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# A CRUSTAL DEFORMATION OBSERVATORY NEAR THE SAN ANDREAS FAULT IN CENTRAL CALIFORNIA (PB3)

Larry E. Slater

University of Colorado
CIRES
Boulder, CO 80309

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# INTRODUCTION

This final technical report discusses several objectives and accomplishments of the first years effort of a project titled A Crustal Deformation Observatory Near the San Andreas Fault in Central California. This period saw the conclusion of the Hollister MWDM effort that has produced nearly continuous, high precision, line length measurements for the last 5 years. The establishment of an observatory similar to that used during the Hollister MWDM effort is underway near San Juan Bautista and both high precision vertical and horizontal measurements will commence in the near future. An interim measurement program was begun near Palmdale in Southern California during October 1980 and is continuing at the present time. Extensive electronic modification to the MWDM instrument has also been successfully completed during this reporting period. Each of these efforts will be discussed in more detail in the following sections of this report.

# HOLLISTER MWDM ARRAY

The Hollister MWDM array was deactivated during this reporting period after completing over 5 years of high precision measurements in a region spanning the Calaveras fault in Central California (Figure 1). The results of this effort are shown in Figure 2. The data collected during the 1847 days of the experiment are listed on computer file at the U.S. Geological Survey facility in Menlo Park, California. The data is found in Multecs under the name LASER. Each data point represents the mean value of approximately 40 consecutive measurements taken each day on that line. Data from lines that exceed 5 km in length have been arbitrarily omitted from the file

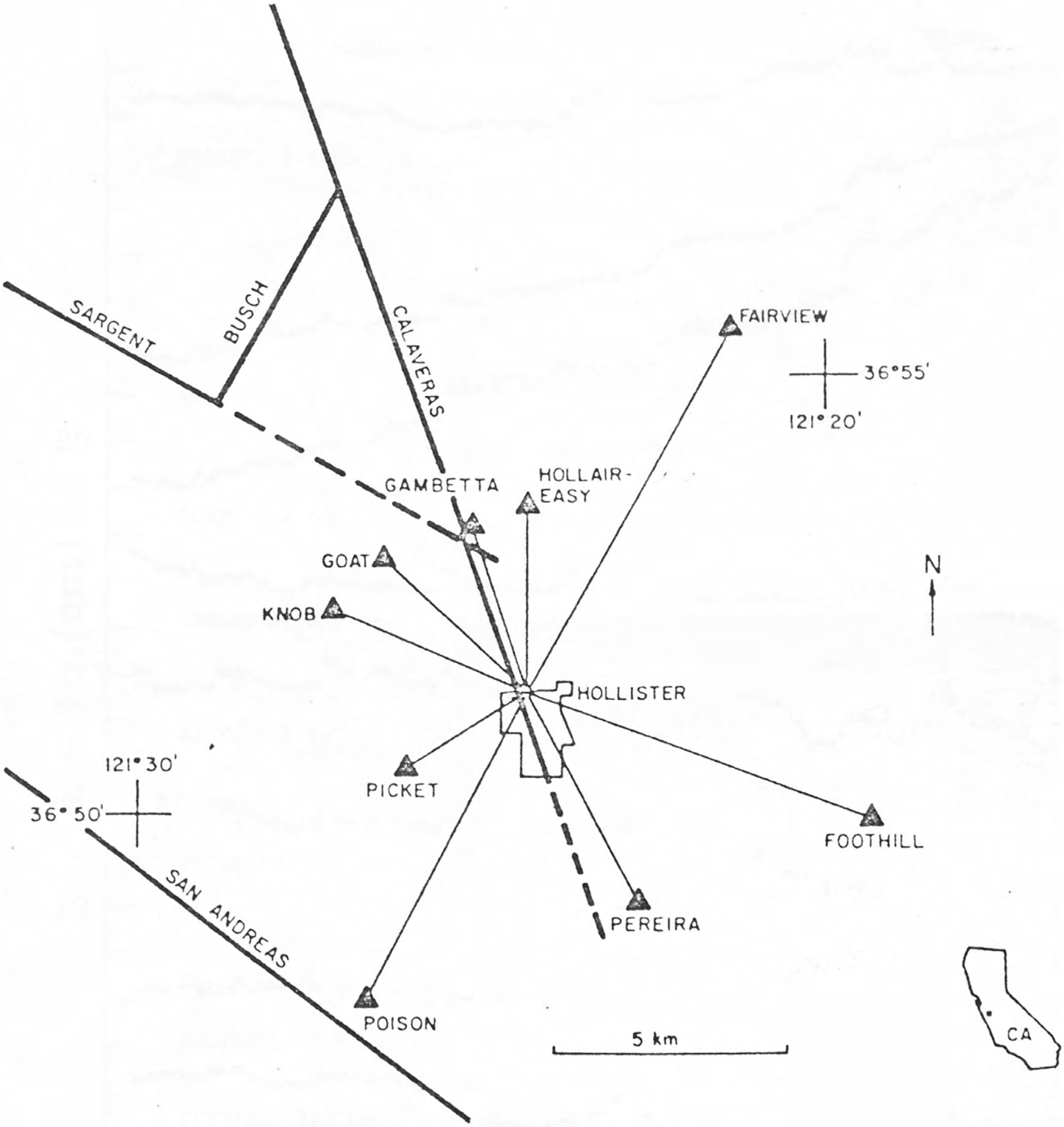



Fig. 1. The Hollister MWDM array.

