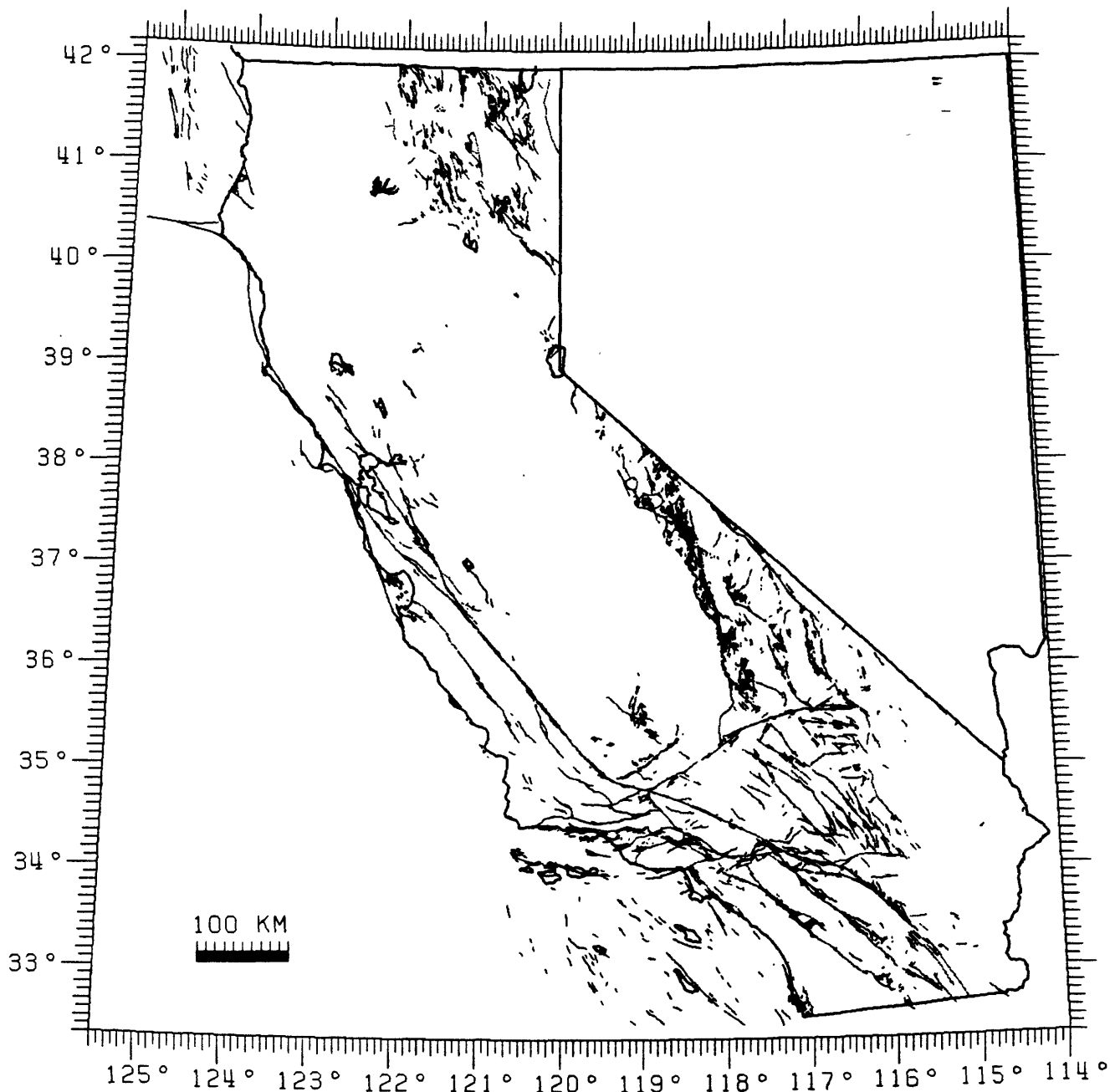


QUATERNARY FAULTS OF CALIFORNIA



UNITED STATES DEPARTMENT OF INTERIOR, GEOLOGICAL SURVEY

QUATERNARY FAULT MAP OF CALIFORNIA IN DIGITAL FORMAT

by J. J. Lienkaemper¹ Open - File Report 85- 211

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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INTRODUCTION

A map composed of all Quaternary-aged fault traces shown in the 1:750,000-scale Fault map of California by Jennings, 1975, is now available in an easily usable digital format. This product results from an experimental effort to use the new technologies of automatic digitizing by laser scanner and raster-to-vector conversion. The purpose of this report is principally to explain in practical terms how to make use of the digital fault map and secondarily to inform those with interests in digital cartography how it was produced. Persons wishing only to make effective use of the fault map may skip over the next section on production.

The cover illustration of this report is a plot made from the digitized fault data using a Versatec plotter owned by the Office of Earthquake and Volcano Engineering (OEVE) and the Fortran program QPLOT written by Fred Klein (1983). The scale at which fault data may be plotted depends only on size and resolution of plotters available and the accuracy of the original compilation of fault traces relative to the accuracy required for the intended use.

