General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

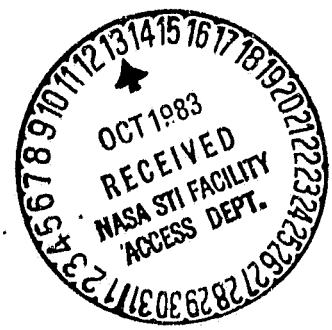
Produced by the NASA Center for Aerospace Information (CASI)

NASA

Technical Memorandum 85091

CRUSTAL DYNAMICS PROJECT OBSERVATIONS: 1982 RESULTS AND PLANS FOR 1983

Herbert Frey



(NASA-TM-85091) CRUSTAL DYNAMICS PROJECT OBSERVATIONS: 1982 RESULTS AND PLANS FOR 1983 (NASA) 26 p HC A03/MF A01 CSCL 08G

N83-35544

Unclas
G3/46 42131

SEPTEMBER 1983

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

CRUSTAL DYNAMICS PROJECT OBSERVATIONS:

1982 RESULTS AND PLANS FOR 1983

Herbert Frey
Assistant Project Scientist
Crustal Dynamics Project

Geophysics Branch
Goddard Space Flight Center
Greenbelt, MD 20771

1.0 INTRODUCTION

The observations made by SLR and VLBI systems in support of the scientifc goals of the Crustal Dynamics Project are summarized below for the calendar year 1982. These observations include (a) plate motion and plate stability measurements, (b) regional deformation measurements in western North America, and (c) intercomparison measurements derived from (a) and (b) where common baselines were measured by both techniques. Plate motion and plate stability observations depend primarily on the global network of fixed or non-moving VLBI and SLR systems. Regional deformation measurements are made principally with highly mobile SLR and VLBI systems supported by fixed base stations.

1982 was the last year in which system development dominated data acquisition. As described below, the number of highly mobile SLR and VLBI systems will double in 1983, and new fixed SLR and VLBI systems will significantly add to the ability of the global networks to make truly global measurements.

The summaries presented below (which will be published annually) are designed to give an idea of the baselines which should be derived from the observations, and which will ultimately be available in the Project's Data Information System (DIS). In general this report will predate final processing of the observations, so no compilation of actual "calculated" baselines will be presented here.

2.0 PLATE MOTION AND PLATE STABILITY MEASUREMENTS IN 1982

2.1 SLR OBSERVATIONS

Table 2.1 presents monthly totals of the returns acquired by the 14 non-moving SLR systems which operated in 1982. Stations are grouped by plate. The numbers in each column represent thousands of points. Asterisks in the GSFC and Hawaii columns indicate that more than one SLR system contributed to

TABLE 2.1 SLR PLATE MOTION, PLATE STABILITY OBSERVATIONS IN 1982

MONTHLY TOTALS IN THOUSANDS OF POINTS

	NORTH AMERICA					PACIFIC			AUSTRALIA		EURASIA						S AM
	QUINCY	PLATTEVILLE	FT. DAVIS	MAZATLAN	GSFC	MONUMENT	HUAHINE	HAWAII	YARAGADEE	ORRORAL	MATERA	WETTZELL	KOOTWIJCK	GRASSE	METSAHOVI	SIMOSATO	AREQUIPA
JAN	1.0	2.3			18.3*	1.4		7.4*	88.1	0.5			1.4				0.2
FEB	1.3	2.3			13.7*	5.5		3.0	63.3	0.9			1.4				0.1
MAR	3.1	4.8			50.4*	0.6		9.5	56.9			2.6	0.7				0.3
APR	16.2	4.5			112.9*	4.4		7.3	27.0			11.1	0.1				0.8
MAY	25.8	3.0			25.5*	7.6		23.1	38.5			7.4		1.0			12.1
JUN	29.9	3.5			15.2	7.2		20.6	13.9			0.9	0.7	2.5			12.9
JUL	25.5	7.6	5.1		30.4*	12.9		21.3	38.3			9.5		1.0			17.4
AUG	16.8	0.7	15.3		23.8	1.5			40.8			5.9		2.8	0.3		10.7
SEP	154.5	1.0	9.9		25.3*	8.0		11.4	47.6			49.0	0.4	1.6	0.7		6.5
OCT	130.1	20.2	2.7		109.1*	39.0		14.4	31.7			10.2	0.9	4.0	0.3	0.4	3.3
NOV	29.5	21.8	1.7		32.7*	12.5		5.2	8.0			13.1	0.7	8.1	0.4	0.1	1.1
DEC	31.3	8.7	5.8		15.3	22.8		22.3	19.3			--	1.0	3.7	0.9	0.8	6.5
	465.0	80.4	40.5		477.6	123.4		145.5	473.4	1.4		109.7	7.3	24.7	2.6	1.3	61.9

NOTES: * Indicates more than one system contributed to the total for this site

the total shown (e.g., both MOBLAS 1 and HOLLAS acquired data from Hawaii in January). The MLRS at Ft. Davis, TX began operations in July and the Orroral Valley system in Australia was shut down in March. Totals for the European systems represent data provided to the DIS through a cooperative exchange agreement.

Totals for the year are shown at the bottom of each column.

Weather effects are apparent in Table 2.1. Arequipa's rainy season lasted until April in 1982, after which the number of returns increased significantly. September through November were the best months for systems in the western United States and Europe.

