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A Proposed Test Area for The Spaceborne Geodynamics Ranging System

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ABSTRACT

This paper presents a recommendation for a test area for the Spaceborne Geodynamics Ranging System (SGRS), a proposed technique for precise geodetic measurements in which an orbiting laser would obtain intersite distances between retroreflectors 25 to 100 km apart on the ground. The recommended area is a rectangle 200 by 400 km in southern California and adjacent Nevada, trending northeast. It includes the entire width of the San Andreas fault zone, the Garlock fault, the thrust faults of the Transverse Ranges, and the active strike-slip faults of the Mojave Desert. Correlative ground data could be obtained from existing surveys. Results from the SGRS should be of value in measuring strain accumulation in the area and in monitoring ground subsidence.

INTRODUCTION

It has been proposed by Vonbun, et al. (1977) to use an orbiting laser in conjunction with ground-emplaced retroreflectors to obtain precise measurements of intersite distances ranging from 25-100 km. Horizontal and vertical measurements with standard deviations of about 2 cm are expected (Fitzmaurice, 1978). This technique, the Spaceborne Geodynamics Ranging System (SGRS), should if successful, provide valuable data on strain accumulation, tectonic activity in general, and ground subsidence. Present tentative plans* call for a test site measuring 200 by 400 km in southern California and adjacent Nevada, which will (1) validate the system and (2) permit acquisition of useful data. The purpose of this note is to recommend a specific site and to explain the basis for the recommendation.

RECOMMENDED SITE

It is recommended that the 42 SGRS retroreflectors be deployed within a rectangle trending northeast-southwest as shown (Figs. 1, 2), across the Transverse Ranges, Mojave Desert, and south ends of the San Joaquin Valley and Sierra Nevada.

In a global tectonic context, this area is on the boundary between the Pacific and North American plates (Fig. 3). The boundary is widely assumed to be the San Andreas fault system, although as Fig. 3 shows, it is actually a broad diffuse zone of tectonic activity of which the San Andreas system is but one element (admittedly the most active in terms of shearing movement). More specifically, the recommended SGRS site covers the entire width of the San Andreas system, the Garlock fault, and the thrust faults of the Transverse Ranges. In the northwest-southeast direction, it covers a region in which the San Andreas fault system changes from a narrow, well-defined feature north of the Transverse Ranges to a broad zone consisting of many parallel faults, of which the San Jacinto is the most active rather than the nominal San Andreas.

*Private communication, D.E. Smith

Reasons for recommending this particular area as a SGRS site follow.

1. Seismic Risk

The proposed SGRS area covers a part of southern California in which there has not been a major earthquake along the San Andreas fault since 1857. Since movement along the San Andreas system, presumably reflecting plate movements, has continued southeast and northwest of this area, the "Big Bend" of the San Andreas would appear to be an area of high seismic risk. However, there is no assurance that the next major strain-releasing earthquake will occur along the San Andreas system. In particular, the various reverse faults of the Transverse Ranges are good candidates for a large event, as demonstrated by the 1971 San Fernando earthquake and geodetic data to be discussed (Thatcher, 1976). The northeast-trending faults roughly parallel to the Garlock fault are also of interest; the 1952 Kern County earthquake was caused by left-lateral reverse movement along the White Wolf fault.

The area proposed for the SGRS experiment is a critical one for seismic risk not only because of potential direct earthquake damage in the Los Angeles basin but because of indirect effects such as damage to facilities of the California State Water Project. A major earthquake along the San Andreas fault in this area, for example, could disrupt the California Aqueduct supplying the Los Angeles basin, as well as many roads, railroads, and pipelines.