PRODUCTION OF THE DIGITAL FAULT MAP

Understanding the following discussion requires some knowledge of computer graphics terminology and of cartographic projections. Brief qualitative descriptions of computer graphics terms shall be used here because the quantitative methods employed by this project are mainly contained in proprietary Sci-Tex computer programs. Terminology of cartographic projections is explained at introductory level in the appendix of Maps for America, Thompson (1981) and at a more advanced level in Snyder (1982).

In October 1982, the National Mapping Division (NMD) Eastern Mapping Center (EMC) of the U.S.G.S. in Reston, VA acquired 2 Sci-Tex laser scanners with associated computers and color video monitors called editing stations. The Sci-Tex system was purchased for a co-operative project with the U.S. Bureau of Census to prepare digital basemaps for the 1990 census. As the Census map-production project got under way, NMD in February 1983 offered the possibility of limited experimental use of the Sci-Tex system by other Divisions within the Geological Survey. The installation in July 1984 of 2 Sci-Tex edit stations at U.S.G.S. Western Mapping Center (WMC) in Menlo Park made possible the experimentation necessary to produce the digital fault map.

A positive color proof of Jennings (1975) Quaternary faults overlay was prepared by WMC using 1:750,000-scale negatives from the publisher by reducing them to 1:929,000-scale. The same proof was also provided with fiducial graticule and miscellaneous base components in a different color from the faults. The scale 1:929,000 was made necessary by the scanner drum size. The northern and southern portions of the State had to be scanned separately for the same reason. Each scan lasted about one hour. These scans were done in July 1984 by U.S.G.S. at EMC. Retouching and joining of north and south portions was done on EMC edit stations. A magnetic tape containing the fault data was sent to WMC for further editing on their newly acquired edit stations.

Up to this stage all computer manipulations and storage of the fault map were made upon data in raster form. A raster is a horizontal row on a video display. Each small point of light in a raster is called a pixel and its location in the image can be described as two coordinates. A third value, on or off, or of a given color or not of that color, is used to describe a particular set of data as a bit map; each location is either 0 or 1 in value.

The next process needed to make a fault map generally usable to many plotters and plotting programs is the creation of a vector formatted file from the raster file. A vector in this sense is two pairs of coordinates which describe a portion of the fault trace. Because the map was scanned at a resolution of 20 pixels per mm, the raster image of each actual fault trace is composed of line segments a few pixels thick. A Sci-Tex program was used to thin the faults and then a second program was used to generalize the remaining pixels into vector form. Capture of dotted fault traces was done separately by classifying all pixel clusters less than a given area limit as dots and running a Sci-Tex program to find the center points of these clusters. The above work was done on U.S.G.S.-WMC editing stations; a tape was then written in Sci-Tex binary format.

The Sci-Tex binary tape containing vectorized fault traces was then read on a VAX 11/750 mini-computer belonging to OEVE. A Fortran program was written to read and byte swap the binary file and decode and select coordinates from a matrix of extraneous codes. The resulting set of coordinates were output to an ASCII vector file still in the planar grid system of Sci-Tex and the Lambert conformal projection in which the map was scanned.

To determine the exact scale of the scanned map's geographic graticule, a program was written to input selected latitude and longitude pairs and output synthetic Sci-Tex coordinates. Longitude 120°W is parallel to the scan direction, so for convenience the computed grid was fixed at 33°N, 120°W. Using 1:929,000 as the scale-factor, the Sci-Tex grid locations of digitized fiducial points fell within ± 3 pixels along 120°W meridian, or ± 140m ground distance. The greatest distortion, 10.7 pixels or nearly 500 m ground distance, was found at 42°N, 125°W, the extreme northwest corner of the map.

A program, using a GS-CAM subroutine available from U.S.G.S. (1981), was written to invert the data from Sci-Tex coordinates to geographic coordinates, i.e. latitudes and longitudes.

USE AND LIMITATIONS OF THE DIGITAL FAULT MAP

The vector file of Quaternary faults is composed of 6 pairs of latitude and longitude per 120-byte record formatted as 12F9.4 with each longitude preceded by a minus sign. Approximately 30,000 pairs of latitude and longitude, separated by zeroes as line-start flags, occupy 840 kilobytes of memory. This file, QFTSCITEX.GEO, plots the entire State in a few minutes by raster plotter, for example by: electrostatic, ink-jet or laser plotters. However, a vestigial raster structure inherent to the algorithm which created this vector file in Sci-Tex makes the structure of this file extremely inefficient for pen-plotting. It takes more than 90 minutes to plot the entire State using QFTSCITEX.GEO.

The time required for pen-plotting depends on two factors, principally, the compactness and proximity of Quaternary faults to each other, and secondarily, the continuity and sequence of plotting of a given fault system. The latter item can not be dealt with easily for this map; the San Andreas fault, for example, is clearly continuous, but this continuity is lost in the segments which are dashed, dotted or contain small discontinuities. Fig. 1-B shows, however, that faults in most of California clump along the coast and east of the Sierra Nevada; if broken up into separate files frequent time-consuming pen excursions from west to east are eliminated.

A small, 120 lines, interactive Fortran program, FAULTBOX, selects all vectors beginning in a given rectangular box. Fig. 1-B shows boundaries of subfiles created from QFTSCITEX.GEO. Numbers 1 through 10 in each box show the order in which the subfiles named in figure 1-A were concatenated to form a new file QFAULTS.GEO. The plotting progression, north to south, is a vestigial effect of the north to south scanner drum movement with east-west laser sweeps. Pen-plotting of the entire State at 1:1,500,000-scale of this restructured file takes about 30 minutes.

