26 : Yield State – Concrete Bulkhead B1: Time-dependent strength Degradation + Glacial Load + Pore Pressure

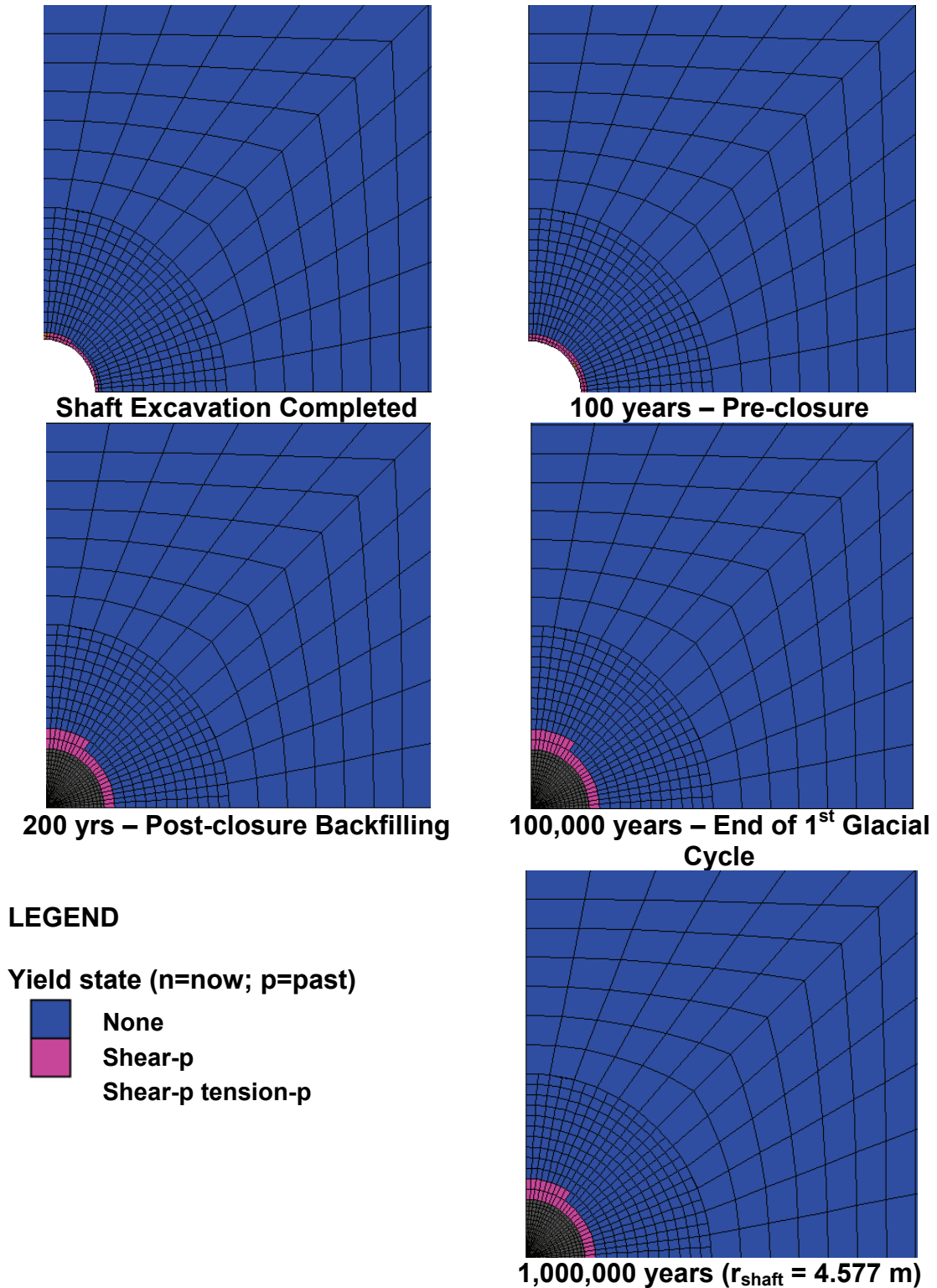


Figure A.27 : Yield State – 22.4 m Above Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Pore Pressure

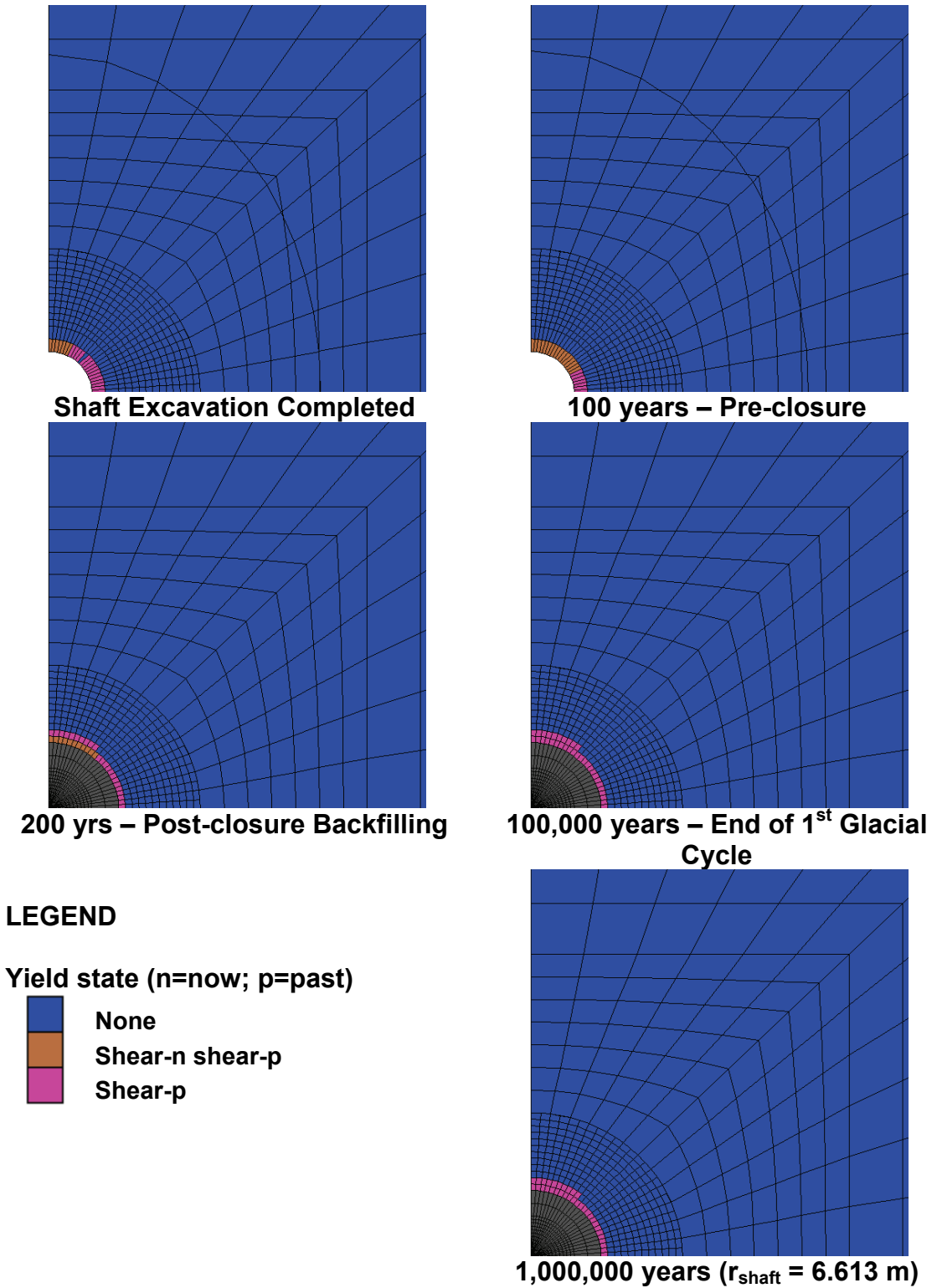


Figure A.28 : Yield State – Middle of Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Pore Pressure