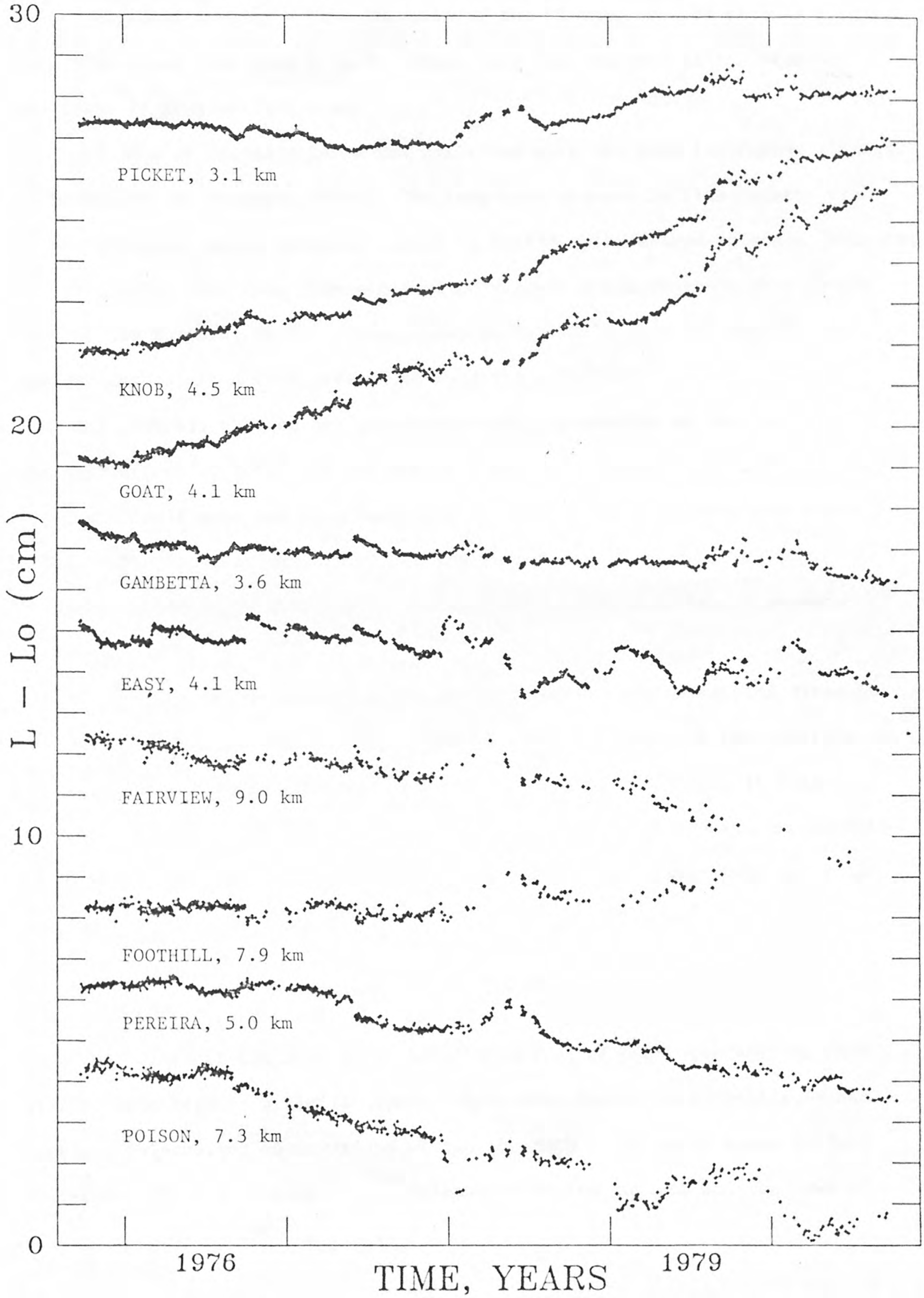

30
20
10
0
L – Lo (cm)
PICKET, 3.1 km
KNOB, 4.5 km
GOAT, 4.1 km
GAMBETTA, 3.6 km
EASY, 4.1 km
FAIRVIEW, 9.0 km
FOOTHILL, 7.9 km
PEREIRA, 5.0 km
POISON, 7.3 km
1976
1979
TIME, YEARS

Fig. 2

if the standard deviation from the mean of the 40 measurements exceeds 2 mm; data from lines less than 5 km in length have been omitted if the standard deviation is greater than 1 mm.

All data in the file LASER was collected with the MWDM instrument (Slater, 1975; Slater and Huggett, 1976). The long-term changes in line lengths within the Hollister array generally occur in fairly well-defined episodes (Huggett, et. al.; 1977) that have been ascribed to slip at depth on the nearby faults (Slater and Burford; 1979). These episodes typically last for several weeks and are intersperced with periods of relative quiescence.

The probability that the instrument site (identified as Park Hill in the MWDM effort or HOLLIS in the Survey's Geodolite program) is within the Calaveras fault zone has been addressed by Savage et. al. (1979) and Slater (1981). The apparent ability of the instrument site to exhibit arbitrary movement considerably complicates the analysis of the line length measurements.

Figure 2 shows an anomalous change in 1978 observed on several lines in the Hollister array. These changes have been associated with the possible propagation of a creep wave across the array by Slater (1980). If this interpretation is correct the creep wave propagation velocity was approximately 40 km/a. The analysis and interpretation of the Hollister MWDM array is ongoing.