The large jump in acquired data beginning in September at Quincy followed installation of the new short pulse Quantel laser. This upgrade is planned for most of the NASA network over the next several years.

A very general rule of thumb is that about 1000 points are required at each of two stations in the same month in order to calculate a baseline between the stations for that month. Applying this guideline to the numbers in Table 2.1 allows determination of the number of monthly baselines which should be available between any two stations in 1982. Table 2.2 presents this information in matrix format so that the number of monthly baselines between stations on different plates (or within the same plate) can be easily found. For example, it should be possible to calculate 11 monthly baselines between Quincy (North American Plate) and Monument Pk (Pacific Plate) because in the same 11 months both stations acquired at least 1000 points. By contrast, only 6 monthly baselines are possible between Ft. Davis and Monument Pk because Ft. Davis only acquired enough data for 6 of the 11 months Monument Pk had 1000 points.

TABLE 2.2 NUMBER OF MONTHS FOR WHICH BASELINES SHOULD BE OBTAINED

	NORTH AMERICA					PACIFIC			AUSTRALIA			EURASIA					S AM
	QUINCY	PLATTE	FT DAVIS	MAZATLAN	GSFC	MONUMENT	HUAHINE	HAWAII	YARAGADEE	ORRORAL	MATERA	WETTZELL	KOOTWIJCK	GRASSE	METSAHOVI	SIMOSATO	AREQUIPA
QUINCY	X	11	6		12	11		11	12			8	3	8	0	0	8
PLATTEVILLE		X	5		11	10		11	11			7	3	7	0	0	7
FT DAVIS			X		6	6		5	6			5	1	6	0	0	6
MAZATLAN				X													
GSFC					X	11		11	12			8	3	8	0	0	8
MONUMENT PK						X		11	11			7	3	8	0	0	8
HUAHINE							X										
HAWAII								X	11			8	3	8	0	0	8
YARAGADEE									X			8	3	8	0	0	8
ORRORAL										X							
MATERA											X						
WETTZELL												X	0	6	0	0	6
KOOTWIJCK													X	1	0	0	1
GRASSE														X	0	0	0
METSAHOVI															X	0	0
SIMOSATO																X	0
AREQUIPA																	X

ORIGINAL PAGE IS OF POOR QUALITY

Figure 2.1 shows baselines measured by the global SLR network in 1982 for which at least 6 monthly measurements of that baseline should be available. A summary Table 2.4 at the end of this section shows the actual number of plate motion and plate stability measurements (monthly determinations) and the number of non-redundant baselines over which these measurements are spread. The 1982 SLR network provided numerous measurements of multiple baselines between North America, Pacific and Eurasia, and multiple baselines within North America. As described below, this situation will improve in 1983.

2.2 VLBI OBSERVATIONS

Monthly VLBI measurements between North America and Europe are made by the National Geodetic Survey POLARIS network, using stations at Westford, MA, Ft. Davis, TX and Onsala, Sweden. These data are provided by NGS to the Crustal Dynamics Project under a data exchange agreement. In addition to these monthly baseline measurements, two North America-to-Europe VLBI experiments were conducted in 1982. Table 2.3 shows the stations involved for each day of the June and December measurements, and the number of plate motion and plate stability baselines which should be derived from these observations (each 24 hour session should yield a baseline between two simultaneously observing stations).

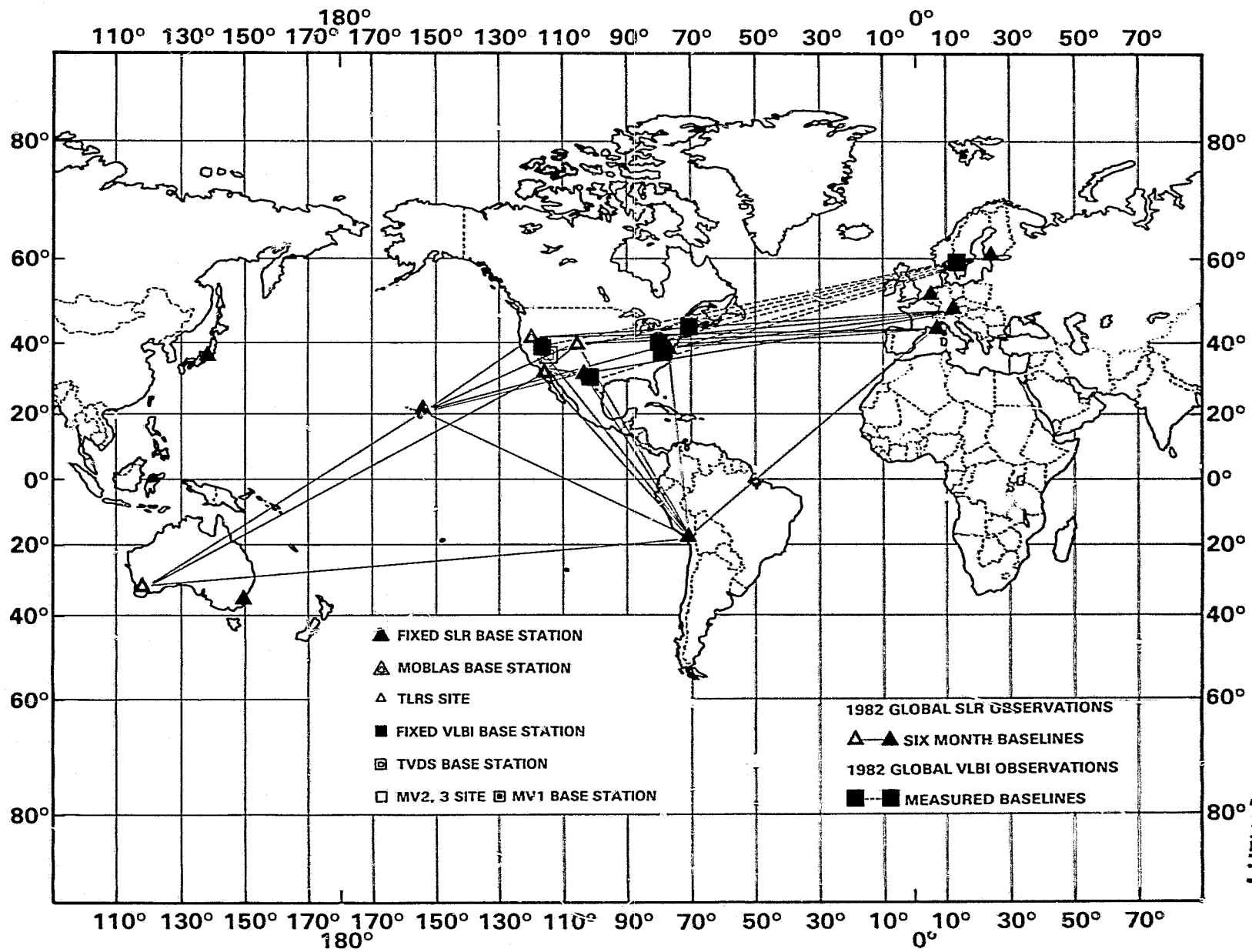
Only a single European station was available for these observations, so no Eurasian plate stability baselines were measured. Within North America the June and December experiments extended plate stability baselines westward to OVRO, CA. These measurements continue a history of cross-county VLBI geodesy which extends back to 1976. Beginning in 1983 a more elaborate North American plate stability experiment will be conducted each year.