2. Areas of Ground Subsidence

Ground subsidence due to fluid withdrawal or peat compaction is a major problem in several parts of California (Poland, 1969). The area proposed for the laser experiment includes four such areas: Arvin-Maricopa, Lancaster, La Verne, and Wilmington; the last-named has been essentially controlled by repressuring. Since these areas are being monitored by conventional techniques, a good correlative data base is available. Subsidence studies will presumably benefit from the vertical accuracy expected for the SGRS, but vertical measurements might also be useful for monitoring slope stability, a perennial problem in southern California.

3. Localized Uplift in the Transverse Ranges ("Palmdale Bulge")

The proposed test area includes the region in which the unusual aseismic uplift centered on Palmdale was discovered by leveling measurements (Castle, et al., 1976; Thatcher, 1976). Thatcher suggested, among other techniques, a program of frequent leveling measurements along 30 to 70 km baselines to study possible earthquake precursory movements; the SGRS would seem well suited to such investigations. The intensive surveys recently conducted to study the "Palmdale Bulge" will of course provide invaluable correlative data.

4. Correlative Surface Geodetic Data

As reported by Bennett and Rodgers (1975) and in the National Ocean Survey (1973) collection, the San Andreas fault has been resurveyed for several decades. In the area proposed for the SGRS laser array, a variety of surveys have been carried out, including leveling, triangulation, and Geodimeter measurements. These projects will provide further correlative data for validation of the proposed orbital laser measurements. The collective results of these ground surveys will be discussed separately. However, it should be noted here that Bennett and Rodgers recommended extending Geodimeter measurements to 100 km on either side of the San Andreas fault to map the strain field; SGRS measurements would be a useful supplement to conventional geodetic nets.

5. Ground Visibility

Any optical ranging technique is obviously dependent on atmospheric conditions. The proposed SGRS experiment is especially vulnerable to bad visibility conditions because of the short duration of Shuttle missions and the orbit design, both of which combine to permit a relatively small number of target opportunities in contrast to long-duration satellites such as Landsat. The area recommended in southern California should provide a reasonably high probability of good ground visibility during any given mission. The Mojave Desert is generally free from clouds and haze dense enough to block an optical pulse from overhead, and the higher elevations in the Transverse Ranges are frequently above the stratus clouds and smog that obscure the Los Angeles Basin. The south end of the San Joaquin Valley, however, shares with the rest of the Central Valley the problem of persistent stratus clouds (especially in winter) confined by the surrounding ranges.

6. Scientific Importance

The area recommended for reflector emplacement is of unusual geological and geophysical interest for a number of reasons. First, as mentioned earlier, the Transverse Ranges are a transition zone in which the San Andreas system changes from a narrow, well-defined fault zone to a broad zone of strike-slip faults, no one of which clearly merits the label "San Andreas fault" (Hileman and Hanks, 1975). A classic problem, in which this transition zone is critical, is the cumulative lateral displacement on the San Andreas fault. As summarized by Crowell (1975), a figure of about 300 km is widely (though by no means universally) accepted in southern California, but nearly twice that, 550 km, seems indicated to the north. Measurements of present activity will probably not contribute much to resolving this contradiction; nevertheless, the problem illustrates the regional importance of the Transverse Ranges and adjacent areas.

A pressing problem to which a geodetic approach is obviously called for is that of strain accumulation around the "Big Bend." The various regional surveys summarized by Bennett and Rodgers (1975) reveal little or no evidence of horizontal movement or strain accumulation along the San Andreas fault. They suggested a locked zone at least 30 km deep to account for this finding. On the other hand, Castle and others (1975) demonstrated the more localized uplift centered on the Palmdale area, and Thatcher (1976) showed that both vertical and horizontal deformation had occurred here. Thatcher inferred strain accumulation on the north-dipping thrust faults south of the San Andreas in the Transverse Ranges. The proposed SGRS measurements should be helpful in understanding the regional strain field by extending horizontal and vertical control, and in principle permitting more frequent measurements.