## SAN JUAN BAUTISTA OBSERVATORY

The effort at San Juan Bautista will consist of MWDM observations that will be conducted in a similar operation to that conducted in Hollister and vertical deformation observations within the MWDM array using a new 2-fluid tiltmeter. Figure 3 shows the location of both instruments and the town of

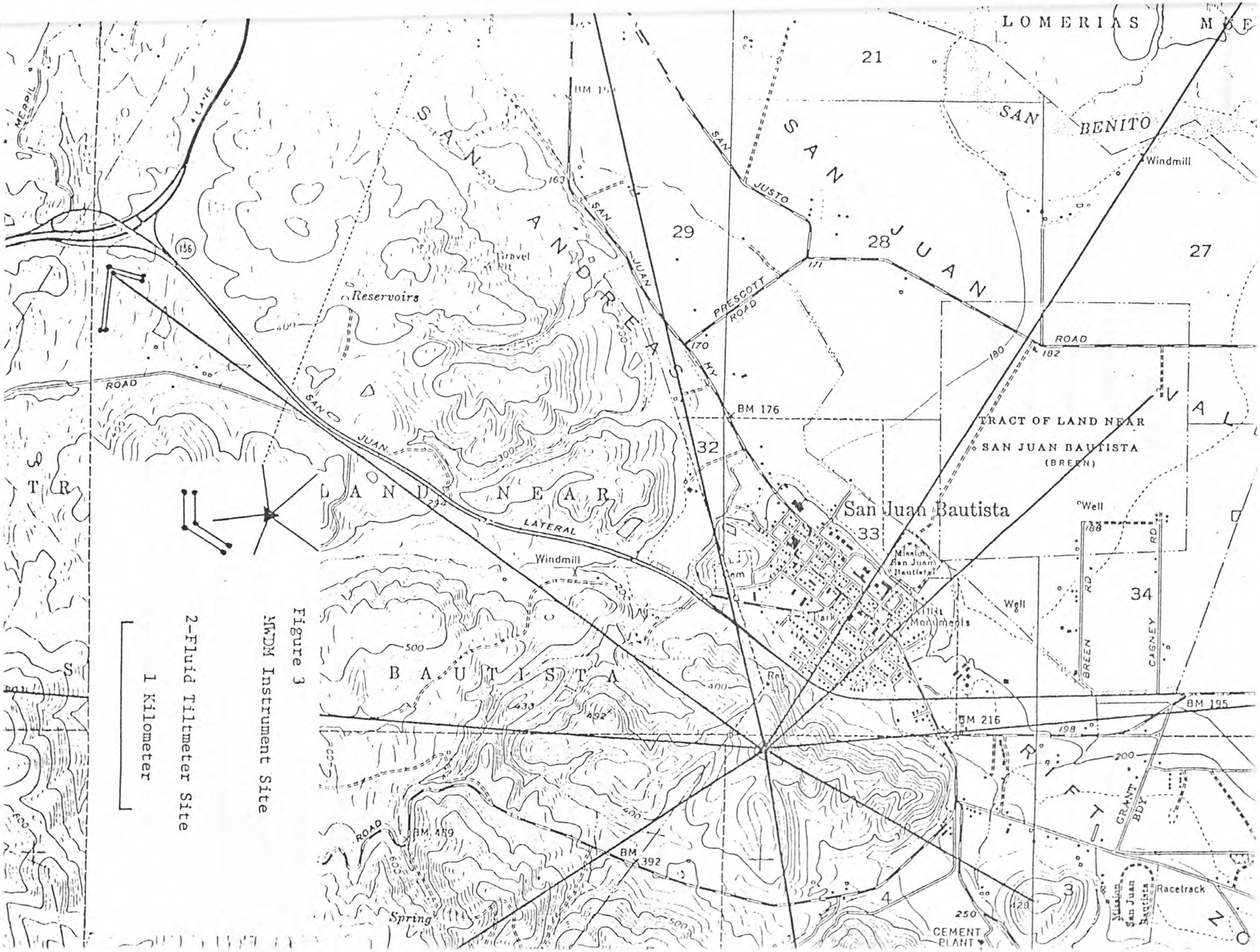



Figure 3
MFDM Instrument Site
2-Fluid Tiltmeter Site
1 Kilometer

San Juan Bautista. The 2-fluid tiltmeter installation is complete and as soon as instrument evaluation tests are completed (within a month from this date) the collection of vertical deformation data will begin. The MWDM observatory should be completed and ready for operation within 2 months if no further delays are incountered with the property owner of the most desired site.

## PALMDALE MWDM MEASUREMENTS

During the interim period between the termination of the Hollister MWDM array and the beginning of the San Juan Bautista effort it was jointly agreed that the University of Colorado and the U.S. Geological Survey should cooperate in an effort to establish a high precision geodetic network in the Palmdale region. A region near Pearblossom, California (Holcomb Ridge) was selected as the site for the MWDM instrument (Figure 4). Measurements were begun in early November 1980 with the expectation that the USGS would be in possession of a commercial version of the MWDM instrument within a few months. Since a satisfactory commercial instrument is not yet available we have jointly continued the effort with the University of Colorado instrument. Data collected to date is shown in Figure 5. Savage et. al. (1981) reported anomolous strain changes in this region that were detected by Geodolite surveys over the last 10 years. Figure 6 presents strain calculations using the recent MWDM data and illustrates similar changes in strain, particularly in the component that is normal to the San Andreas fault. Changes as large as a micro strain appear over time periods as short as a few months. These changes may be associated with variation in the state of stress across the fault such as those suggested by Slater (1981) within the Hollister MWDM array.