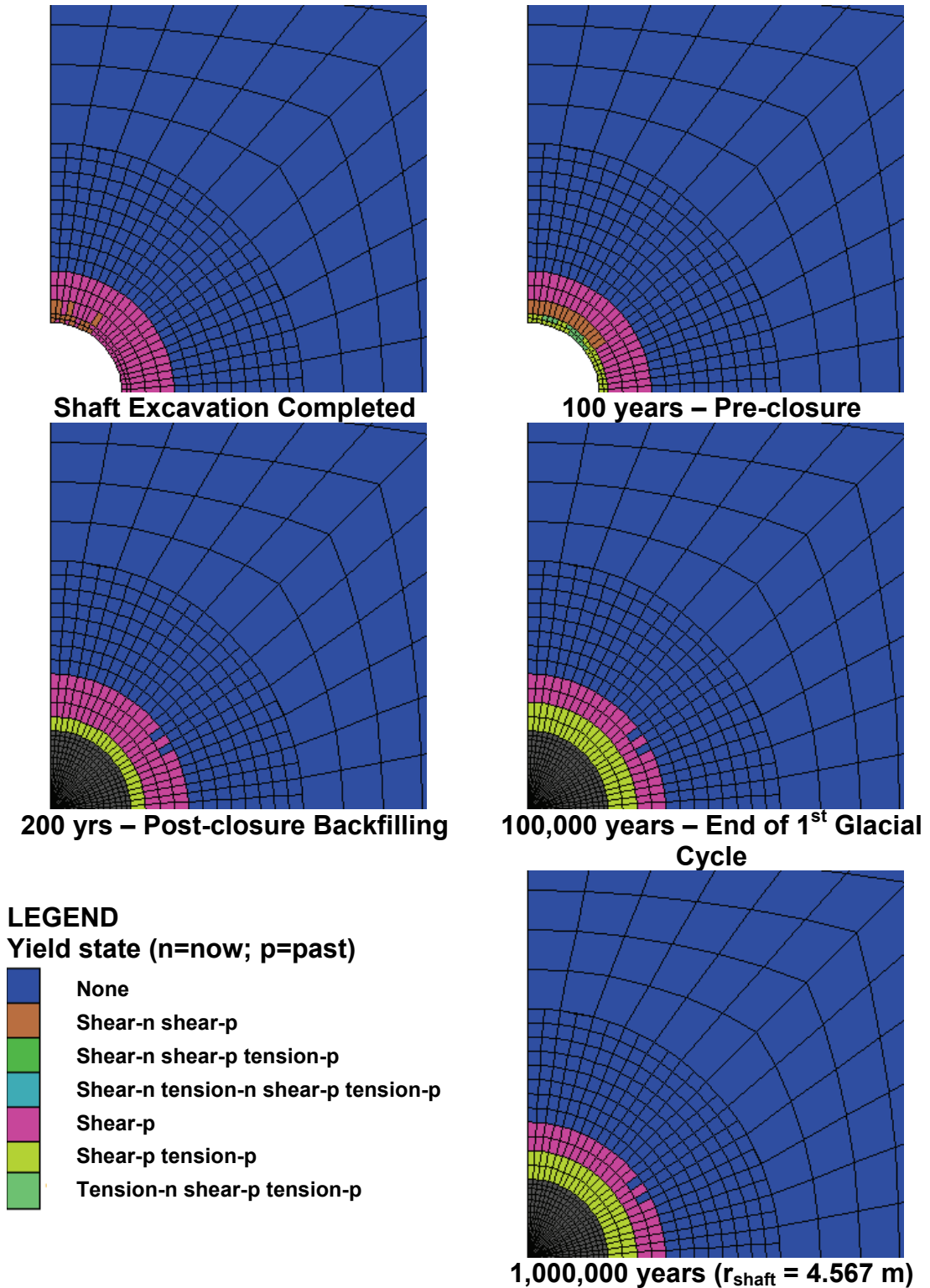


Figure A.29 : Yield State – 22.4 m Below Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Pore Pressure

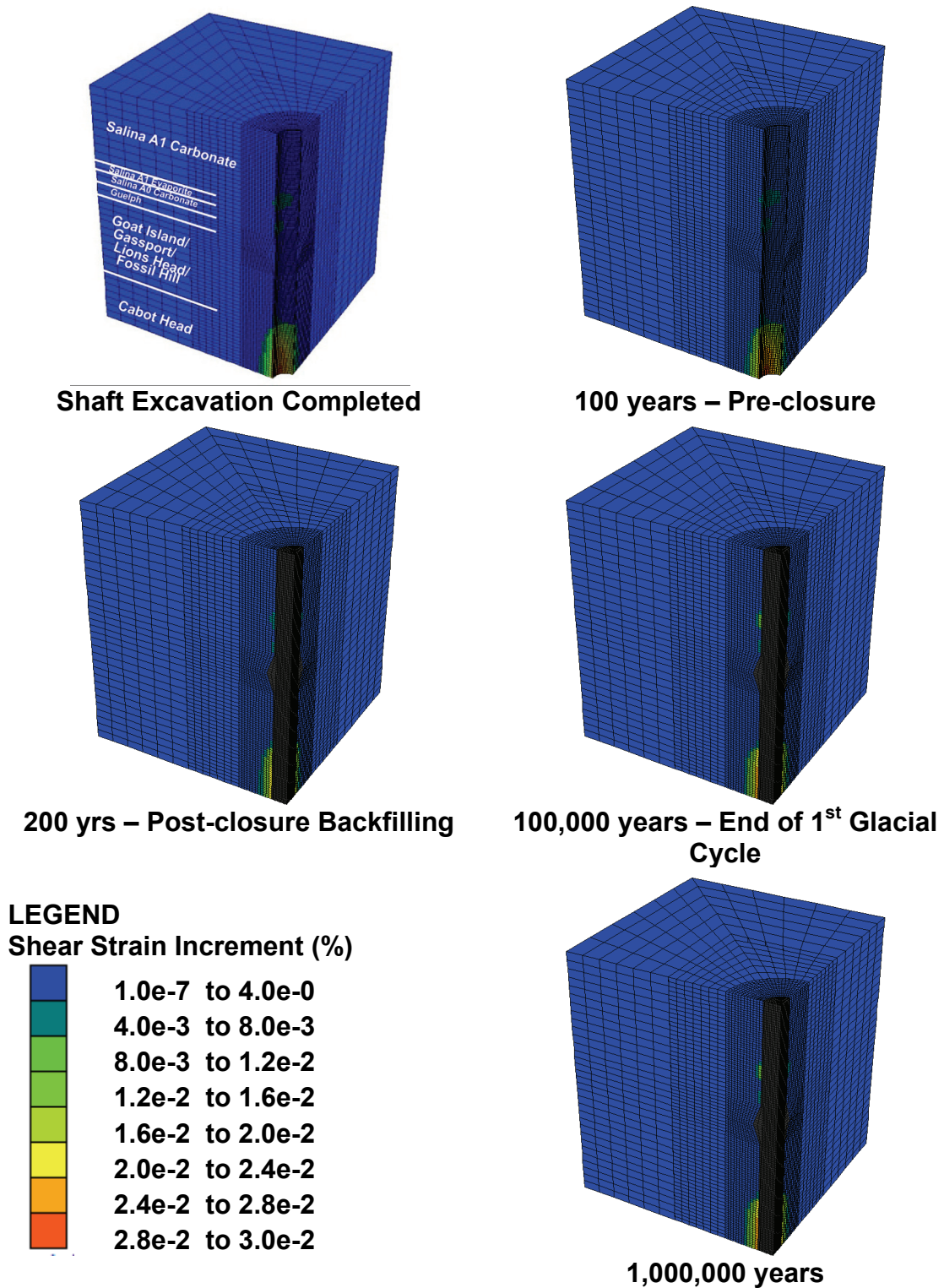


Figure A.30 : Shear strain – Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Pore Pressure

