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Seismic Responses of Underground Excavations in Jointed Rock Mass

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GoldenRocks 2006

Golden, Colorado; June 17–21, 2006



Outline

-
- **Introduction**
 - **Objectives**
 - **Case investigations**
 - **Lucky Friday Mine field study**
 - **Laboratory testing of scale model study**
 - **Conclusions**



Introduction

- **Damages of underground excavations due to single event of seismic ground motion have been widely recognized**
- **Effects of repetitive ground motions received little attention**
- **Evidence indicates that a jointed rock mass exhibits fatigue behavior: accumulation of joint shear displacements**



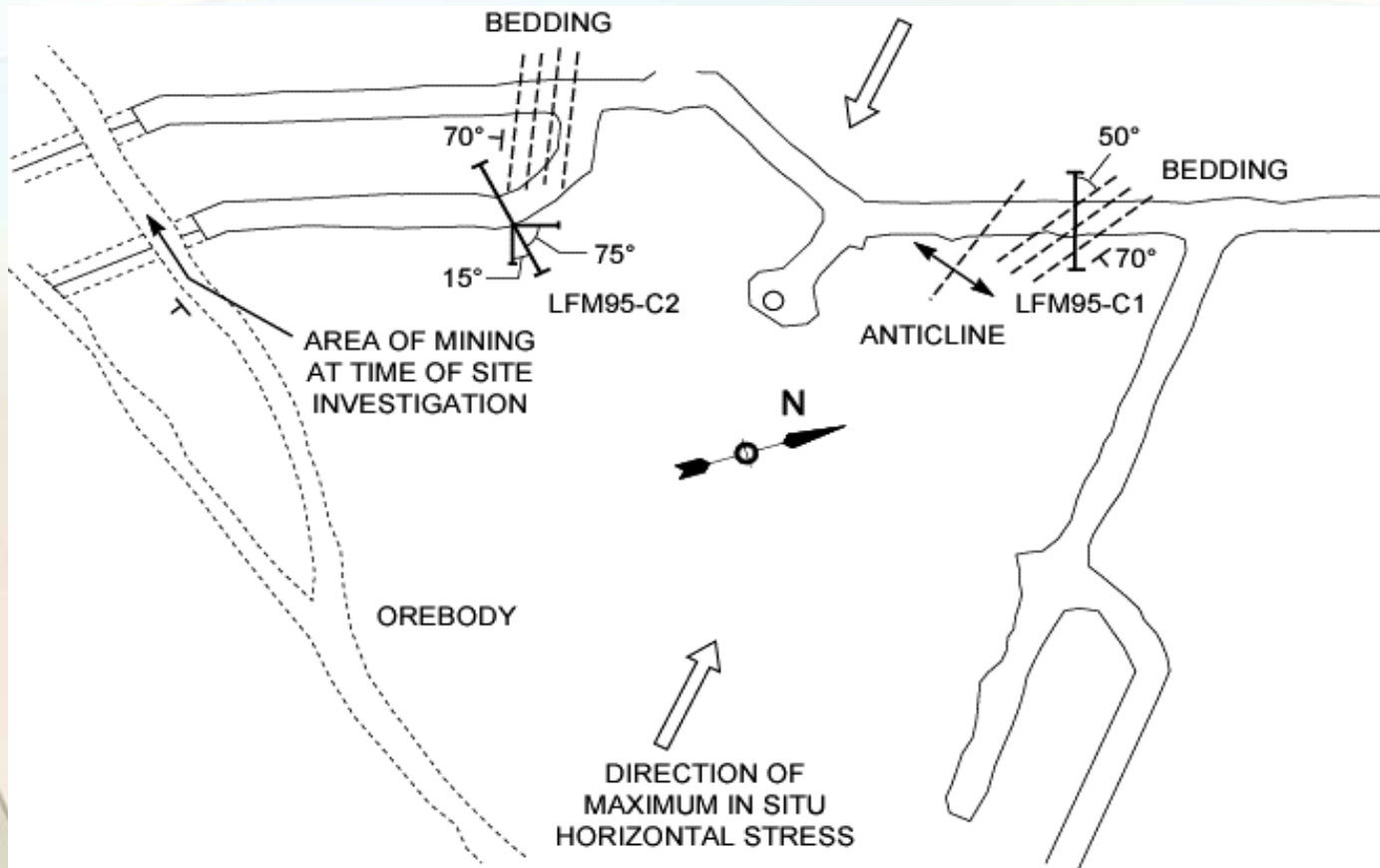
Objectives

- **Develop a better understanding of repetitive seismic ground motion effects on excavation stability through field instrumentation and experiments in a controlled environment**
- **Generate reference data for quantifying the relationship between ground motions and rock mass responses**

