Winnetka deformation zone: Surface expression of coactive slip on a blind fault during the Northridge earthquake sequence, California

Evidence that coactive faulting occurred in the Canoga Park, Winnetka, and Northridge areas during the 17 January 1994, Northridge, California earthquake

by

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Table of Contents

List of Figures

List of Tables

List of Plates (in pocket)

Abstract

Measurements of normalized length changes of streets over an area of 9 km^2 in San Fernando Valley of Los Angeles, California, define a distinctive strain pattern that may well reflect blind faulting during the 1994 Northridge earthquake. Strain magnitudes are about 3×10^{-4}, locally 10^{-3}. They define a deformation zone trending diagonally from near Canoga Park in the southwest, through Winnetka, to near Northridge in the northeast. The deformation zone is about 4.5 km long and 1 km wide. The northwestern two–thirds of the zone is a belt of extension of streets, and the southeastern one–third is a belt of shortening of streets. On the northwest and southeast sides of the deformation zone the magnitude of the strains is too small to measure, less than 10^{-4}. Complete states of strain measured in the northeastern half of the deformation zone show that the directions of principal strains are parallel and normal to the walls of the zone, so the zone is not a strike–slip zone. The magnitudes of strains measured in the northeastern part of the Winnetka area were large enough to fracture concrete and soils, and the area of larger strains correlates with the area of greater damage to such roads and sidewalks. All parts of the pattern suggest a blind fault at depth, most likely a reverse fault dipping northwest but possibly a normal fault dipping southeast. The magnitudes of the strains in the Winnetka area are consistent with the strains produced at the ground surface by a blind fault plane extending to depth on the order of 2 km and a net slip on the order of 1 m, within a distance of about 100 to 500 m of the ground surface. The pattern of damage in the San Fernando Valley suggests a fault segment much longer than the 4.5 km defined by survey data in the Winnetka area. The blind fault segment may extend several kilometers in both directions beyond the Winnetka area.

This study of the Winnetka area further supports observations that a large earthquake sequence can include rupture along both a main fault and nearby faults with quite different senses of slip. Faults near the main fault that approach the ground surface or cut the surface in an area have the potential of moving coactively in a major earthquake. Movement on such faults is associated with significant damage during an earthquake. The fault that produced the main Northridge shock and the faults that moved coactively in the Northridge area probably are parts of a larger structure. Such interrelationships may be key to understanding earthquakes and damage caused by tectonism.

Acknowledgments

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Introduction

This is the second in a series of papers on the Northridge, California earthquake (Johnson and others, 1996), dealing with evidence for coactive faulting. In addition to the fault that produced the main shock, other faults moved during the same event and produced high, localized ground deformation. Some coactive faults appear to cause extensive localized damage to structures, utilities, highways, and other lifelines. Although such damage typically is attributed to elastic ground shaking, such shaking cannot explain the large, permanent ground deformations that we measure (Johnson and others, 1996).

The main shock of the Northridge earthquake (6.7 Ms), was at 12:31 UTC (4:31 a.m., Pacific Standard Time), 17 January 1994 (Hauksson and others, 1995). The hypocenter was about 18 km beneath the town of Northridge in the San Fernando Valley, and significant damage was caused up to 64 km from the epicenter (Stewart and others, 1995). The sense of differential displacement on the main fault was predominantly reverse, with the southern block upthrown. The slip near the epicenter of the main fault was about 1 m with a maximum slip of about 2.2 m at a depth of 12.4 km (Shen and others, 1996; Wald and others, 1996), with the hanging wall pushed upward. The earthquake producing fault strikes N70°–80°W and dips 35°–45°S (Hauksson and others, 1995). Had it propagated with this orientation to the ground surface, the fault rupture would have appeared in the vicinity of the crest of the Santa Susana Mountains to the north of the San Fernando Valley. Although attention centers on the main shock in an earthquake event, the Northridge earthquake event was a sequence of hundreds, or thousands of earthquakes, many of which were not on the fault that produced the main shock (Hauksson and others, 1995).

This study focuses on the Winnetka deformation zone, a zone of relatively high strains consisting of a belt of extension on one side and a belt of shortening on the other, about 500–1000 m wide, extending at least 4500 m in the northeast–southwest direction through Canoga Park in the southwest, Winnetka in the center and Northridge in the northeast (fig. 1, Plate 1). The Winnetka deformation zone was discovered during a preliminary field examination of ground fracturing—examining fractures in sidewalks, streets and houses—in the Northridge area shortly after the January 1994 earthquake sequence. We also examined damage in the area for 5 days during the spring and summer of 1995. A single site within the Winnetka deformation zone has been examined by Holzer and others (1996) who have concluded that the deformation there is a result of superficial deformation of soils by movement on a weaker layer at depth, not of deep-seated tectonism.

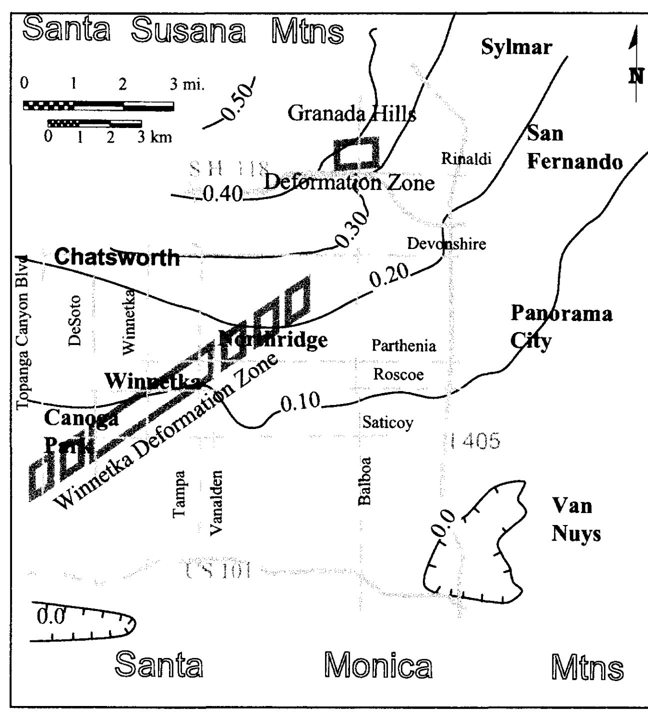


Figure 1. Location of San Fernando Valley, between Santa Susana Mountains to the north and Santa Monica Mountains to the south. The epicenter of the main shock at Northridge is in the center of the valley. Contours of differential vertical displacement between 1980 and 1994 show general, fan-shaped tilting of San Fernando Valley and Santa Susana Mountains relative to an assumed fixed point in the southwest corner of the valley. The Granada Hills and Winnetka deformation zones are shown with bold outlines.

The study of the Winnetka deformation zone reported here supports the general conclusion of our study of the Granada Hills area (Johnson and others, 1996): that the Granada Hills deformation zone is the surface expression of coactive slip on a blind blade of the Mission Hills fault, at the foot of the Santa Monica Mountains. The principal evidence that leads to this conclusion for the Granada Hills deformation zone is as follows:

1. There is a local steepening of vertical uplift on the hanging–wall block that moved during the main shock of the Northridge earthquake sequence.

2. There is a belt of extension fractures in the northern part of the Granada Hills deformation zone and a sub-parallel belt of shortening structures in the southern part of the zone.

3. Measurements of length and angle changes among survey monuments at street intersections produce strain patterns that agree with the observed distribution of extension and shortening structures in streets, sidewalks and locally in the ground surface.

4. A theoretical model of slip on a simple blind reverse fault, dipping northward reproduces the concentration of differential vertical uplift together with associated parallel belts of extension and shortening.

Nowhere in the San Fernando Valley have we directly observed the surface expression of a fault breaking the ground surface so the evidence is circumstantial. Saul (1974), however, mapped the Mission Hills fault near Rinaldi and Amestoy. Perhaps a blade of this fault moved to produce the Granada Hills deformation zone. A blind blade in the Granada Hills zone fault would have to be very short, because the zone of deformation is only about 500 m wide (northwest-southeast direction) and only 500 to 800 m long (northeast-southwest direction). The belt of anomalously large strains centered on the Winnetka area is about 1 km wide (northwest-southeast direction) but extends at least 4.5 km, from near Canoga Park in the southwest through Winnetka to at least Northridge in the northeast (Plate 2). Thus, concern about the size of the belt is minimized in the Winnetka area.

The belt extends into areas of relatively high damage to buildings to the southwest in Canoga Park and in the northeast in Northridge. For example, the California State University at Northridge campus would be in the center of the belt of damage if it extended further to the northeast. The campus suffered heavy damage during the earthquake, including a collapsed parking structure at the northeast corner of campus. The Northridge Fashion Mall, where several stores collapsed would be the northwest side of an extension of the Winnetka belt. The Northridge Apartments, where most of the earthquake fatalities occurred, would also be on the northwest side of the belt. Farther still to the northeast along the line of the belt is the collapsed Kaiser Permanante administration building. To the southwest of the Winnetka area along the trend of the belt is Canoga Park's Topanga Plaza, another shopping mall that suffered heavy damage. Including these structures in the Winnetka deformation zone would make the zone greater than 10 km long (Plate 2).

A belt of damage that might coincide with the Winnetka deformation zone shows up in the maps of distributions of pipe breakage or red-tagged buildings in San Fernando Valley (e.g., Stewart and others, 1994, fig. 4.5 and 4.6, p. 77 and 78). Examination of these maps indicates that the belt of damage could extend from Sylmar in the northeast corner of the valley to Hidden Hills in the southwest. The Granada Hills area lies to the north of this zone, and probably represents movement on a blade of the Mission Hills fault (Johnson and others, 1996). Thus the belt of localized damage is much longer and relatively narrower in the Winnetka area than at Granada Hills. In several ways, however, the belts are similar.

Herein we infer that the Winnetka deformation zone is a surface expression of movement on a blind fault. We informally refer to this fault as the Winnetka fault. The Winnetka area includes the

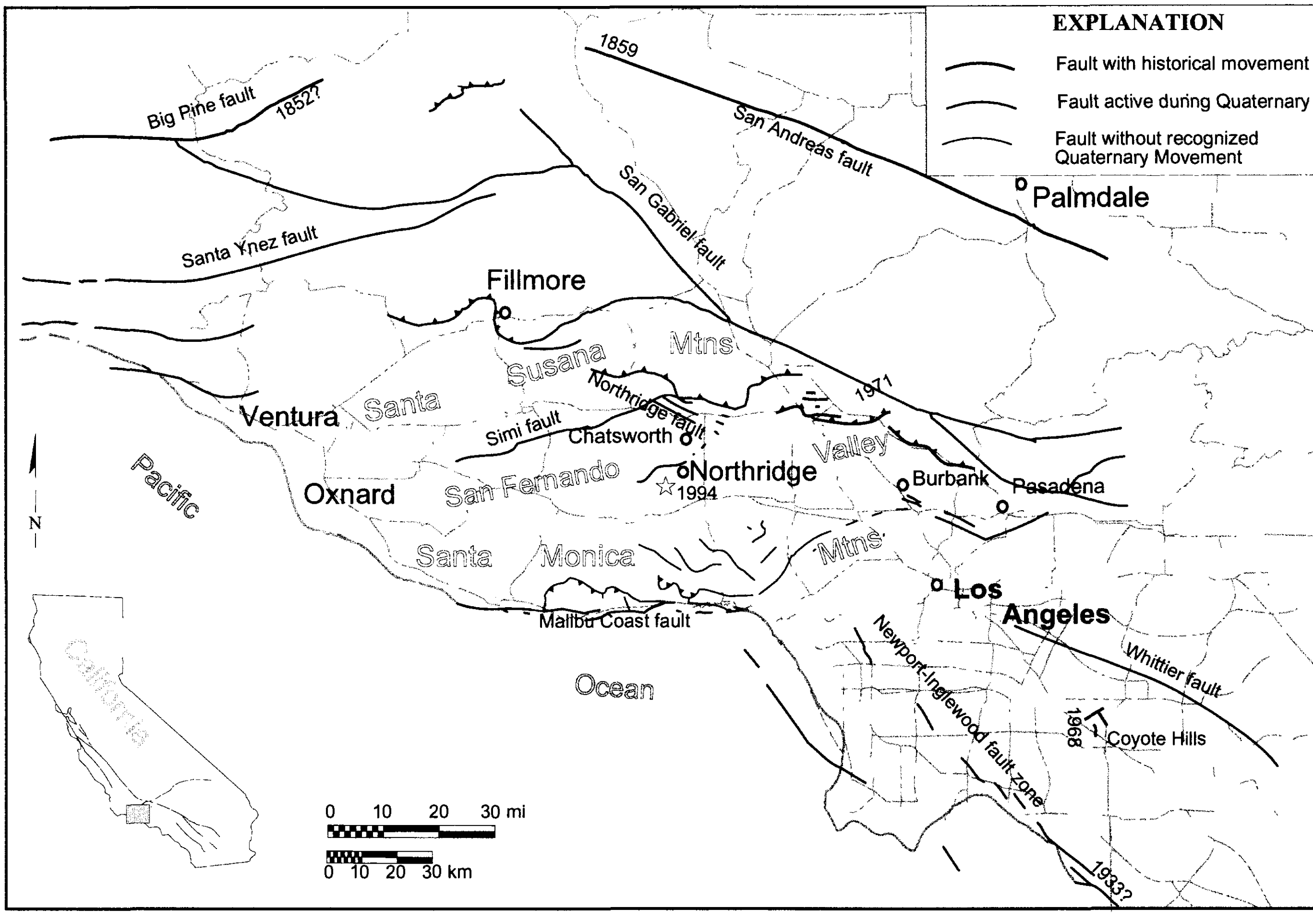


Figure 2. Location of the Northridge earthquake, showing partial traces of various faults that have been recognized in the area. Time of latest movement during an earthquake is indicated with a date. (After Ziony and Jones, 1989).

epicentral area of the main shock and is in the hanging–wall block of the Pico thrust fault. As far as we know, nobody has previously recognized the Winnetka fault. For example, it is not shown on the most recent geologic map of the Valley (Tinsley and others, 1985; Yerkes and Campbell, 1993). There is a nearby fault, the Chatsworth fault, in the vicinity of the Chatsworth Reservoir (fig. 2 and Plate 1), and trending generally northeasterly (Barnhart and Slosson, 1973; Jennings, 1973). There is no historic movement on the Chatsworth fault, although there is recognized Quaternary movement according to the fault map of California (Jennings, 1975).

Besides horizontal deformation of the earth's surface in the Winnetka area, movement on the Winnetka fault appears to be reflected in perturbations in the pattern of uplift and tilting of the San Fernando Valley (fig. 3 and Plate 1). As we have indicated elsewhere (Johnson and others, 1996), there are several perturbations in the pattern of uplift, perhaps associated with movement on smaller faults during the earthquake sequence, in the Winnetka, Chatsworth, and Granada Hills areas (fig. 3 and Plate 1). Movement on the Winnetka fault appears to be reflected in an area of flattening of the surface of differential vertical uplift south of a northeast–trending belt of steepening through Canoga Park, Winnetka and Northridge and an outward bowing of contours south of Northridge. The details of the contours shown in Plate 1, though, are highly interpretive because the data are from lines 5-6 km apart. The location of level lines is indicated by small numbers along streets in Plate 1.

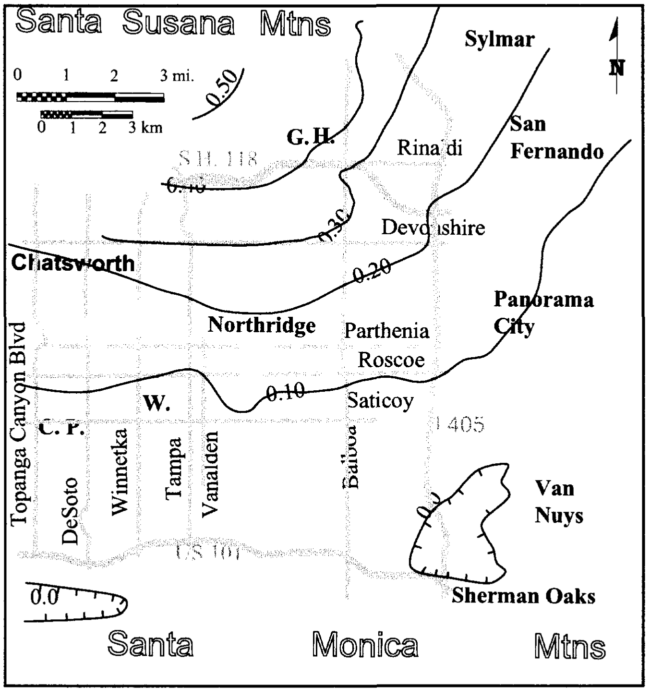


Figure 3. Contours of differential vertical displacement between 1980 and 1994, showing perturbations in the general tilting at Winnetka (W), Canoga Park (CP), Northridge, Granada Hills (GH), Chatsworth. There probably are blind faults at these areas. See Plate 1 for more details.