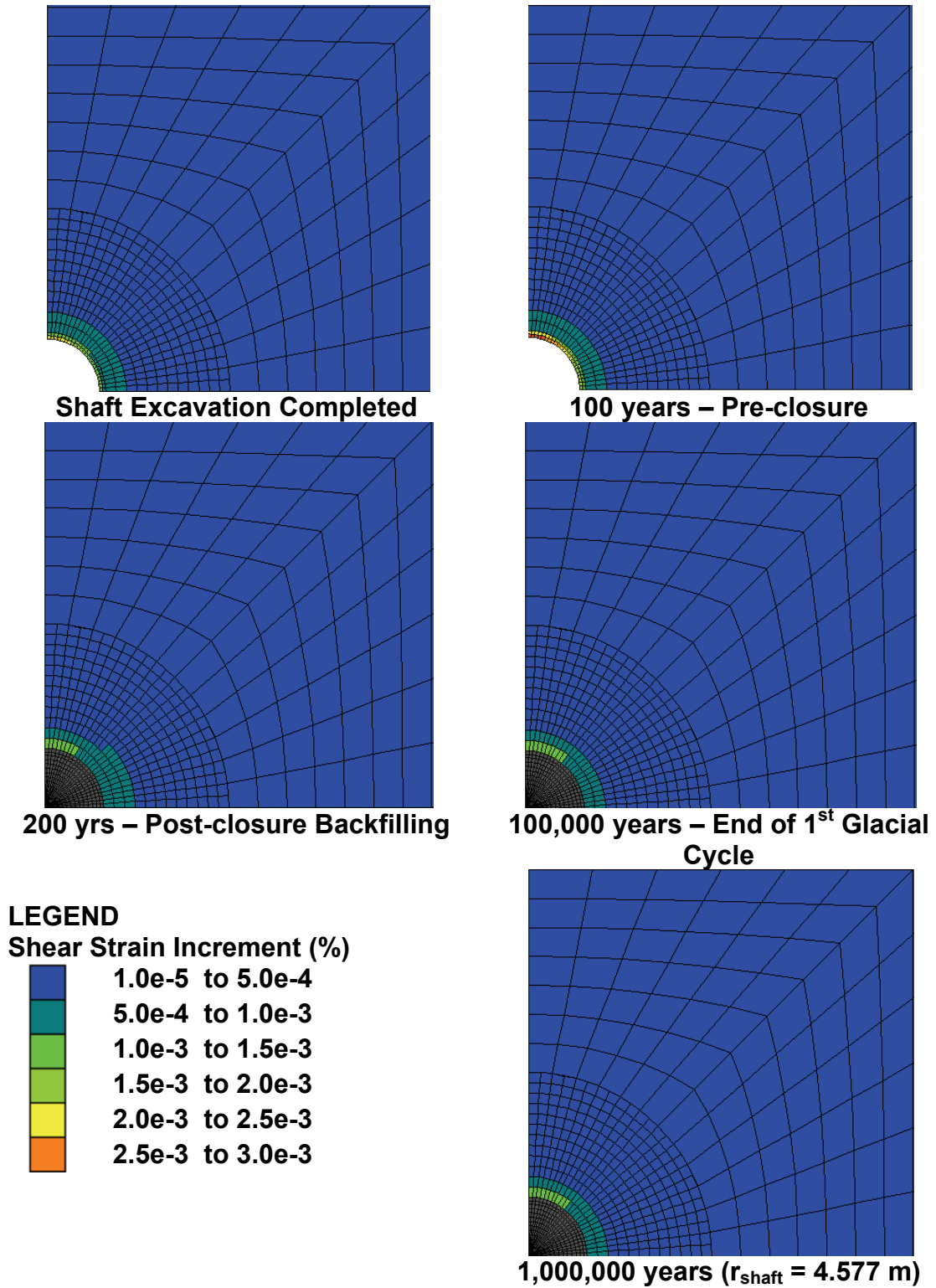


Figure A.31 : Shear Strain – 22.4 m Above Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Pore Pressure



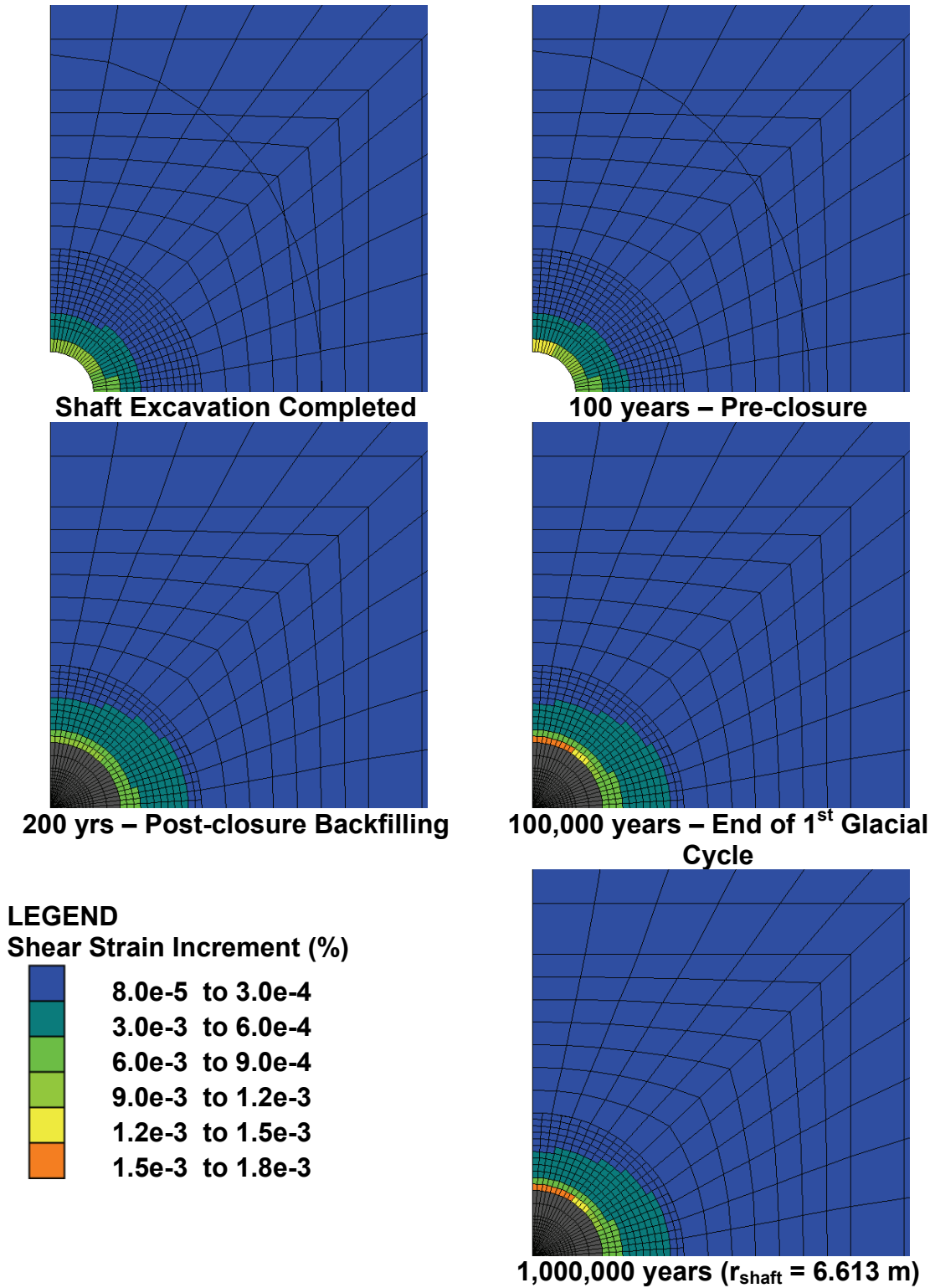
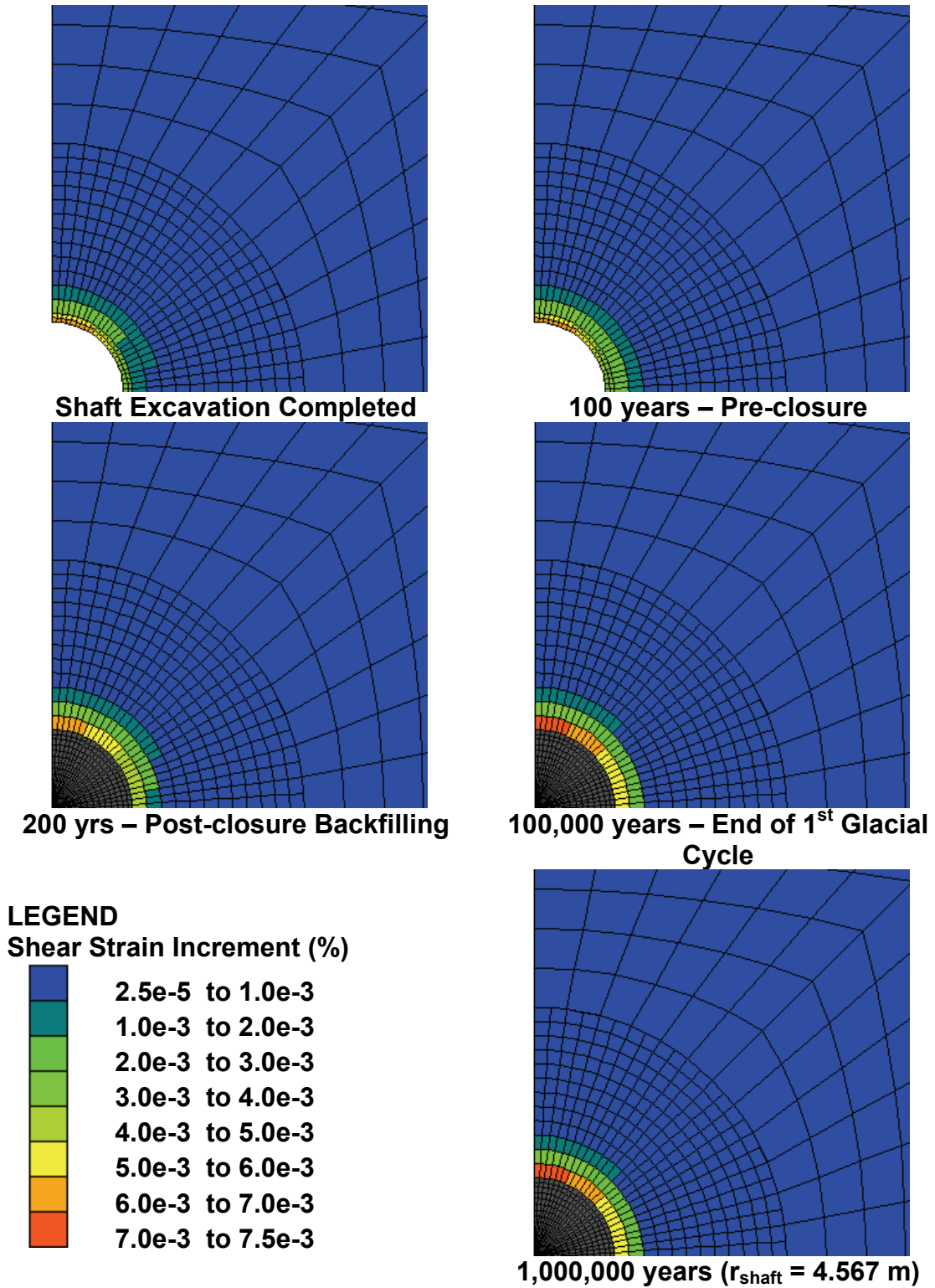