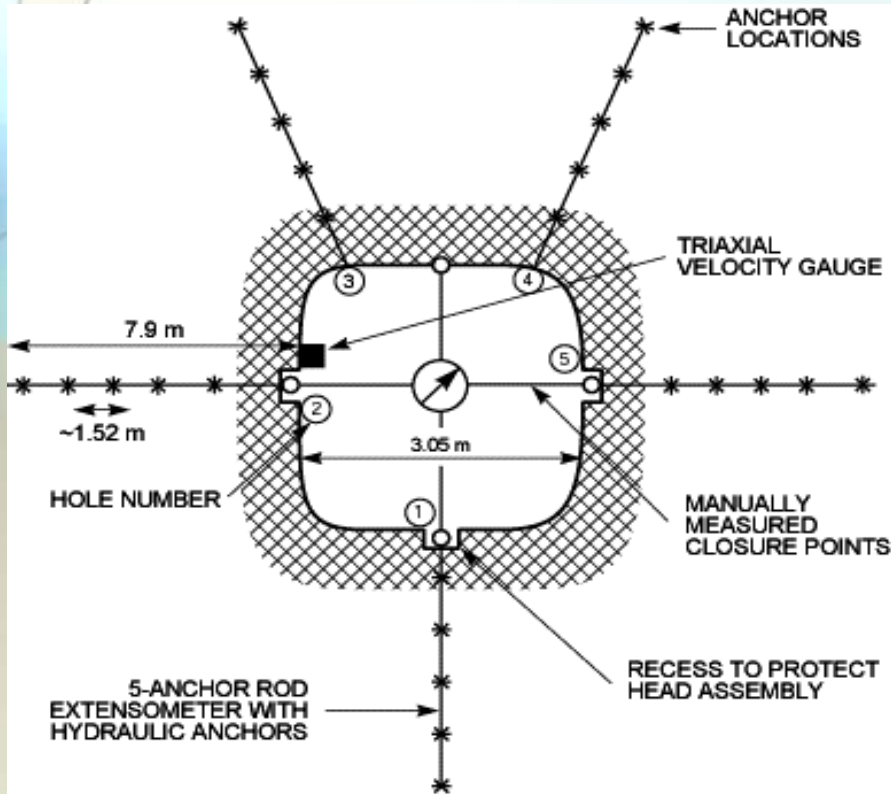


Instrumentation Locations of Field Study

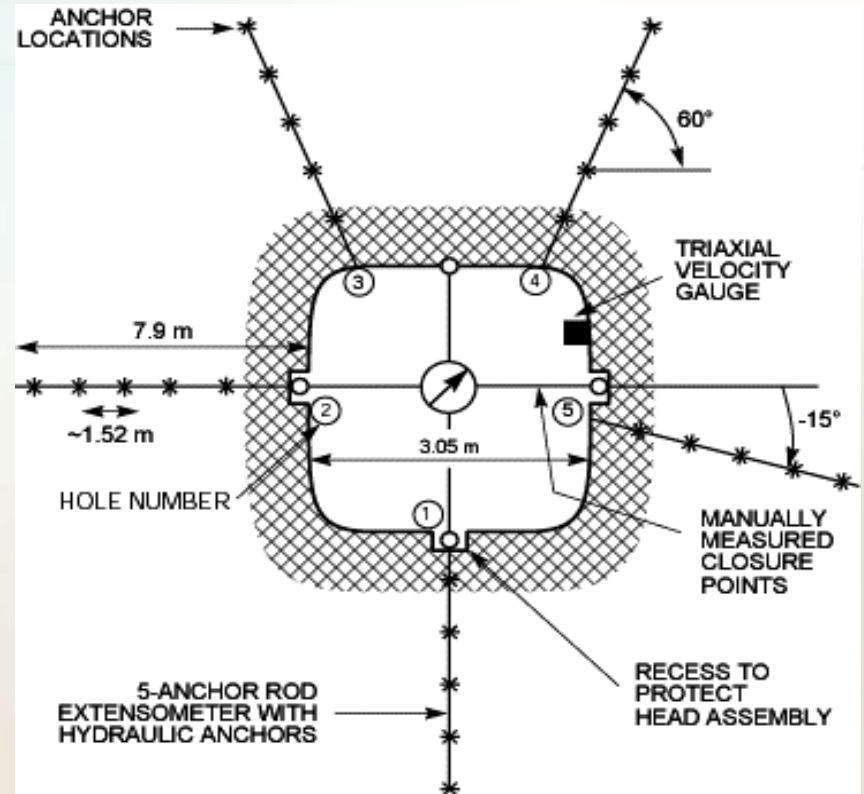
- Locations of instrumentation at the 5,210 ft level of the Lucky Friday mine