We intend to continue this interim work for a few more months until a

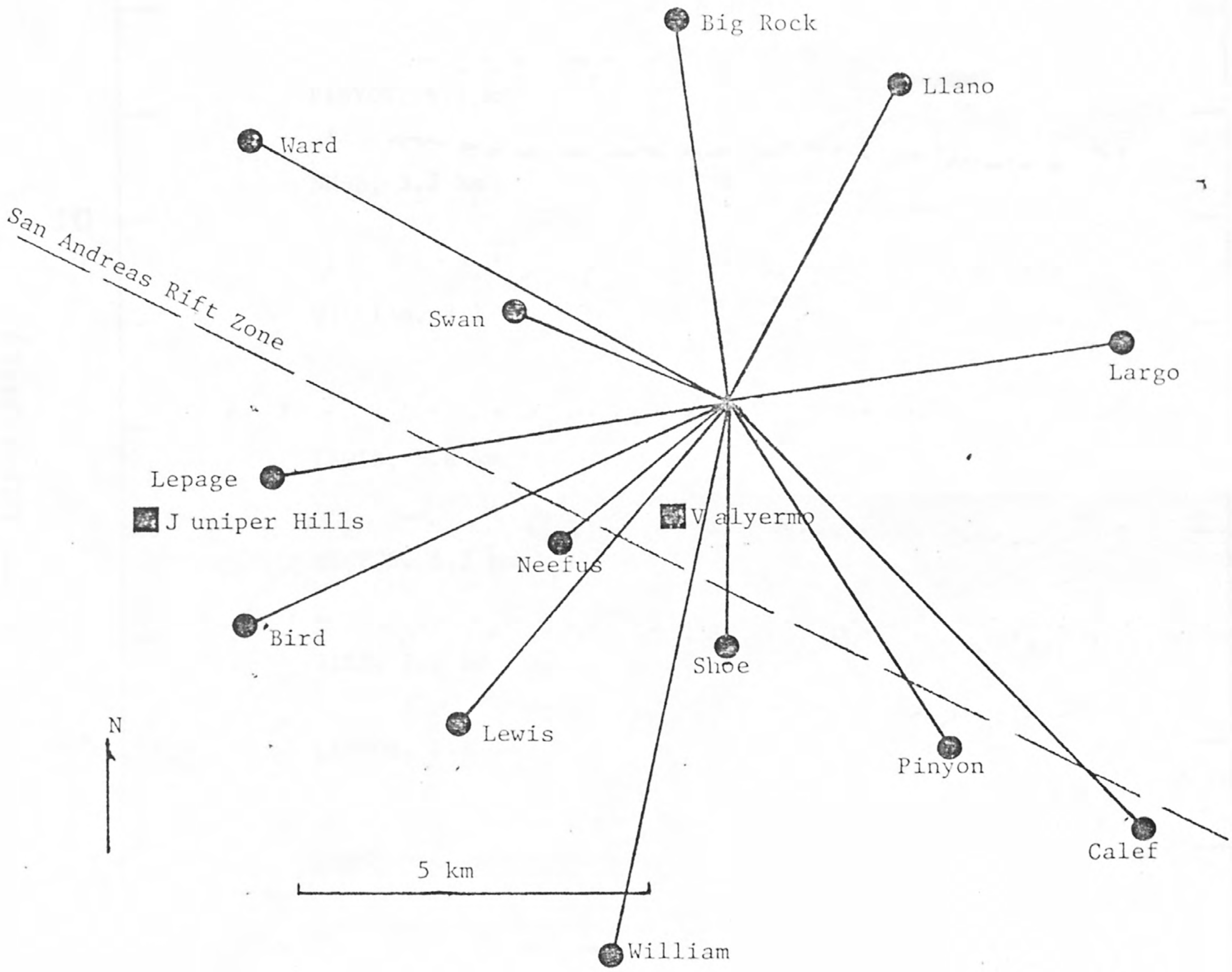



Fig. 4 Palmdale MWDM array.