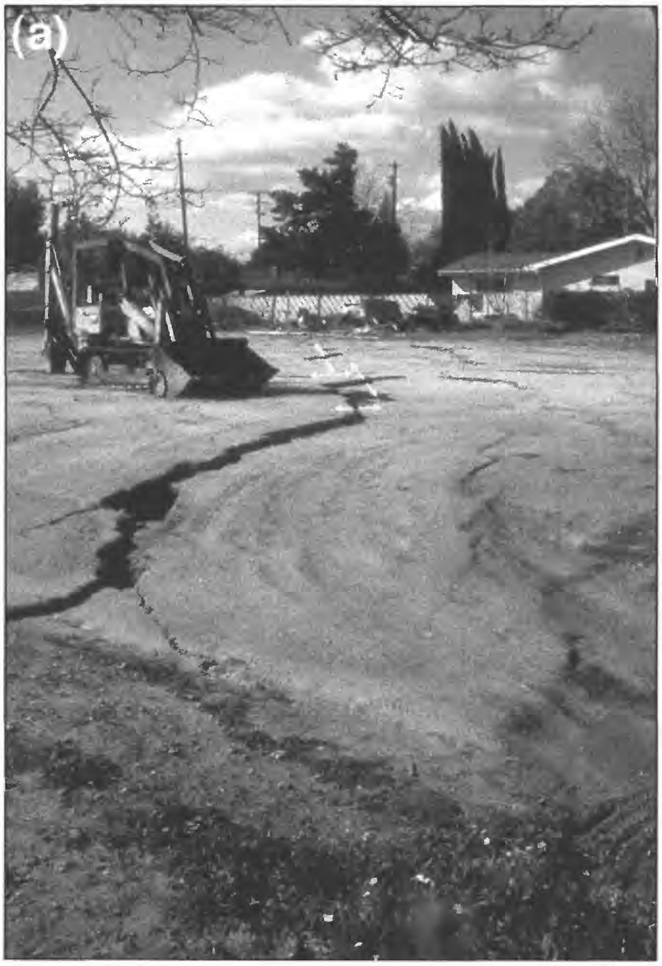
Surface Damage

While examining earthquake damage in the San Fernando Valley following the January 17, 1994 Northridge earthquake it became apparent that the damage was not uniformly distributed throughout the valley, but rather was concentrated locally. Areas that appeared to have more damage than surrounding areas were more carefully examined. One of these areas contained a rift that had formed in a vacant lot off Malden Street (fig. 4). The rift was adjacent to a large section of Tampa Avenue that had been repaved shortly after the earthquake. The rift was about 4 m wide, and oriented about N40°E. Each side consisted of a series of open fractures with two preferred orientations. Each side was displaced vertically about 1 dm. The view in figure 4 is to the southwest. To the northeast the rift projected into Malden Street. There the rift was reduced to a few tension cracks in the curb.

Although damage in the area of Malden Street was noticeably greater than in the surrounding area the level of damage was less than in the Balboa Avenue area in Granada Hills (Hecker and others, 1996; Hecker and others, 1995; Johnson and others, 1996).

On the west side of Tampa Avenue (Plate 2), there are several closely spaced north-south streets. North of Chase Street the sidewalks and roads are in good repair. South of Chase there are no sidewalks, and the road surface is not in good condition. Even though recognition of earthquake damage was nearly impossible south of Chase, immediately after the earthquake there was running water in the streets from numerous broken water pipes. Extensive damage to water mains was observed in other areas of extensive surface damage, such as Granada Hills (Johnson and others, 1996).

North of Chase Street, along Aura, the first street to the west of Tampa Avenue, there were thrusting and extension features in the curb. A 60 m long section of the road was also replaced, starting about 60 m north of Chase. Cracks in the curb along Aura were open from 0.5 to 3 cm.



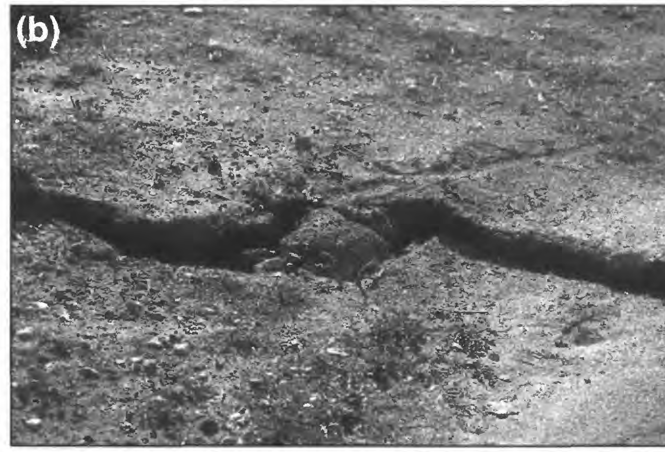


Figure 4. (a) Photograph of rift just south of Malden, and east of Tampa Ave. This large rift went across two vacant lots. View is to the southwest. The trend of the rift is about N40°E, and it is made up of biconjugate faults. (b) Details of the east side of the rift. The scarp is almost a decimeter high.

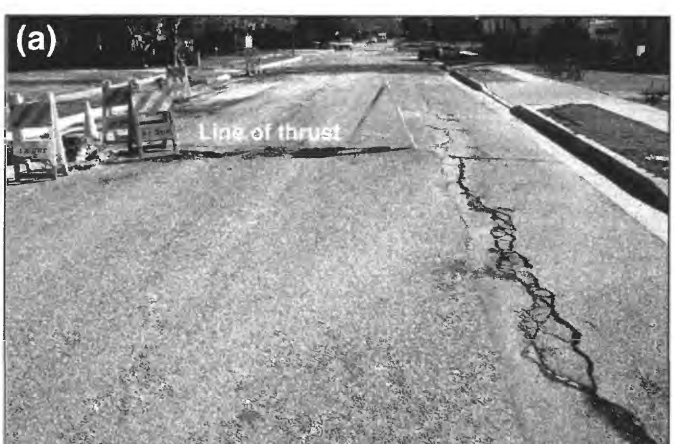
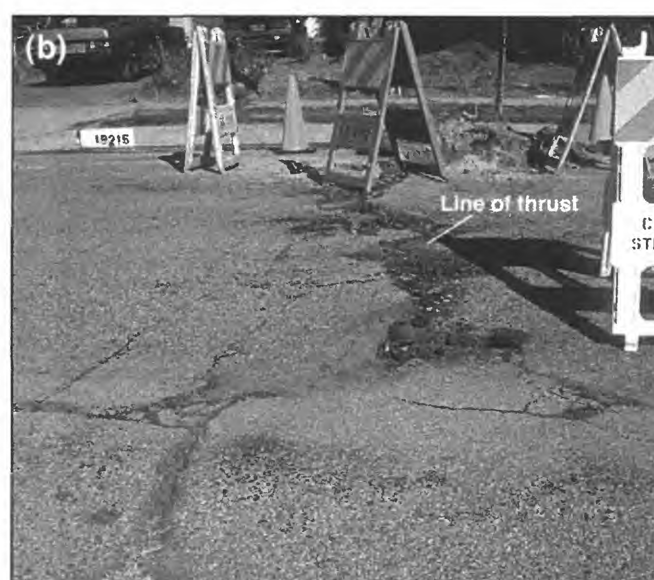


Figure 5. Two views of thrust or shortening fracture in Malden, an east-west street just east of the north-south Tampa Avenue. The thrust is about 20 m west of where the trend of the rift shown in figure 4 would cross Malden. Offset markers in the center of the road indicate 4.5 cm of thrusting.



The Surveys

Repeated surveys of streets throughout the Los Angeles area provide unusually detailed information about horizontal components of ground deformation during earthquakes. Throughout large parts of the city, the relative horizontal positions of monuments at most street intersections have been measured on a periodic basis. The first surveys were made by contractors in the 1950's and 1960's. After the 1971 San Fernando earthquake sequence, intersections throughout the northern part of the city were resurveyed by the City of Los Angeles.

In 1995 the City of Los Angeles resurveyed the Granada Hills area and part of the Winnetka area. The surveys were completed and angle measurements closed over an area of about 2 km long and 2 km wide. The City remeasured lengths between subsurface monuments in an adjacent area about 2 km wide and 4 km long, but did not turn angles and close surveys over that entire area.

Details of the monuments, surveying techniques and accuracy of measurements are discussed in Appendix 2. The points are located at the centerlines of roads and at the centers of intersections. Most of these are subsurface monuments, which are of two types, both of which are anchored to ground beneath the road–fill prism. One is a special target hole punched into a cap on a steel pipe, encased in concrete below road level; (generally the top of the target is about 0.3 m below the road surface). These targets are accessed through steel covers, about 10 cm in diameter, at road level. The second is a series of four punch marks in the sides of concrete sewer-access vaults. The access vaults extend below the road–fill material to the sewer level. The punches are at a depth of about 0.5 m. The point where lines connecting opposing punches cross is the target in these cases.

The City of Los Angeles regards its determination of distances to be accurate to 3.1 mm. For a street length of 100 m, the normalized error would be 3×10^{-5}. Angle measurements should have an error of less than three seconds. The corresponding error in shear strain is the tangent of the angle, so the error is 1.45×10^{-5}. Thus angle measurements have an error that is less than distance measurements, and shear strains can be determined to about 10^{-5}. We use 10^{-4} as a cutoff for strain determinations, so strains judged to be significant are three to seven times larger than the estimated instrument error.

Extensions

Changes in Length of Streets

The 1995 resurvey by the City of Los Angeles measured street lengths over the entire study area, however angles were only closed for the northeast part of the study area. Where only street lengths were measured the complete state of strain cannot be determined. We will first discuss the pattern of length changes, and then the pattern of strains in the area where angles were closed.

Over an area of about 8 km^2 in the Winnetka area we can calculate changes in lengths of street segments using resurveys of street lengths. The lengths of the segments range from about 10 to 500 m, but they tend to be 400, 200 or 100 m (fig. 6). We determine the strains of street segments by calculating the extension, the current length minus the reference length divided by the reference length. The reference lengths were generally measured in the 1970's, but could include data from the 1950's and 60's.

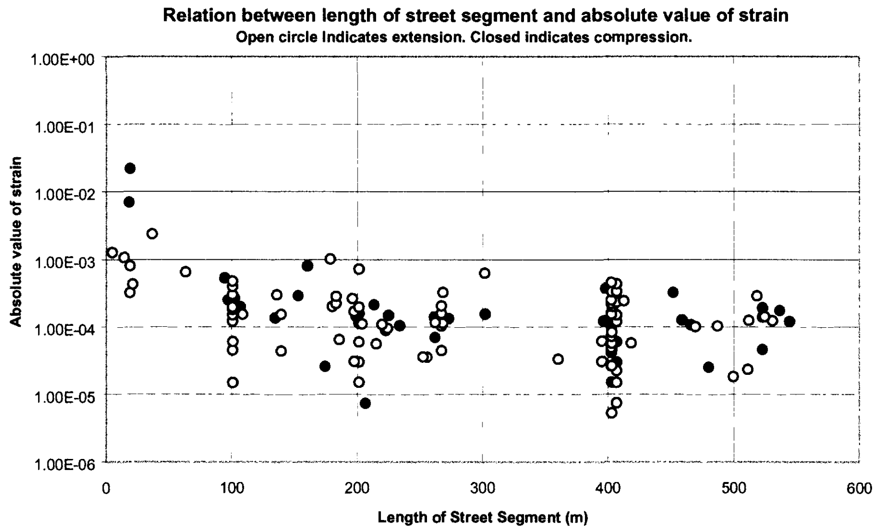


Figure 6. Relation between length of street segment and absolute value of normalized length change (strain) of street segment. The street segments tend to be 400, 200 and 100 m long. The larger strain values, for street segments shorter than 50 m, are based on surface monuments, and so are discounted. For street segments longer than 50 m, the strains appear to range widely, regardless of length.

There is a potential source of bias in the data in the reference lengths of streets. Is there a measurement length over which strains are maximized? If deformation were highly localized, some short street segments should show large strains and other short street segments should show no strain. Also, for short segments the reference lengths can be so short that errors in length measurement can overshadow the strains. Long street segments should show smaller strains than the highly strained short segments because the segments can average out the localized extensions and shortenings. Figure 6 shows the relation between values of strain, as defined above, and lengths of street segments. Strains smaller than 10^{-4} are negligible, so data in the lower part of the diagram can be neglected. The results show that strain of street segments longer than about 50 m ranges widely, from about 10^{-5} to 10^{-3} regardless of the lengths of the segments.

For street segments of about 30 m long, the strains range to a somewhat higher value of about 3×10^{-3}. Examination of the original data (Appendix 3) indicates that the data for the short street segments were all based on measurements of surface monuments founded in the pavement or in sidewalks. The largest strains were obtained along Malden Street, adjacent to a rift (fig. 4) in a vacant lot between Malden and Chase, and between Tampa Avenue and Van Alden (fig. 7).

Figure 4 shows the rift and figure 7 shows the measurements of strains of streets in the area of the large deformation. The larger extensive strain was measured with surface monuments (spike and washer or spike and tin monuments, see Appendix 2 for explanation of monument types) in a street segment about 30 m long that is a jog connecting two straight segments. We observed an opening fracture in this street segment. The largest compressive strain was calculated for a lot west of Beckford (inset map in fig. 7) using measurements of the change in length between "+" marks chiseled into the sidewalk to mark lot boundaries. The largest compressive strain was calculated for lengths measured immediately adjacent to a thrust fault in pavement (fig. 5) and an adjacent transform fault that had accommodated 4.5 cm of right–lateral offset (fig. 7).

Thus, if we discount the very large deformations measured over very short street segments or over widths of individual lots, the deformations appear to be independent of the lengths of street segments. The very large strains are due to localized deformation in pavement and cement, and do not represent some form of bias in the survey procedure, or choice of street length.