Instrumentation Arrays

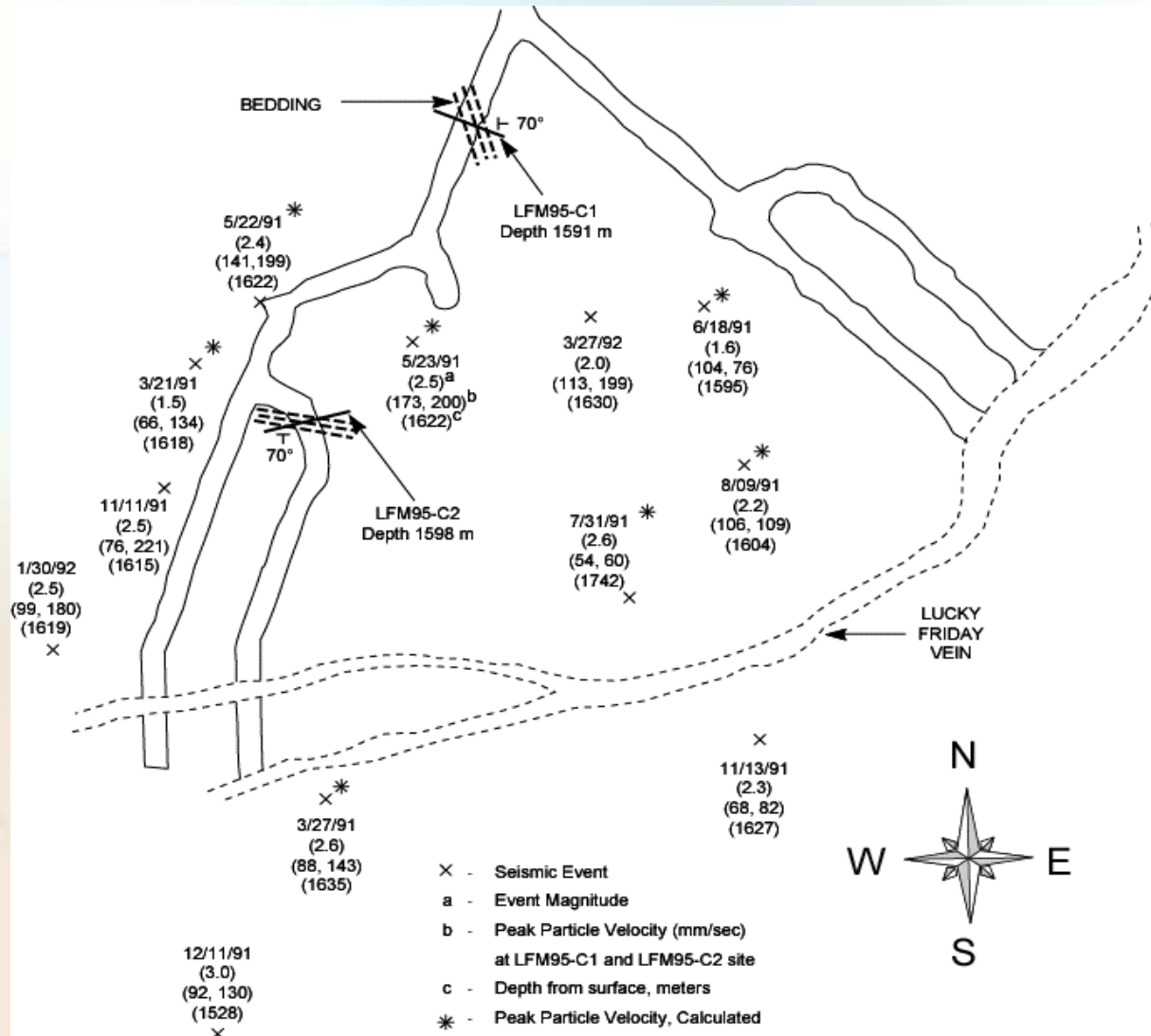


(a) LFM 95-C1 Site

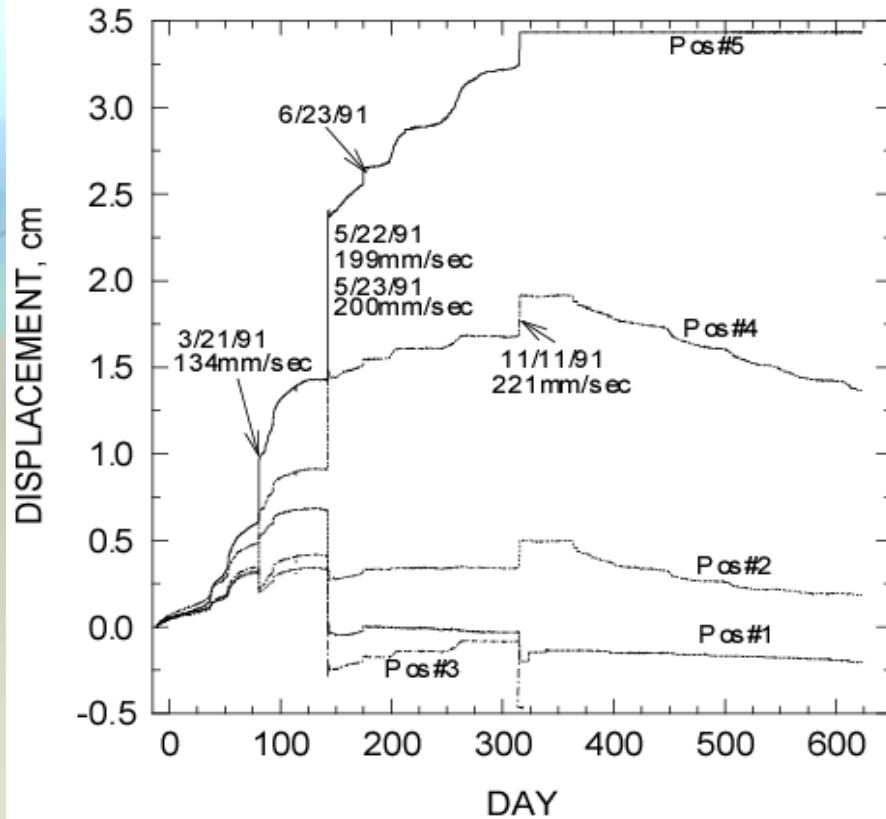


(b) LFM 95-C2 Site

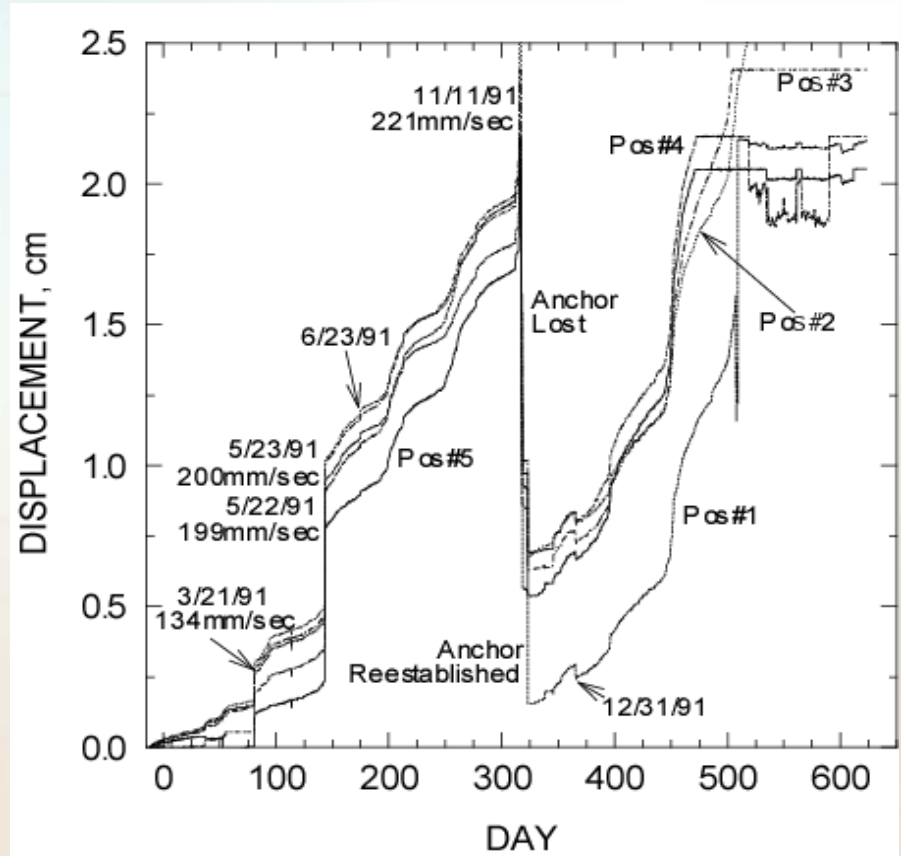
Recorded Mine Seismic Events Near the Instrumentation Sites