Figure 2.1 shows VLBI baselines measured in 1982 between North America and Europe. The summary Table 2.4 shows that the total number of measurements

TABLE 2.3 VLBI PLATE MOTION, PLATE STABILITY MEASUREMENTS IN 1982

	JPL	OVRO	MOJAVE	DSS 13	HAT CREEK	FT. DAVIS	WESTFORD	HAYSTACK	MD. POINT	NRAO	FAIRBANKS	ONSALA	# PLATE MOTION BASELINES	# PLATE STABILITY BASELINES
82 June 16	*	*		*			*					*	4	3
17		*					*					*	2	1
18		*					*		*			*	3	3
19		*					*		*			*	3	3
20		*				*	*	*				*	4	6
21		*				*	*					*	3	3
82 Dec 15		*				*	*			*		*	4	6
16		*				*	*			*		*	4	6
17		*				*	*	*				*	4	6
													31	37

GLOBAL CRUSTAL DYNAMICS PROJECT SITES



ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 2.1

TABLE 2.4 PLATE MOTION, PLATE STABILITY MEASUREMENTS FOR 1982

( ) Indicates number of non-redundant baselines

	SLR		VLBI	
PLATE MOTION				
North America - Eurasia	63	(11)	28	(6)
North America - Pacific	76	(8)		
North America - Australia	41	(4)		
North America - South America	29	(4)		
Pacific - Eurasia	33	(6)		
Pacific - Australia	22	(2)		
Pacific - South America	15	(2)		
Australia - Eurasia	18	(3)		
Australia - South America	8	(1)		
PLATE STABILITY				
North America	51	(6)	31	(10)
Pacific	11	(1)		
Australia	--	-		
Eurasia	6	(1)		
South America	--	-		

Notes: SLR baseline measurements are monthly baselines.
VLBI baseline measurements are 24-hr observations.

ORIGINAL PAGE IS
OF POOR QUALITY

exclusive of the POLARIS observations was 28 spread over 6 baselines between North America and Europe, and 31 measurements over 10 baselines within North America.

3.0 REGIONAL DEFORMATION MEASUREMENTS IN 1982

3.1 SLR OBSERVATIONS

The highly mobile TLRS-1 visited 4 sites in western North America in 1982. Table 3.1 shows the location and number of points acquired by TLRS each month, the points acquired each month by the supporting base stations, and the number of baselines which should be available from this data each month. The criteria for enough points to calculate a baseline is the same as above: at least 1000 points at each station during the month.

The Ft. Davis occupation was for colocation measurements with the new MLRS, as indicated by the asterisks. Vernal, UT was reoccupied in 1982, and baselines between this site and both Platteville and Quincy can be compared with similar measurements made in 1981. OVRO was also occupied by TLRS-1 in 1981. Visits to OVRO by SLR systems constitute part of the very important intercomparison program, described in the following section, in which base stations for one observing technique (e.g., VLBI) are visited by highly mobile systems of the other type (e.g., SLR).

Figure 3.1 shows the regional deformation baselines measured by both SLR and VLBI systems in the western United States in 1982.