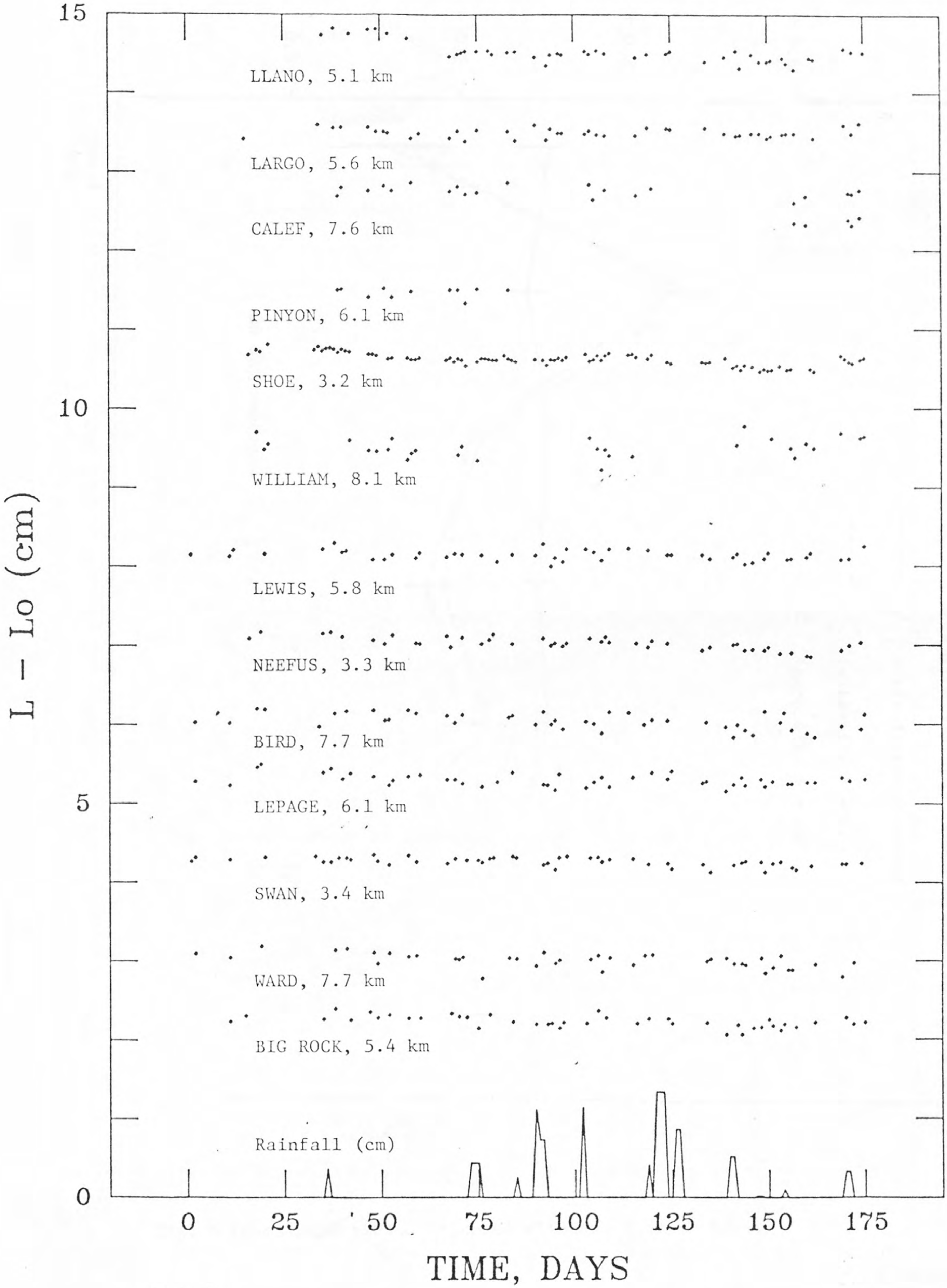

15
10
5
0
L - Lo (cm)
LLANO, 5.1 km
LARGO, 5.6 km
CALEF, 7.6 km
PINYON, 6.1 km
SHOE, 3.2 km
WILLIAM, 8.1 km
LEWIS, 5.8 km
NEEFUS, 3.3 km
BIRD, 7.7 km
LEPAGE, 6.1 km
SWAN, 3.4 km
WARD, 7.7 km
BIG ROCK, 5.4 km
Rainfall (cm)
0
25
50
75
100
125
150
175
TIME, DAYS

Fig. 5

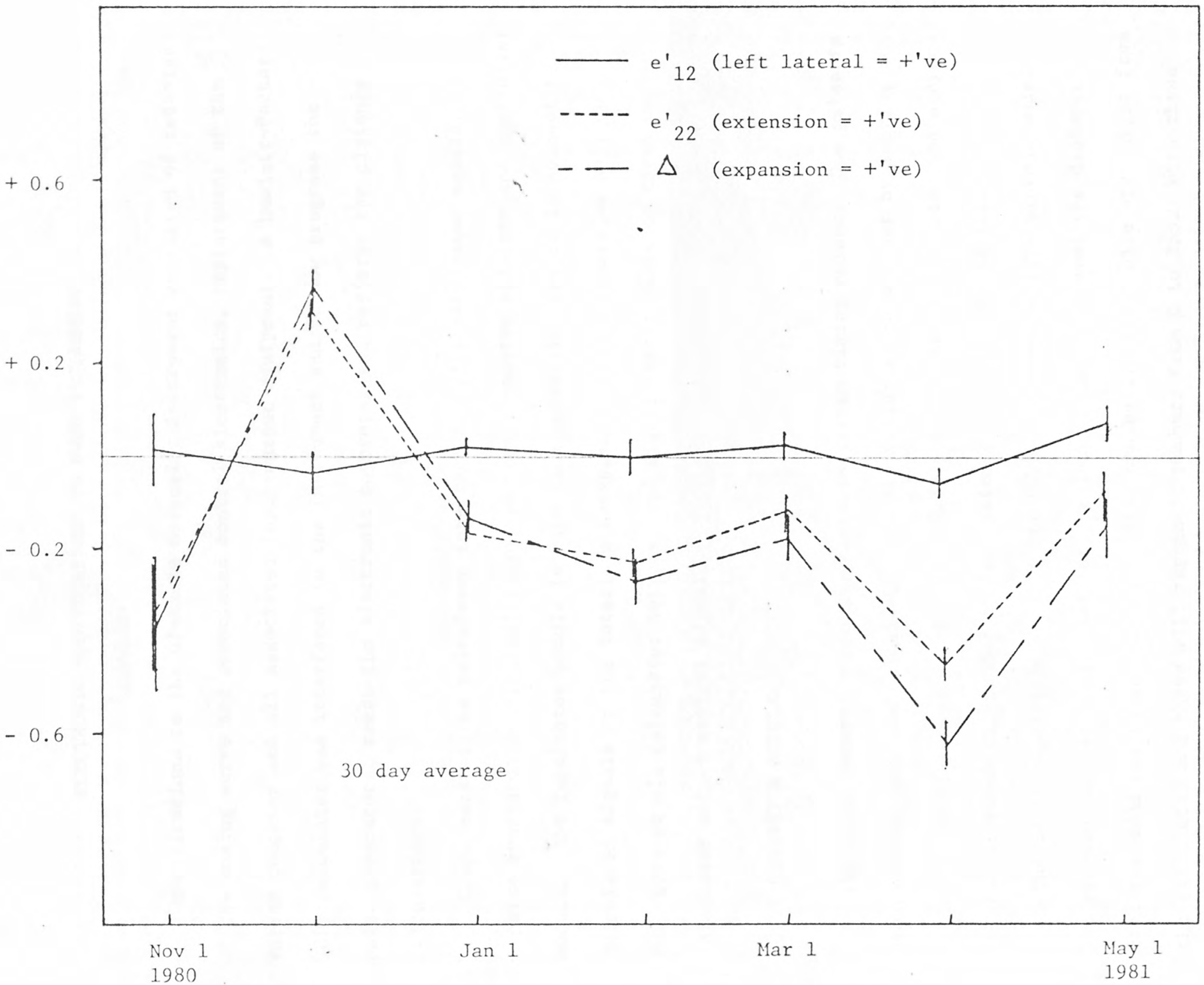



Fig. 6 Calculated strain oriented with San Andreas fault.

