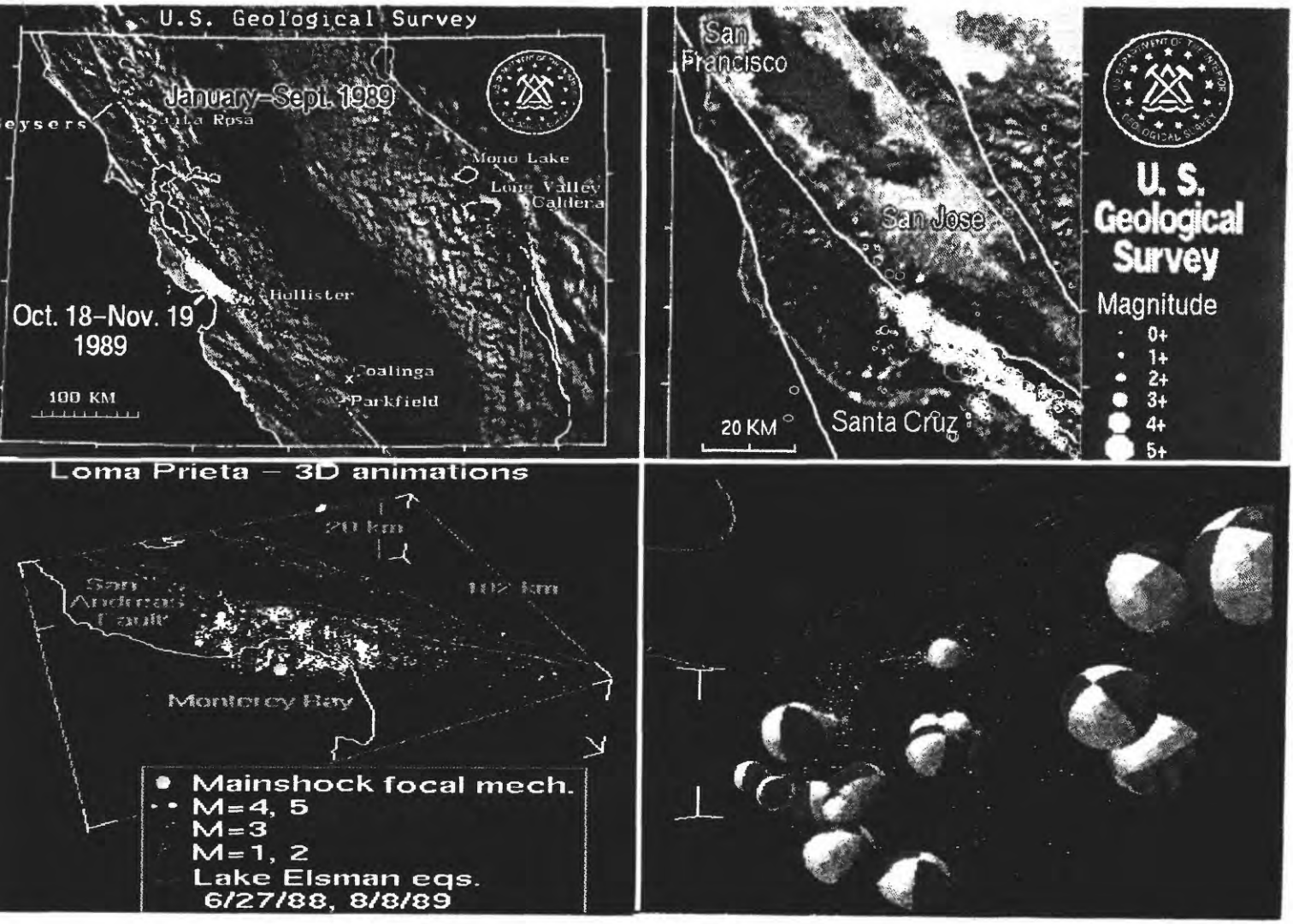

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

AFTERSHOCKS OF THE LOMA PRIETA EARTHQUAKE: COMPUTER ANIMATIONS

(A video tape)

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Open File Report 89-669

This report accompanies the videotape **Aftershocks of the Loma Prieta Earthquake: Computer Animations.** It provides a guide to the various animations on the videotape, a glossary of terms used in the narration, and information on how copies of the videotape can be obtained.