Seismicity-Induced Step Changes in Displacements at LFM95-C2 Site



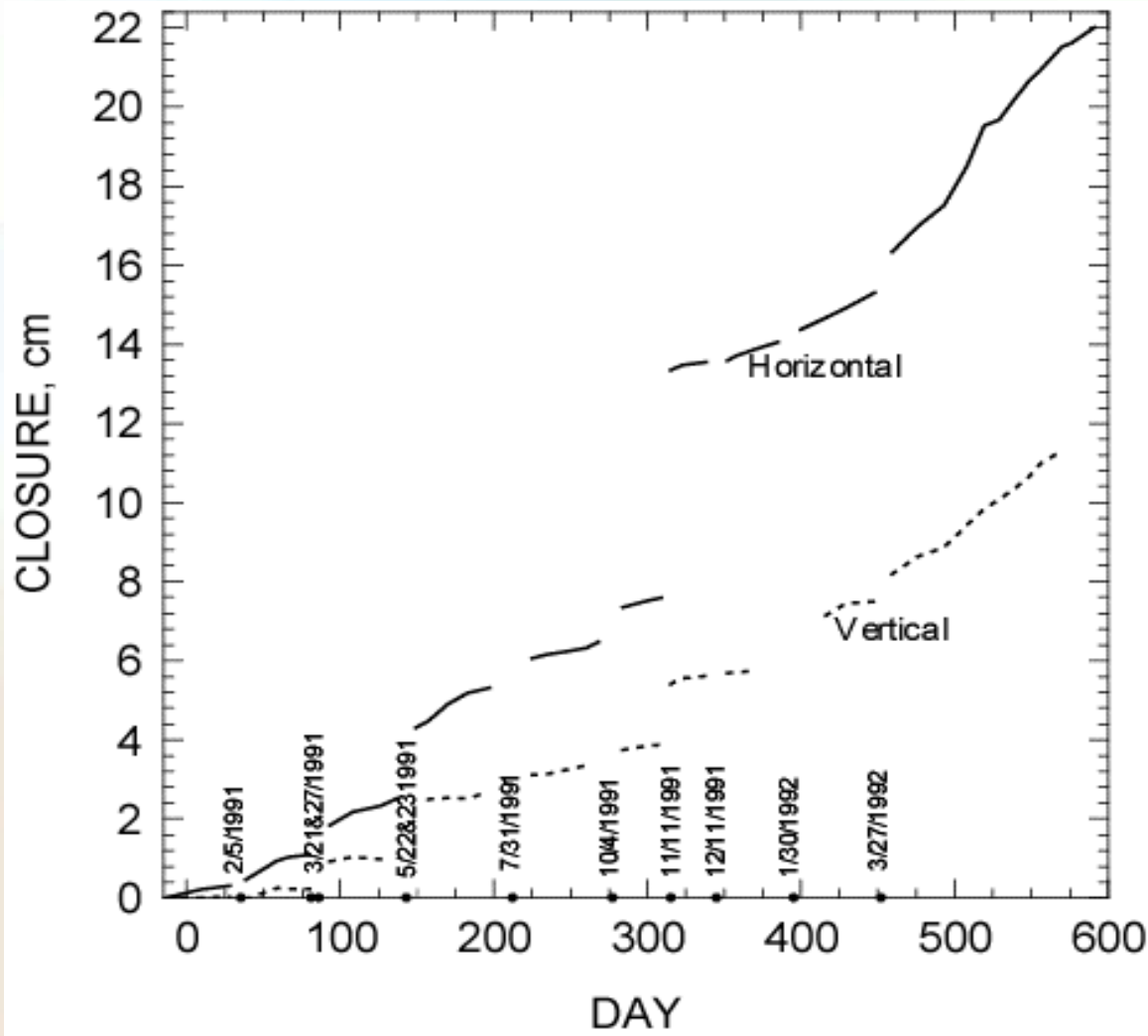
Extensometer No. 1



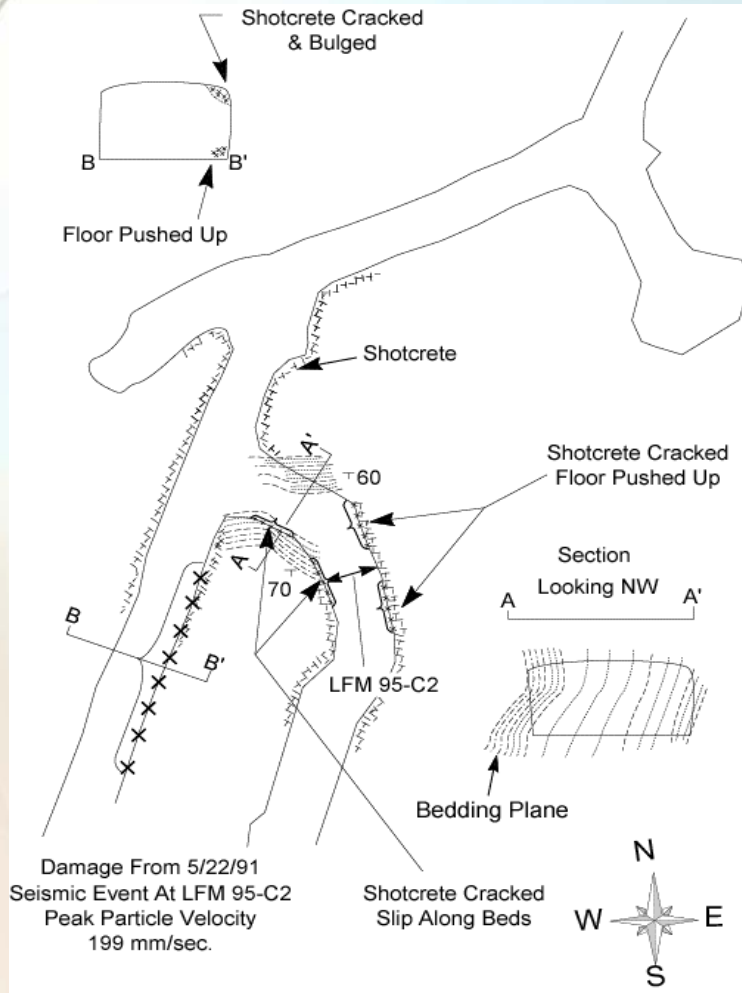
Extensometer No. 5



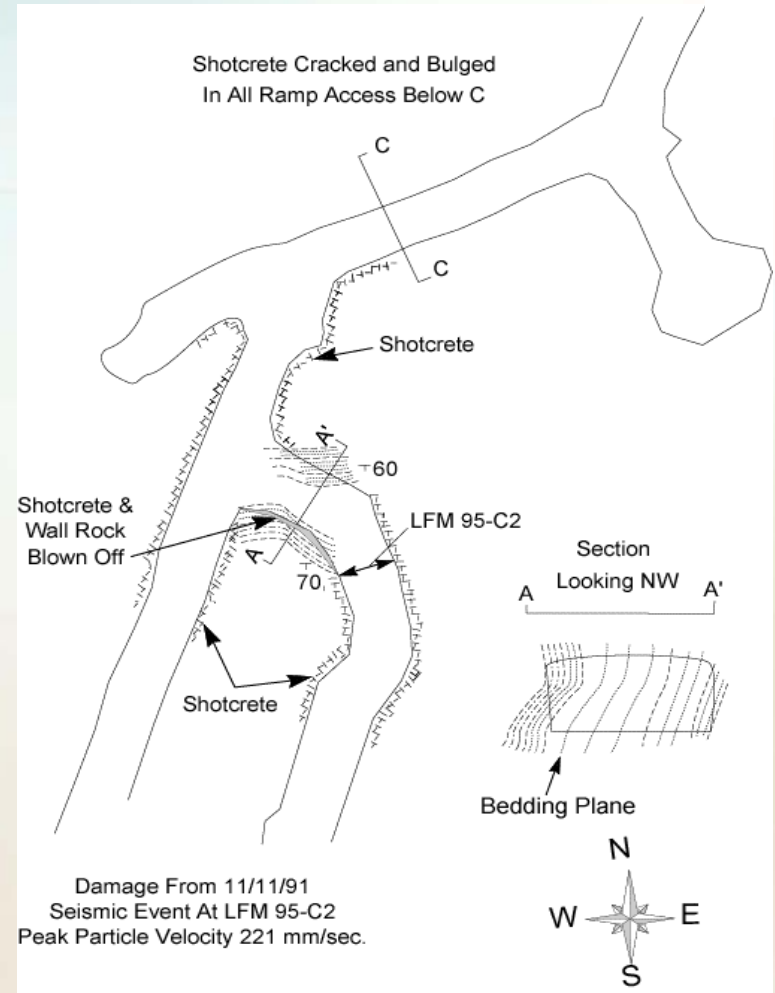
Seismicity-Induced Step Changes in Closure at LFM95-C2 site