Pattern of Normalized Length Changes

The measurements of normal strain, defined as the normalized length changes, measured along

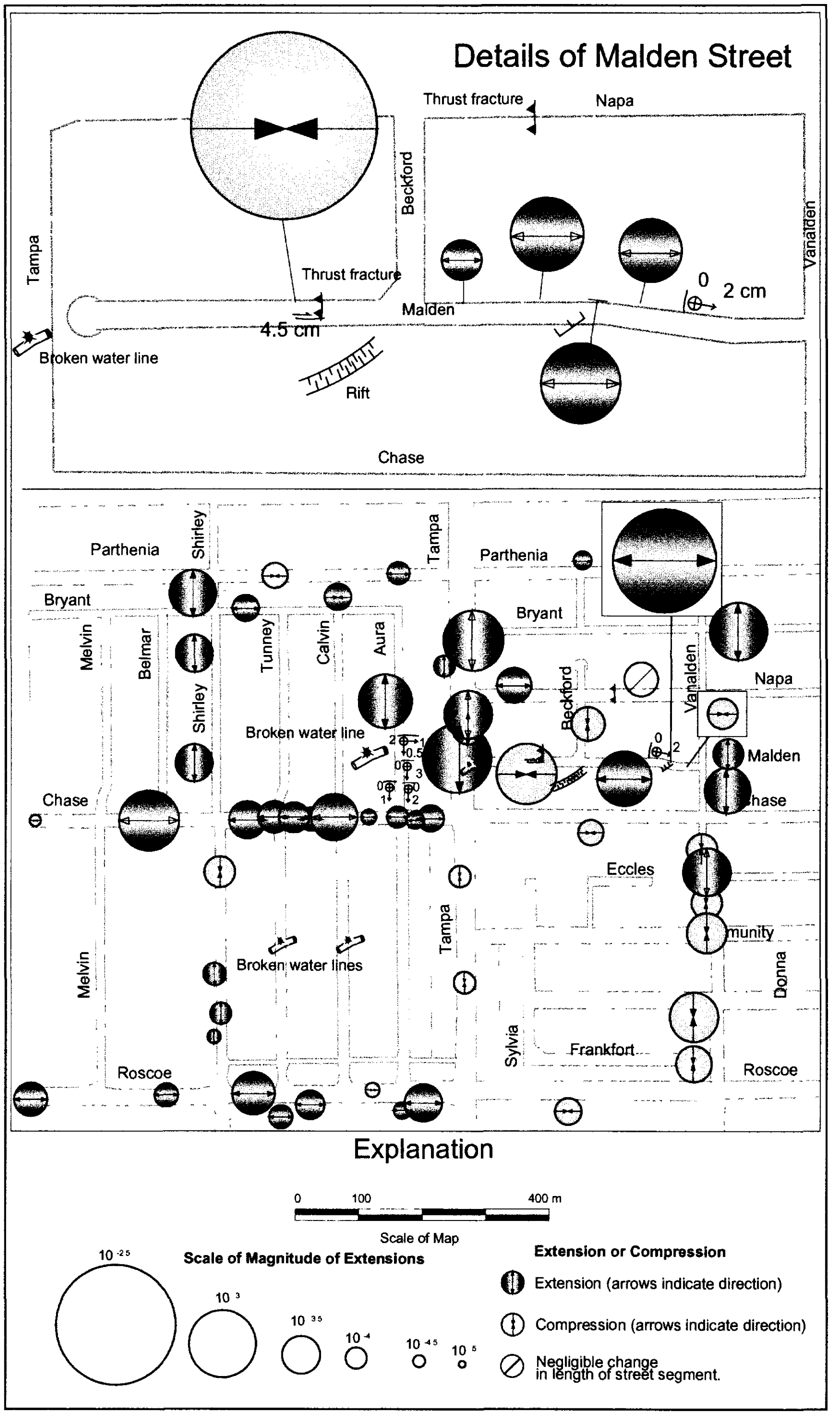


Figure 7. Details of normalized length changes and damage to streets and sidewalks in the northeastern end of the Winnetka area. The lower part of the diagram is a map of the area, showing the magnitudes, directions and signs of the extensions in the area, as well as the types of damage to streets and sidewalks, and broken water lines. The large extension (inset figure) is for the misaligned street segment of Malden Street, which is about 30 m long. It was measured using surface monuments (spike and washer). All the measurements along Malden are based on surface monuments and therefore must be discounted. All five strain figures in the detail at the top of the figure is for Malden Street and is based on length changes of "+" marks chiseled into sidewalks by the builder at the times of construction to mark lot boundaries. The large shortening of a lot west of Beckford apparently reflects a thrust fault that is visible in the street (fig. 5). The relatively uniform extensions of the four lots east of Beckford and north of Malden apparently do not reflect the tension crack in the south side of Malden.

street segments, are shown in figure 8 and Plate 2. The extended streets are indicated with darker circles and the compressed streets with lighter circles. The magnitude of the strain can be determined by comparing the size of a circle with the size of scaled circles shown in the *Explanation.* The direction of the street segment that was measured is indicated by the direction of the arrows. The circles with a diagonal line represent measurements where the strains are in the range of error, less than 10^{-4}.

A smaller-scale map of the distribution of strains (Plate 2) shows that trending diagonally through the Canoga Park, Winnetka and Northridge area there is a deformation zone, which contains two belts of deformation. One belt is mostly extension and the other is mostly compression (fig. 8). The belt of extension is perhaps 0.6 km wide and about 4 or 4.5 km long, in the northwesterly part of the deformation zone. The belt of shortening is about 0.4 km wide and about 4 km long, in the southeasterly part of the deformation zone. On the northwest and southeast sides of the deformation zone the magnitude of the strains is too small to measure, that is, less than about 10^{-4}.

The pattern of extension and shortening indicates that there are relatively large deformations within a zone about 1 km wide (northwest–southeast) and 4 or 4.5 km long (northeast–southwest), and that the deformations in the northwest part of the zone are dominated by extension whereas the deformations in the southeast part of the zone are dominated by shortening. This pattern suggests a blind fault at depth, either a reverse fault dipping northwest or a normal fault dipping southeast (Johnson and others, 1996).

The magnitudes of extension and shortening decrease from northeast to southwest. Even if, for reasons explained above, we discount the unusually large circles in the upper right of the area, near the intersection of Van Alden and Parthenia, we see that the deformations tend to be larger in the area of Tampa Avenue and Chase than elsewhere in the area of measurement. The larger deformations in the same general area—on either side of Tampa Avenue and between Parthenia

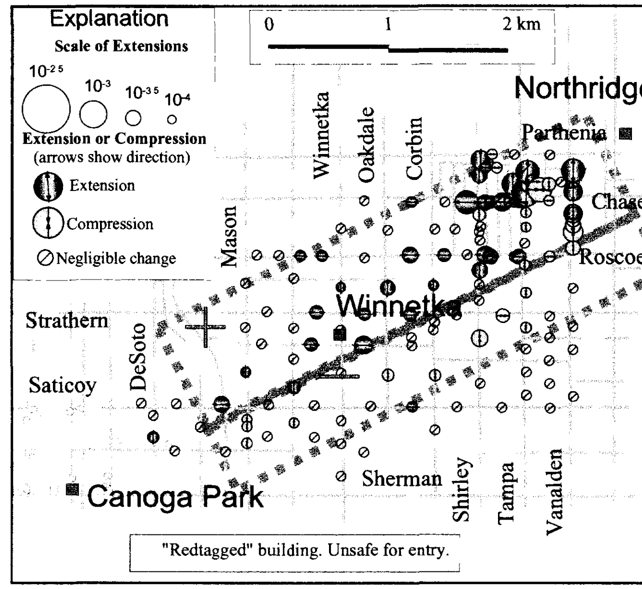


Figure 8. Computed extension of streets in Canoga Park-Winnetka-Northridge area between the 1950's to 1970's and 1985, and after the Northridge earthquake sequence. Magnitude of the largest extension (regardless of sign) indicated by radius of heavy circle. Where extensions were smaller than error, measurement indicated with circle with diagonal line. Significant strains form a deformed zone trending northeast-southwest, about 1 km wide and 4.5 km long. Extension predominates in northwest part (area shown with a "+") and compression in the southeast part (area shown with a "-"). The deformation zone may continue to southeast, as indicated in figure 1, into areas with many red-tagged buildings. More details are shown in Plate 2.

and Chase—correlate with greater damage to structures such as roads and sidewalks.

The kinds of rupturing of roads and sidewalks are consistent with the kinds of strain. The strains in the northeast part of the area, between Tampa and Van Alden, and north of Chase, are predominantly extensile. The rupturing is similarly predominantly extensile. The rift between Malden and Chase, at Beckford, indicates northwest extension. The tension cracks along Aura, north of Chase, indicate roughly north-south extension. The thrusting of sidewalks at street corners, between Strathern at Tampa southwesterly toward Canoga Park is consistent with shortening strains in this area.

This pattern of shortening and extension and the correlation of the types of damage to the types of strains, suggest a blind fault at depth, either a reverse fault dipping northwest or a normal fault dipping southeast.

Strains

Measurement of Strains

In the northeastern part of the area shown in Plate 2 we have complete information required to determine strains at many street intersections. That is, we have pre- and post-earthquake measurements of street lengths and angles. This allows us to compute the principal strains and their orientations at an intersection. We use the measurements of changes of lengths of streets and angles between streets to determine strains (Fleming and Johnson, 1996 (in review); Johnson and others, 1996). The procedure is summarized in Appendix 1.

We have developed a way of displaying the state of strain near a point via an extension figure we call a *shmoo*[1]. A special case is a *nerd*. The shmoo or nerd shows, in one diagram, the absolute magnitude of the largest principal strain as well as the directions of the maximum and minimum, principal strains (see *Explanation* in Appendix 1 and on Plate 3).

Shmoos and nerds graphically display the strain state near a point. The magnitude of the strain is indicated by the radius of the larger–extension circle, which can be compared to a scale of such circles. The directions of the maximum and minimum principal strains correspond to the directions of the maximum and minimum dimensions of the curvilinear part of the strain figure, so the shmoo or nerd indicates the direction of the principal strains.

To determine the magnitudes of the strains, the size of the circle is compared to a series of calibrated circles in the *Explanation* in Plate 3. The circles are for $10^{-2.5}$ ($\cong$ 0.003), 10^{-3} (0.001), $10^{-3.5}$ ($\cong$ 0.0003) and 10^{-4} (=0.0001). Where the multi–shaped line is inside the circle there is shortening, and where it is outside the circle there is extension. For example, the shmoo immediately southeast of the intersection of Rosco and Shirley in Plate 3 (see also fig. 9) shows the multi–shaped, light line is outside the heavy circle, indicating that there is extension in all directions, although the extension is larger in the direction N45°E. The magnitude of the larger principal strain is on the order of ±0.0005 (about $10^{-3.3}$), the principal extensions are positive, and the strains are largely dilational for this example. The shmoo on the southeast of the intersection of Strathern and Corbin shows a common, figure–eight shape of the light line, and indicates that there is extension in the northwest–southeast direction, where the light line is outside the circle, and shortening in the northeast–southwest direction, where the light line extends slightly inside the circle. In this example the magnitude of the larger principal strain is on the order of ±0.0003 ($10^{-3.6}$). The roughly equal values of maximum shortening and extension in this example suggest shear without area change. Simple shear relative to the orientation of Strathern would be left–lateral. Simple shear relative to the orientation of Corbin would be conjugate, that is, right–lateral.

Thus, the direction of maximum extension (or minimum shortening) is defined, to within an unknown rigid–body rotation, by the long dimension of the multi–shaped line. The sense of shear (relative to the east–west or north–south streets) can be read from the inclination of the long dimension of the shmoo.

[1]We call the extension figure the shmoo, after an object with remarkable properties introduced about 50 years ago in the comic strip, *Li'l Abner*.

The shmoo extension figure near the intersection of Strathern and Tampa in Plate 3 is a nerd, indicating approximately northwest–southeast maximum shortening and very minor northeast–southwest extension. The magnitude of the larger principal strain is on the order of +0.0006 ($10^{-3.2}$). Similar nerds, with similar orientations, are shown nearby.

Pattern of Strains

The strain figures (Plate 3) clarify the internal structure of the deformation zone in the Winnetka area defined by the extension and shortening figures shown for the larger area in Plate 2. The strains in the Winnetka deformation zone are defined by northwest–southeast extension in the northwest belt of the zone and by northwest–southeast shortening in the southeast belt of the zone (fig. 9). The walls of the belts, of course, are only roughly defined, and the belts defined on the basis of strains shown in figure 9 have not been forced to match those defined on the basis of normalized extensions, shown in figure 8. The critical observation is that the directions of principal strains are parallel and normal to the walls of the deformation zone, indicating that the zone is not a strike–slip zone, but, most likley is a reverse zone.

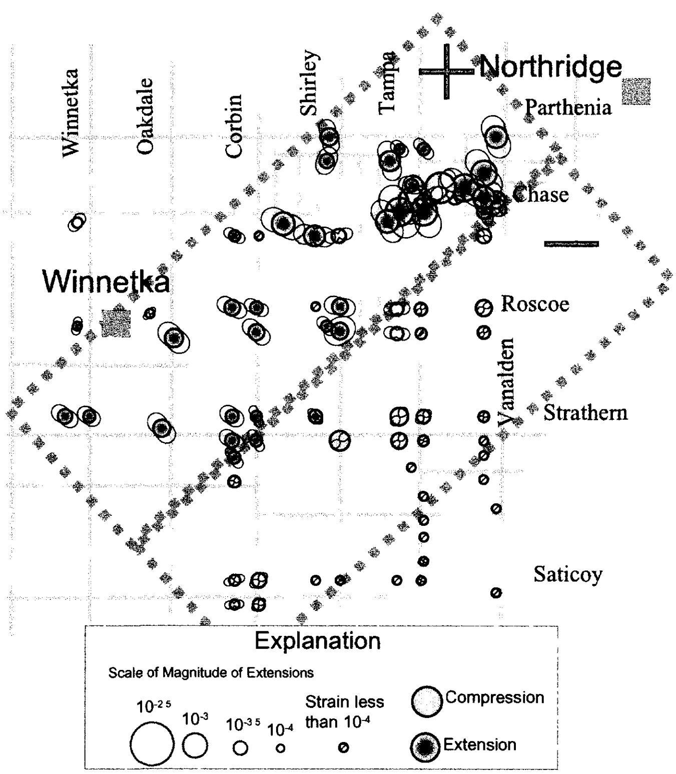


Figure 9. Computed strain figures (shmoos and nerds) of streets in Winnetka/Northridge area between the 1950's to 1970's and 1985, and after the Northridge earthquake sequence. The strain figures show that the belt of extension in the Winnetka deformation zone is dominated by principal extensions in the northwest and southeast direction, and that the belt of compression is dominated by a principal compression in the same direction. The pattern indicates that the Winnetka deformation zone would not be a strike-slip fault, but rather a reverse or normal fault. See Plate 3 for details.

Explanation of Large Magnitudes of Strains

A problem that we did not address at the Granada Hills area is the large magnitudes of strains (Johnson and others, 1996). There the strains were commonly 3×10^{-3} and ranged up to 10^{-2}, and the strains were closely reflected in extensive and intensive surface damage to man-made structures. In the Winnetka area, the strains are about an order of magnitude smaller, commonly 3×10^{-4} and range up to about 10^{-3}.

Two questions, besides those addressed above, arise concerning the strains. First, how do such strains compare to those required to fracture unconsolidated soil. Second, how could these very large strains be generated.

Concerning the first question, we note that a brittle rock, such as granite (e.g., Peng and Johnson, 1972), fails under atmospheric confining pressures at compressive axial strain values of between –2 to –6 x 10^{-3}. In the Aspen Grove landslide in Utah (Baum and others, 1993; Baum and others, 1988; Fleming and Johnson, 1989) the soil in a developing landslide toe cracked at strains of about –1.4 to -2×10^{-2} and in a newly forming pull–apart, the strains were about 6×10^{-3} before a tension crack formed and 3.5×10^{-2} after the tension crack had formed.

Comparing these values with those measured in the Granada Hills area, we note that the typical strains of 3×10^{-3}, with maximum strains ranging in magnitude up to 10^{-2}, should have been large enough to produce tension cracks in concrete and soil and reverse faults, at least in concrete. Such fracturing was abundant there (Johnson and others, 1996). Comparing these values with those measured in the Winnetka area, 3×10^{-4} and ranging up to 10^{-3}, it would seem that the strains should not have produced much fracturing in sidewalks or in soil. Again, this is what we observed. Furthermore, since the strains decrease from northeast to southwest in the Winnetka area, we would expect the ground deformation to decrease in that direction, as we observed. Thus, the conclusions are consistent with our observations in both areas.

The second question concerns the origin of such large strains. In order to address this question, we consider an idealized fault in an elastic material. Let us determine the order of magnitude of strains produced at the ground surface, a distance *x*, from the mid-length of the fault, along a plane passing through the fault ($y = 0$). We emphasize that this is a rough calculation, because we have not matched the boundary conditions along the free surface, but our experience indicates that, to first order, we would obtain the same answer, to within a factor of two, from the exact solution. Also, the actual strains will be normal strains rather than shear strains because the ground surface is free of shear.

