Presentation Summary

- The Parkfield Earthquake Prediction Experiment: 1988 was not too late
- SAFOD The San Andreas Fault Observatory at Depth: 2002 was too late
- Hope for both the current and future generation

Parkfield

M-6

Rupture Zone & Hypocenters

<table>
<thead>
<tr>
<th>Year</th>
<th>Hypocenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1857</td>
<td>?</td>
</tr>
<tr>
<td>1881</td>
<td>?</td>
</tr>
<tr>
<td>1901</td>
<td>?</td>
</tr>
<tr>
<td>1922</td>
<td>*</td>
</tr>
<tr>
<td>1934</td>
<td>*</td>
</tr>
<tr>
<td>1966</td>
<td>*</td>
</tr>
<tr>
<td>88-92</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>*</td>
</tr>
</tbody>
</table>

>25 km
Waveform comparisons: 1922, 1934, 1966, 2004

Japanese James Dean Society
Memorial sculpture near his crash site
Memorial reads:
“That which remains hidden
is of the essence…”

(Russ Evan of the BGS for scale)
More Examples of Repeating Earthquakes

Relative Locations of SAFOD Target Earthquakes (Repeaters)

Felix Waldhauser 2004, and Nadeau et al. 2004

Non-volcanic seismic tremor

Results from borehole seismic network

(Figure from R. Nadeau, personal com.)

San Andreas Fault Observatory at Depth: Science Goals

Testing fundamental theories of earthquake mechanics:

- Determine structure and composition of the fault zone.
- Measure stress, permeability and pore pressure in situ.
- Determine physical and chemical processes controlling faulting.
- Characterize 3 D volume of crust containing the fault.
- Monitor strain, pressure and temperature during seismic cycle.
- Observe near field earthquake nucleation and rupture processes.
SAFOD
Pilot Hole and Main Hole

Drilling:
- Pilot Hole 2002
- Main Hole 2004 - 2007
- Phase 1: fault approach
- Phase 2: fault crossing
- Phase 3: lateral cores

SAFOD Instrumentation
- Stage 1: Pilot Hole
- Stage 2: Main Hole
- Stage 3: Long-Term

Surface Trace of San Andreas Fault

2nd SODB WS S1-07-4
Pilot Hole VSP Array 32 Level 3-Component 15 Hz install between 800 to 2,100 m

Pilot Hole VSP Array – Installed on 2 3/8" Production Tubing

PH MEQ VSP

"SEISMIC WHILE DRILLING" REFLECTION IMAGING PROJECT
SURPRISE NO. 1
"THE CATASTROPHE AT SAP"
or
HOW AND WHY
THE EARTHQUAKE (ALMOST) ESCAPED

Joint Observations of July 6, 2005 M 2.8 Earthquake at Distance of 4 km

35 years in development:
1978 Mojave 0.8 km 4Hz V
1980 Mojave 0.8 km 4Hz V
1981 Oroville Hydro locks
1983/5 PKF 0.3 km 2Hz 3D
1987 PKF 1.7 km 42 4Hz V
1990/93 Coso 0.2 km 4Hz 3D
1994/98 Electronic enhancement
1999 LVEW 3km 2Hz 3D
2001 Monty 0.2km 2Hz 3D
2002 SAFOD 2km 32 15Hz 3D
2004 SAFOD 3km 4Hz 3D
SAFOD 3km 3D MEMS
....then back to 1987

Paulsson Geophysical Services, 80 Level 3C Seismic Array

Microearthquake M0.0 May 5, 2005
Event locates at 3415 m (m.d.) along MH
Non Volcanic Tremor Wave Field

Fault zone guided wave types – Old and New at 10,480 fault

Creeping fault intersections

Result:
SAF zone ~150 m wide

Result:
SAF core ~30 m wide
The long term monitoring problem

Oct 1 2008 Event: Vel, Acc, MT

Oct 1 2008 Event: Stacked Raw and Low Pass MT

The compromise
Analog high temperature (200 C) 15 Hz geophones
(IESE, University of Auckland, New Zealand)

M *3.1 Earthquake Recorded at SAFOD on February 8, 2012 at 04:00 UTC. Range * 100 meter*

THANKS FOR YOUR ATTENTION!

PS. It was named after my thesis advisor
Robert Phinney