3.2 VLBI OBSERVATIONS

Little VLBI regional deformation observing was done in 1982 so that available manpower and resources could be devoted to completion of the second highly mobile VLBI system, MV-3. In October a hybrid MV 2/3 system visited the SLR base stations at Quincy and Monument Pk, providing baselines between these and

TABLE 3.1 SLR REGIONAL DEFORMATION MEASUREMENTS IN 1982
THOUSANDS OF POINTS RETURNED

	TLRS-1 SITE	POINTS	QUINCY	PLATTEVILLE	FT. DAVIS	MONUMENT PK.	# BASELINES
JAN	Mt. Hopkins, AZ	0.3	1.0	2.3	-	1.4	3
FEB	Mt. Hopkins, AZ	3.6	1.3	2.3	-	5.5	6
MAR	Mt. Hopkins, AZ	8.7	3.1	4.8	-	0.6	3
APR	Mt. Hopkins, AZ	3.3	16.2	4.5	-	4.4	6
MAY			25.8	3.0	-	7.6	3
JUN	Vernal, UT	12.2	29.9	3.5	-	7.2	6
JUL	Vernal, UT	6.2	25.5	7.6	5.1	12.9	10
AUG	Ft. Davis, TX*	18.5	16.8	0.7	15.3	1.5	6
SEP	Ft. Davis, TX*	1.8	154.5	1.0	9.9	8.0	10
OCT	OVRO, CA	<0.1	130.1	20.2	2.7	39.0	6
NOV	OVRO, CA	3.3	29.5	21.8	1.7	12.5	10
DEC	OVRO, CA	8.8	31.3	8.7	5.8	22.8	10
		66.7	465.0	80.4	40.5	123.4	79

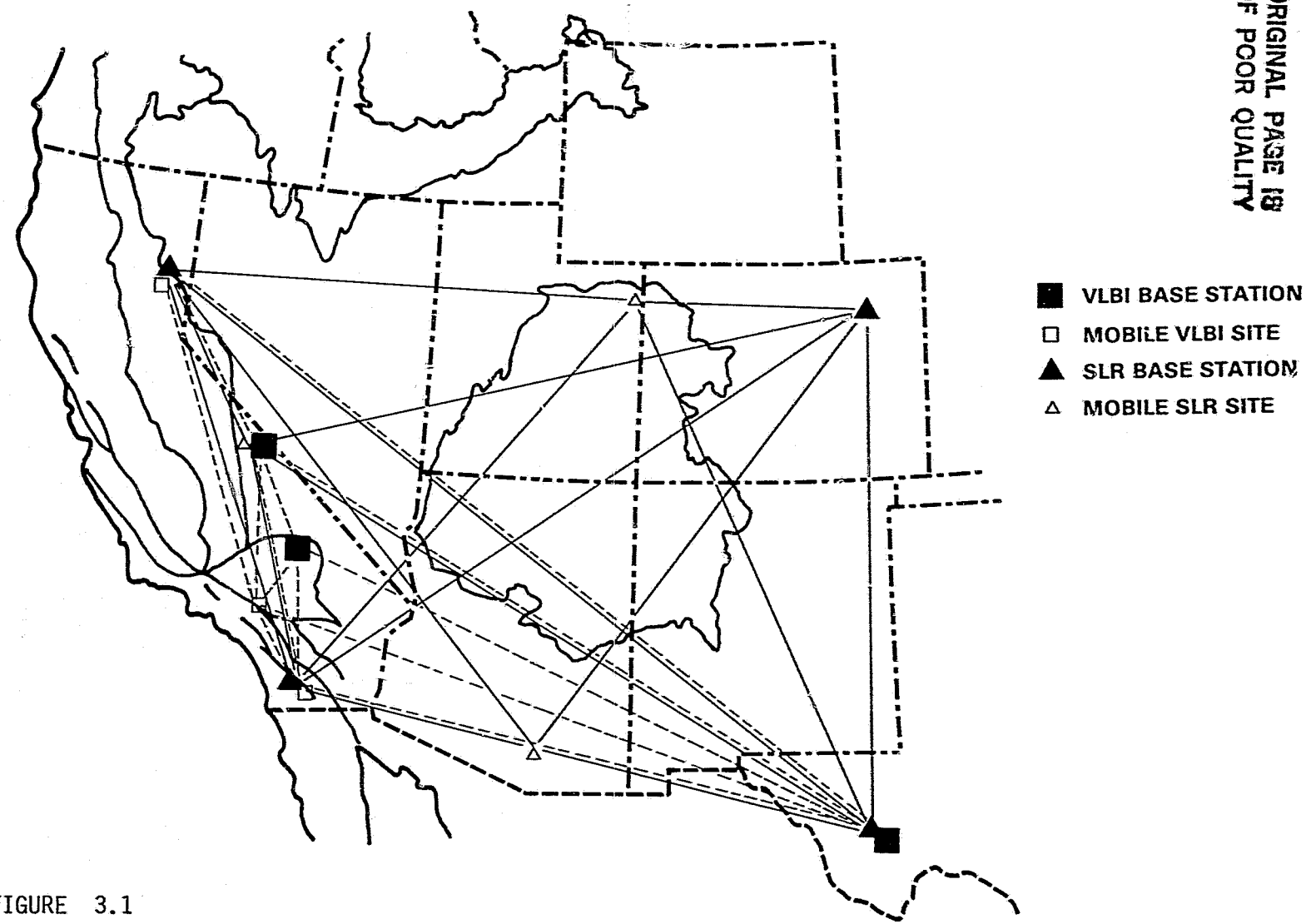
NOTES: * indicates colocation observations with MLRS at Ft. Davis

TABLE 3.2 VLBI REGIONAL DEFORMATION MEASUREMENTS IN 1982

		MV 2/3 SITE	JPL	OVRO	MOJAVE	DSS 13	HAT CR	FT. DAVIS	# BASELINES
82 OCT	15	MONUMENT PEAK	*	*		*		*	10
	17	MONUMENT PEAK		*		*		*	6
	21	QUINCY	*	*		*		*	10
	22	QUINCY		*		*		*	6
									32

REGIONAL CRUSTAL DYNAMICS PROJECT SITES

WESTERN NORTH AMERICA REGIONAL DEFORMATION 1982



ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 3.1

the VLBI base stations at OVRO and Goldstone. As shown in Table 3.2, Ft.Davis also participated in these observations, which are important intercomparison measurements of baselines also measured by SLR systems (see section 4.0).