second MWDM instrument is available at which time the University of Colorado instrument will be relocated at the San Juan Bautista site. We plan to study focal plane solutions of nearby earthquakes during the period of the MWDM measurements in an attempt to determine if the occurrence of thrust and strike slip earthquakes are correlated with the observed periods of increasing and decreasing normal strain.

# ELECTRONIC MODIFICATIONS TO MWDM INSTRUMENT

Modifications to the distance measuring instrument consisted of redesign of the analog servo and associated control electronics, replacement of the Varian computer and all associated input-output equipment. A Hewlett-Packard 9815 calculator was interfaced to the instrument and it now programs the pulse generators, reads the electronic counters, and performs the distance calculations.

Components of the calculator interface are 1) a terminator module, 2) a pulse generator module, and 3) an electronic counter selector and controller module. The terminator module is used as a connection device to connect the calculator signals to the interface backplane. It also contains pull up resistors to all calculator outputs, and signal conditioners to clean up calculator output control signals.

## PULSE GENERATOR MODULE

The pulse generator module generates system timing pulses. One pulse is programmable from the calculator, two are variable and are set by setting switches, and three occur at fixed times. All pulses are started and stopped at precise times referenced to the system clock, a 1 Mhz device.

The basic repetition rate of the MWDM processes is 1024 microseconds. 256 microseconds is ample time for the laser light to travel the distance from the MWDM instrument to a reflector and back. Eight bits are output from the calculator and these will represent numbers from 0 to 255. With these constraints, it was decided to construct the interface so that the calculator could program the MOD 1 transmit pulse to occur at any microsecond boundary in the first 256 microsecond portion of the 1024 microsecond period.

Pulses MOD 2, INT, STEP, and RESET can occur at fixed times due to the nature of the measurement process. They all occur in the second 256 microsecond period, and their start and stop times are shown in Figure 7. INT is the integrate (or sample) pulse which is normally fixed with respect to the MOD 2 pulse. A variable pulse generator was used for the INT pulse, however, so that its start time or duration can be changed in the future, if necessary. Both the INT and spare variable pulse generators can be set to start at any time in the second 256 microsecond period, and to stop at any time. If the stop time setting is greater than the start time the pulse will stop in the second 256 microsecond period. Otherwise the pulse will stop in the third period.

Five of the six output pulses are used by the MWDM instrument, the timing of the pulses is shown in Figure 7. Fixed times which occur in the second 256 microsecond period are indicated in microseconds relative to the start of that period.

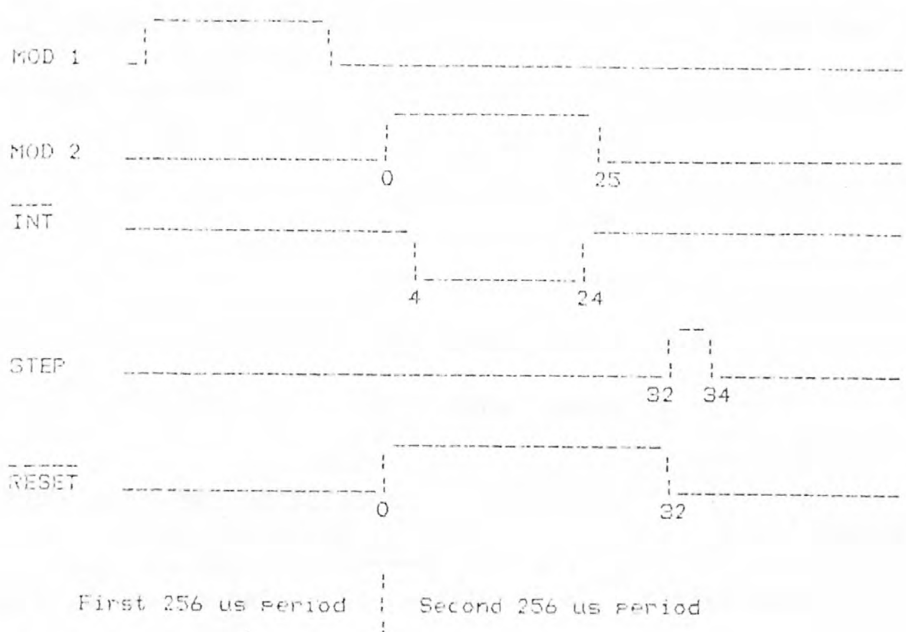



Fig. 7

Pulse MOD 1 is programmed by the calculator to start and stop at any time from 1 to 255 microseconds in the first period. Programming of the MOD 1 pulse generator is accomplished by outputting a zero followed by the start time and stop time in microseconds. The zero is used to reset the logic and cannot be used as a start time. WBYTE 4 is the calculator program step used to output data to the pulse generators. The MOD 1 pulse will stop in the second period if the programmed stop time is before the programmed start time.