Cumulative Damages Observed at Lucky Friday Mine

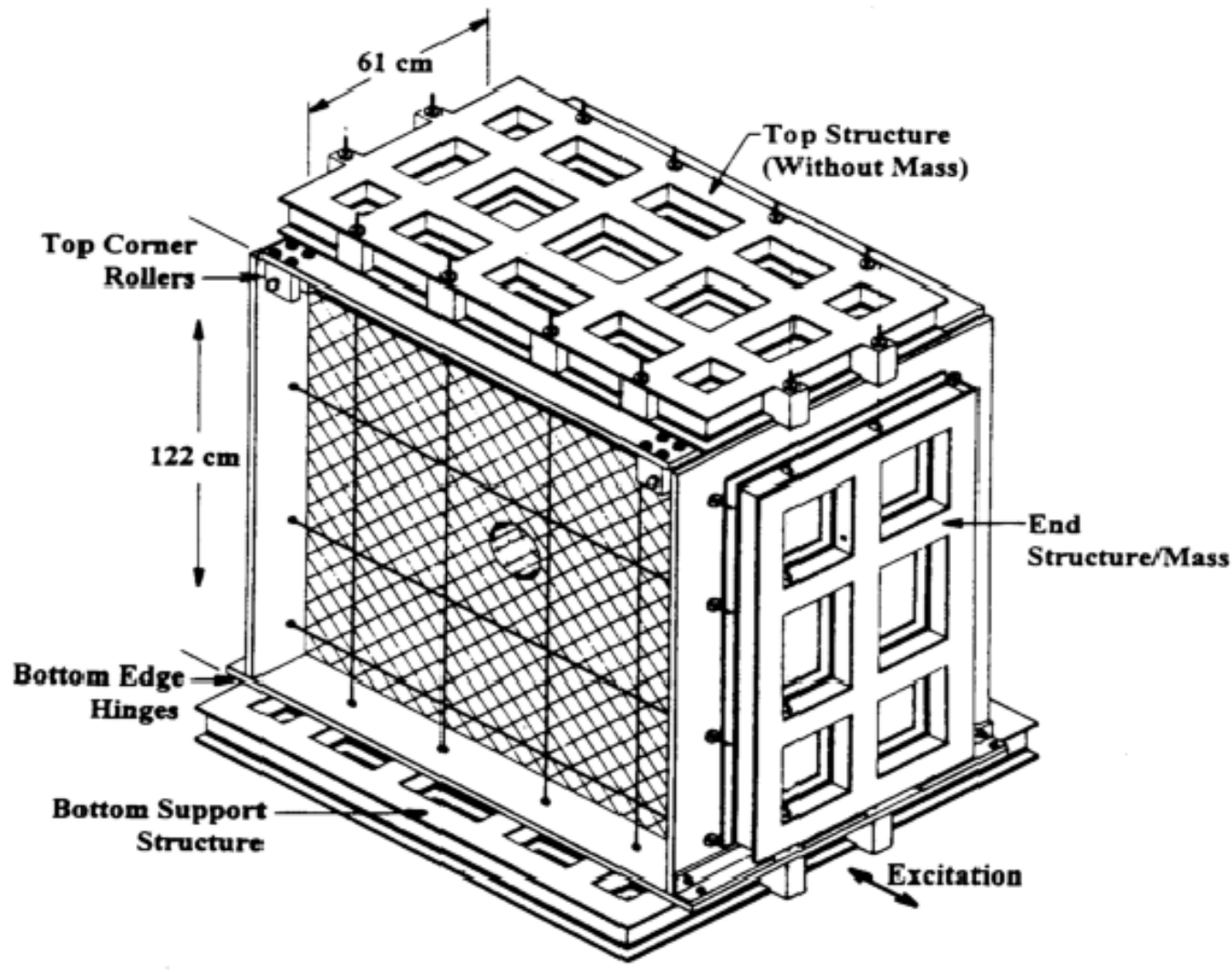


May 22 and 23, 1991 Events



November 11, 1991 Event

Small Scale Rock Mass Experimental Setup