The location of the MV-1 at JPL during October permitted two 24 hour measurements of the JPL-OVRO-Goldstone triangle in 1982, continuing the long history of such measurements.

The baselines measured as part of the 1982 regional deformation program are shown in Figure 3.1.

4.0 INTERCOMPARISON MEASUREMENTS IN 1982

Direct intercomparison of the SLR and VLBI measurements is an important part of the observational program. Intercomparison is accomplished by measuring common baselines by both techniques, which requires sites being occupied by both SLR and VLBI systems. Present observing plans call for dual measurement of 29 of the 55 possible baselines between sites in western North America. These intercomparison baselines are shown by the open circles in Table 4.1.

Those intercomparison baselines measured in 1982 are indicated by either a V (VLBI) or S (SLR) inside the circle. 5 baselines were measured by both systems in 1982. In addition, there were four VLBI measurements and 7 SLR measurements of other baselines which will, in the future, be measured by both systems. For intercomparison purposes a VLBI measurement is at least one 24 hour session, and an SLR measurement is at least one monthly baseline. There is no requirement that these observations occur at the same time.

5.0 MAJOR CHANGES PLANNED FOR 1983

Below are the major changes planned for calender year 1983. Details of the Crustal Dynamics Project Observing Program are available in a document by

TABLE 4.1 INTERCOMPARISON SITES IN WESTERN NORTH AMERICA FOR 1982

	QUINCY/HAT CR.	OVRO	GOLDSTONE	VANDENBERG	BLACK BUTTE	MONUMENT PK.	YUMA	VERNAL	PLATTEVILLE	FLAGSTAFF	FT. DAVIS
QUINCY/HAT CR.	X	V,S	V			,S		,S	,S		V,S
OVRO		X	V			V,S			,S		V,S
MOJAVE			X			V,					V,
VANDENBERG				X							
BLACK BUTTE					X						
MONUMENT PK.						X					V,S
YUMA							X				
VERNAL								X	,S		,S
PLATTEVILLE									X		,S
FLAGSTAFF										X	
FT. DAVIS											X

NOTES: V = VLBI baseline measurement
S = SLR baseline measurement

ORIGINAL PAGE IS
OF POOR QUALITY

the same name. Between 1982 and 1985 the program grows because new observing systems become available. A significant growth occurs between 1982 and 1983 as discussed below.

5.1 PLATE MOTION AND PLATE STABILITY MEASUREMENTS.

5.1.1 SLR OBSERVATIONS

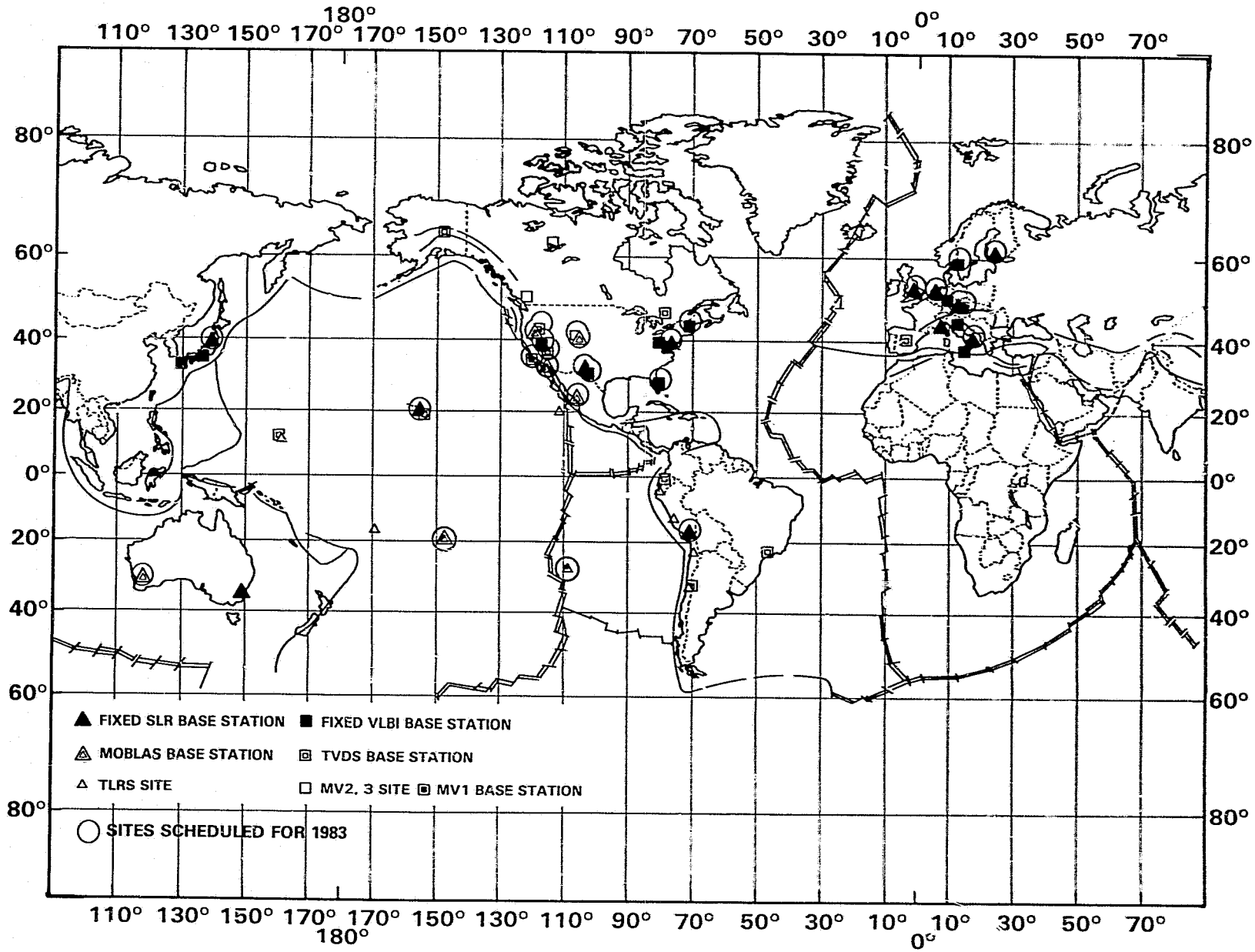
The global network of SLR systems will be augmented by five new stations in 1983. GSFC MOBLAS sites have been established in Mazatlan, Mexico and Huahine (near Tahiti) in French Polynesia. An SAO fixed laser will begin operations in Matera, Italy. The new highly mobile TLRS-2 will make the first of its annual 5 month occupations of Easter Island. Late in the year a high precision laser at the Royal Greenwich Observatory in England will begin operations. These sites are circled in Figure 5.1.