According to Tada and others (1985), the shear strain is a function of the distance, *x*, from mid-length of the fault according to the relation,

$$\varepsilon_{xy} = \frac{1}{1-\nu}\left(\frac{u_{max}}{a}\right)\left(\frac{1}{\sqrt{1-(a/x)^2}} - 1\right) \quad (1a)$$

in which u_{max} is the maximum slip due to a stress drop on the fault, a is the half–length of the fault, and v is Poisson's ratio. For incompressible material, Poisson's ratio is 0.5; for granite, it is about 0.2. Assuming incompressibility, eq. (1a) becomes

$$\varepsilon_{xy} = 2\left(\frac{u_{max}}{a}\right)\left(\frac{1}{\sqrt{1-(a/x)^2}} - 1\right) \quad (1b)$$

We use the form of this equation to calculate, approximately, the strains at the ground surface,

$$\varepsilon \approx \frac{u_{max}}{a} f(d/a) \quad (1c)$$

in which ε is strain, the factor, $f(d/a)$, is determined by the distance, d, (where $x = d + a$), from the end of the fault to the ground surface. Values are given in table 1.

Table 1. Relation between relative depth, d/a, of tip of fault beneath ground surface to factor, f, that determines the magnitude of the maximum strain at the ground surface.

Relative Depth *(d/2a)*	Fault depth factor *f(d/a)*
0.5	0.31
0.05	2.80
0.005	12.20
0.0005	43.00

Let us assume a fault with a normalized maximum slip of $u_{max}/a = 10^{-3}$. This value would correspond to a maximum slip of 1 m for a fault with a length of 2 km, or a slip of 10 cm for a fault with a length of 200 m. The former seems a more reasonable estimate for a fault to produce a zone of high deformation between 500 and 1000 m wide. For a maximum normalized slip of

$u_{max}/a = 10^{-3}$, the strain near the ground surface would be on the order of 3×10^{-4} if the tip of the blind fault were a distance equal to the half length of the fault from the ground surface ($d/2a = 0.5$). It would be an order of magnitude larger, or about 3×10^{-3}, if the tip of the fault were a distance of one–five hundredths the length of the fault from the ground surface ($d/2a = 0.05$). The maximum strain near the ground surface would be about 10^{-2} if the tip of the fault were a distance of one–fiftieth the length of the fault from the ground surface ($d/2a = 0.005$). Thus we see that it is quite reasonable to expect a blind fault, near the ground surface, to produce strains on the order of those measured in the Winnetka area as well as in the Granada Hills area. Presumably the fault slip was less or the fault was more deeply buried in the Winnetka area than in the Granada Hills area.

Thus, the magnitudes of the strains in the Winnetka area are consistent with the strains produced at the ground surface by a blind fault plane with a length on the order of 2 km and a net slip on the order of 1 m, within a distance of 0.5 to 0.1 of the half length of the fault to the ground surface. The localization of fracturing damage in the northeastern end of the known part of the Winnetka deformation zone is consistent with the localization of larger strains in that area. The strains are on the order of strains required to fracture concrete and soil. By way of counterproof, where the strains are smaller, in the southwest end of the Winnetka deformation zone, there was relatively little damage to streets and sidewalks.

Discussion

The 1994, Northridge, California earthquake sequence illustrates again that a large earthquake can include rupture along both a main fault and nearby faults with quite different kinematic signatures. Faults near the main fault that approach the ground surface or cut the surface in an area, have the potential of moving coactively in a major earthquake sequence (Allen and others, 1972; Aydin and others, 1992; Haegerud and Ellen, 1990; Johnson and Fleming, 1993; Johnson and others, 1996; Martosudarmo and others, 1996).

The fault that produced the main shock and the faults that moved coactively in the Northridge area are probably parts of a larger, growing structure (Johnson and others, 1994). However, Stein and others (1994) suggest that the Northridge earthquake was a consequence of the change in stress conditions due to an earlier major earthquake in the Los Angeles area. Thus, Stein and others would interpret coactive movement of other faults in the Northridge sequence as a result of the change in stress caused by the main shock rather than coactive movement in a growing structure.

Coactive faulting produces the high, localized ground deformation along blind or visible faults. In the case of Northridge (fig. 10), the earthquake fault appears to be part of a large, heart structure (fig. 11). The heart structure includes a horst block about 35 km wide and 20 km deep bounded by listric reverse faults (fig. 11). In the center of the heart structure is the basin of San Fernando Valley, and on either side are broad anticlinal highs, the Santa Monica Mountains to the south and the Santa Susana Mountains to the north (fig. 10). The anticlinal high in the Santa Susana Mountains is complicated by a large thrust block, overlying the Santa Susana thrust fault, that is overriding that limb of the heart structure (fig. 11). A heart structure is a type of fault–related fold subjected to horizontal compression.

The tectonic origin of the horizontal compression in the San Fernando Valley is well known. The Los Angeles area is immediately south of the Transverse Ranges, where the broad zone of generally right–lateral San Andreas fault systems south of Los Angeles take a left jog and reorganize into a narrower zone of strike–slip faults

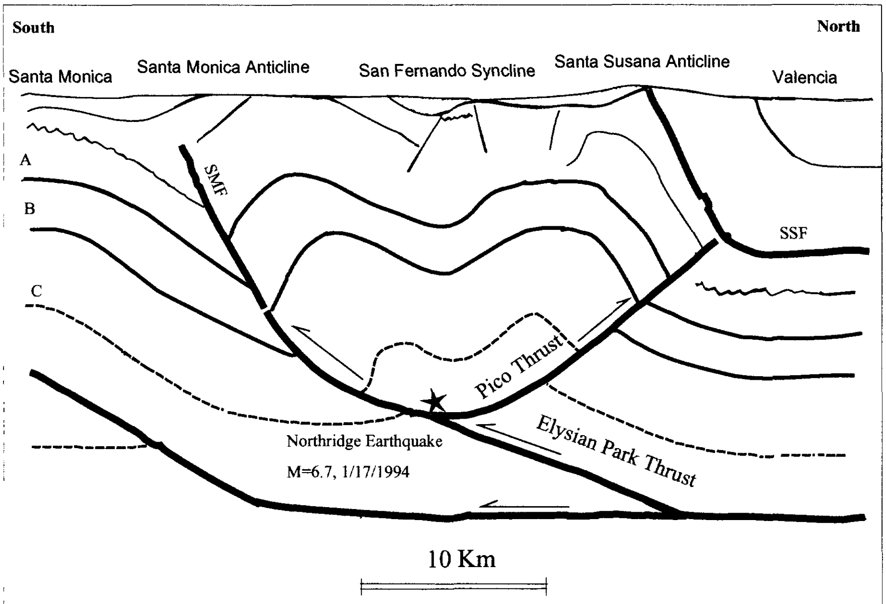


Figure 10. Interpretative structural cross–section of San Fernando Valley area, showing a dish–shaped fault that underlies the center of the valley and that ends beneath the Santa Monica Mountains to the south and the Santa Susana Mountains to the north. (Map modified after Davis and Namson, 1994). The epicenter of the Northridge earthquake was at about 19 km depth, apparently along the Pico thrust fault. The Pico thrust fault is interpreted to be listric in order to explain the tilting of the San Fernando Valley toward the south.

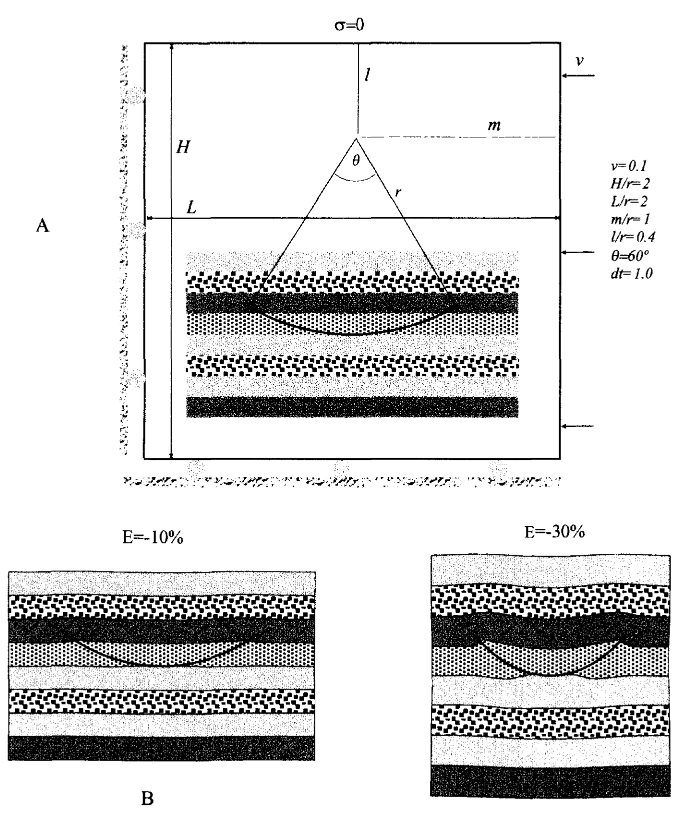


Figure 11. Heart structure, a type of faulted fold.The heart structure is produced by a dish fault in homogeneous flowing material with passive markers. The flowing material is incompressible, so the cross–section is balanced. A. Loading conditions, consisting of uniform shortening and thickening. B. Form of passive layering after 10% shortening. Heart structure is starting to take form. C. Form of passive layering, defining a clear heart structure, after 30% shortening.

north of the Transverse Ranges, producing an area of roughly north-south compression within the Transverse Ranges. The San Fernando Valley heart structure is a result of this compression. The tilting of the San Fernando Valley during the Northridge earthquake is, we believe, a result of larger slip on the Pico thrust fault than on the Santa Monica fault (fig. 11) (Johnson and others, 1996). Furthermore, incision and downcutting in Vallejo on the south flank of the Santa Susana Mountains and alluvium-filled valleys on the north flank of the Santa Monica Mountains are evidence that this pattern of tilting extends significantly back in time.

The coseismic deformation in the Winnetka area supports a growing body of evidence that any active fault approaching or at the ground surface in an area has the potential of moving coactively at the time of a major earthquake. If, in fact, further research supports the notion that some earthquakes result from seismogenic slip on faults within a large tectonic structure and that rapid growth of the structure involves coactive fault movement (Johnson and others, 1994), then predictions of damage during earthquake sequences in such structural blocks must broaden, from a narrow focus on the main fault producing the main shock and the ground shaking attendant to the main shock, to include permanent deformation along these coactive fault zones. These may be faults or shear zones that generate aftershocks, or faults or shear zones that shift aseismically. Conversely, in studying the setting of seismogenic faults, we may need to narrow our view in some cases, from a broad tectonic region such as a plate boundary or a subduction zone (Scholz, 1990, p. 227-235) to tectonic structures within such regions. In any case, we should recognize that damage to man-made structures may be caused by permanent ground deformation accompanying slip on coactive faults, as well as by transient ground shaking.

Conclusions

On the basis of our study in the Winnetka area of the Northridge earthquake sequence we draw the following conclusions:

1. There is a deformation zone, with magnitudes of strains generally about 3×10^{-4} and locally 10^{-3}, trending diagonally from near Canoga Park in the southwest, through Winnetka, to near Northridge in the northeast, a horizontal distance of some 4.5 km. The deformation zone is about 1 km wide. The northwest two–thirds of the zone is a belt of extension of streets and the southeast third is a belt of shortening. The deformation zone may be the surface expression of a blind fault that extends southwest-northeast for some 10 km or more.

2. On the northwest and southeast side of the deformation zone the magnitude of the strains is too small to be measurable, that is, less than about 10^{-4}.

3. Complete states of strain were measured in the northeast half of the belt of elevated deformation, providing more information about the kind of deformation accommodated within the zone. The strain figures show that the directions of principal strains are parallel and normal to the walls of the deformation zone. Thus the zone is not a strike–slip zone but probably is a reverse zone.

4. The strains measured in the area of larger deformations in the northeast part of the area—on either side of Tampa Avenue and between Parthenia and Chase streets—were large enough to fracture concrete and soils. The larger strains, indeed, correlate with greater damage to structures such as roads and sidewalks in that area. For example, in one area of concentrated damage there is a small rift in a vacant lot between Malden and Chase. At Beckford, and along Malden there is a thrust west of Beckford, and there is an

opening crack east of Beckford. This area also had the largest strains in the entire Winnetka deformation zone (fig. 7).

5. All parts of the pattern of a deformation zone, consisting of an extension zone and a shortening zone parallel to the walls and with principal strains parallel or normal to the walls, are consistent with a blind fault at depth, either a reverse fault dipping northwest or a normal fault dipping southeast, as we have explained in our paper on the Granada Hills area (Johnson and others, 1996). Furthermore, the magnitudes of the strains in the Winnetka area are consistent with the strains produced at the ground surface by a blind reverse fault plane with a length on the order of 2 km and a net slip on the order of 1 m, within a distance of one–half to one–tenth the half–length of the fault to the ground surface.

6. The magnitudes of extension and shortening within the zone decrease from northeast to southwest within the deformation zone. There may be a separate blade in the Canoga Park area (we do not have strain measurements there), explaining the high concentration of damage to houses there (Plate 2). The pattern of strains and damage in the Winnetka area suggests a blade longer than the zone, which is 4.5 km long, centered near Northridge, including the area where large commercial structures and the campus of California State University, Northridge were damaged.

7. The study at Winnetka provides a counterproof to the part of our study of the study at Granada Hills where we concluded that the extensive damage to sidewalks and streets was a result of elevated ground deformation, with strains generally on the order of 3×10^{-3} (Johnson and others, 1996). We have shown that, in the northeast end of the Winnetka area, the strains are similar in magnitude, about 10^{-3}, and the ground fracturing was quite visible. The counterproof would be, that where the ground deformations are smaller, the damage would be less. In our study of the Winnetka area, we show that, in the southwest part of the deformation zone, where the strains were much smaller, generally on the order of 3×10^{-4}, ground fracturing and damage to sidewalks and streets was light. Thus we see that the movement on a blind fault can, but need not, produce major damage to man–made structures.

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Appendix 1

Strain Measurement and Calculations

We have explained elsewhere (Johnson and others, 1996) how we use the measurements of changes of lengths of streets and angles between streets to determine strains.

Knowing only the angles between, and not the orientations of street segments, and knowing only the pre– and post–deformation states, the rotation of lines parallel to the maximum extension direction cannot be determined. Thus, we determine only the strains. If *A* is the initial and *a* the final length of an east–west street, *B* is the initial and *b* the final length of a north–south street, and Θ is the initial and θ the final angle between the north-south and east-west street segment, then the components of the deformation gradient are (fig. A- 1):

$$\frac{\partial x}{\partial Y} = \frac{(b/B)\cos(\theta) - (a/A)\cos(\Theta)}{\sin(\Theta)} \quad \text{(A-1a)}$$

$$\frac{\partial y}{\partial Y} = \frac{(b/B)\sin(\theta)}{\sin(\Theta)} \quad \text{(A-1b)}$$

$$\frac{\partial x}{\partial X} = \frac{a}{A} \quad \text{(A-1c)}$$

in which *X* and *Y* define initial and *x* and *y* defined final positions of points. These results determine the three nonzero components of the deformation gradient.