Plotting on either raster or pen plotters proceeds much more quickly if the data file is smaller. Fig. 2 shows the regions described in Fig. 1 with the size in blocks of each subfile, blocksize is about $\frac{1}{2}$ kilobyte. For example, the file SFBAY.GEO, about 60 kilobytes, would fit easily into memory devices of most micro-computers or into an individual's disk directory on a mini-computer, and would plot in a few seconds. Regions such as those shown in figure 1 can be concatenated to form larger regions suited to a particular use, or other regional map files can be made using the program FAULTBOX. The user should notice in figure 2 that vectors in each subfile do not necessarily end at the specified boundaries of a box, see for example the boundary between SFBAY.GEO and CARMEL.GEO, and he should thus be mindful of meeting completeness requirements of his particular application. If in doubt create a larger box.

Limitations of this map depend heavily on the nature of its intended use. It has not been revised for completeness, thus it reflects the state of knowledge of Quaternary faults 12 years ago. Important additions should be made to the data, but this is a time consuming process which has not been feasible to do yet. Other limitations depend principally on scale and accuracy maintained both in the production process as discussed in the previous section, and in the geologic generalizations made in compiling.

With the exception of the extreme NW corner, the net cartographic error from all sources, as judged by distortions of the graticule, is generally less than ± 200 m ground distance for the entire State; the data are stored at a resolution of about ± 50 m.

Compilation accuracy is generally at a similar level, but the user must satisfy himself that his own needs are met. Figure 3 shows an extreme illustration of conflict between geologic criteria for mapping and cartographic rigor. The site labeled SPBL in reality is located exactly on the Hayward fault, but the figure shows the fault 500 m to the east of it. Inspection of the fault in Jennings (1975) shows it to be adequately located with respect to the shoreline as it appears on the basemap, thus it appears that inaccuracy of the original base map contributed to this error. The nature

and accuracy of the other digital data to be plotted along with the Quaternary faults will govern which map scales and what symbol usage are valid for a given application.

AVAILABILITY OF THE DATA

Persons wishing to acquire the fault data in digital format should send a 600 ft., 9-track tape to the author. Tapes will be written as follows unless other specifications are needed: Unlabeled, fixed block, ASCII code, 1600 BPI, LRECL=108, BLOCKSIZE=2160.

The files included will be:

- 1) FAULTBOX.FOR Fortran program to select subsets.
- 2) CALSTATE.GEO State outline and miscellaneous lakes.
- 3) QFAULTS.GEO Faults of entire State optimized for pen-plotting.
- 4) EUREKA.GEO,.... Faults in regional boxes shown in figures 1 and 2.

An appendix to this report for OEVE personnel is also available on request from the author. It gives information pertinent to plotting using QPLOT on VMS-VAX systems used at Menlo Park, although it might be useful to others using QPLOT or VMS operating systems.

SUMMARY

Beginning with the Quaternary fault overlays from the California fault map of Jennings (1975), using an automatic laser scanner, the fault traces were digitized and by various computer manipulations recast into a digital format of latitude and longitude pairs which may be plotted by computer driven plotters.

A version of the digital map, QFAULTS.GEO, is optimized for pen-plotting of the entire State; it contains about 30,000 coordinate pairs. A small Fortran program, FAULTBOX creates subsets of the complete fault map for faster plotting and more compact computer storage of smaller areas within the State.

Cartographic accuracy, as defined by checks of the digitized graticule against theoretical values, is usually within ± 200 m ground distance and rarely exceeds ± 300 m. Compilation accuracy in terms of geographic coordinates is usually in the same range as the cartographic accuracy, but the user should be aware of limitations of scale as they pertain to his application. Likewise a user should be aware that information about Quaternary faults in California gained since 1973 has not been included in this digital map.

Given exactly the same digitizing job to do over, all mechanical and computational tasks could be performed in less than one day with trained personnel in a fully equipped facility.

ACKNOWLEDGEMENTS

Many people were involved in making this experiment successful. Roger Borchardt (OEVE) conceived of the application of Sci-Tex for acquiring the faults in digital form, and refused to believe those who thought it impossible. The numerous technical obstacles were overcome at IND by Doug Aitken, Eileen Flannigan, and Tom McCulloch; and at OEVE by Tim MacDonald and Howard Bundock. In conversation and in his book Jon Snyder (1982) helped demystify map projections for me. Rick Lester (OEVE) digitized the lakes, coastlines, and state boundaries shown in the frontispiece and figures, and included in data available as file name CALSTATE.GEO.

References

- Jennings, C. W., 1975, Fault map of California: *California Division of Mines and Geology*, scale 1:750,000.
- Klein, F. W., 1983, User's guide to QPLOT, an interactive computer plotting program for earthquake and geophysical data: *U.S. Geological Survey Open-File Report 83-621*, 11 p.
- Snyder, J. P., 1982, Map projections used by the U.S. Geological Survey *Bulletin 1532*, 313 p.
- Thompson, M. M., 1981, Maps for America: *U.S. Geological Survey special book*, 265 p.
- U.S. Geological Survey, 1981, GS-CAM: *U.S. Geological Survey cartographic automatic mapping program documentation*.