The Huahine site brings to three the number of continuously operating SLR systems on the Pacific Plate (the others are Hawaii and Monument Pk). This significantly enhances the determination of plate stability in the eastern Pacific, as well as the measurement of motion between the Pacific and North American Plates. The Easter Island site is the first of two proposed SLR sites on the Nazca Plate, and provides the opportunity to measure baselines which are expected to be changing rapidly: Easter to Hawaii and Easter to Huahine as well as Easter to Arequipa in South America.

The Italian site at Matera extends the European plate stability measurements south and east, and provides an important base station for future highly mobile operations in the Mediterranean.

The new site at Mazatlan on the west coast of Mexico extends the old SAFE measurements between the Pacific and North American plates (which are continuing) southward across the spreading in the Gulf of California, and also serves as an additional station for measuring the stability of the North American Plate.

GLOBAL CRUSTAL DYNAMICS PROJECT SITES



ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 5.1

5.1.2 VLBI OBSERVATIONS

A dedicated VLBI geodetic station at Wettzell, Germany will become operational in 1983, and will join the monthly POLARIS and less frequent Crustal Dynaimcs Project measurements between North America and Europe. Late in the year a third U.S. POLARIS station will begin operations at Richmond, FL. Both of these sites will also contribute to the routine plate stability measurements on the two separate continents.

The new stations participating in 1983 are shown in Figure 5.1.

Plate stability measurements in North America will include a special experiment in which a highly mobile VLBI system will be deployed to Platteville, CO. This provides an intermediate point between the OVRO and Westford sites from which cross-country VLBI measurements will be made. Ft. Davis, Hat Creek and Mojave will also participate in this experiment.

5.2 REGIONAL DEFORMATION MEASUREMENTS

The number of highly mobile SLR and VLBI systems doubles (from 1 to 2 each) in 1983, making possible not only more site occupations but also more selective baseline measurements. In particular, it becomes possible to work two highly mobile systems as a pair and measure the baseline between them as well as between the mobiles and the fixed base stations. The 1983 regional deformation program will be both more extensive and more complicated (see Crustal Dynamics Project Observing Program for details). Figures 5.2 and 5.3 show the sites which are scheduled to be occupied in the Western United States and California.

5.2.1 SLR OBSERVATIONS

A reoccupation of the old SAFE site at Otay Mt will occur in 1983. TLRS-2 will visit this site for approximately 4 months, tracking both the LAGEOS and BE-C satellites to aid in the tie between the new SAFE-type measurements (Monument