The seismicity examined in the animations features aftershocks of the 0004 (GMT) October 18, 1989 Loma Prieta earthquake. The Magnitude 7.1 earthquake was the largest to strike Central California since the 1906 San Francisco earthquake. Study of the prior seismicity and Loma Prieta aftershocks shows such information as:

1. the seismicity in Central California during the nine months prior to the Loma Prieta earthquake,

2. the fault area that ruptured during the Loma Prieta sequence,

3. the "locked" and seismically quiet nature of the fault before the earthquake,

4. the pattern and decay of the aftershock sequence over time, and

5. the various slip planes that moved in response to the applied stress field and their directions of movement.

The videotape features several time-lapse and 3-dimensional "fly over" animations. It includes an audio narration accompanied by background music. Animation is an attractive technique for displaying earthquake data because it shows both the 3-dimensional aspects of the earthquake locations and the time sequence in which they occurred. However, only in recent years have the hardware and software become readily available that permit seismic data to be easily animated for purposes of study and display. This videotape represents our first efforts at displaying seismicity using these new tools.

The animations and title screens were produced on an **Amiga 2000** computer using the **Digiview, Deluxe Paint-III, Videoscape 3D,** and **A-Talk III** programs. The plotting of maps and cross sections was done on a VAX computer using the Amiga to save and animate the plots. The three dimensional objects were created on the VAX and downloaded to the Amiga for animation.

The earthquake data shown in the animations were gathered and processed solely by the U.S. Geological Survey. The data is preliminary and will be reprocessed. Some earthquakes may be missing and the magnitudes of earthquakes which occurred soon after the Loma Prieta mainshock may be revised.

ANIMATIONS AND STILL SEQUENCES ON THE VIDEO TAPE

This section is intended as a quick guide to the contents of the videotape. Additional information about the earthquake data and animations is in the narration. The times, in minutes and seconds, are start times from the beginning of the tape.

(1) Title and introduction (00:00)

(2) Probability map (01:20)

This figure shows the chances of future large earthquakes on the San Andreas Fault. It shows that the Loma Prieta segment had been identified as a likely site for a future, large earthquake.

(3) Seismicity map - Central California (02:15)

The map shows earthquakes that occurred in central California between January and November 1989. The Loma Prieta aftershocks, San Andreas Fault, creeping section of the San Andreas, Geysers area, Alum Rock area, Coalinga seismic zone and the Mammoth Mountain earthquake swarm areas are individually highlighted.

(4) Time lapse animation - central California (04:23)

This animation shows earthquakes from January through November, 1989. Each frame of the animation plots 48 hours of earthquakes. Successive frames are spaced 8 hours apart. The frame rate is 7.5 (2.5 days) per second. An earthquake appears as a filled circle for two frames and as an open circle for the next four frames before disappearing. The animation shows all earthquakes detected by the USGS central California network of seismograph stations that were processed for location and magnitude. The size of the plotted circle scales with earthquake magnitude. The earthquake data are partly computer processed and partly hand processed. Most quarry blasts were removed. The shaded relief map was derived from a digital elevation model at a latitude and longitude spacing of 15 seconds.

(5) Facts about the earthquake (07:10)

Source parameters and block diagram of slip in the earthquake.

(6) Time lapse animation - Loma Prieta aftershocks (07:50)

This animation shows seismicity during the early part of the aftershock sequence in the San Francisco Bay area. Each frame of animation plots 3 hours of earthquakes and successive frames are plotted every hour. The frame rate is 4 frames (4 hours) per second. An earthquake appears as a filled circle for one frame and an open circle for the next two frames before disappearing. The size of the plotted circle increases with earthquake magnitude. The base map is a Landsat image with epicenters of after shocks for October 18-31, 1989 superimposed.

(7) Animation - map view to cross section (09:10)

This animation shows a rotation from map view to vertical cross section of the San Andreas

Fault surface.

(8) Time lapse animation - cross section (09:30)

Time-lapse animation of a cross section of the Loma Prieta aftershock zone for October 18-22, 1989. The animation parameters are the same as animation number 6.

(9) Pre- and post-Loma Prieta seismicity (11:00)

Map and cross section comparing pre-Loma Prieta seismicity with aftershocks of the Loma Prieta earthquake.

(10) 3-D animation - rotation (12:15)

Three dimensional animation of aftershocks seen from a "camera" flying in a circle around the Loma Prieta area.

(11) 3-D animation - perpendicular arc (13:23)

Three dimensional animation of aftershocks seen from a "camera" flying in a vertical arc perpendicular to the fault plane. The animation starts with a map view and ends with a cross-section view from the northeast side.