Still another problem centered on this part of California is the nature of the Garlock fault and the few others parallel to it (possibly including the White Wolf fault), and of the many active right-lateral faults in the Mojave Desert parallel to the San Andreas. A recent study of this area has been made by Cummings (1976), who proposed that the Mojave region could be modeled by a Prandtl cell, in which a plastic material is compressed between two rigid plates. The distribution of strike-slip faults in the Mojave and their sense of displacement appears to correspond fairly well to a Prandtl cell. In any event, the problem of the Mojave block and the Garlock fault seems ideally suited to geodetic investigations, specifically the spaceborne laser approach.

DISCUSSION

There are obviously many pressing problems whose solution the spaceborne laser ranging experiment could contribute to if successful. However, it must be pointed out that the area recommended for a test site is not the best one if considered solely from the viewpoint of validating the technique. A similar test site farther north, for example, oriented across the San Andreas fault and San Joaquin Valley, would include areas of ground subsidence and would involve a much less complicated structural situation. The site recommended is one of unusually complex structure, and furthermore one in which crustal movements may be episodic, localized, and of variable direction.

Against these problems must be set the availability of a wide variety of ground surveys and in situ instrumentation, which should permit technique validation even in this complex area. Most important, success in the SGRS would almost certainly make significant contributions to our knowledge of several extremely important geological problems, especially that of earthquake hazard reduction.

In summary, the recommended test site for the retroreflectors appears to combine the advantages of permitting technique verification and providing new data on several critical problems.

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FIGURE CAPTIONS

Figure 1: Landsat mosaic prepared by Soil Conservation Service showing southwest United States. See Figure 2 for landmarks and other data.

Figure 2: Tectonic map of Figure 1, from Lowman (1976), showing SGRS site.

Figure 3: Map of global tectonic activity, showing SGRS site in relation to global tectonics.