ELECTRONIC COUNTER MODULE

The calculator can only read one counter at a time, so the electronic counter control module selects one of the two counter outputs for input to the calculator and informs the calculator when that counter is ready to read. It also synchronizes the counters so that they both count at the same time. This latter function is accomplished by using the inhibit input to the counters to inhibit counting until they have both been read by the calculator.

Programming the calculator to input counter data is done using the handshake 1 mode. First, a zero is output as with the pulse generators to reset the counter logic. Then data is input using two read sequences. The program steps for each sequence are:

```
0001   START 4
0002   STAT  4
0003   IF -
0004   GOTO  0002
0005   READ  4
```

ANALOG SERVO AND 5 MHz OSCILLATOR

This card now contains the redesigned electronics from both the previous analog servo card and the 5 MHz oscillator card. All of the analog switch transistors and drivers have been replace by a single intergrated circuit, IC7 (see Figure 8). The other major difference is that one of the optical isolators has been eliminated, and buffering for the counter outputs is done on another card. Operation of the card is as follows:

IC1 integrates the input signal (IC7 gates the input to IC1 and also resets it when done).

IC2 is a sample and hold which holds the intergrated signal until the next sample is integrated (IC7 gates the sample into this sample and hold circuit).

IC3 buffers the output of the sample and hold before it is input to the next stage which has an unbalanced input impedance.

IC4 has a gain of plus or minus 1 (-1 when the section of IC7 is turned on) so that one input signal can be subtracted from the other.

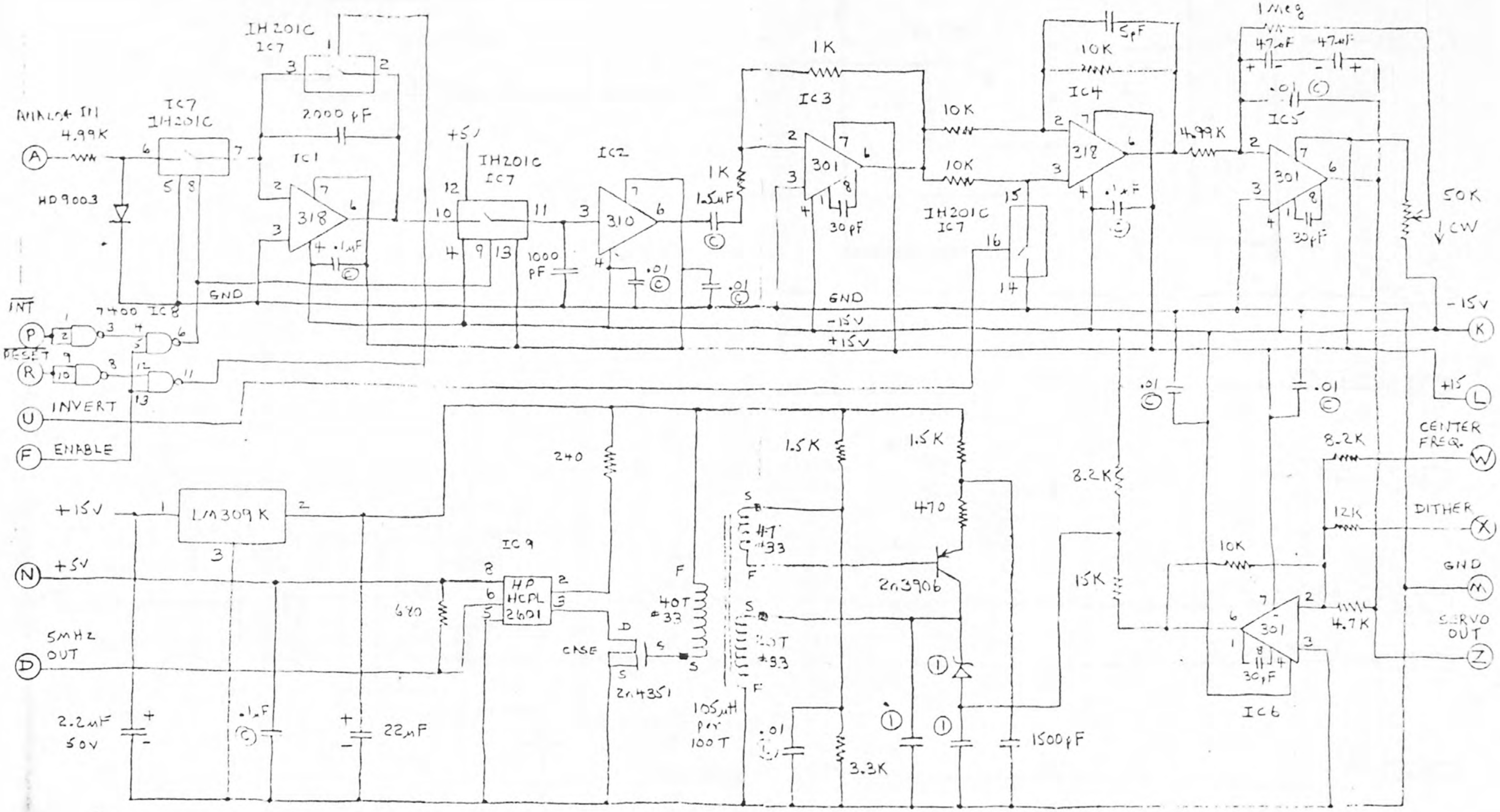
IC5 integrates (averages) the frequency error and feeds the error to the oscillator.

IC6 is an adder which adds dither, the servo output from IC5, and the center frequency input from the meter panel. It also has an output voltage range which is correct for input to the oscillator varactor.

IC9 is an optical isolator which buffers the oscillator output.