We have developed an intuitive way of displaying the state of strain near a point via an extension figure we call a *shmoo*. We call the extension figure the shmoo, after a resemblance to an object with remarkable properties introduced about 50 years ago in the comic strip, *Li'l Abner*. A special case of a shmoo is a *nerd*. The shmoo or nerd shows, in one diagram, the absolute magnitude of the largest principal strain as well as the directions of the maximum and minimum, principal strains (see *Explanation* in Plate 3). The extension shmoo is a plot of the extension as a function of orientation. The extension shmoo is constructed as follows. One element consists of a *larger–extension circle*, the radius of which, ρ, is related to the order of magnitude of principal strains. It is

$$\rho = \sqrt{\frac{GE_{ref}}{\pi}} \quad \text{(A-2)}$$

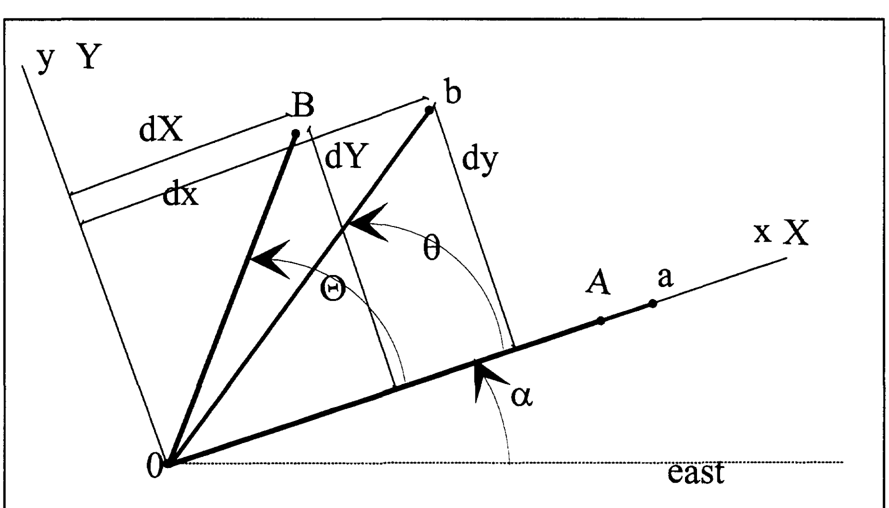


Figure A-1. Lengths and angles of street segments used to compute deformations at intersections in the Winnetka area. Hypothetical street pattern, surveyed prior to the 1994 earthquake (in the 1970's). The initial state is represented by capital letters. Deformed state is represented by lower–case letters. Lengths such as 0A and 0a, 0B and 0b, and angles Θ and θ are known, but angle a is unknown. For the calculations, street segments 0A and 0a are assumed to be parallel before and after the earthquake sequence, and the x– and X–axes are chosen to be parallel to these segments. Only the rotational part of the deformation is missed by this special assumption.

in which G is an arbitrary scaling factor, and E_{ref} is either $|E_1|$ or $|E_2|$, depending on whether the maximum extension or maximum shortening is larger in magnitude. Defined in this way, the area of the circle with a radius ρ is proportional to the strain.

For the second element of the shmoo, we plot a radius vector, R, that is determined by the extension in an arbitrary orientation, θ_c,

$$S_c = 1 + E_c = \frac{\sqrt{I_2}}{\sqrt{\left(\frac{\partial y}{\partial Y}\cos(\theta_c) - \frac{\partial y}{\partial Y}\sin(\theta_c)\right)^2 + \left(\frac{\partial y}{\partial Y}\sin(\theta_c) - \frac{\partial y}{\partial Y}\cos(\theta_c)\right)^2}} \qquad \text{(A-3a)}$$

The radius vector is designed so that it represents zero strain at the larger–extension circle itself, and becomes no larger than twice the radius of the circle:

$$R = \rho\left(\frac{E_c}{E_{ref}} + 1\right) \quad ; \quad 0 \le \left(\frac{R}{\rho}\right) \le 1 \quad \text{(A-3b)}$$

If the extension, Ec, is positive, the radius vector is larger than ρ so it extends from the center to some distance beyond the larger–extension circle. If the extension is negative (shortening), the radius vector R is shorter than ρ, so it is within the larger–extension circle (Plate 3). Note that (E_c/E_{ref}) lies between +1 or –1 and ranges to either limit depending on whether the larger extension is positive or negative.

Together, plots of eqs. (A-2) and (A-3b) define the extension shmoos, consisting of a heavy, larger–extension circle and a light, multi–shaped line that commonly has a crude figure–eight shape. If the figure–eight is within the heavy circle, the shmoo becomes a nerd.

Shmoos and nerds graphically display the strain state near a point. The magnitude of the strain is indicated by the radius of the larger–extension circle, which can be compared to a scale of such circles. The directions of the maximum and minimum principal strains correspond to the directions of the maximum and minimum extensions, so the shmoo or nerd indicates the direction of the principal strains.

The extension shmoos are plotted near the street intersections on the map, (Plate 3). Appendix 3 presents the data used to compute the shmoo extension figures. All the quantities have been defined except *x*–offset and *y*–offset. These define where the shmoo is plotted relative to the intersection. Here *x* is east and *y* is north of the intersection.

One can determine, quantitatively, the amount of extension or shortening in any direction by measuring the radius vectors, R, of a shmoo or nerd and using the relation (please refer to *Explanation* in Plate 3)

$$E_c = \left(\frac{R}{\rho} - 1\right) E_{ref} \qquad \text{(A-4)}$$

Appendix 2

Details of Horizontal Surveys

This appendix explains the survey data presented in Appendix 3 and used in the computer program presented in Appendix 4 to determine strains in the Winnetka area. The data were compiled from the survey notebooks of the City of Los Angeles. This appendix also contains a discussion of the types of monuments resurveyed for this study, and notes on the survey procedures.

There are two reasons we chose not to calculate coordinates for points and then to determine displacement fields. First, error accumulates in such a procedure. Second, it is difficult to interpret the results, partly because a fixed point is determined arbitrarily, and partly because most damage to the ground and to structures is a result of differential displacement (strain), not of absolute displacement. Thus we determine length and angle changes and compute estimates of strains. It is necessary that the strain calculations are estimates because much of the differential displacement can result from differential displacement across discontinuities, rather than of uniform deformation. The angle changes and the normalized length changes will represent components of strain only if the deformation is homogeneous at the scale of the measurements. Generally, one cannot know whether the deformations are actually homogeneous.

Surveying Procedures

All distances and angles were measured using double centering (Moffitt and Bouchard, 1992). The total station surveying instrument was set up over the benchmark using an optical plummet. Targets were also set over benchmarks on tripods, using optical plummets. On many streets, in addition to the benchmarks at intersections, there are often several points along the centerline of a street. These could be used to help relocate a lost point at an intersection. These markers would be lined up, and the resulting line extrapolated to the center of the intersection. Doing this along several streets would then give the position of the point in the intersection. In several cases the lines from opposite streets would not match. The difference would then be split in relocating the point. When measuring deviations from a line along the center of the street, the instrument would be aligned, then pointed at the benchmark on the ground. The instrument operator then determines the offset by taking a reading directly off a steel tape placed on the ground.

The angle measurement procedure with the instrument at point A, and reflectors on points B and C, would be as follows:

The small angle between B and C could be measured in the Face 1 and Face 2 positions. The angle would then be corrected. The lower base of the total station would then be turned about 120°. The large angle between B and C would then be measured in the Face 1 and Face 2 positions, and this angle would be corrected. The large and small angle would then be summed, and the difference taken from 360°. The angles would then be adjusted by the same amount so that they summed to 360°. If any of the corrections required numbers greater than a few seconds, the angle measurements would be repeated. The turning of the lower base of the total station ensures that angles are measured on a different part of the horizontal circle, helping to distribute error.

Use of Data

The survey data are used to compare distances between the same material points at some time before and some time after the 1994 earthquake. This is perhaps the most accurate way to work with survey data. By using field measurements of distances between specific monuments, we restrict the errors to those inherent in obtaining those particular measurements. Thus, an error in survey data will be restricted to a single intersection or single street segment, and will not propagate through a network of measurements. In contrast, there will be additional errors in angle measurements because they are corrected by closing around a block or a larger area, and the error is distributed, generally according to the lengths of the survey legs.

Accuracy of Survey Data in Relation to Strain Determinations

In our previous study of deformations near an earthquake rupture along the Emerson fault zone near Landers, California (Fleming and others, 1997 (in review)), we determined that normalized length changes and angle changes, as determined photogrammetrically in a small area and by land surveying for several square miles, were significant only if they were greater than about 3×10^{-4}. Our present study, using land survey data collected by the City of Los Angeles, indicates that the data collected in Los Angeles are significantly more accurate. As explained below, we estimate that we can detect strains as small as about 10^{-5}, as compared to 3×10^{-4} at Landers. In order to insure that we are studying strain rather than error at Los Angeles, though, as explained below, we assume that strains smaller than 10^{-4} in Los Angeles are negligible.

The City of Los Angeles regards their determination of distances to be accurate to one hundredth of a foot (0.01 ft) or 3.1 mm. For a street length of 100 m, the normalized error would be 3×10^{-5}. This can be verified by comparing results of different surveys done in the same areas (provided there is no deformation between surveys!). In interpreting the strain patterns from this study we have assumed that normalized length changes must be at least three times this large, at least 10^{-4}, to be significant. Thus, we assume that the error is on the order of 5 mm over a 50 m long block and 20 mm over a 200 m long block, with a change in angle of 0.27 seconds. Assuming that any error is distributed over both sets of measurements, the lengths would have to be mismeasured by 2.5 to 10 mm, and angles by 16 seconds, in order to produce a "strain" of the size that we would regard as significant.

We can get an idea about the worst case error in distance measurement by looking at the instrument specifications. The electronic distance meter on the total station (Topcon GTS–3B) used for the measurements is accurate to 5 mm ± 3 mm/km. The total station used in the surveys was taken out to a surveyed baseline and calibrated before use in Granada Hills. Over a small block, about 50 m in length, the error in distance measurement could be as large as 5 mm ± 3 × 0.05 mm, or 5.15 mm. Over a longer block distance, say 200 m, the error in distance measurement could be 5 ± 3 × 0.2 mm, or about 5.6 mm. Thus, the relative errors in length determination are of the order of 6×10^{-5} for the long block and 5×10^{-4} for the short block. In principal, then, strains of 10^{-4} to 10^{-5} can be determined.

We would note that strains in the order of 10^{-4} or smaller on blocks as short as 50 m, may represent error in the measurements. Strains of 10^{-3} on short blocks will represent deformation. For longer blocks, strains of 10^{-4} and larger will represent deformation. The blocks for which the data are questionable at the 10^{-4} level are the east-west streets connecting the north-south alleys on either side of Balboa Avenue, since these are very short street segments. None of the strains in this area is as small as 10^{-4}; they are on the order of 10^{-3} or larger. Thus, even on the short blocks, the deformation is large enough to make us confident of the survey results.

According to the Los Angeles surveyors, angle measurements should have an error of less than 2 seconds; the total station used can measure angles to 3 seconds. The repeated measurement of an angle, however, and the use of double centering will improve the accuracy of the angles, (e.g., Moffitt and Bouchard, 1992). For an analysis of error, we will assume an error of 3 seconds. The shear strain is the tangent of the angle, so an angular error of 3 seconds corresponds to an apparent shear strain of 1.45×10^{-5}. Thus, angle measurements have an error that is comparable, if not less than, distance measurements, and shear strains can again be determined to about 10^{-5}. Again, since we are comparing two measurements which may contain this error, the real error can twice the magnitude of a single measurement.

We use 10^{-4} as a cutoff for strain determinations, so the strains are about an order of magnitude larger than the instrument error.

Monument Types

A source of error that we cannot quantify is the mislocation of points. Since the total station and reflectors are centered over a tack or a punch hole, these errors will be less than 1 mm, and will not be systematic. Such errors are smaller than the errors of the distance meter in the total station, and thus cannot be detected. There are, however, different types of targets used for the surveys.

This study used both surface and subsurface, center line monuments for the City of Los Angeles, located at the centerlines of roads and the centers of intersections. Sub–surface monuments are buried beneath the road–fill prism. They normally consist of a concrete pillar encasing a steel pipe, with a cap on the pipe. The monument is accessed through a small cover. A second type of subsurface monument is the sewer access vault, which extend below the road–fill material to the sewer level. These monuments consist of four hooks on the inside walls of the vault which, when joined by string, define the survey point. The vault was inspected for signs of cracking or deformation during the survey.

Surface monuments are normally spikes or nails driven into the pavement. The spike may also be driven through a washer[2] or a circle of tin[3]. Other surface markers are lead–filled holes, with small tacks pounded into the lead[4], and old railroad spikes, which have been marked with a punch to define the survey marks.

Relocation of Points

Both surface and subsurface monuments are backed–up by a series of "tie–outs" or "throw–overs." Tie–outs are surface monuments that are a known distance and direction away from the center line monument. There are usually at least four tie–outs. At some large intersections the tie–outs for subsurface monuments may be other subsurface monuments. Lost centerline monuments can be relocated using the tie–outs, or by determining the intersection of the centerlines of joining streets. Generally, tie–outs are used to determine the area where a careful search should be made for the original monument. Many times an old monument has been obscured by street paving and patching. Within the study area, some of the intersections near Balboa Avenue were relocated using tie–outs, or matching centerlines of adjacent streets. This would put the data from these intersections (Intersections 17, 19, 20, 26, 29, 50) in doubt. According to the Survey Division of the City of Los Angeles, relocation of these points is probably within 0.1 feet (3 cm). For the intersections along Balboa Avenue, the changes in street length are going to be much larger than the error in relocating a point. The sense of strain (extension or shortening) will not change, but the magnitude of the strain may be in error. We note that along Balboa Avenue, the total change in length between centerline monuments was the same as that measured using lot survey marks along the sidewalk.

[2]S & W for shorthand.
[3]S & T for shorthand.
[4]L & T for shorthand.

Appendix 3

The Survey Data

This appendix contains the data used in this study. The data were compiled from a map produced by the City of Los Angeles and the Surveyor's field notebooks. A further explanation of the column names is given in Appendix 1 where the strain calculations are explained.

Explanation of Table of Survey Data

Column Name	Explanation
No.	Intersection Number. This corresponds to the numbering scheme used in this report.
Intersection	Street names for the intersection.
Type	Type of monument (see tables below).
Field Books	City of Los Angeles field book numbers of the intersection. These field books contain all the data about monuments at that intersection.
x	Final position of street intersection (see Appendix 1)
z	Final position of street intersection (see Appendix 1)
Corner	Quadrant, with respect to intersection, for which measurements were made.
x–Offset	Value used to control position where strain figure is plotted.
z–Offset	
α_θ	Orientation of street from reference axis.
Year	Year of centerline survey.
a	Street length in feet (see fig. A- 1).
b	Street length in feet (see fig. A- 1).
β_θ (°)	Measured angle between street centerlines. Degree part.
β_θ (')	Measured angle between street centerlines. Minute part.
β_θ ('')	Measured angle between street centerlines. Second part.

Surface Monument Type

Monument Type	Field Book Abbreviation
Spike and Tin	S&T
Spike and Washer	S&W
Lead and Tack	L&T
Spike	Spk
Chiseled X	Chx

Subsurface Monument Type

Monument Type	Field Book Abbreviation
Standard Survey Disc Monument	SSDM
Standard Survey Monument	SSM
Sewer Manhole Monument (Lead and Tack in manhole chimney.)	SMHM

Land Survey Data

No.	Intersection	Type	Field Books	X	Z	Corner	x Offset	z Offset	αθ	Year	a (feet)	b (feet)	βθ (°)	βθ (')	βθ (")
1	Winnetka and Strathern	SSM	162-07-54	0	6.8	NE	0.5	0.5	0	1970	1323.07	1679.05	89	57	57
			192-117-186							1995	1323.34	1679.26	89	58	30
						NW	–.5	0.5	0	1970	1320.00	1679.05	89	57	33
										1995	1320.33	1679.26	89	56	30
2	Oakdale and Strathern	SMHM	192-117-186	3.5	6.8	NW	0	0	0	1970	1323.07	1699.89	90	1	43
										1995	1323.34	1700.38	90	0	3
3	Corbin and Strathern	SSDM	189-117-115	6.9	6.8	NE	0.5	0.5	0	1970	1320.74	1720.72	89	56	55
			192-117-185							1995	1320.61	1720.97	89	57	52
						NW	–.5	0.5	0	1970	1320.31	1720.72	90	2	9
										1995	1320.60	1720.97	90	1	29
						SW	–.5	–.5	0	1970	1320.31	860.16	89	57	59
										1995	1320.60	860.26	89	58	59
						SE	0.5	–.5	0	1970	1320.74	860.16	90	3	5
										1995	1320.61	860.26	90	1	40
4	Shirley and Strathern	SSM	189-117-112	10.35	6.8	NW	–.5	0.5	0	1970	1320.74	860.61	90	3	25
			192-117-185							1995	1320.61	860.55	90	1	59
						SE	0.5	–.5	0	1970	1320.94	1306.36	90	3	19
										1995	1320.61	1305.87	90	5	40
5	Tampa and Strathern	SSM	189-117-109	13.8	6.8	NE	0.5	0.5	0	1970	1321.83	1320.29	90	0	17
			192-117-187							1995	1321.76	1320.09	89	58	52
						NW	–.5	0.5	0	1970	1320.94	1320.29	90	3	24
										1995	1320.61	1320.09	90	5	39
						SW	–.5	–.5	0	1970	1320.94	660.19	89	56	34
										1995	1320.61	660.08	89	55	8
						SE	0.5	–.5	0	1970	1321.83	660.19	89	59	57
										1995	1321.76	660.08	90	0	21
6	Van Alden & Strathern	SMHM	189-121-101	17.3	6.8	NW	–.5	0.5	0	1970	1321.83	1786.18	90	0	5
			192-117-187							1995	1321.76	1785.96	90	0	48
						SW	–.5	–.5	0	1970	1321.83	660.17	89	59	55
										1995	1321.74	660.13	89	59	45
7	Corbin and Saticoy	SSM		7	0	NE	0.5	0.5	0	1970	1320.52	1759.94	89	57	34
										1995	1320.47	1759.63	89	55	52
						NW	–.5	0.5	0	1970	1320.87	1759.94	90	2	44
										1995	1321.08	1759.63	90	3	30
						SW	–.5	–.5	0	1970	1320.87	1300.86	91	57	16
										1995	1321.08	1300.70	91	57	7
						SE	0.5	–.5	0	1970	1320.52	1300.86	90	2	26
										1995	1320.47	1300.70	90	3	31
8	Shirley and Saticoy	SSM		10.35	0	NE	0.5	0.5	0	1970	1320.58	1334.00	89	57	45
										1995	1320.65	1333.99	89	57	39
						NW	–.5	0.5	0	1970	1320.52	1334.00	90	2	15
										1995	1320.47	1333.99	90	2	51
9	Tampa and Saticoy	SSM		13.7	0	NE	0.5	0.5	0	1970	1321.74	660.20	90	0	24
										1995	1321.75	660.13	90	0	3
						NW	–.5	0.5	0	1970	1320.58	660.20	90	2	40
										1995	1320.65	660.13	90	2	56