FIGURE 1A - SUBFILE NAMES OF OFAULTS.GEO

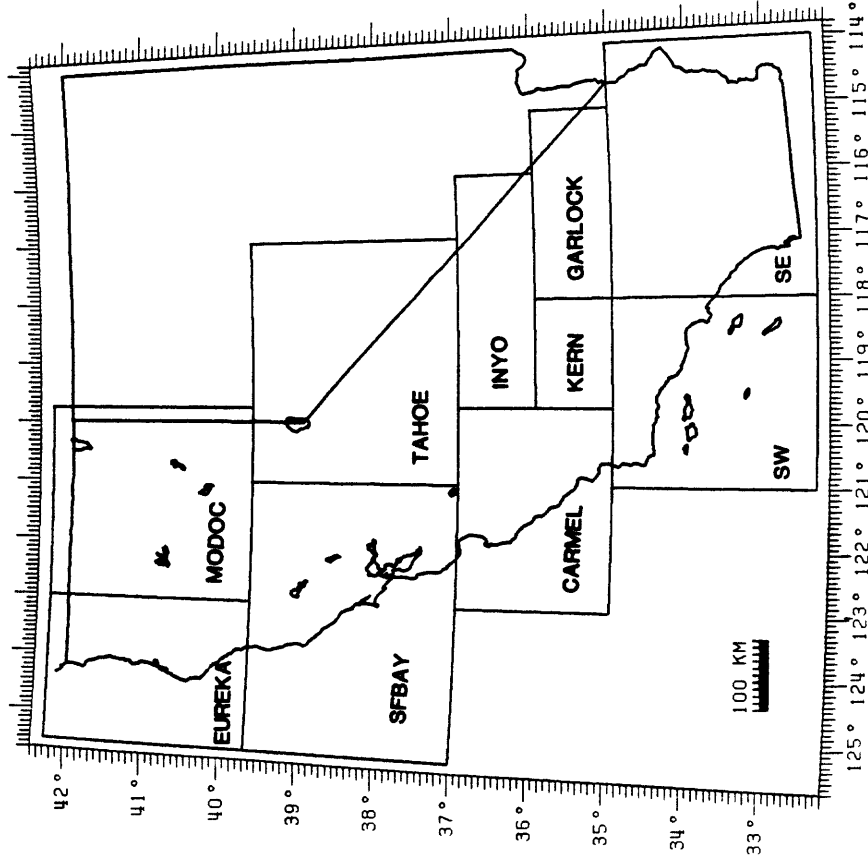


FIGURE 1B - PLOTTING SEQUENCE IN OFAULTS.GEO

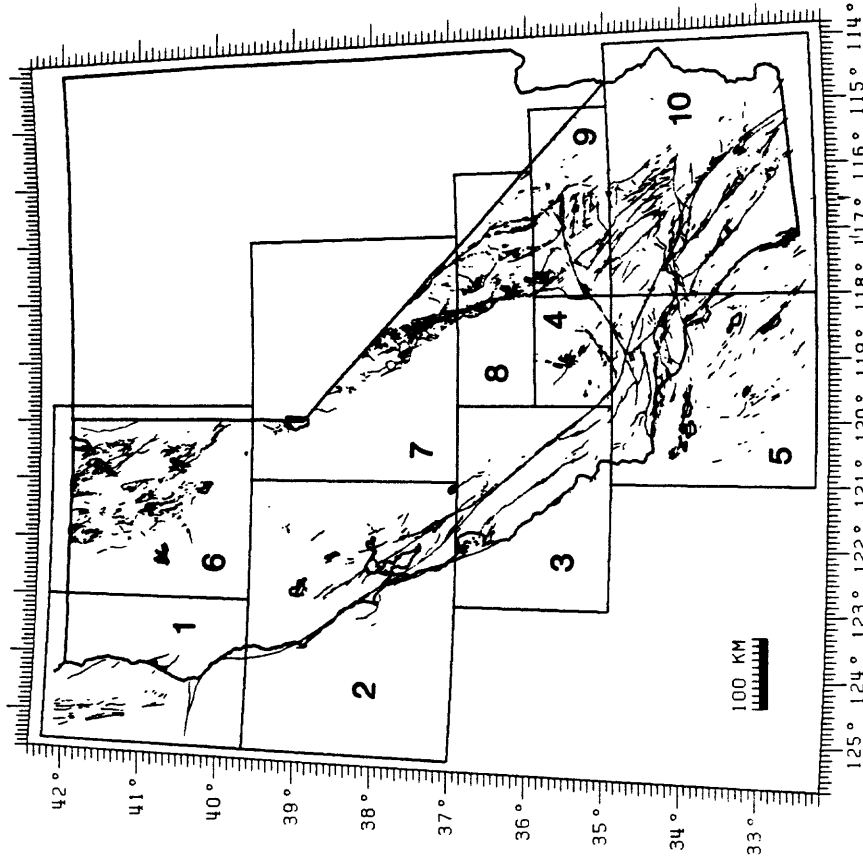
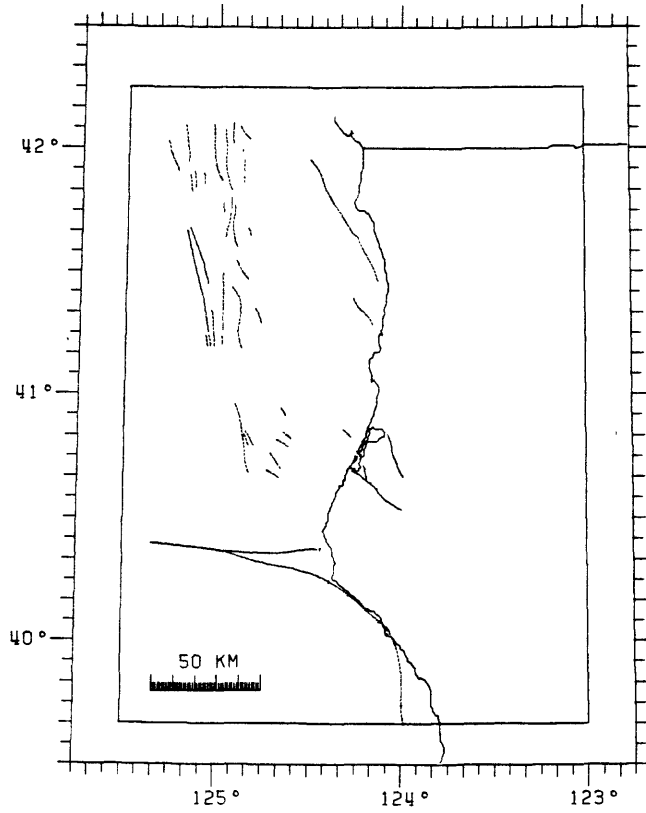