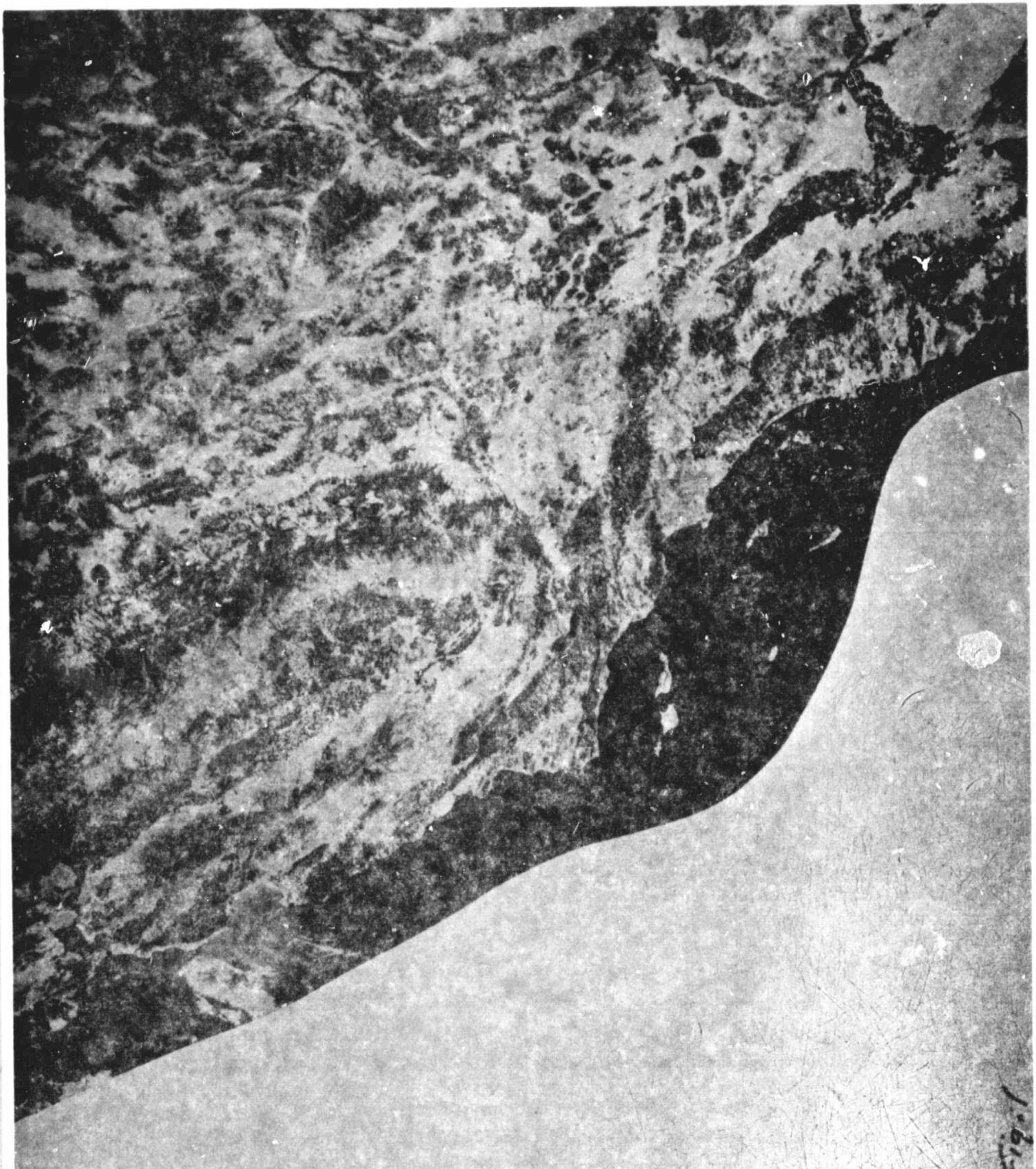