ORIGINAL PAGE IS
OF POOR QUALITY

NORTH AMERICAN CRUSTAL DYNAMICS PROJECTS SITES

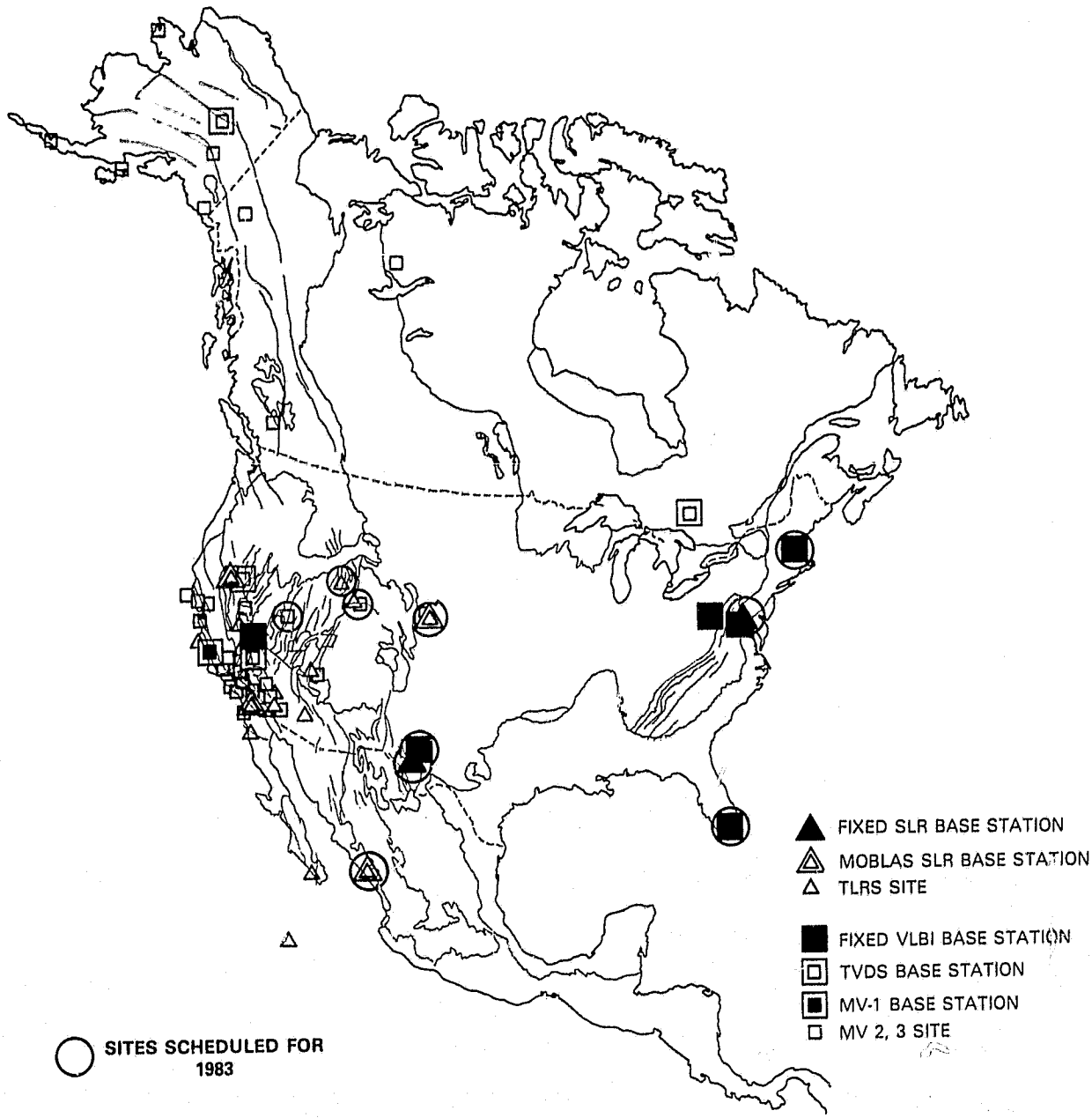


FIGURE 5.2

Pk-Quincy) and the older history of baseline determinations. This experiment is augmented by the observations at Mazatlan. TLRS-1 is scheduled to visit Yuma, Bear Lake, Quincy for a short colocation with the upgraded MOBLAS, Monument Pk for colocation with the MOBLAS there, and the VLBI base station at Vandenberg.

5.2.2. VLBI OBSERVATIONS

The 1983 VLBI Regional Deformation Observing Program has the following critical elements for 1983:

a) Use of MV-2 and MV-3 in paired configuration;

b) Location of MV-1 at Vandenberg as a permanent base station for California observations;

c) Operation of a dedicated fixed base station at Mojave;

d) Two separate California observing bursts (one in southern California, one in northern California); and

e) The first VLBI measurements of regional deformation in the Basin and Range.

The paired configuration capability is extremely important as it allows selection of the optimum geometry for measurements of expected motion. The Vandenberg base station provides a reference point on the western side of the San Andreas, improving the measurement of baselines crossing the plate boundary. The greater longitude separation from Mojave (the dedicated geodetic VLBI station in California) yields better overall geometric configurations between the base stations and mobile systems.

The two California observing bursts will be repeated each year. There is a significant amount of redundancy in site occupation: in southern California most sites are involved in two days of measurements as the mobile stations alternately move to new locations.