No.	Intersection	Type	Field Books	X	Z	Corner	x Offset	z Offset	αθ	Year	a (feet)	b (feet)	βθ (°)	βθ (')	βθ (")
10	Van Alden and Saticoy	SSDM		17.3	0	NW	0	0	0	1970	1321.74	660.22	89	59	36
										1995	1321.75	660.18	89	59	48
11	Winnetka and Roscoe	SSM	192-113-123	0	11	SE	0	0	0	1970	1321.80	1679.05	90	56	9
			192-117-186							1995	1321.78	1679.26	90	56	21
12	Oakdale and Roscoe	SSM	192-117-186	3.5	11	NW	–.5	0.5	0	1970	1321.80	1574.38	90	57	25
										1995	1321.78	1574.34	90	58	13
						SE	0.5	–.5	0	1970	1321.84	1699.89	90	55	50
										1995	1322.28	1700.38	90	54	12
13	Corbin and Roscoe	SSDM	192-117-167	6.9	11.25	NE	0.5	0.5	0	1970	600.50	1551.31	89	1	18
			192-117-185							1995	600.63	1551.32	90	–58	7
						NW	–.5	0.5	0	1970	1321.84	1551.31	90	59	20
										1995	1322.28	1551.32	90	58	6
						SE	0.5	–.5	0	1970	600.50	1720.72	90	56	28
										1995	600.63	1720.97	90	54	50
14	Shirley and Roscoe	SSM	192-117-114	10.35	11.3	NE	0.5	0.5	0	1970	330.32	828.01	88	59	40
			192-117-185							1995	330.45	828.04	89	0	12
						NW	–.5	0.5	0	1970	720.15	828.01	91	0	20
										1995	720.23	828.04	91	0	10
						SE	0.5	–.5	0	1970	330.32	880.61	90	56	55
										1995	330.45	880.90	90	57	31
15	Tampa and Roscoe	SSDM	192-117-109	13.7	11.2	NE	0.5	0.5	0	1970	1320.66	766.96	89	0	15
			192-117-184							1995	1320.45	766.88	88	59	20
						NW	–.5	0.5	0	1970	330.40	766.96	90	59	24
										1995	330.49	766.88	90	59	39
						SW	–.5	–.5	0	1970	330.40	441.40	89	3	13
										1995	330.49	441.34	89	3	31
						SE	0.5	–.5	0	1970	1320.66	441.40	90	57	8
										1995	1320.45	441.34	90	57	30
16	Van Alden and Roscoe	SMHM	192-121-143	17.3	11.25	NW	–.5	0.5	0	1970	1320.66	501.80	90	59	53
			192-117-184							1995	1320.45	501.66	91	1	18
						SW	–.5	–.5	0	1970	1320.66	1786.18	89	2	36
17	Winnetka and Chase	SSDM	192-113-119	0	15.25	SE	0	0	0	1970	1321.60	1597.16	89	57	41
										1995	1321.71	1597.33	89	58	16
18	Oakdale and Chase	Unknown	192-117-186	3.5	15.2										
19	Corbin and Chase	SSDM	192-117-166	7	15.2	SW	–.5	–.5	0	1970	1321.28	1551.31	90	1	0
			192-117-185							1995	1321.49	1551.32	90	1	46
						SE	0.5	–.5	0	1970	572.82	1551.31	89	58	45
										1995	572.81	1551.32	89	58	22
20	Shirley and Chase	S&W	192-117-163	10.3	15.2	SW	–.5	–.5	0	1970	661.68	699.95	90	0	17
			192-117-185							1995	662.16	699.80	90	1	14
						SE	0.5	–.5	0	1970	330.21	699.95	90	0	1
										1995	330.31	699.80	90	1	1
21	Tampa and Chase	SSDM	192-117-106	13.8	15.2	NE	0.5	0.5	0	1970	1320.52	585.32	90	0	17
			192-117-183							1995	1320.33	585.92	90	4	4
						NW	–.5	0.5	0	1970	330.18	585.32	89	59	11
										1995	330.23	585.92	89	55	4

No.	Intersection	Type	Field Books	X	Z	Corner	x Offset	z Offset	αθ	Year	a (feet)	b (feet)	βθ (°)	βθ (')	βθ (")
22	Van Alden and Chase	SSDM	192-121-124	17.3	15.2	NW	–.5	0.5	0	1970	1320.52	660.27	89	59	52
			192-117-183							1995	1320.33	660.40	89	58	11
						SW	–.5	–.5	0	1970	1320.52	335.00	90	0	8
										1995	1320.33	334.93	90	1	18
23	Shirley and Parthenia	SSM	195-117-156	10.4	18.8	SE	0	0	0	1970	652.97	329.99	89	59	35
			192-117-181							1995	652.88	330.15	89	58	28
24	Tampa and Parthenia	SSM	195-117-107	13.8	18.8	SW	–.5	–.5	0	1970	668.36	735.31	90	0	43
			192-117-183							1995	668.43	735.38	90	1	9
						SE	0.5	–.5	0	1970	1320.57	735.31	89	59	22
										1995	1320.67	735.38	89	58	13
25	Van Alden &Parthenia	SSM	195-121-103	17.3	18.8	SW	0	0	0	1970	1320.57	660.22	90	0	29
			192-117-183							1995	1320.67	660.70	90	2	10
26	Shirley and Bryant	RRspike	195-117-117	10.3	17.8	SE	0	0	0	1970	356.54	445.73	89	58	34
			192-117-181							1995	356.60	445.86	89	59	6
27	Aura and Bryant	Unknown	195-117-119	12.9	17.8	SW	0	0	0	1970	990.92	990.62	90	0	22
			192-117-181							1995	990.77	991.25	90	1	49
28	Aura and Chase	Unknown	192-117-181	12.8	15.3	NW	0	0	0	1970	330.25	990.62	89	59	32
			192-117-126							1995	330.26	991.25	89	56	26
29	Tampa and Napa	SSDM	192-117-104	13.8	16.8	NE	0	0	0	1970	642.93	735.31	90	0	29
			192-117-183							1995	643.10	735.38	90	0	41
30	Beckford and Napa	S&W	192-121-113	15.1	16.8	SW	–.5	–.5	0	1970	642.93	319.21	90	3	15
			192-117-183							1995	643.10	319.13	90	0	42
						SE	0.5	–.5	0	1970	677.63	319.21	89	56	45
										1995	677.62	319.13	89	55	32
31	Tampa and Malden	S&W	192-117-105	13.8	16.2	NE	0	0	0	1970	526.16	585.32	90	0	23
			192-117-183							1995	525.74	585.92	89	59	11
32	Beckford and Malden	Unknown	192-121-119	15.5	16.2	NE	0.5	0.5	0	1970	207.53	319.21	90	3	7
			192-117-183							1995	207.66	319.13	90	9	29
						NW	–.5	0.5	0	1970	526.16	319.21	89	56	51
										1995	525.74	319.13	90	3	52
33	Van Alden and Malden	S&W	192-121-116	17.3	16.2	SW	0	0	0	1970	350.03	1320.49	89	59	26
			192-117-183							1995	349.96	1321.09	90	0	42
34	Van Alden and Napa	SMHM	192-121-111	17.3	16.8	NW	–.5	0.5	0	1970	677.63	660.22	89	59	40
			192-117-183							1995	677.62	660.70	89	55	16
						SW	–.5	–.5	0	1970	677.63	330.11	90	0	20
										1995	677.62	330.18	90	5	8
35	Tampa and Keswick	SMHM		13.8	1.8	NE	0.5	0.5	0	1970	1321.72	660.15	90	0	18
										1995	1321.75	660.16	90	0	16
						SE	0.5	–.5	0	1970	1321.72	660.20	89	59	42
										1995	1321.75	660.13	90	0	0
36	Van Alden and Keswick	SMHM		17.3	1.8										

No.	Intersection	Type	Field Books	X	Z	Corner	x Offset	z Offset	αθ	Year	a (feet)	b (feet)	βθ (°)	βθ (')	βθ (")
37	Van Alden and Ingomar	SMHM		17.3	3.5	NW	0	0	0	1970	1321.75	660.17	90	0	3
										1995	1321.81	660.21	89	59	49
38	Tampa and Ingomar	SMHM		13.8	3.5	NE	0.5	0.5	0	1970	1321.75	660.12	90	0	15
										1995	1321.81	660.14	90	0	19
						SE	0.5	–.5	0	1970	1321.75	660.15	89	59	45
										1995	1321.81	660.16	89	59	46
39	Tampa and Arminta	SMHM		13.8	5.2	SE	0	0	0	1970	1321.79	660.12	89	59	50
										1995	1321.86	660.14	89	59	49
40	Van Alden and Arminta	SMHM		17.3	5.2	NW	–.5	0.5	0	1970	1321.79	660.17	90	0	13
										1995	1321.86	660.13	90	0	9
						SW	–.5	–.5	0	1970	1321.79	660.17	89	59	47
										1995	1321.86	660.21	89	59	58
41	Corbin and Arminta	SSM		7	5.1	NW	–.5	0.5	0	1970	1320.23	880.16	90	1	55
										1995	1320.20	880.26	90	0	36
						SW	–.5	–.5	0	1970	1320.23	1759.94	89	57	47
										1995	1320.20	1759.63	89	57	3
42	Melvin and Chase	SSDM	192-117-164	8.5	15.2	SE	0	0	0	1970	661.68	1539.66	89	58	57
										1995	662.16	1539.82	89	56	36
43	Melvin and Roscoe	Unknown	192-117-115	10.3	11	NE	0	0	0	1970	720.15	1539.66	89	0	26
			192-117-185							1995	720.23	1539.82	89	1	6

Appendix 4

Listing of QuickBasic Computer Programs Used to Analyze Strains

Microsoft QuickBASIC program NERDWINN & DIFFLENG for entering survey data computing strains and preparing an AutoCAD DXF file