Instrumentation on One Side of the Model

Nomenclature

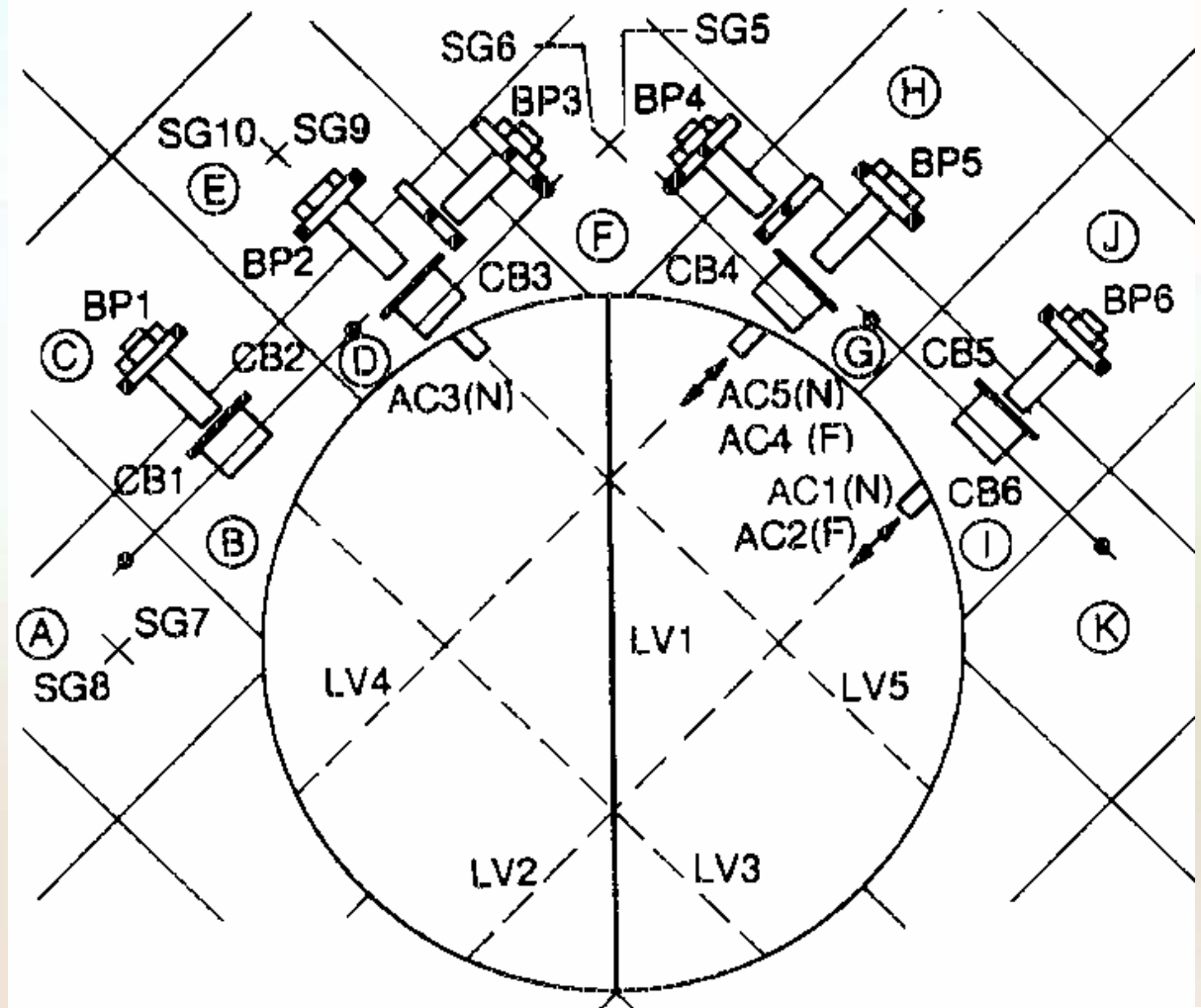
LV: LVDT

CB: Cantilever
beam

BP: Bentley probe

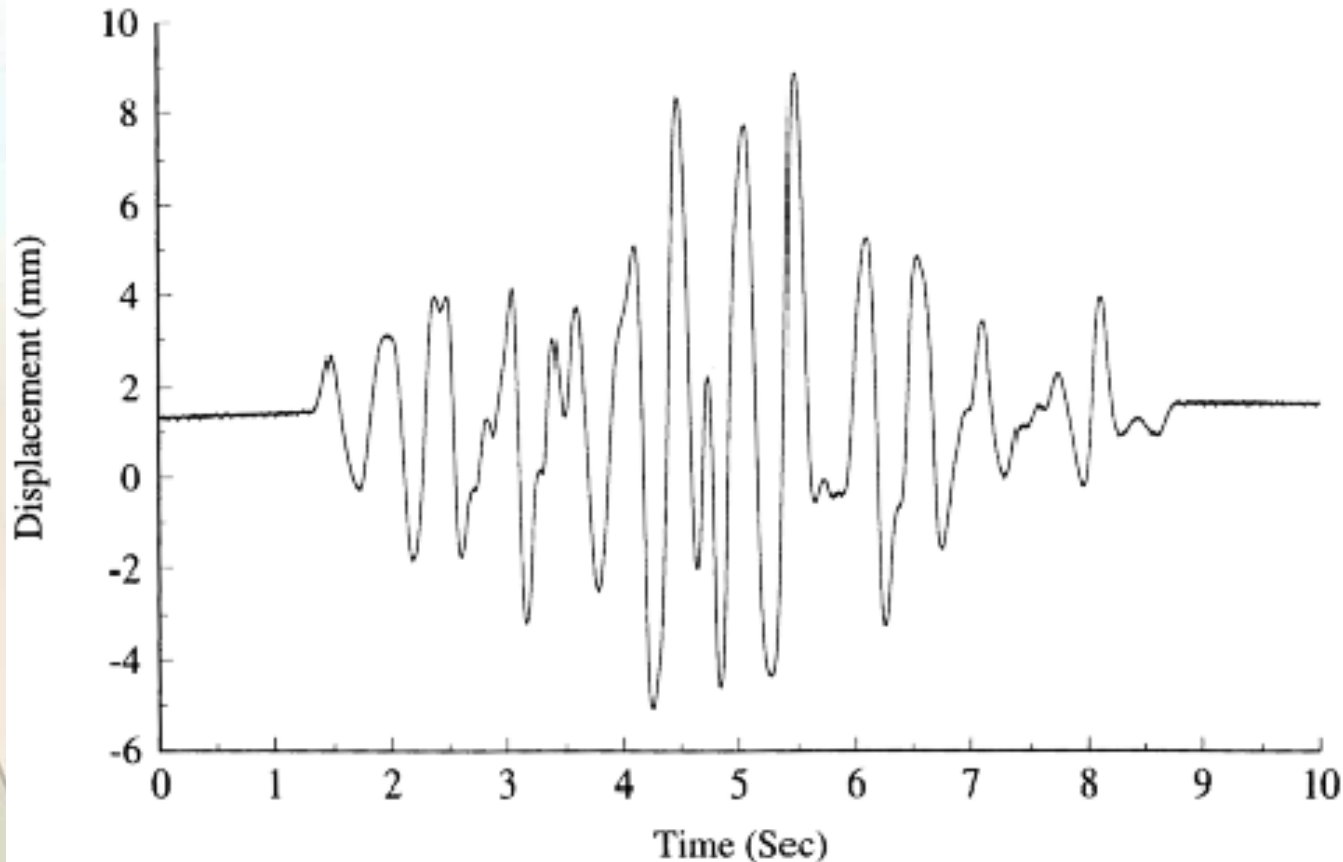
AC: Accelerometer