ORIGINAL PAGE IS
OF POOR QUALITY

CALIFORNIA CRUSTAL DYNAMICS PROJECT SITES

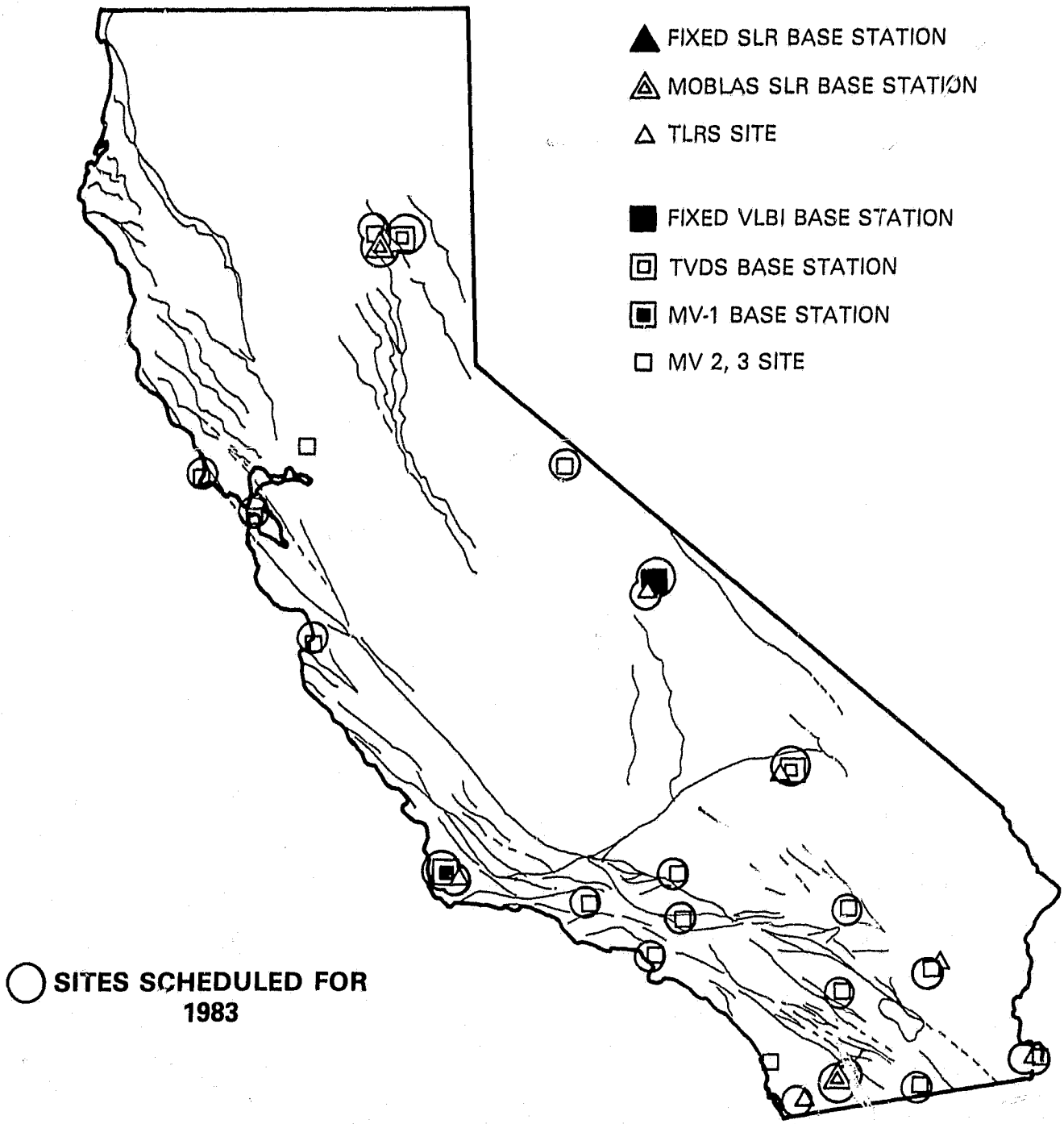


FIGURE 5.3

The Basin and Range measurements duplicate and extend SLR measurements in this same region, and combine with cross-country plate stability measurements (discussed above).

5.3 INTERCOMPARISON MEASUREMENTS

Table 5.3 shows the intercomparison baselines which the SLR (Table 5.1) and VLBI (Table 5.2) regional deformation measurements will provide in 1983. If all the planned observations are made, 14 of the 29 intercomparison baselines will be measured by both SLR and VLBI systems. 11 more baselines will be measured by VLBI alone and only 4 of the intercomparison baselines will not be measured in 1983.

TABLE 5.3 INTERCOMPARISON SITES IN WESTERN NORTH AMERICA FOR 1983

	QUINCY/HAT CR.	OVRO	MOJAVE	VANDENBERG	BLACK BUTTE	MONUMENT PK.	YUMA	VERNAL	PLATTEVILLE	FLAGSTAFF	FT. DAVIS
QUINCY/HAT CR.	X	V,S	V,	V,S		V,S		V,	V,S		V,S
OVRO		X	V,			V,S			V,S		V,S
MOJAVE			X		V,	V,					V,
VANDENBERG				X		V,S	V,				V,S
BLACK BUTTE					X	V,					V,
MONUMENT PK.						X	V,S				V,S
YUMA							X				V,S
VERNAL								X	V,		V,
PLATTEVILLE									X		V,S
FLAGSTAFF										X	
FT. DAVIS											X

NOTES: V = VLBI baseline measurement
S = SLR baseline measurement

ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE CAPTIONS

FIGURE 2.1 Plate motion baselines measured by SLR (solid lines) and VLBI (dashed lines) in 1982. SLR baselines are only shown when 6 or more monthly baselines can be computed from the data (see text).

FIGURE 3.1 Regional deformation baselines measured by SLR (solid lines) and VLBI (dashed lines) in 1982. SLR baselines represent at least one monthly baseline(see text). Note baselines measured by both techniques(intercomparison baselines).

FIGURE 5.1 Sites planeed for global SLR and VLBI measurements in 1983. See text for details of sites new for 1983.

FIGURE 5.2 Sites planned for regional deformation measurements in 1983 in North America.

FIGURE 5.3 Sites planned for regional deformation measurements in 1983 in California.