A.M. Johnson
Purdue University

July 1996

NERDWINN.BAS

```
REM  Saved as <NERDwinn.bas>
        ' This version of nerdshmoo is customized for Winnetka area.
        ' July 1996
        CLS
        nMax = 100: PRINT
        hold$ = "r"
        'x and y are coordinates of intersection,AA,a are lengths in x–direction
        ' BB, b are lengths in other street direction, xoffset and yoffset determine
        ' where shmoo is to be plotted. Atheta(i) is orientation of a relative to E
        ' counterclockwise angles positive.
        ' Four sets of data, 1, 2 3,4  for three times.
        DIM x(nMax), y(nMax), Monumenttype$(nMax)
        DIM year$(4), Quad$(4)
        DIM a(4, 4, nMax), B(4, 4, nMax)
        DIM xoffset(4, nMax), yoffset(4, nMax), Alpha(4, nMax)
        DIM name$(nMax), index%(nMax)
        DIM Atheta(4, 3, 4, nMax), Btheta(4, 3, 4, nMax)
        DIM E1(4, nMax), E2(4, nMax), BBtheta(kk, nMax)
        DIM dxdX(4, nMax), dxdY(4, nMax), dydX(4, nMax), dydY(4, nMax)
        CLS
        Quad$(1) = "NE": Quad$(2) = "NW": Quad$(3) = "SW": Quad$(4) = "SE"
        pi = 4 * ATN(1)
        co = pi / 180
        format1$ = "#####.##"
        format2$ = "########"
        GOSUB first.part:
        n = 0
        PRINT "To proceed, you need to select an option:"
        PRINT "If there is no file, do <1>. Else, do another option"
        PRINT
        PRINT
options:
        PRINT "Type <1> to ENTER Intersection DATA from keyboard."
        ' Note that <1> STARTS a NEW file.
        PRINT "Type <2> to CHANGE or ADD Some Intersection DATA."
        PRINT "Type <3> to ADD Length and Angle Data from keyboard."
```

```
        PRINT "Type <4> to CHANGE some Length or Angle Data."
        PRINT "Type <5> to READ and EXAMINE a data file."
        PRINT "Type <6> to FILL IN a data file or LPRINT a data file."
        PRINT "Type <7> to READ a *.dat file, PROCESS the data, CREATE a *.pro file"
        PRINT " and CREATE a *.dxf file for an autocad map."
        PRINT "Type <8> to READ a *.pro file and CREATE a *.dxf file for an autocad map"
        PRINT "Type <9> to READ a *.pro file, CHANGE RESULTS, and CREATE a *.dxf file for
        AutoCAD."
        PRINT "Type <10> to READ and EXAMINE a *.pro file."
        PRINT "Type <11> to READ a *.dat file and MAKE a document file."


        INPUT "Which is it, <1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or 11> ->"; ans
        IF ans > 11 OR ans < 1 THEN GOTO options:


'***********************START THE OPTIONS**********************
IF ans <> 1 THEN GOTO skip1:
'       ENTER Intersection,length and angle DATA from keyboard.
        CLS

        PRINT "Enter only first part of name. <.dat> or <.dat> will be added automatically"
        PRINT "Name must be 7 or fewer letters and numbers"
        INPUT "Data are to be in file with name"; filename$

        GOSUB enter.intersection.data:
skip1:
'**********
IF ans <> 2 THEN GOTO skip2:
'         CORRECT Intersection DATA.
        GOSUB file:
        CLS
        PRINT "Do you wish to ADD or CHANGE DATA <n, y—Enter is y>": INPUT answer$
        IF answer$ = "n" THEN GOTO skip2:
        CLS
        PRINT "Do you wish to CHANGE DATA <n, y—Enter is y>": INPUT answer$
        IF answer$ = "n" THEN GOSUB add.some:
        GOSUB fix.another.intersection:
        GOSUB save:
skip2:
'**********
IF ans <> 3 THEN GOTO skip3:
'         ADD Length and Angle Data from keyboard.
        GOSUB file:
        GOSUB add.lengths.angles:
        GOSUB save:
skip3:
'********
IF ans <> 4 THEN GOTO skip4:
'         CHANGE some Length or Angle Data
```

```
        GOSUB file:
        GOSUB change.results:
        GOSUB save:
skip4:
'********
IF ans <> 5 THEN GOTO skip5:
'         READ and EXAMINE a data file.
        GOSUB file:
        GOSUB examine.data:
skip5:
'********
IF ans <> 6 THEN GOTO skip6:
'         READ and a data file, FILL in missing data and then LPRINT it.
        GOSUB file:
        GOSUB fill.in.angles:
        INPUT "Do you wish to Lprint data file (type <y> or <n>)"; ans$
        IF ans$ = "y" OR ans$ = "yes" THEN GOSUB lprint.the.data:
skip6:
'*******
IF ans <> 7 THEN GOTO skip7:
'         READ a *.dat file, PROCESS the data, CREATE a *.pro file
'         and CREATE a *.dxf file for an autocad map.
        CLS
        GOSUB file:
        GOSUB create.pro:
        GOSUB make.autocad.file:
skip7:
' ******
IF ans <> 8 THEN GOTO skip8:
'         READ a *.pro file and CREATE a *.dxf file for an autocad map.
        GOSUB read.profile:
        GOSUB make.autocad.file:
skip8:
'*******
IF ans <> 9 THEN GOTO skip9:
'         READ a *.pro file, CHANGE RESULTS, and CREATE a *.dxf file for an autocad map.
        GOSUB read.profile:
        GOSUB make.changes:
        GOSUB save.profile:
        GOSUB make.autocad.file:
skip9:
' *******
IF ans <> 10 THEN GOTO skip10:
'         READ and EXAMINE a *.pro file.
        GOSUB read.profile:
        CLS
        GOSUB examine.pro:
skip10:
IF ans <> 11 THEN GOTO skip11:
'         READ a *.dat file and MAKE a document file.
```

```
        GOSUB file:
        GOSUB print.the.data.to.a.file:
skip11:
' *****Send a carriage return and end program.
LPRINT CHR$(27) + CHR$(69)        ' this ejects paper.
END
' *********************END OF MAIN PROGRAM************************
' *******************************************************************
'**********************BEGIN SUBROUTINES**************************
' *******************************************************************
REM ******************save:**********************
' save *.dat file.
save:
        PRINT
        PRINT "FILE IS BEING SAVED TO HARD DISK"
        filein$ = filename$
        m = INSTR(filein$, ".")
        IF m <> 0 THEN filein$ = LEFT$(filein$, m - 1)
        filein$ = filein$ + ".dat"
        CLS
        OPEN filein$ FOR OUTPUT AS #2
        FOR j = 1 TO 4                  ' j is no of year
                WRITE #2, year$(j)
        NEXT
        FOR i = 0 TO nn
          '  i is number of street intersection
                WRITE #2, name$(i), x(i), y(i)
                WRITE #2, Monumenttype$(i)
                FOR kk = 1 TO 4
                        WRITE #2, xoffset(kk, i), yoffset(kk, i), Alpha(kk, i)
                        ' j is the year
                        FOR j = 1 TO 4
                                WRITE #2, a(j, kk, i), B(j, kk, i)
                                FOR K = 1 TO 3  ' k is degr, min or sec
                                        WRITE #2, Btheta(j, K, kk, i)
                                NEXT
                        NEXT
                NEXT
        NEXT
        CLOSE #2
RETURN

'*******************enter name of files***********************
name.of.file:
        PRINT "Enter only first part of name. <.dat> will be added automatically"
        PRINT "Name must be 7 or fewer letters and numbers"
        CLS
        INPUT "Data are in file with name"; filename$
RETURN

' *********************file**************************
```

```
' Open the data file.
file:
        PRINT
        GOSUB name.of.file:
        filein$ = filename$
        m = INSTR(filein$, ".")
        IF m <> 0 THEN filein$ = LEFT$(filein$, m - 1)
        filein$ = filein$ + ".dat"
        CLS
        OPEN filein$ FOR INPUT AS #2
        FOR j = 1 TO 4                  ' j is no of year
                INPUT #2, year$(j)
        NEXT
ii = 0
DO UNTIL EOF(2)
         ' ii is number of street intersection
                INPUT #2, name$(ii), x(ii), y(ii)
                INPUT #2, Monumenttype$(ii)
                FOR kk = 1 TO 4
                        INPUT #2, xoffset(kk, ii), yoffset(kk, ii), Alpha(kk, ii)
                        ' j is the year
                        FOR j = 1 TO 4
                                INPUT #2, a(j, kk, ii), B(j, kk, ii)
                                FOR K = 1 TO 3   ' k is degr, min or sec
                                        INPUT #2, Btheta(j, K, kk, ii)
                                NEXT
                        NEXT
                NEXT
ii = ii + 1
LOOP
CLOSE #2
nn = ii - 1
RETURN
' ***************************create.pro***********************
create.pro:
REM READ a *.dat file, PROCESS the data and create a *.pro file.
enter1:
        REM ****select the two years****
        INPUT "Which data set will be initial state <1, 2,3 or 4>"; j1
        INPUT "Which data set will be final state"; j2
        PRINT "Initial state will be"; year$(j1), "and final state will be"; year$(j2)
        INPUT "Do you wish to select an optional year in case year 1 is blank <y,n Enter is n>?";
answer$
        j3 = j1
        IF answer$ = "y" THEN
        INPUT "optional year <1,2 or 3>"; j3
        END IF
        IF j3 = 0 OR j3 > 3 THEN
        PRINT "Must be between 1 and 3; try again, idiot!"
        GOTO enter1:
```

```
        END IF
        INPUT "Are these O.K. <if yes, just enter; if no, type n>"; answer$
        IF answer$ = "n" THEN GOTO enter1:
        GOSUB determine.extension.components:
        GOSUB save.profile:
RETURN
' ***************************read.pro file ************************
read.profile:
'  read file with .pro extension (extensions)
   IF filename$ = "" THEN GOSUB name.of.file:
   filein$ = filename$
        m = INSTR(filein$, ".")
        IF m <> 0 THEN filein$ = LEFT$(filein$, m - 1)
        filein$ = filein$ + ".pro"
        CLS
        OPEN filein$ FOR INPUT AS #2
        i = 1
        INPUT #2, year1$, year2$, j1

        DO UNTIL EOF(2)
         ' i is number of street corner
                INPUT #2, name$(i), x(i), y(i)
                INPUT #2, Monumenttype$(i)
                FOR kk = 1 TO 4
                INPUT #2, xoffset(kk, i), yoffset(kk, i), Alpha(kk, i)
                INPUT #2, E1(kk, i), E2(kk, i), dxdX(kk, i), dxdY(kk, i), dydX(kk, i), dydY(kk, i)
                NEXT
        i = i + 1
        LOOP
        CLOSE #2
        ' set maximum number of data to i-1
        nn = i - 1
RETURN
' ******************************save.profile.********************
save.profile:
REM    save file of processed extension data
        fileout$ = filename$
        CLS
        m = INSTR(fileout$, ".")
        IF m <> 0 THEN fileout$ = LEFT$(fileout$, m - 1)
        fileout$ = fileout$ + ".pro"
        OPEN fileout$ FOR OUTPUT AS #2
        WRITE #2, year$(j1), year$(j2), j1
        FOR i = 0 TO nn
         ' i is number of street corner
                WRITE #2, name$(i), x(i), y(i)
                WRITE #2, Monumenttype$(i)
                FOR kk = 1 TO 4
                WRITE #2, xoffset(kk, i), yoffset(kk, i), Alpha(kk, i)
                WRITE #2, E1(kk, i), E2(kk, i), dxdX(kk, i), dxdY(kk, i), dydX(kk, i), dydY(kk, i)
```

```
            NEXT
        NEXT
        CLOSE #2
RETURN
REM ************************Determine.extension.Components***************************
determine.extension.components:
j0 = j1
FOR i = 0 TO nn
        CLS
        j1 = j0
  FOR kk = 1 TO 4
         ' the following is just a dummy value, to identify case of no data
         E1(kk, i) = 9999
         IF ABS(Btheta(j1, 1, kk, i) * Btheta(j2, 1, kk, i)) < 1 THEN
        IF ABS(Btheta(j3, 1, kk, i) * Btheta(j2, 1, kk, i)) < 1 THEN GOTO skip50:
        j1 = j3
         END IF

         IF a(j2, kk, i) * a(j1, kk, i) < 1 THEN GOTO skip50:
         IF B(j2, kk, i) * B(j1, kk, i) < 1 THEN GOTO skip50:
         Sa = a(j2, kk, i) / a(j1, kk, i)
         Sb = B(j2, kk, i) / B(j1, kk, i)
         IF Sa = 1 AND Sb = 1 THEN GOTO skip50:
         Ea = Sa - 1
         Eb = Sb - 1
         Bthet = 0
         Bcapthet = 0
        FOR K = 1 TO 3
                Bthet = Bthet + Btheta(j2, K, kk, i) / (60 ^ (K - 1))
                Bcapthet = Bcapthet + Btheta(j1, K, kk, i) / (60 ^ (K - 1))
        NEXT
        jump$ = "yes"
        IF ABS(Bthet) < 89 OR ABS(Bthet) > 91 THEN jump$ = "no"
REM ****assign the sign according to the quadrant
        IF kk = 2 OR kk = 4 THEN index% = 2
        IF kk = 1 OR kk = 3 THEN index% = 1
        Bcapthet = 180 * (index% - 1) - Bcapthet * (-1) ^ index%
        Bthet = 180 * (index% - 1) - Bthet * (-1) ^ index%

          Bt = Bthet + Alpha(kk, i)
          Bct = Bcapthet + Alpha(kk, i)
          'IF Alpha(kk, i) < 0 THEN Alpha(kk, i) = Alpha(kk, i) + 360
          IF Bct < 0 THEN Bct = Bcapthet + Alpha(kk, i) + 360
          IF Bt < 0 THEN Bt = Bthet + Alpha(kk, i) + 360
        PRINT "We are working on intersection"; name$(i)
        dxdY(kk, i) = (Sb * COS(Bthet * co) - Sa * COS(Bcapthet * co)) / SIN(Bcapthet * co)
        dxdX(kk, i) = Sa
        dydX(kk, i) = 0
        dydY(kk, i) = Sb * SIN(Bthet * co) / SIN(Bcapthet * co)
```

```
adjust.deform.gradients:
        CLS 2
        PRINT "dxdX="; dxdX(kk, i), "dxdy="; dxdY(kk, i), "dydy="; dydY(kk, i)
          ' scale the window
          yscale = 5 * (ABS(1 – dxdX(kk, i)) + ABS(dxdY(kk, i)) + ABS(1 – dydY(kk, i))) / 3
SCREEN 2
          VIEW (20, 2)–(620, 172), , 1

          WINDOW (0, –1)–(360, 1)
          CLS 2
          ' print two known stretches
          LINE (Bt – 4, Eb / yscale + .04)–(Bt + 4, Eb / yscale – .04), , B
          LINE (Bct – 4, Eb / yscale + .04)–(Bct + 4, Eb / yscale – .04), , B
          LINE (Bt + 180 – 4, Eb / yscale + .04)–(Bt + 180 + 4, Eb / yscale – .04), , B
          LINE (Bct + 180 – 4, Eb / yscale + .04)–(Bct + 180 + 4, Eb / yscale – .04), , B
          LINE (Alpha(kk, i) – 4, Ea / yscale + .04)–(Alpha(kk, i) + 4, Ea / yscale – .04), , B

          ' print the curves

         REM Fit data to extension distribution
         FOR thet = 0 TO 360 STEP 5
        D = (dxdX(kk, i) * dydY(kk, i) – dxdY(kk, i) * dydX(kk, i))
        temp1 = (dydY(kk, i) * COS(thet * co) – dxdY(kk, i) * SIN(thet * co)) ^ 2
        temp2 = (–dydX(kk, i) * COS(thet * co) + dxdX(kk, i) * SIN(thet * co)) ^ 2
        E1st = (–1 + D / SQR(temp1 + temp2)) / yscale
        IF thet > 0 THEN
                LINE (thet0 + Alpha(kk, i), t1)–(thet + Alpha(kk, i), E1st)
                ' LINE (thet0 + Alpha(kk, i), t2)–(thet + Alpha(kk, i), E2nd)
        END IF
        thet0 = thet
        t1 = E1st
         NEXT
         ' i1 = (dxdX(kk, i) ^ 2) + (dydY(kk, i) ^ 2) + (dxdY(kk, i) ^ 2) + (dydX(kk, i) ^ 2)
         ' i2 = D ^ 2
        ' test = (i1 ^ 2) – 4 * i2

         ' IF test < 0 THEN
        ' test = 0
        ' PRINT "Warning—Negative square root!!!"
         ' END IF
         ' S1 = SQR((1 / 2) * (i1 + SQR(test)))
         ' S2 = SQR((1 / 2) * (i1 – SQR(test)))
         ' since the strains are very small, use the infinitesimal approximations
        exy = .5 * (dydX(kk, i) + dxdY(kk, i))
        exx = dxdX(kk, i) – 1
        eyy = dydY(kk, i) – 1
        emean = (exx + eyy) / 2
        edeviat = (exy ^ 2) + ((exx – eyy) / 2) ^ 2
        E1(kk, i) = emean + SQR(edeviat)
        E2(kk, i) = emean – SQR(edeviat)
```

```
   ' There is no check if streets are at right angles
  IF jump$ = "yes" THEN GOTO skip23:

  VIEW PRINT 1 TO 5

  PRINT name$(i), "E1"; E1(kk, i), "E2"; E2(kk, i)
  PRINT "Just Checking. Points should lie on line. Push a key to continue"
   DO: LOOP WHILE INKEY$ = ""       ' wait for a key press

   CLS 2  '  clear text viewport
skip23:
CLS 1
CLS 2
   IF print$ = "yes" THEN
  LPRINT
  LPRINT
  LPRINT "extension data for intersection"; i
  LPRINT name$(i), "quadrant", Quad$(kk)
  LPRINT "coordinates", x(i), y(i)
  LPRINT "offsets", xoffset(kk, i), yoffset(kk, i)
  LPRINT "lengths", a(j1, kk, i), a(j2, kk, i), B(j1, kk, i), B(j2, kk, i)
  LPRINT "deformation gradient dxdX, dxdy, dydX, dydy"
  LPRINT dxdX(kk, i), dxdY(kk, i), dydX(kk, i), dydY(kk, i)
  LPRINT "principal extensions E1, E2"; E1(kk, i), E2(kk, i)
  LPRINT "The deformation gradient dxdX is in the direction "; n; ";90–Alpha(kk,i);"; E; ""
  LPRINT "and dydy is at right angles."
  LPRINT : LPRINT : LPRINT
  END IF
skip50:

 NEXT
NEXT
IF print$ = "yes" THEN LPRINT CHR$(27) + CHR$(69)
RETURN
REM******************************calculation of extensions complete**********

REM **********************************make.autocad.file*******************

make.autocad.file:
  CLS
  PRINT "Please be patient. This takes a little time."
  PRINT "I will ask you to push a key when I am finished."