Figure 2

EUREKA.GEO 54 BLOCKS
125.5000W 123.0001W 42.2500N 39.6667N



SFBAY.GEO 118 BLOCKS
125.5000W 121.0001W 39.6666N 37.0001N

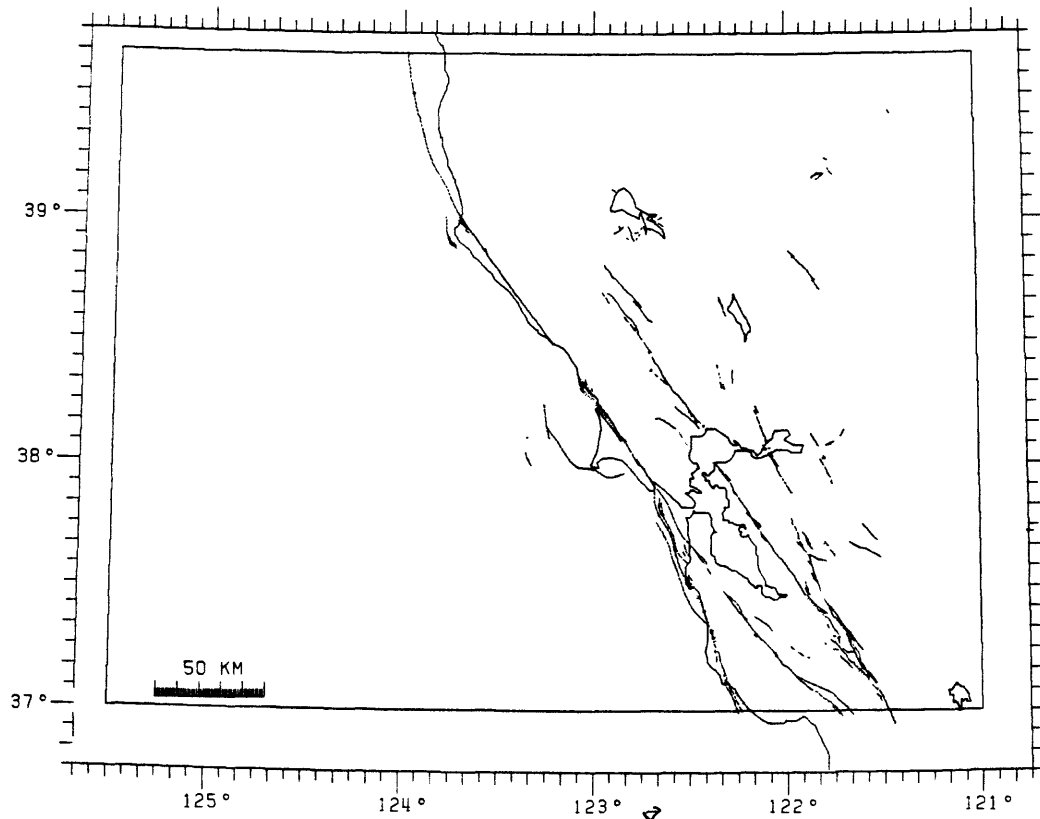
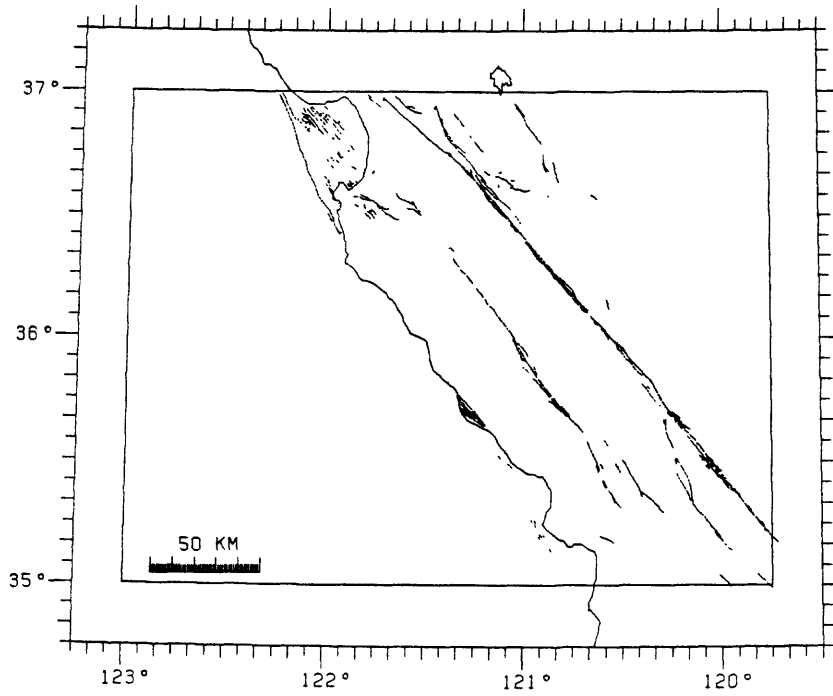