Figure A.32 : Shear Strain – Middle of Concrete Bulkhead: Time-dependent Strength Degradation + Glacial Load + Pore Pressure



**Figure A.33 : Shear Strain – 22.4 m Below Concrete Bulkhead B1: Time-dependent Strength Degradation+ Glacial Load+ Pore Pressure**

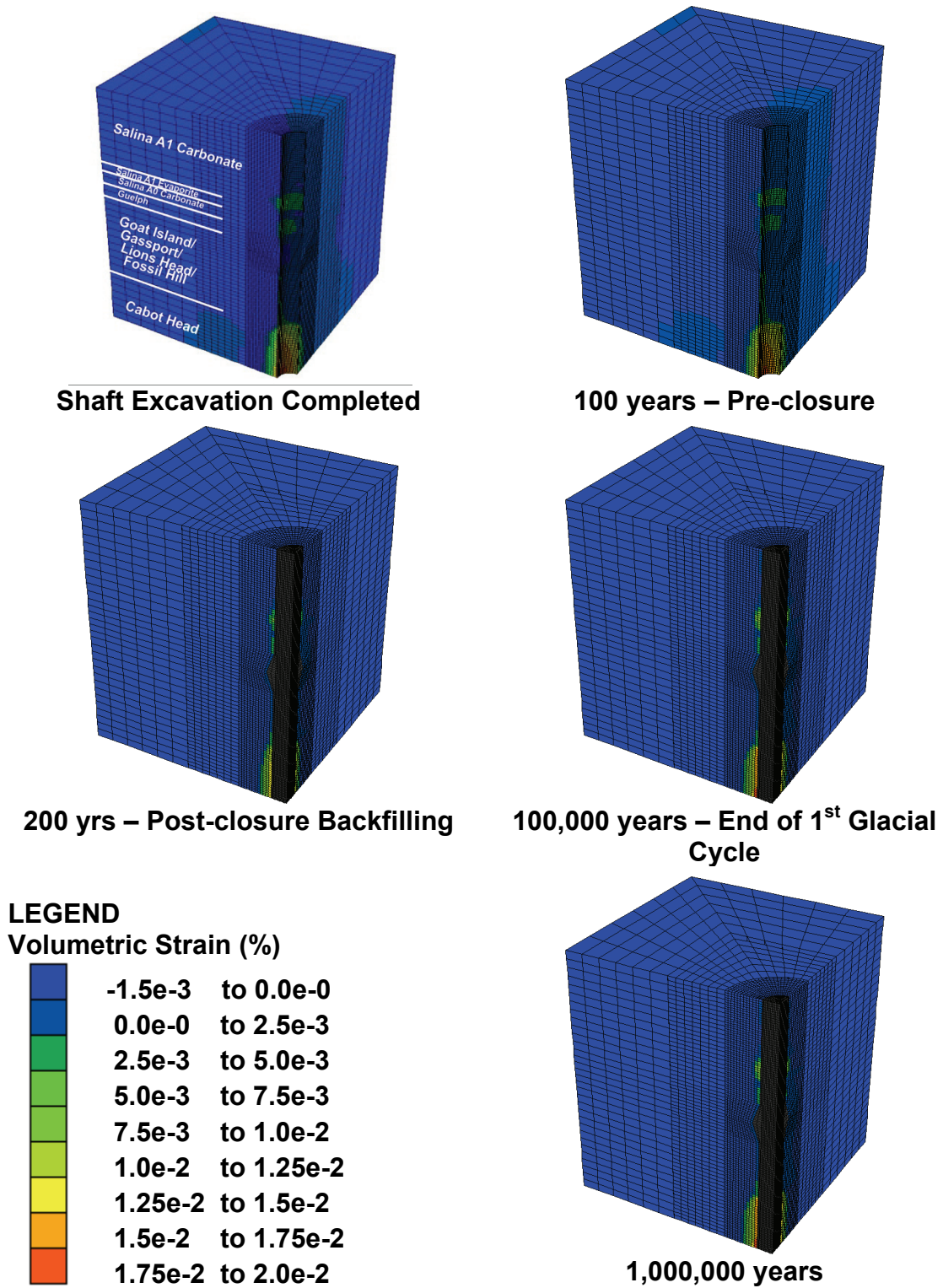
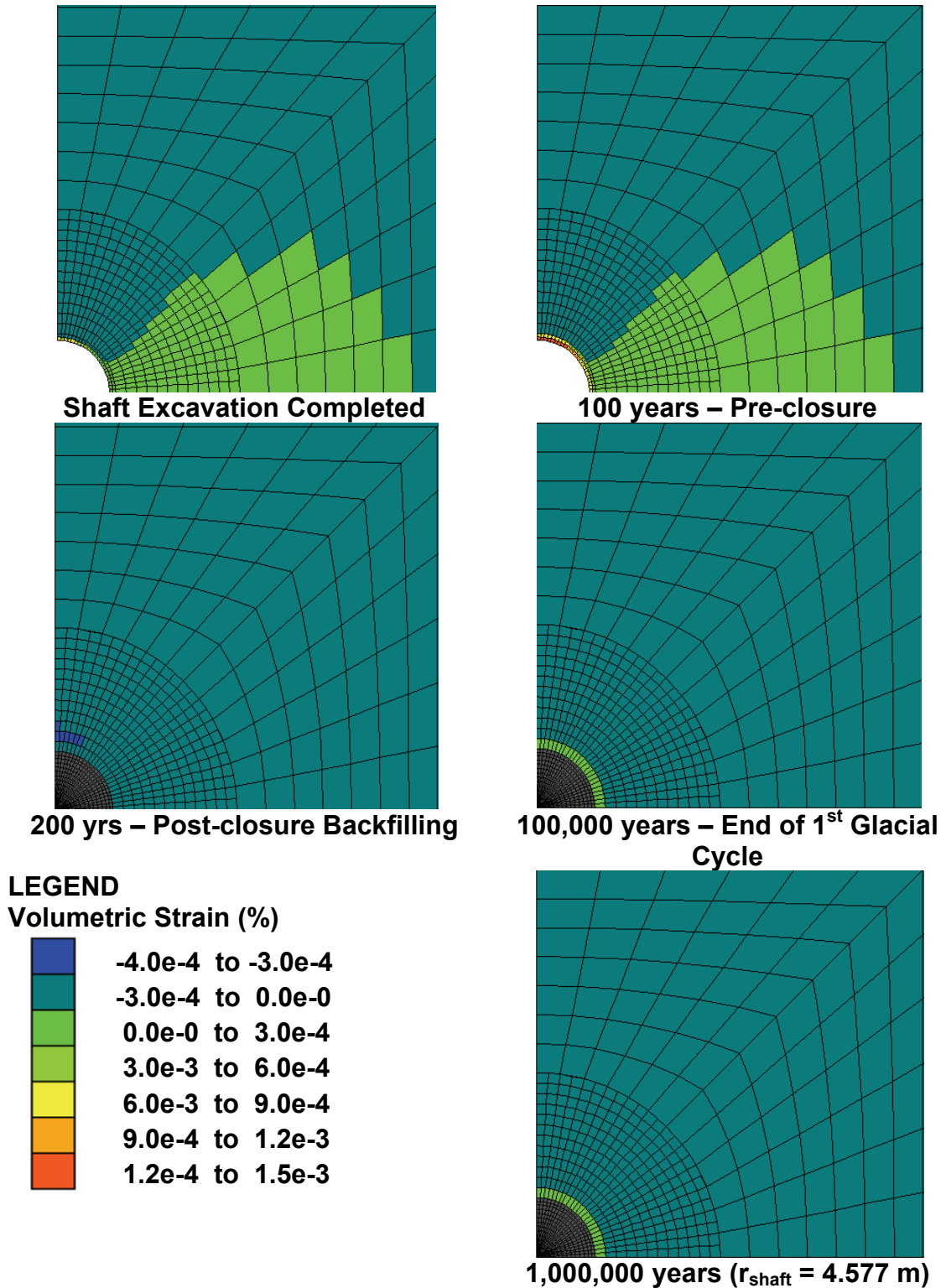