PIN SWITCH DRIVER, DITHER, AND ENABLE LOGIC

Output levels of the pin switch driver are +1 volt during standby and approximately 0 volts when driving the pin switch. The drive voltage is adjustable. IC3 divides the basic 1024 KHz down to produce the red and blue enable signals, and the dither signal. IC4 selects one of the two oscillator outputs (red or blue) and sends it to the microwave signal generator. IC4




Ⓒ Blue ceramic capacitor

Ⓘ Selected values

ANALOG SERVO AND
5 MHz OSCILLATOR

Fig. 8

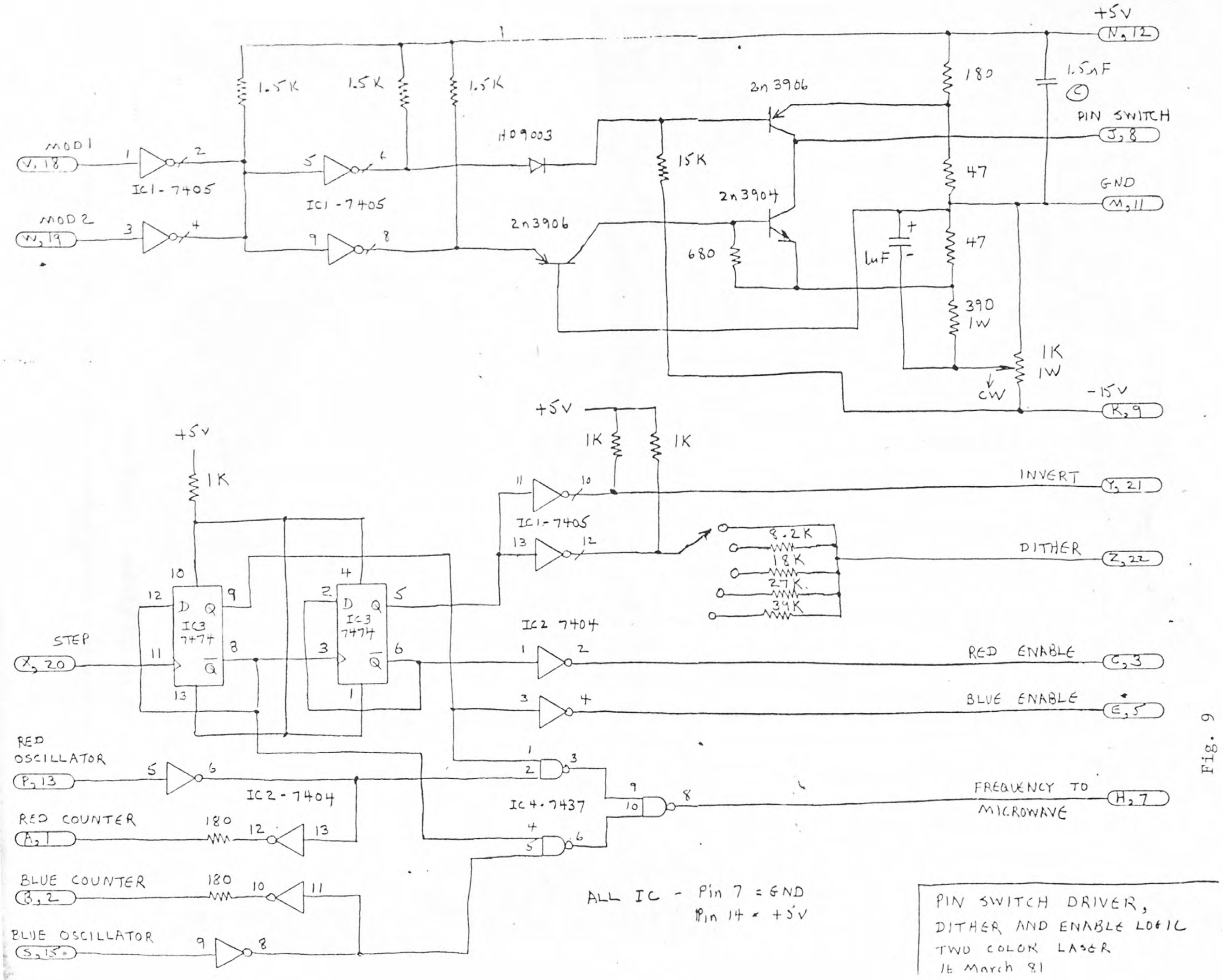

+5V
N, 12
1.5K
1.5K
1.5K
180
1.5nF
2n3906
PIN SWITCH
J, 8
MOD 1
V, 18
IC1 - 7405
H09003
15K
47
GND
M, 11
MOD 2
W, 19
IC1 - 7405
2n3904
2n3906
680
1uF
47
390 1W
1K 1W
CW
-15V
K, 9
+5V
1K
1K
+5V
1K
INVERT
Y, 21
IC1 - 7405
DITHER
Z, 22
8.2K
18K
27K
39K
IC3 7474
IC3 7474
IC2 7404
STEP
X, 20
RED ENABLE
C, 3
BLUE ENABLE
E, 5
RED OSCILLATOR
P, 13
IC2 - 7404
IC4 - 7437
FREQUENCY TO MICROWAVE
H, 7
RED COUNTER
A, 1
180
BLUE COUNTER
B, 2
180
BLUE OSCILLATOR
S, 15
ALL IC - Pin 7 = GND
Pin 14 = +5V
PIN SWITCH DRIVER,
DITHER AND ENABLE LOGIC
TWO COLOR LASER
16 March 81

Fig. 9

buffers the red and blue enable signals, and buffers the oscillator outputs for transmission to the frequency counters.

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