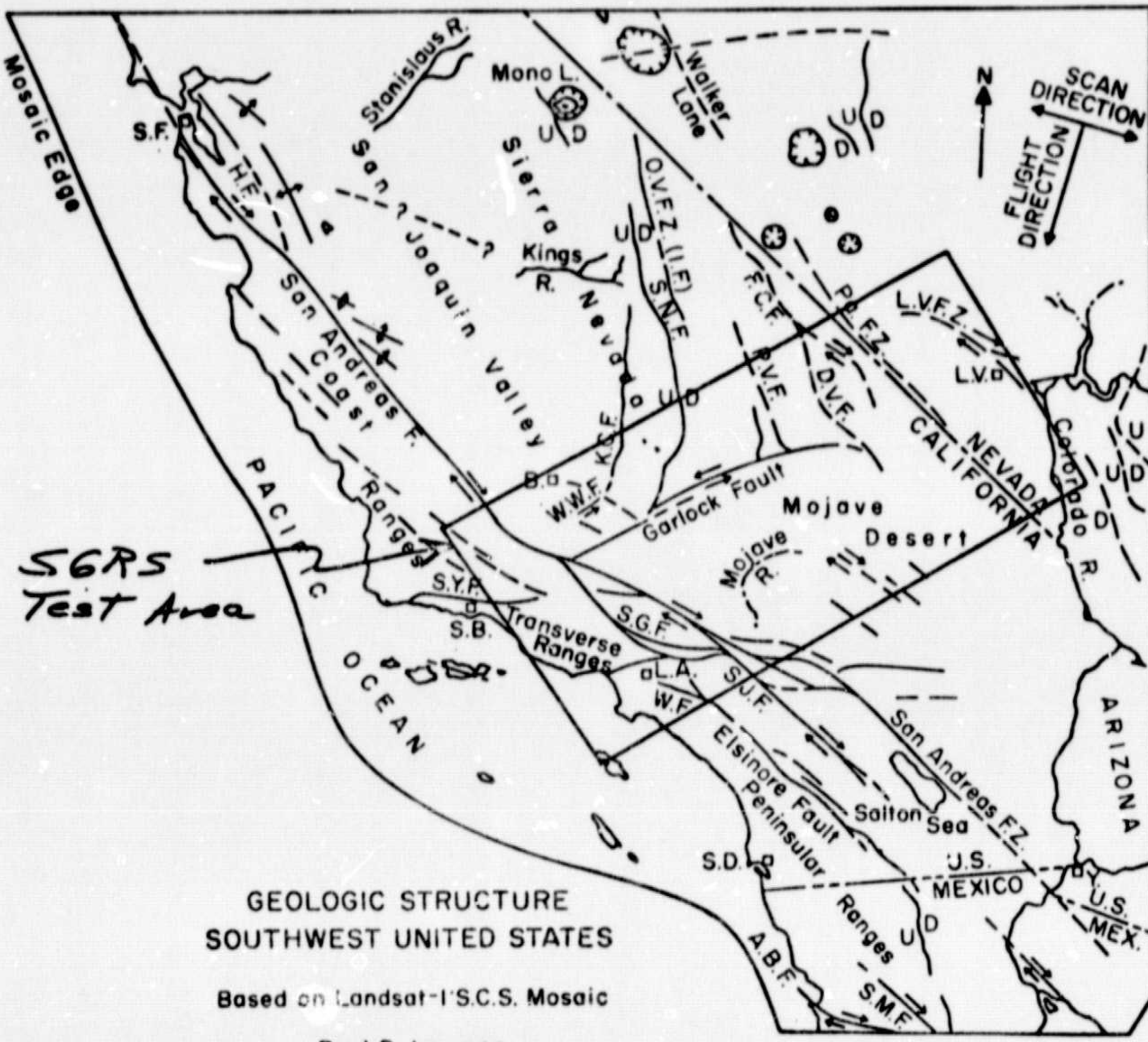