Figure A.34 : Volumetric Strain – Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Pore Pressure



**Figure A.35 : Volumetric Strain – 22.4 m Above Concrete Bulkhead B1:  
 Time-dependent Strength Degradation + Glacial Load + Pore Pressure**

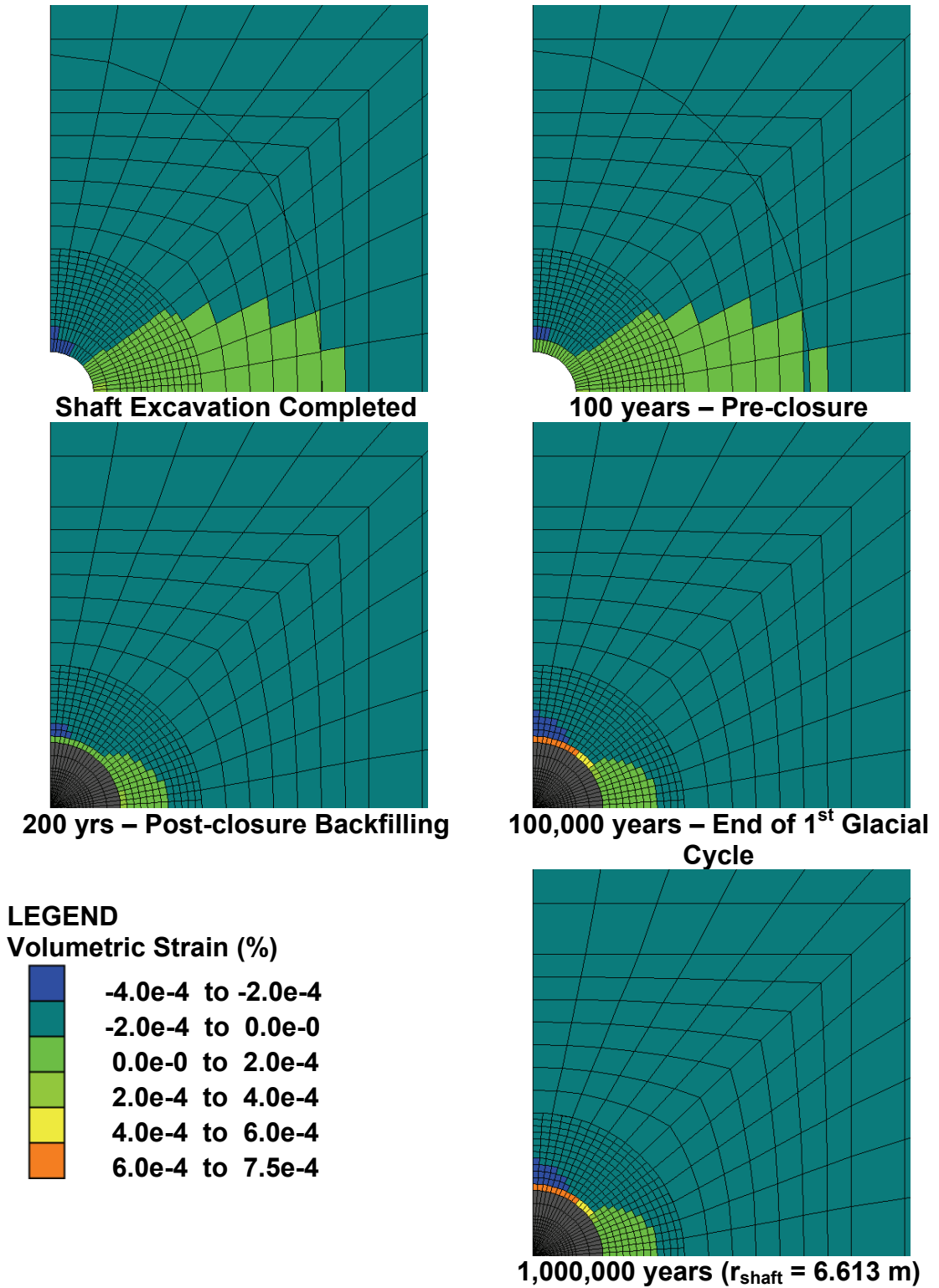
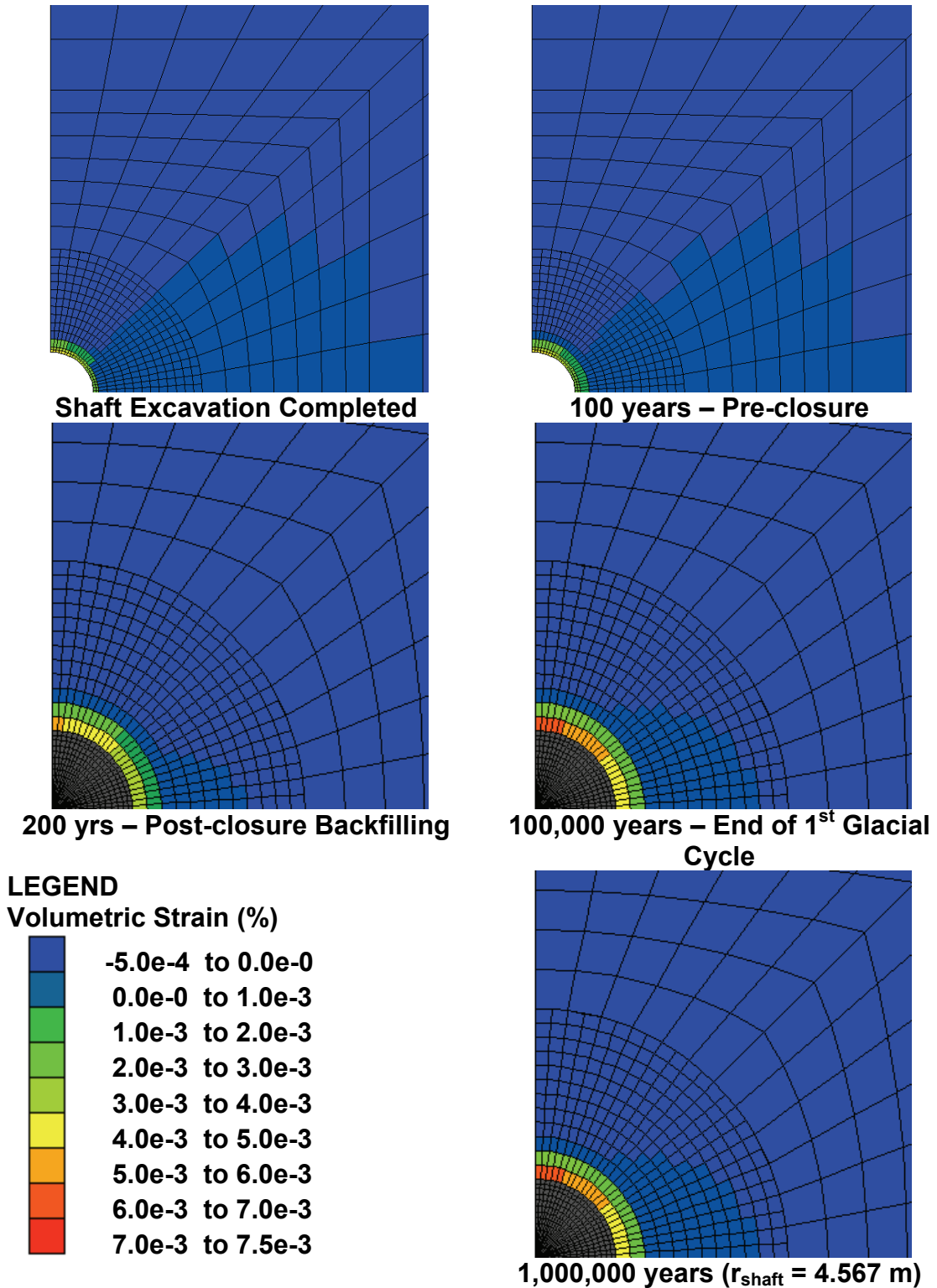
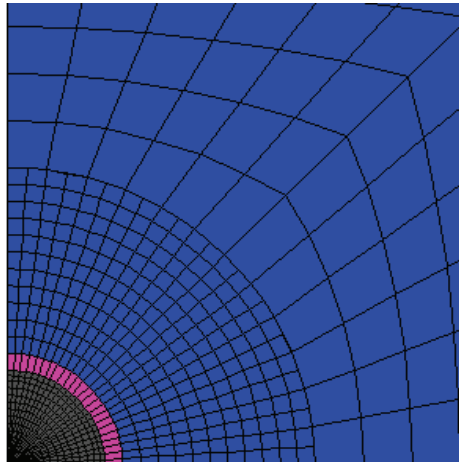