Fig. 2 (continued)

CARMEL.GEO 113 BLOCKS
123.0000W 119.7501W 37.0000N 35.0001N



SW.GEO 268 BLOCKS
121.0000W 118.0001W 35.0000N 32.3334N

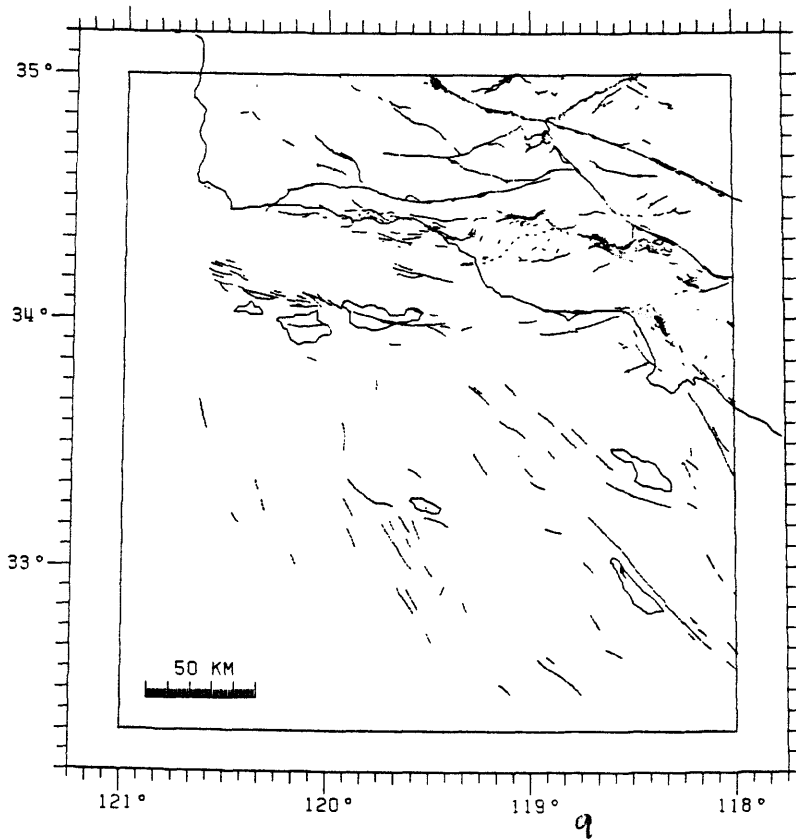
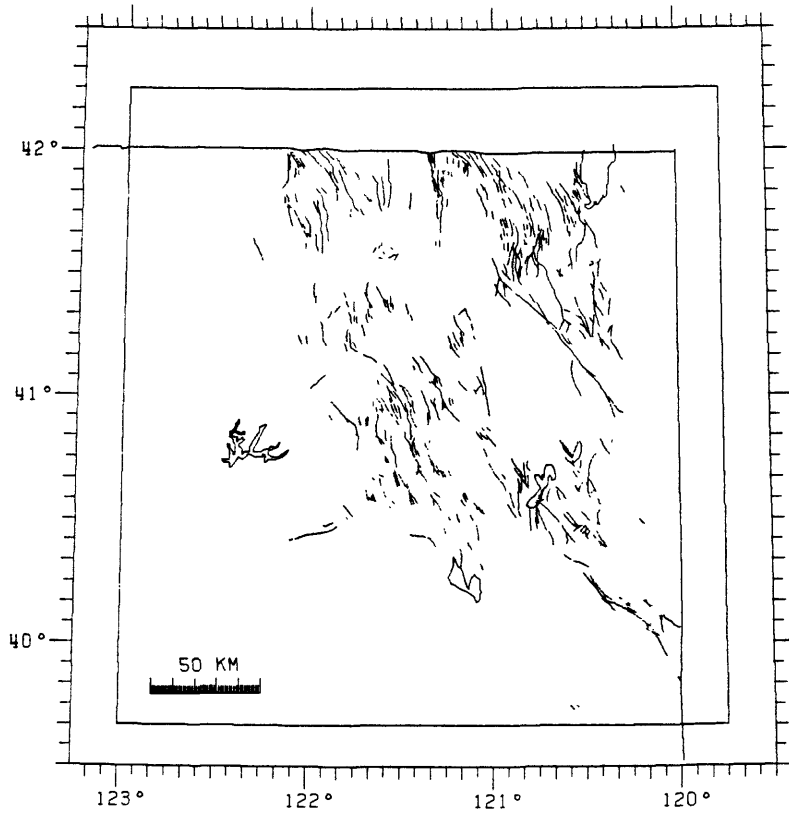


Fig. 2 (cont.)