Fig. 1



GEOLOGIC STRUCTURE
SOUTHWEST UNITED STATES

Based on Landsat-1 S.C.S. Mosaic

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Goddard Space Flight Center

January, 1976

160 Km.
100 Miles

Legend

Fault (solid where confirmed, dashed where inferred)

Anticline

Volcanic center

Reference

1. Geologic Atlas of California
2. Tectonic Map of N. America (King, 1969)
3. Rowan and Wetlaufer (1975)

Tectonic base map from California Geology, v.29, no.4, p.75-81, April 1976, "Geologic structure in California: three studies with Landsat-1 imagery," P.D. Lowman

Fig. 2

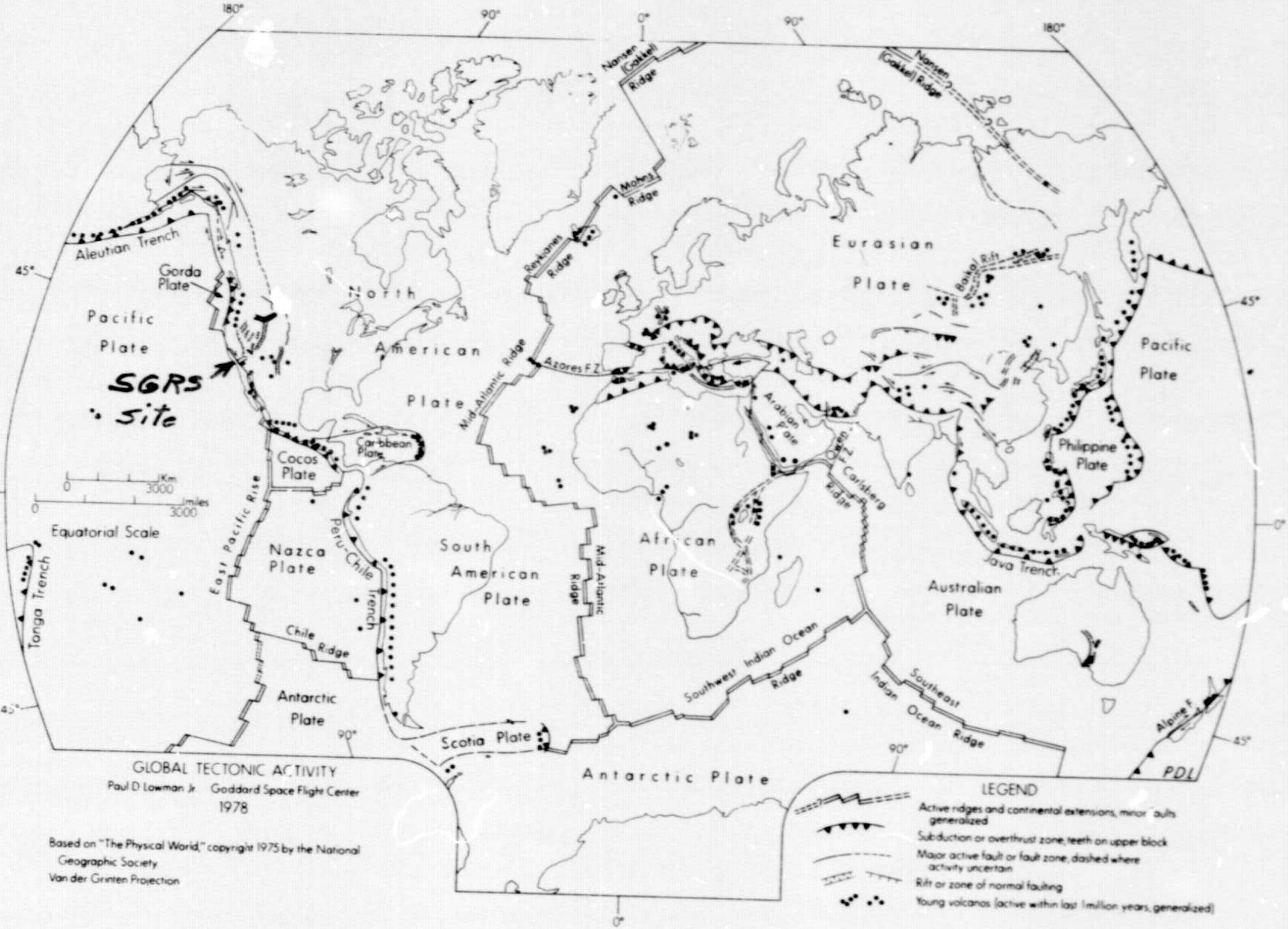
GLOBAL TECTONIC ACTIVITY
Paul D Lowman Jr. Goddard Space Flight Center
1978
Based on "The Physical World," copyright 1975 by the National Geographic Society
Van der Grinten Projection
SGRS site
Pacific Plate
Gorda Plate
Aleutian Trench
North American Plate
Cocos Plate
Caribbean Plate
Nazca Plate
East Pacific Rise
Peru-Chile Trench
Chile Ridge
South American Plate
Antarctic Plate
Scotia Plate
Tonga Trench
Equatorial Scale
Mid-Atlantic Ridge
Azores F.Z.
Reykjanes Ridge
Mohns Ridge
Nansen (Gakkel) Ridge
Eurasian Plate
Baikal Rift
African Plate
Arabian Plate
Owen F.Z.
Carlsberg Ridge
Southwest Indian Ocean Ridge
Southeast Indian Ocean Ridge
Australian Plate
Java Trench
Philippine Plate
Alpine F.
PDL
LEGEND
Active ridges and continental extensions, minor faults generalized
Subduction or overthrust zone, teeth on upper block
Major active fault or fault zone, dashed where activity uncertain
Rift or zone of normal faulting
Young volcanos (active within last 1 million years, generalized)

Fig. 3

BIBLIOGRAPHIC DATA SHEET

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16. Abstract

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