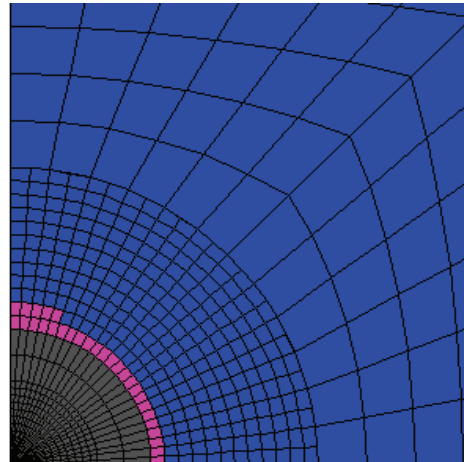
Figure A.36 : Volumetric Strain – Middle of Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Pore Pressure



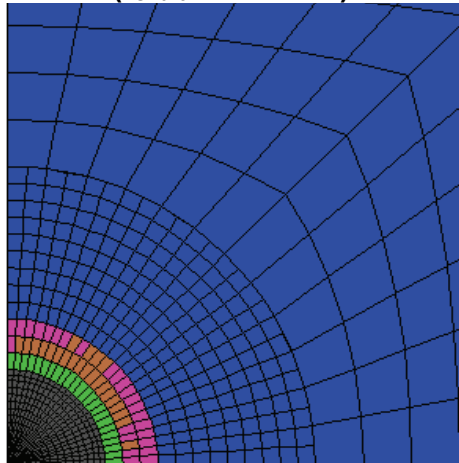
**Figure A.37 : Volumetric Strain – 22.4m Below Concrete Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Pore Pressure**



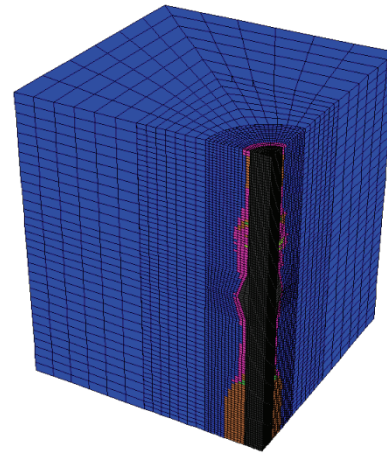
22.4 m above concrete bulkhead  
( $r_{\text{shaft}} = 4.574 \text{ m}$ )



Middle of concrete bulkhead B1  
( $r_{\text{shaft}} = 6.612 \text{ m}$ )



22.4 m below concrete bulkhead  
( $r_{\text{shaft}} = 4.561 \text{ m}$ )



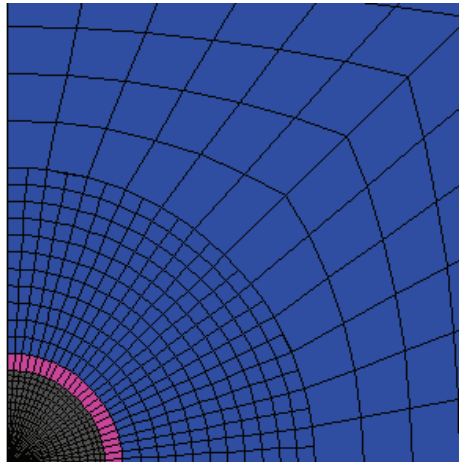
Isometric view

**LEGEND**

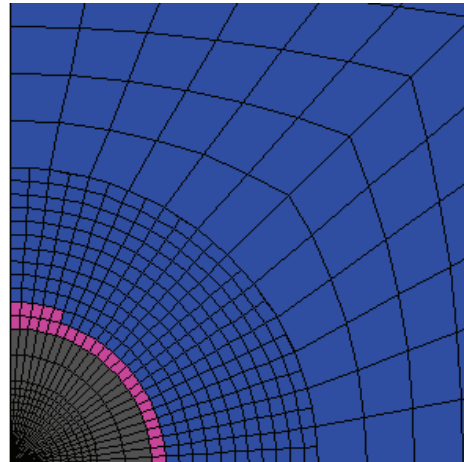
Yield state (n=now; p=past)

	None
	Shear-p
	Shear-p tension-p

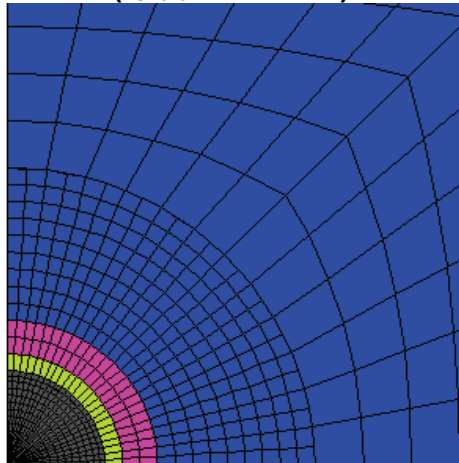
**Figure A.38 : Yield State – Bulkhead B1: Time-dependent Strength Degradation + Glacial Load Before Earthquake**



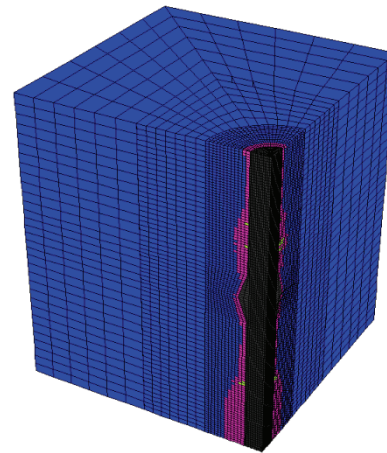
22.4 m above concrete bulkhead  
( $r_{\text{shaft}} = 4.572 \text{ m}$ )



Middle of concrete bulkhead B1  
( $r_{\text{shaft}} = 6.565 \text{ m}$ )



22.4 m below concrete bulkhead  
( $r_{\text{shaft}} = 4.569 \text{ m}$ )