MODOC.GEO 180 BLOCKS
123.0000W 119.7501W 42.2500N 39.6667N



TAHOE.GEO 158 BLOCKS
121.0000W 117.0001W 39.6667N 37.0001N

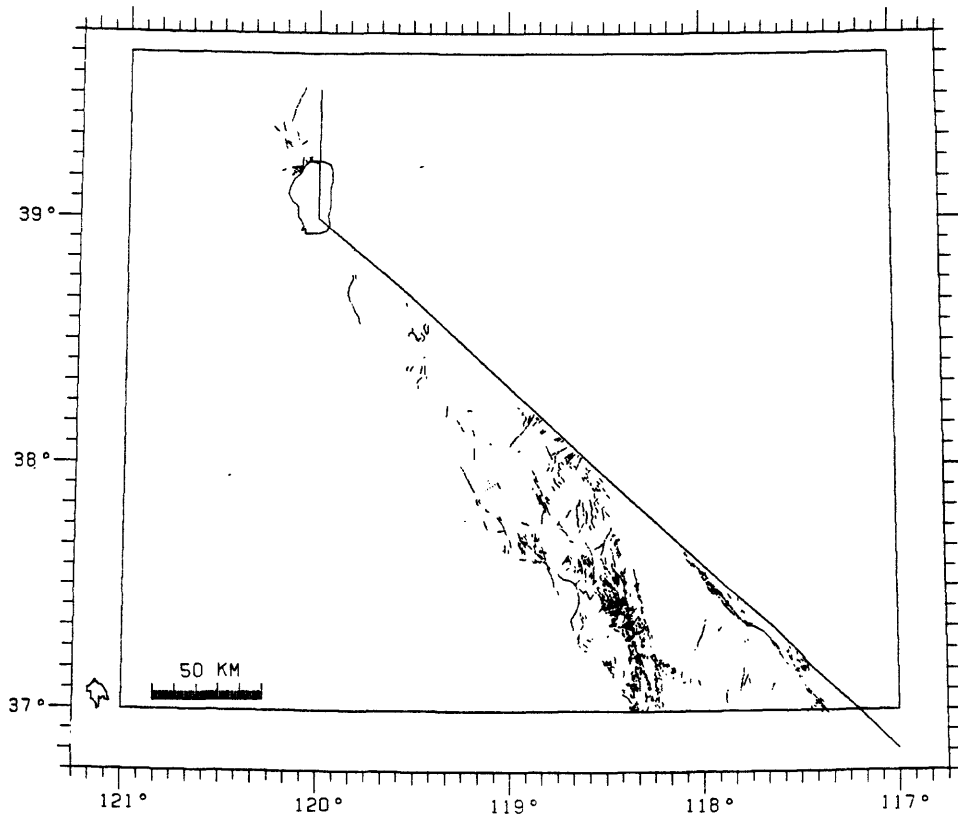
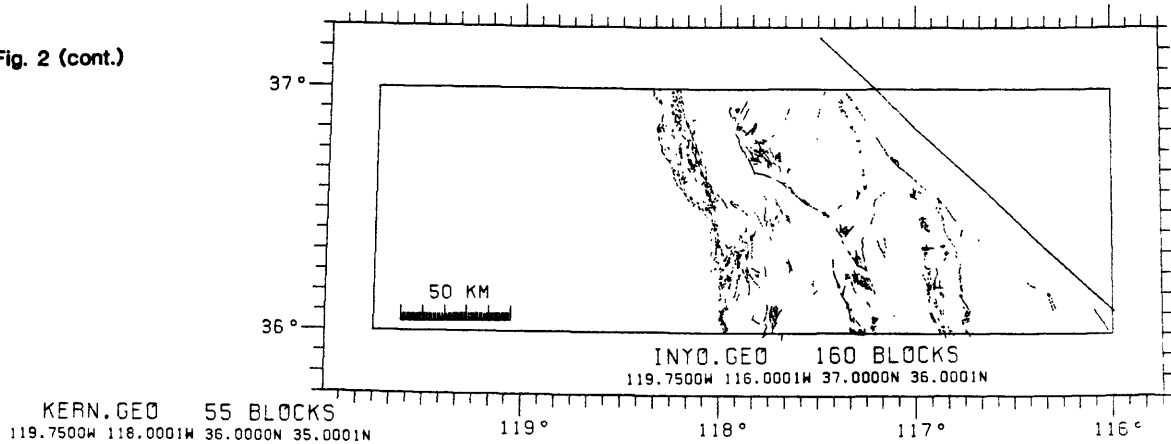
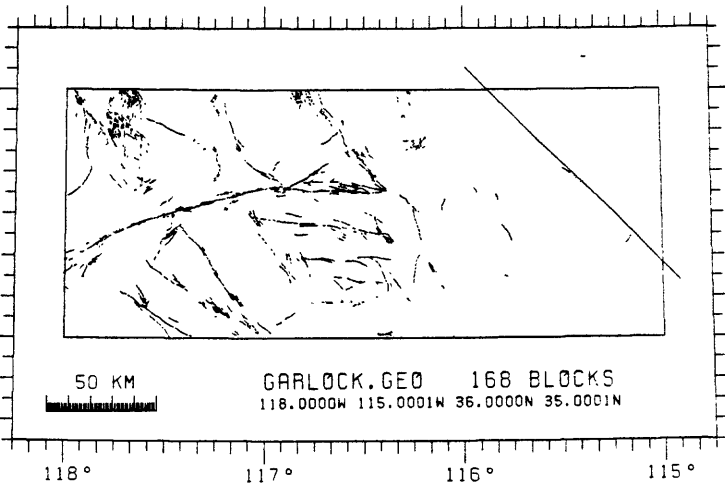
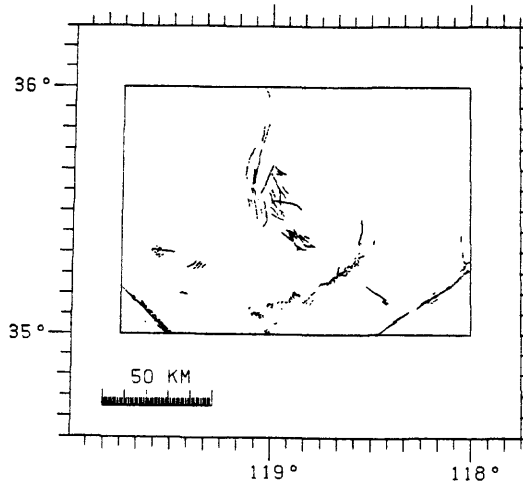