SG: Strain gage



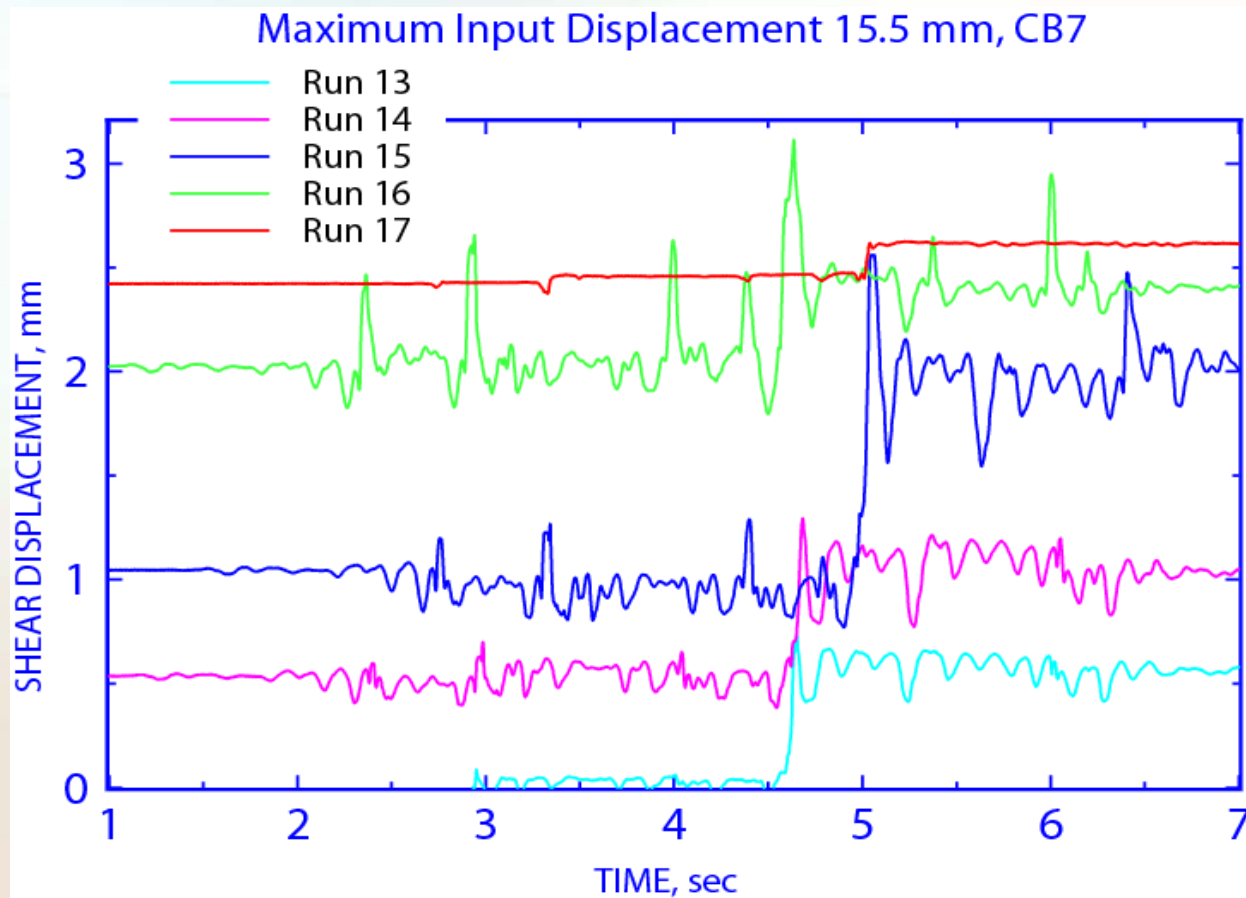
Displacement Input Signal

- **Displacement amplitude of this signal was scaled up or down for various excitation levels.**