Isometric view

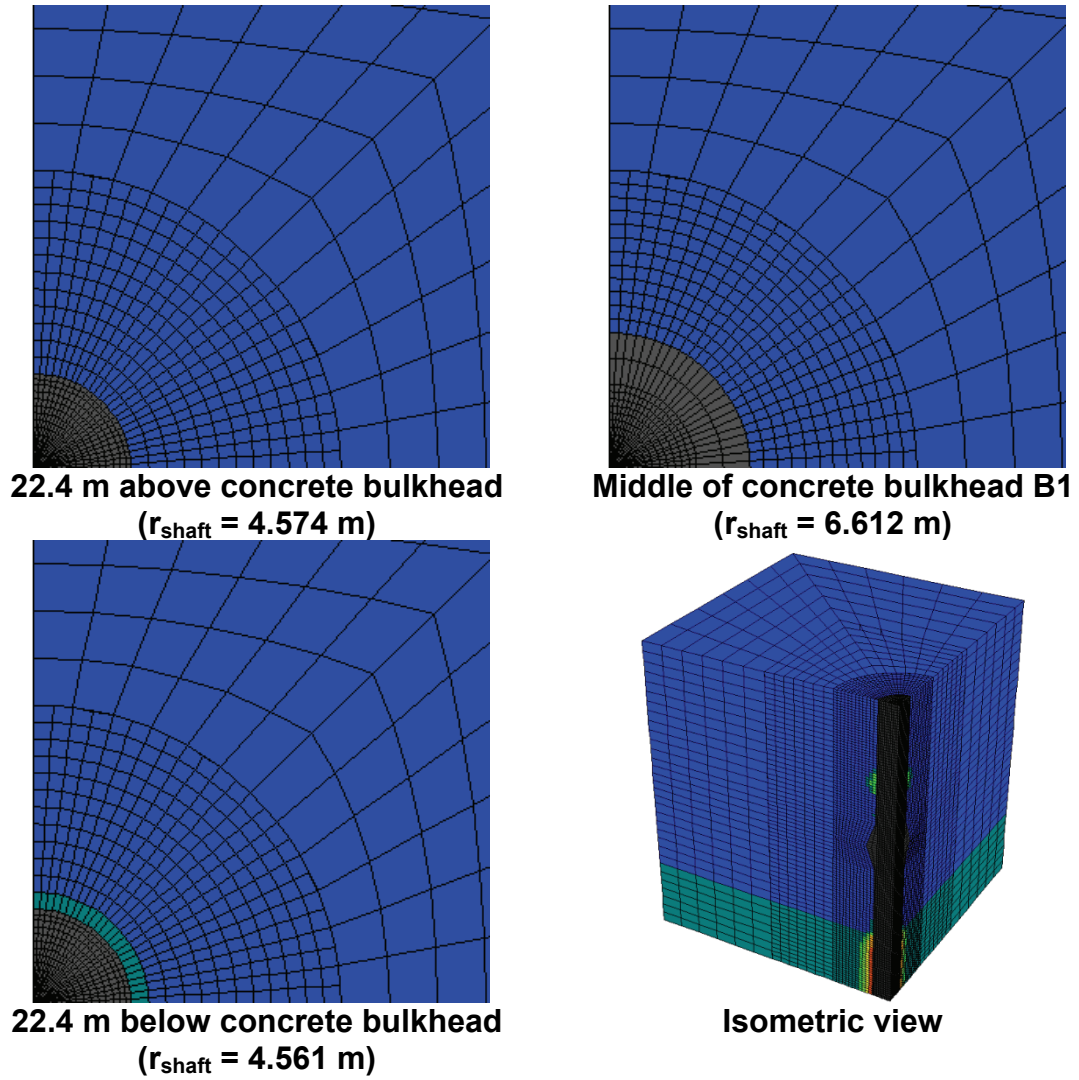
**LEGEND**

Yield state (n=now; p=past)

	None
	Shear-p
	Shear-p tension-p

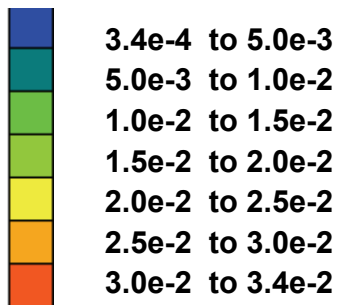
**Figure A.39 : Yield State – Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Earthquake**



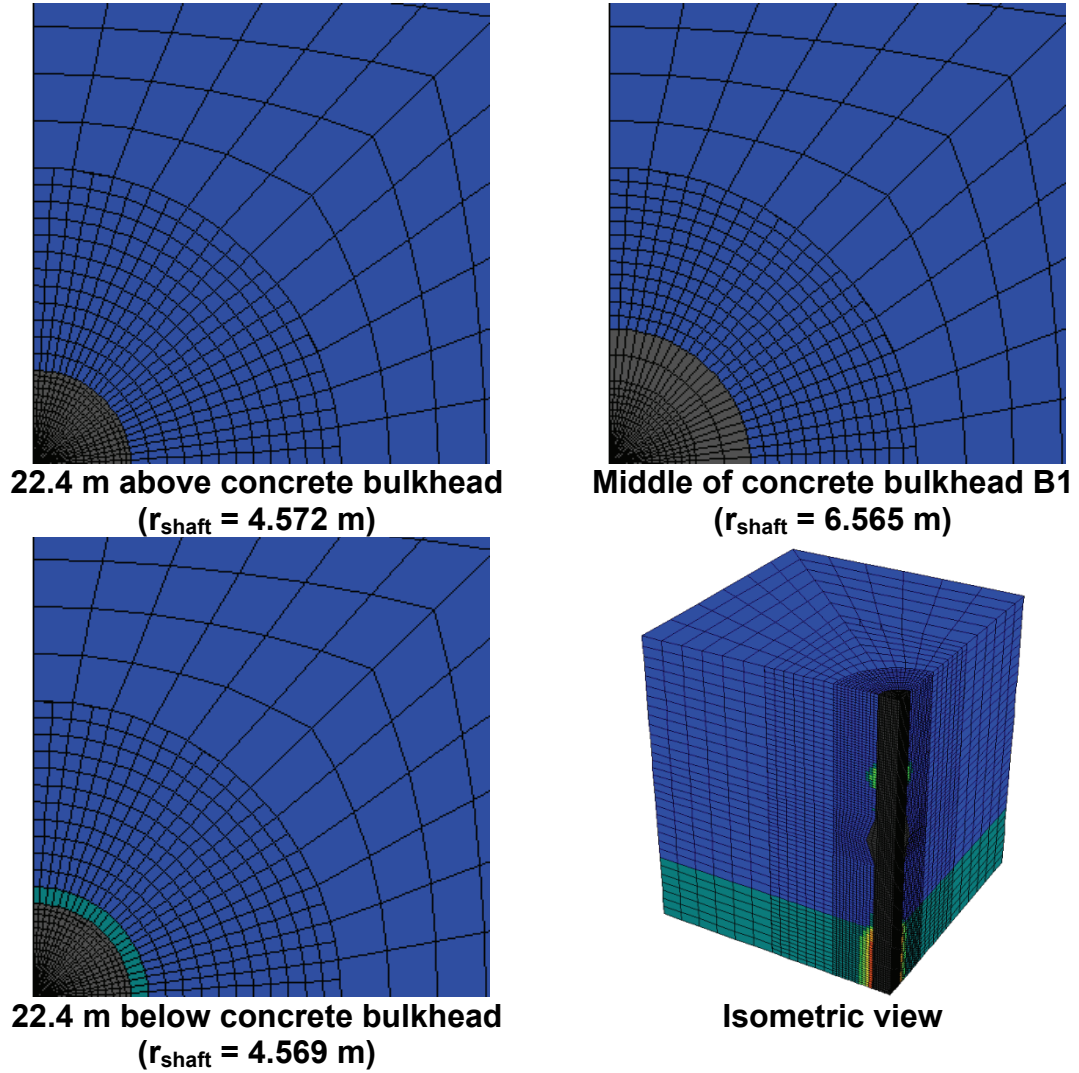


**LEGEND**

Shear Strain Increment (%)