Fig. 2 (cont.)



KERN.GEO 55 BLOCKS
119.7500W 118.0001W 36.0000N 35.0001N



SE.GEO 410 BLOCKS
118.0000W 114.0001W 35.0000N 32.3334N

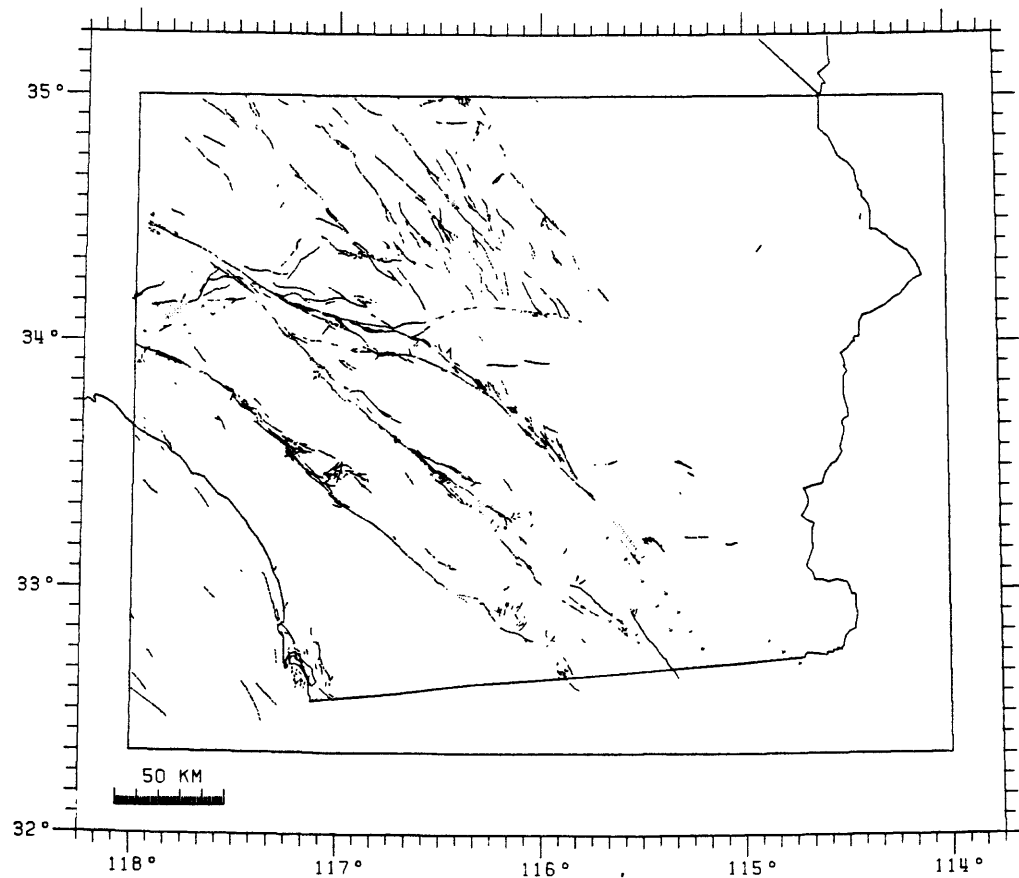


Figure 3

ALINEMENT ARRAY SITES