(12) 3-D animation - along the fault (15:00)

Three dimensional animation of aftershocks seen from a "camera" flying along an arc in the plane of the fault.

(13) Focal sphere map (16:15)

Map view of colored focal spheres of selected aftershocks. The spheres represent the possible slip planes of the earthquake.

(14) 3-D animation of focal spheres (17:20)

Three dimensional animation of a "fly by" and "fly over" of the focal spheres of selected aftershocks.

(15) Short summary sequence (19:10)

(16) Credits (19:57)

(17) END (22:15)

GLOSSARY OF TERMS USED IN THE NARRATION

ACTIVE FAULT - A fault that is considered likely to undergo renewed movement within a period of concern to humans.

AFTERSHOCKS - Secondary earthquakes that may follow and occur close to the largest shock or mainshock of an earthquake sequence. Aftershocks may extend over a period of weeks, months or years.

CONDENSATE - The water resulting when steam is cooled below the boiling point of water, as in a geothermal power plant.

CREEP - Slow, more or less continuous movement that may occur either along faults owing to ongoing tectonic deformation or along slopes owing to gravitational forces.

EARTHQUAKE SWARM - A series of minor earthquakes, none of which may be clearly identified as the mainshock, occurring in a limited area and time.

EPICENTER - That point on the Earth's surface vertically above the HYPOCENTER of the earthquake.

FAULT - A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture or fault plane.

FAULT PLANE SOLUTION - An analysis to determine the causative fault and its direction of slip from the radiation pattern of seismic waves for an earthquake. The analysis most commonly uses the direction of first motion of primary waves recorded at numerous stations and yields two possible orientations for the fault and the direction of seismogenic slip. Slip can occur on one of two perpendicular nodal planes. If the nodal planes are nearly vertical, either right lateral slip occurred on one plane or left lateral slip occurred on the other plane. The principal axes of stress in the region of the earthquake can be inferred from fault plane solutions.

FIRST MOTION - See FAULT PLANE SOLUTION.

FOCAL SPHERE - An arbitrary reference sphere drawn about the HYPOCENTER of an earthquake to which body waves recorded at the Earth's surface are projected for studies of fault plane solutions.

GEODESY - A science concerned with the size, shape, and deformation of the Earth and the precise location of points on its surface. Geodesy can be used to estimate the displacement on faults below the ground surface.

HYPOCENTER - The point within the Earth where the earthquake rupture initiates.

LEFT LATERAL STRIKE SLIP FAULT - A fault for which, in plan view, motion of the side opposite the observer moves to the left.

MAGNITUDE - A number that characterizes the size of an earthquake, usually based on the maximum amplitude or duration of shaking recorded by a seismograph.

NODAL PLANE - See FAULT PLANE SOLUTION.

NORMAL FAULT - A non-vertical fault in which the hanging (upper) wall moves downward relative to the foot (lower) wall.

PRESHOCK - A smaller earthquake that precedes a larger earthquake by weeks or months and has a hypocenter near the later mainshock. A foreshock is also spatially and temporally related to the mainshock, but may precede it by seconds to weeks.

RIGHT LATERAL STRIKE SLIP FAULT - A fault for which, in plan view, motion of the side opposite the observer moves to the right.

SEISMIC - Pertaining to an earthquake or earth vibration, including those that are artificially induced.

SEISMIC GAP - A part of an active fault that has recently experienced few small earthquakes. Seismic gaps are believed to mark locked sections of faults where stresses accumulate to be relieved in a subsequent large earthquake.

SEISMIC WAVE - An elastic wave generated by an impulse such as an earthquake or explosion.

SEISMICITY - The geographical and historical distribution of earthquakes.

SLIP DIRECTION - Within a fault plane, the direction that one side of the fault moves relative to the other.

STRESS - Force per unit area acting on a surface within a body.

STRIKE SLIP FAULT - A fault in which movement is principally horizontal.

THRUST FAULT - A fault in which the hanging (upper) wall moves upward relative to the foot (lower) wall.

VERTICAL CROSS SECTION - A diagram that shows features transected by a vertical plane.

A copy of this video tape is available for viewing in the libraries of the U.S. Geological Survey in Menlo Park California, Denver Colorado and Reston Virginia. The tape runs about 22 minutes. Videotape copies in NTSC, PAL, or SECAM and in all standard formats may be purchased from:

Video Transform
2450 Embarcadero Way
Palo Alto CA 94303
415-494-1529

A VHS Copy of this video may also be obtained with the order of the paper copy from Books and Open Files Services Section