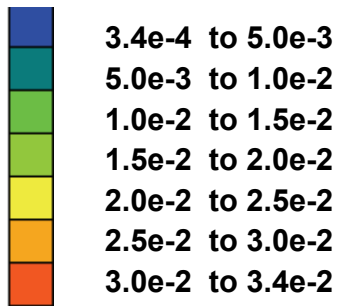


**Figure A.40 : Shear Strain – Bulkhead B1: Time-dependent Strength Degradation + Glacial Load Before Earthquake**

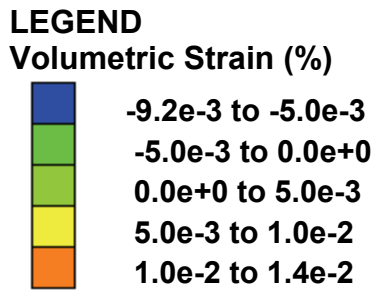
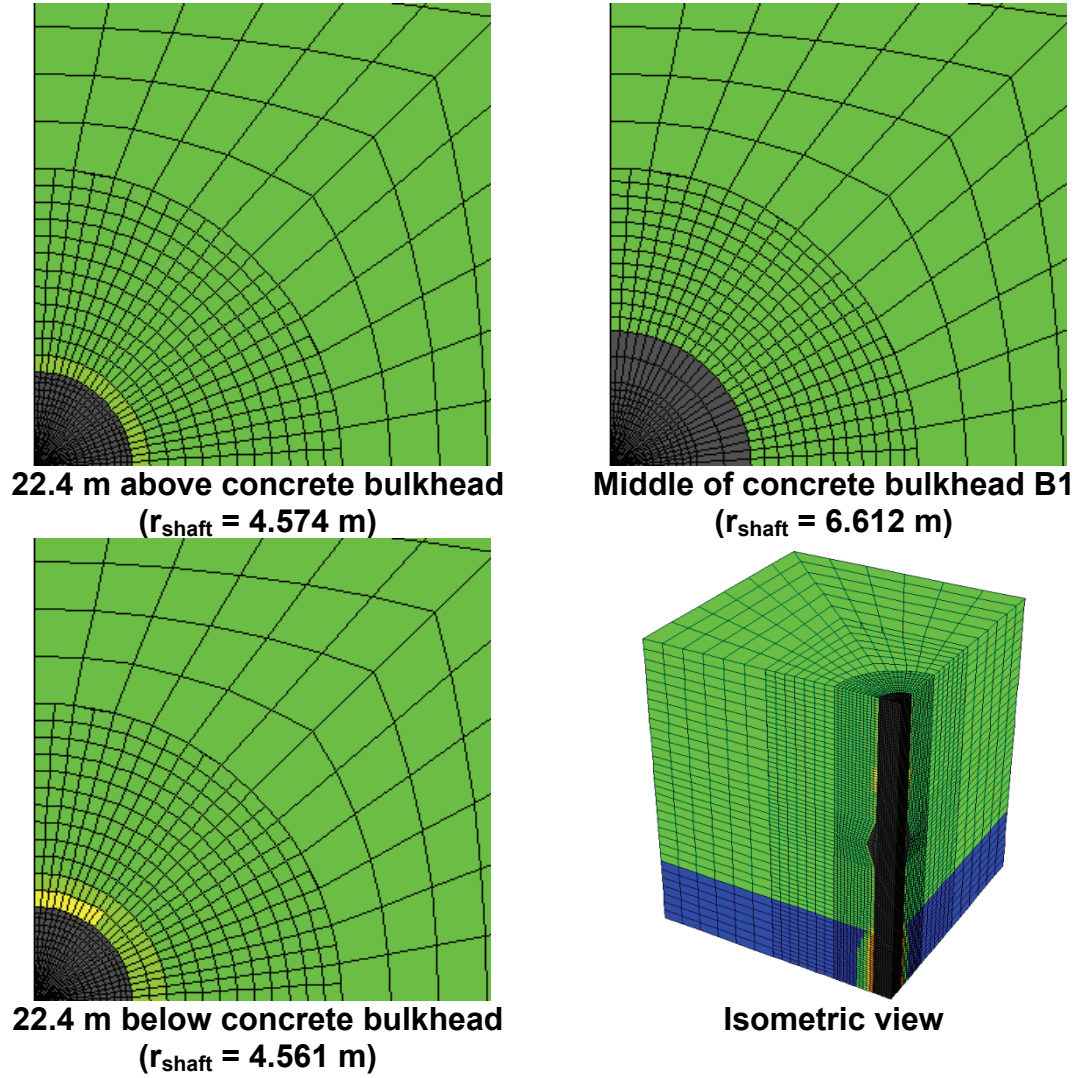


**LEGEND**

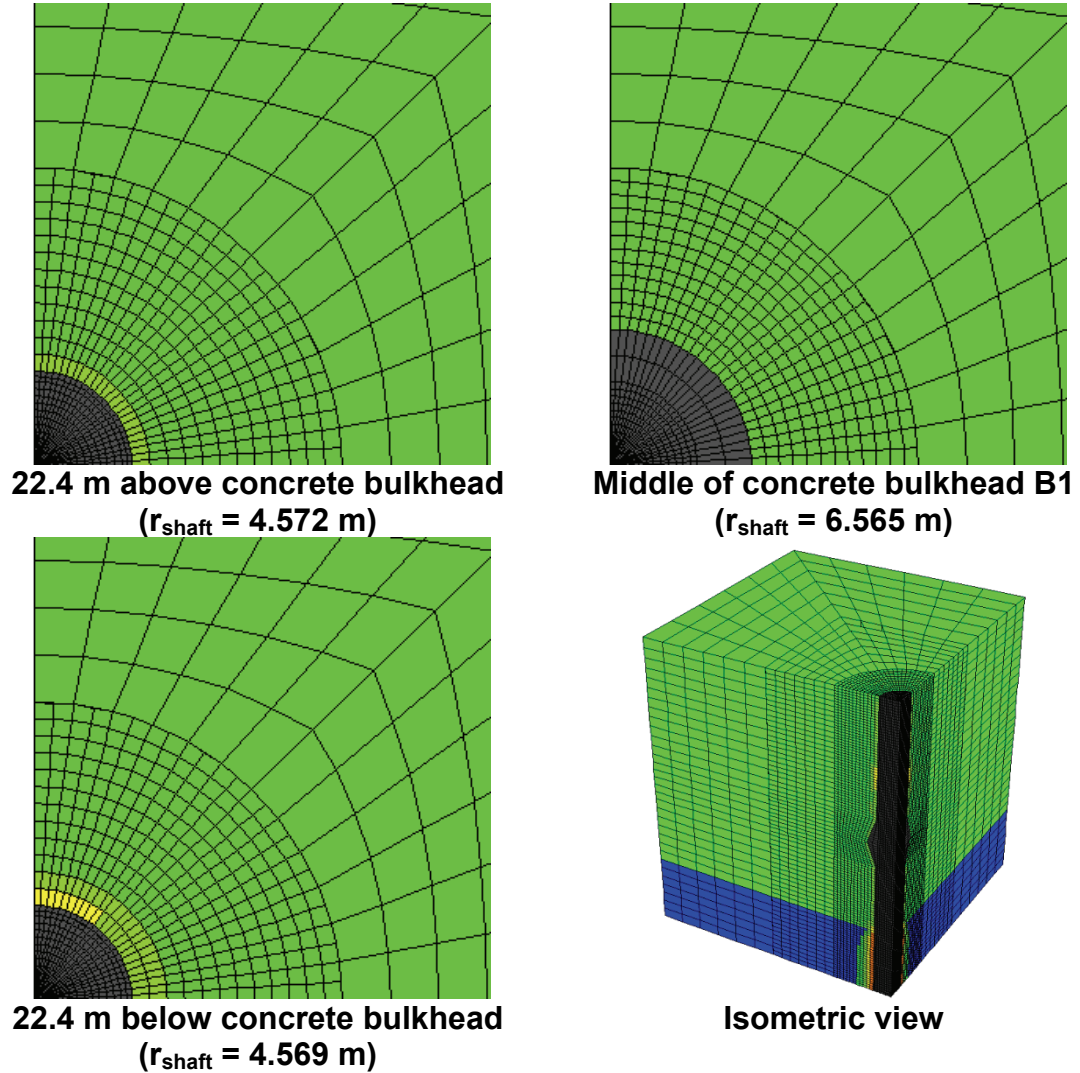
Shear Strain Increment (%)



**Figure A.41 : Shear Strain – Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Earthquake**

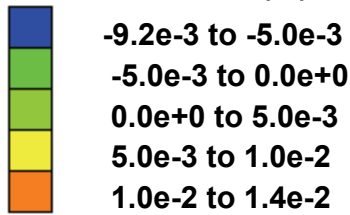


**Figure A.42 : Volumetric Strain – Bulkhead B1: Time-dependent Strength Degradation + Glacial Load Before Earthquake**



**LEGEND**

**Volumetric Strain (%)**



**Figure A.43 : Volumetric Strain – Bulkhead B1: Time-dependent Strength Degradation + Glacial Load + Earthquake**