Accumulation of Joint Shear Displacements for Five Repetitive Runs

- **Joint shear displacement measured by CB7 located at the far side of the tunnel with a maximum input displacement of 15.5 mm**
- **Tests (Runs) were repeated 5 times using the same seismic motion**



Visual Observation of Accumulation of Joint Normal and Shear Displacements

- Maximum input displacement of 15.5 mm
- Same seismic motion was used for each run



Run 13



Run 16

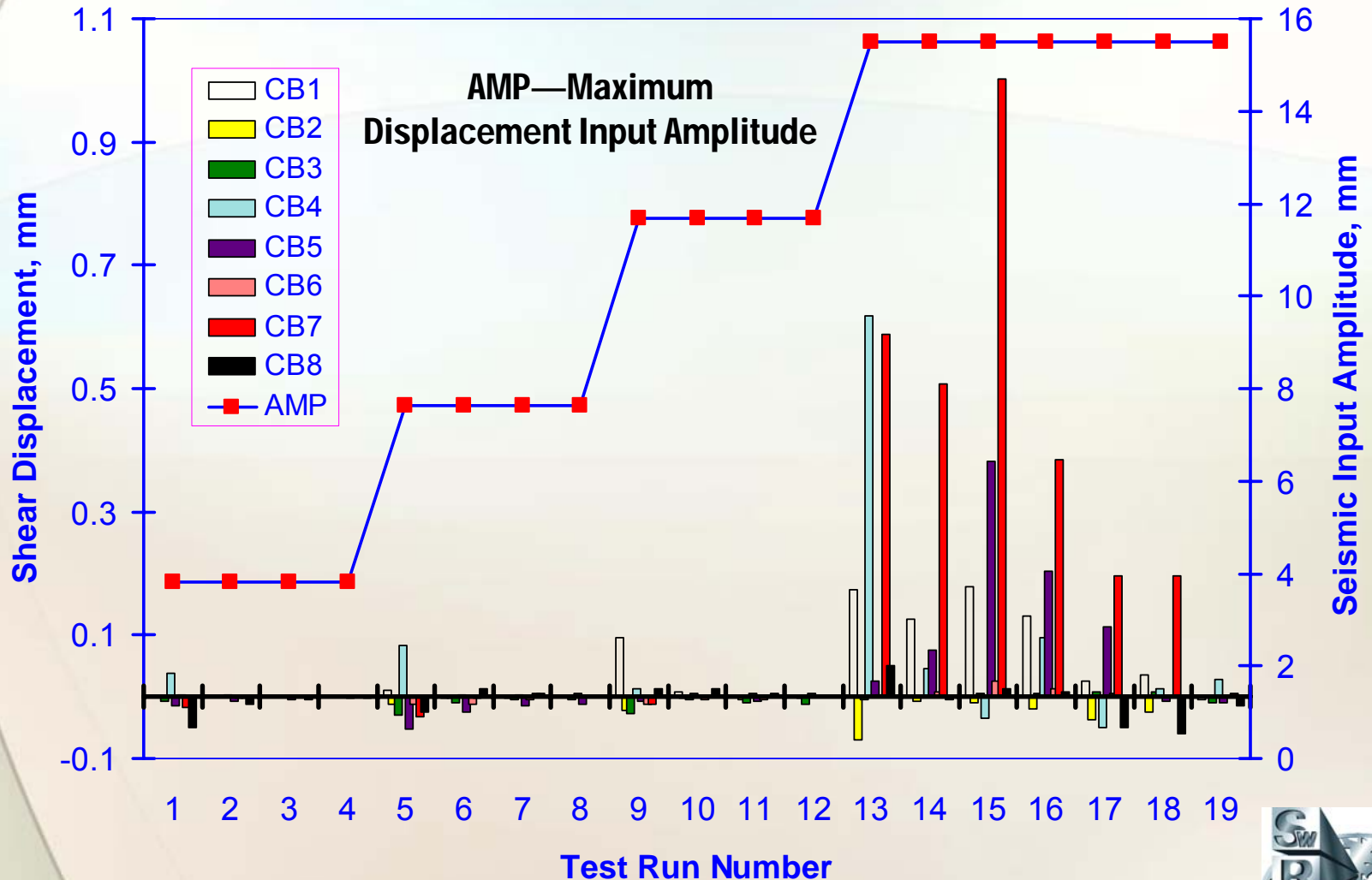


Run 17



Run 19

Increments of Permanent Joint Shear Displacements From Small-Scale Experiments



Conclusions

- **Ground motions induce step changes in displacements of the rock mass around excavations and excavation closures**
- **A seismic threshold appears to exist before significant permanent rock mass deformation will occur and begin to accumulate**
- **Accumulation of rock mass displacements around excavations may cause instability or damage of the excavations**



Conclusions (cont'd)

- **Observations demonstrate the fatigue behavior of rock mass reduces the strength of rock mass over time**
- **Damage to an excavation may occur due to a number of seismic events with relatively smaller magnitudes**



DISCLAIMER

- **The preparation of this paper was supported by the U.S. Nuclear Regulatory Commission (NRC) Office of Nuclear Material Safety and Safeguards, Division of High-Level Waste Repository Safety under Contract No. NRC-02-02-012.**
- **The activities reported here was performed on behalf of the NRC Office of Nuclear Regulatory Research under Contract No. NRC-02-88-005.**
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