  PRINT "Thank you, oh patient master!"
  PRINT " The extension analysis is based on the following notions:"
  PRINT " (1) The extension is exactly described in terms of four components"
  PRINT " of the deformation gradient, dx/dX, dx/dy, dy/dX, dy/dy."
  PRINT " The stretches are measured along two directions, a and b."
  PRINT " The original angle (cap theta) between a and b and the final"
  PRINT " angle (theta) are known. Theta positive if counterclockwise from"
  PRINT " a–axis. Rotation is of no interest, we we can assume dy/dX = 0."
```

```
        PRINT " The axis a is the reference direction, before and after deformation."
        PRINT " The change in orientation of b relative to a is determined by simple"
        PRINT " shear parallel to a. This determines dx/dy. The stretch in a is dx/dX."
        PRINT " The stretch in b is adjusted until the measurements define a possible"
        PRINT " state of extension. In general, the component dy/dy is closely related to"
        PRINT " the stretch in b; is should be equal if the final angle between a and b"
        PRINT " is 90 degrees. Finally, the results are checked by plotting extension as a"
        PRINT " as a function of lower–and upper–case thetas."

        section$ = "SECTION"
        polyline$ = "POLYLINE"
        entities$ = "ENTITIES"
        vertex$ = "VERTEX"
        seqend$ = "SEQEND"
        endsec$ = "ENDSEC"
        eof$ = "EOF"
        fileout$ = filename$
        m = INSTR(fileout$, ".")
        IF m <> 0 THEN fileout$ = LEFT$(fileout$, m – 1)
        filout1$ = fileout$ + "1.dxf"
        filout2$ = fileout$ + "2.dxf"
        filout3$ = fileout$ + "3.dxf"
        blank$ = CHR$(0)
        nMin = 4.9

OPEN filout1$ FOR OUTPUT AS #3
        PRINT #3, 0
        PRINT #3, section$
        PRINT #3, 2
        PRINT #3, entities$
        PRINT #3, 0
OPEN filout2$ FOR OUTPUT AS #4
        PRINT #4, 0
        PRINT #4, section$
        PRINT #4, 2
        PRINT #4, entities$
        PRINT #4, 0
scale.strain.figures:
CLS
PRINT "You need to scale the figures."
PRINT "What is the largest magnitude of strain you expect?"
INPUT "What is exponent, n, in 10^(–n)"; nX
        IF n < 0 THEN
                PRINT "You jest, presumably. Try again or change program."
                GOTO scale.strain.figures:
        END IF
        PRINT "Now you need to know how big you want the largest strain figures to be."
        PRINT "The data are plotted in centimeters as now set up."
        PRINT "How large (cm) do you want the radius of the largest strain figure to be?"
        PRINT "If in doubt, select 1 cm. You can experiment."
```

```
        PRINT "Note that each reference strain figure will be 1/sqr(10) that of"
        PRINT "the larger one. That is, if 10^–1 is the largest and is one cm"
        PRINT "then 10^–2 will be about 1/3 cm and 10^3 will be 1/9 cm etc."
        PRINT : PRINT
        INPUT "Radius of largest strain figure (cm)"; r

        G = pi * (r ^ 2) / (10 ^ (–nX))

        PRINT "G is"; G
        PRINT
        PRINT "The largest strain figure, for a strain of + or – 10^–"; nX; " is"; r; "cm"
        r1 = SQR(G * (10 ^ –(nX + 1)) / pi)
        r2 = SQR(G * (10 ^ –(nX + 2)) / pi)
        PRINT "This implies that the radius for a strain figure of 10^–"; nX + 1; " is"; r1; "cm"
        PRINT "and that the radius of a strain figure of 10^–"; nX + 2; " is"; r2; "cm"
        PRINT "If you wish to revise, answer <n>. <y or Return> is yes"
        INPUT "Are these values satisfactory"; ans$
        IF ans$ = "n" THEN GOTO scale.strain.figures:
        co = pi / 180
FOR i = 0 TO nn
        FOR kk = 1 TO 4
                IF E1(kk, i) = 9999 THEN GOTO jump51:
                temp1 = ABS(E1(kk, i))
                temp2 = ABS(E2(kk, i))
                refstr = temp1
                IF refstr < temp2 THEN refstr = temp2
        IF refstr < (10 ^ (–nMin)) THEN
                        radius = .5 * SQR(G * (10 ^ –nX) / pi)
                        PRINT "Strain is too small to plot for point"; i
                        PRINT #3, polyline$
                        PRINT #3, 8
                        PRINT #3, 0
                        PRINT #3, 66
                        PRINT #3, 1
                        PRINT #3, 0
                        xx = xoffset(kk, i) + x(i) + radius * COS(45 * co)
                        yy = yoffset(kk, i) + y(i) + radius * SIN(45 * co)
                        PRINT #3, vertex$
                        PRINT #3, 8
                        PRINT #3, 0
                        PRINT #3, 10
                        PRINT #3, xx
                        PRINT #3, 20
                        PRINT #3, yy
                        PRINT #3, 0
                        xx = xoffset(kk, i) + x(i) – radius * COS(45 * co)
                        yy = yoffset(kk, i) + y(i) – radius * SIN(45 * co)
                        PRINT #3, vertex$
                        PRINT #3, 8
                        PRINT #3, 0
```

```
            PRINT #3, 10
            PRINT #3, xx
            PRINT #3, 20
            PRINT #3, yy
            PRINT #3, 0
        PRINT #3, seqend$
        PRINT #3, 8
        PRINT #3, 0
        PRINT #3, 0
ELSE
        radius = SQR((G * refstr) / pi)
        D = dxdX(kk, i) * dydY(kk, i) – dxdY(kk, i) * dydX(kk, i)
        PRINT #3, polyline$
        PRINT #3, 8
        PRINT #3, 0
        PRINT #3, 66
        PRINT #3, 1
        PRINT #3, 0
        FOR thet = 0 TO 360 STEP 5
            th = (thet + Alpha(kk, i)) * co
            tmp = ((dydY(kk, i) * COS(th) – dxdY(kk, i) * SIN(th)) ^ 2)
            tmp = tmp + ((–dydX(kk, i) * COS(th) + dxdX(kk, i) * SIN(th)) ^ 2)
            str = (–1 + D / SQR(tmp)) / refstr
            xx = xoffset(kk, i) + x(i) + radius * (1 + str) * COS(th)
            yy = yoffset(kk, i) + y(i) + radius * (1 + str) * SIN(th)
            PRINT #3, vertex$
            PRINT #3, 8
            PRINT #3, 0
            PRINT #3, 10
            PRINT #3, xx
            PRINT #3, 20
            PRINT #3, yy
            PRINT #3, 0
        NEXT
        PRINT #3, seqend$
        PRINT #3, 8
        PRINT #3, 0
        PRINT #3, 0
END IF
        ' start a new image
        PRINT #4, polyline$
        PRINT #4, 8
        PRINT #4, 0
        PRINT #4, 66
        PRINT #4, 1
        PRINT #4, 0
        FOR thet = 0 TO 360 STEP 5
            th = (thet + Alpha(kk, i)) * co
            xxc = xoffset(kk, i) + x(i) + radius * COS(th)
            yyc = yoffset(kk, i) + y(i) + radius * SIN(th)
```

```
                PRINT #4, vertex$
                PRINT #4, 8
                PRINT #4, 0
                PRINT #4, 10
                PRINT #4, xxc
                PRINT #4, 20
                PRINT #4, yyc
                PRINT #4, 0
            NEXT
            PRINT #4, seqend$
            PRINT #4, 8
            PRINT #4, 0
            PRINT #4, 0
jump51:
        NEXT
NEXT

        ' The following routine provides data for scales of shmoos

        FOR ra = (nX – 1) TO (nMin + .5) STEP .5
            radius = SQR(G * (10 ^ (–ra)) / pi)
            xx = –5
            yy = 45 + 4 * ra
            ' start a new image
            PRINT #4, polyline$
            PRINT #4, 8
            PRINT #4, 0
            PRINT #4, 66
            PRINT #4, 1
            PRINT #4, 0
            FOR thet = 0 TO 360 STEP 5
                th = thet * co
                xxc = xx + radius * COS(th)
                yyc = yy + radius * SIN(th)
                PRINT #4, vertex$
                PRINT #4, 8
                PRINT #4, 0
                PRINT #4, 10
                PRINT #4, xxc
                PRINT #4, 20
                PRINT #4, yyc
                PRINT #4, 0
            NEXT
            PRINT #4, seqend$
            PRINT #4, 8
            PRINT #4, 0
            PRINT #4, 0
        NEXT

        PRINT #4, seqend$
```

```
        PRINT #4, 8
        PRINT #4, 0
        PRINT #4, 0
        PRINT #4, endsec$
        PRINT #4, 0
        PRINT #4, eof$
        PRINT #4,
CLOSE #4
        PRINT #3, seqend$
        PRINT #3, 8
        PRINT #3, 0
        PRINT #3, 0
        PRINT #3, endsec$
        PRINT #3, 0
        PRINT #3, eof$
        PRINT #3,
CLOSE #3

                ' start lines for streets
OPEN filout3$ FOR OUTPUT AS #5
        PRINT #5, 0
        PRINT #5, section$
        PRINT #5, 2
        PRINT #5, entities$
        PRINT #5, 0
                CLS
read.next.line:
                PRINT #5, polyline$
                PRINT #5, 8
                PRINT #5, 0
                PRINT #5, 66
                PRINT #5, 1
                PRINT #5, 0
read.next.point:
                READ xxc, yyc
                IF xxc = 9999 THEN GOTO no.more.streets:
                IF xxc = 999 THEN GOTO end.of.line:
                        PRINT #5, vertex$
                        PRINT #5, 8
                        PRINT #5, 0
                        PRINT #5, 10
                        PRINT #5, xxc
                        PRINT #5, 20
                        PRINT #5, yyc
                        PRINT #5, 0
                        GOTO read.next.point:
end.of.line:
                PRINT #5, seqend$
                PRINT #5, 8
                PRINT #5, 0
```

```
                PRINT #5, 0
                GOTO read.next.line:
no.more.streets:
        PRINT #5, seqend$
        PRINT #5, 8
        PRINT #5, 0
        PRINT #5, 0
        PRINT #5, endsec$
        PRINT #5, 0
        PRINT #5, eof$
        PRINT #5,
CLOSE #5
RETURN

REM **************************fill.in.data.set*************************
fill.in.lengths:
        FOR iii = 0 TO nn
        FOR jj = 1 TO 4
                FOR K = 1 TO 4
                        kc = 5 - K
                        IF a(jj, K, iii) = 0 THEN a(jj, K, iii) = a(jj, kc, iii)
                        kp = 3 - K
                        IF K > 3 THEN kp = kp + 4
                        IF B(jj, K, iii) = 0 THEN B(jj, K, iii) = B(jj, kp, iii)
                NEXT
        NEXT
        NEXT
RETURN
' ***********************fill.in.angles********************************
fill.in.angles:
FOR iii = 0 TO nn
        FOR jj = 1 TO 4
        deg = 0: min = 0: sec = 0: ct = 0
          IF Btheta(jj,1,1,iii)*Btheta(jj,1,2,iii)*Btheta(jj,1,3,iii) <> 0 THEN ij=4: ct=1
          IF Btheta(jj,1,4,iii)*Btheta(jj,1,1,iii)*Btheta(jj,1,2,iii) <> 0 THEN ij=3: ct=ct + 1
          IF Btheta(jj,1,3,iii)*Btheta(jj,1,4,iii)*Btheta(jj,1,1,iii) <> 0 THEN ij=2: ct=ct + 1
          IF Btheta(jj,1,2,iii)*Btheta(jj,1,3,iii)*Btheta(jj,1,4,iii) <> 0 THEN ij=1: ct=ct + 1
        IF ct <> 1 THEN GOTO skip52:
                FOR K = 1 TO 4
                        IF K <> ij THEN
                        deg = deg + Btheta(jj, 1, K, iii)
                        min = min + Btheta(jj, 2, K, iii)
                        sec = sec + Btheta(jj, 3, K, iii)
                        END IF
                NEXT
        mint = INT(sec / 60)
        IF Btheta(jj, 1, ij, iii) = 0 THEN
                Btheta(jj, 3, ij, iii) = 60 - (sec - mint * 60)
                min = min + mint
                degt = INT(min / 60)
```

```
                Btheta(jj, 2, ij, iii) = 59 – (min – degt * 60)
                Btheta(jj, 1, ij, iii) = 359 – deg + degt
            END IF
skip52:
        NEXT
NEXT
RETURN
'*******************************print.intersection**********************
print.intersection:
PRINT "Intersection number= "; i, "Location "; name$(i), "x= "; x(i), "y= "; y(i)
RETURN
' ********************print data**********************
print.data:
PRINT Quad$(kk); " corner(no."; kk; ")"; "xo= "; xoffset(kk, i), "yo= "; yoffset(kk, i); "  Alpha; Orientation
of street a:"; Alpha(kk, i)
PRINT "                                   "; year$(1); "              "; year$(2); "              "; year$(3); "
"; year$(4)
PRINT "length a       :"; : PRINT USING format1$; a(1, kk, i); a(2, kk, i); a(3, kk, i); a(4, kk, i)
PRINT "length b       :"; : PRINT USING format1$; B(1, kk, i); B(2, kk, i); B(3, kk, i); B(4, kk, i)
PRINT "Angle Btheta:";
PRINT USING format2$; Btheta(1, 1, kk, i); Btheta(1, 2, kk, i); Btheta(1, 3, kk, i);
PRINT "_";
PRINT USING format2$; Btheta(2, 1, kk, i); Btheta(2, 2, kk, i); Btheta(2, 3, kk, i);
PRINT "_";
PRINT USING format2$; Btheta(3, 1, kk, i); Btheta(3, 2, kk, i); Btheta(3, 3, kk, i);
PRINT "_";
PRINT USING format2$; Btheta(4, 1, kk, i); Btheta(4, 2, kk, i); Btheta(4, 3, kk, i)
RETURN

REM ************************lengths.and.angles************************
lengths.and.angles:

        CLS
        GOSUB print.intersection:
        FOR kk = 1 TO 4
                GOSUB print.data:
        NEXT
change.quadrant:
          CLS
        PRINT : PRINT "To do a different intersection, or to quit, enter 0"
        INPUT "Which corner <kk> <1,2,3,4 or 0 to switch>"; kk
        IF kk = 0 THEN GOTO skip21:
        IF kk > 4 THEN GOTO change.quadrant:
          PRINT "Corner is"; Quad$(kk); " quadrant"
          PRINT : PRINT "The x–offset of the shmoo (in cm!)": INPUT " –>"; xoffset(kk, i)
          PRINT "The y–offset of the shmoo (in cm!)": INPUT " –>"; yoffset(kk, i)
          INPUT "Orientation of street a is (degrees)"; Alpha(kk, ii)
        CLS
please:
        PRINT "Now enter information on year, lengths and angles"
```

```
        PRINT "To do a different intersection, or to quit, enter 0"
        INPUT "Which year <1,2 3,4 or 0 to switch>"; j
        IF j = 0 THEN GOTO change.quadrant:
        IF j > 4 THEN
                PRINT "Enter correct year for data set, dumbo!"
                GOTO please:
        END IF
        PRINT "Data for year"; year$(j)
        INPUT "Is this the correct year< n or y Enter is y>"; answer$
  IF answer$ = "n" THEN
        PRINT "Enter correct quadrant and year for data set, you cretin!"
        GOTO please:
  END IF
        CLS
        PRINT "intersection"; i, name$(i)
        PRINT "Quadrant"; Quad$(kk), "Lengths and Angle:"
        PRINT "a and b and Btheta"; a(j, kk, i); B(j, kk, i), Btheta(j, 1, kk, i);
        PRINT Btheta(j, 2, kk, i); Btheta(j, 3, kk, i)
        INPUT "Change lengths or angle <n, y or q; Enter is y>"; answer$
        IF answer$ = "n" OR answer$ = "q" THEN GOTO skip21:
        GOSUB enter.lengths:
        GOTO please:
skip21:
GOSUB save:
RETURN
REM ************************enter.lengths*******************************
enter.lengths:
        CLS
        PRINT "intersection"; i, name$(i), "Quadrant"; Quad$(kk)
        PRINT "year is "; year$(j), "   Lengths and Angle:"
        PRINT "length a="; a(j, kk, i)
        INPUT "Is this length O.K. <y,n Enter is y>"; answer$
        IF answer$ = "n" THEN
          PRINT "What is length of street a (runs ca E–W)": INPUT a(j, kk, i)
        END IF
        PRINT "length b="; B(j, kk, i)
        INPUT "Is this length O.K. <y,n Enter is y>"; answer$
        IF answer$ = "n" THEN
          PRINT "What is length of street b (runs ca N_W)": INPUT B(j, kk, i)
        END IF
        PRINT "The lengths of strees a and b are"; a(j, kk, i), B(j, kk, i)
        GOSUB fill.in.lengths:
        PRINT "Now enter angles angles as degrees, minutes and seconds"
                PRINT "Note! Measure angles counterclockwise from east!"
                PRINT
                PRINT "The orientation of street a is"; Alpha(kk, i)
        INPUT "If this is O.K. then push Enter, Else type n"; answer$
        IF answer$ <> "" THEN
                PRINT : PRINT "The orientation of street a": INPUT "degrees –>"; Alpha(kk, i)
        END IF
```

```
        PRINT : PRINT "The angle between streets a and b in"; Quad$(kk), " quadrant is";
                PRINT Btheta(j, 1, kk, i); Btheta(j, 2, kk, i); Btheta(j, 3, kk, i)
                PRINT "To hold this angle at 0, enter 360"
                INPUT "If this is O.K. then push Enter, Else type n"; answer$
                IF answer$ <> "" THEN
                        PRINT "The angle between streets a and b is"
                        INPUT "degrees ->"; Btheta(j, 1, kk, i)
                        INPUT "minutes ->"; Btheta(j, 2, kk, i)
                        INPUT "seconds->"; Btheta(j, 3, kk, i)
                END IF

         ko = kk
         FOR kk = 1 TO 4
                 GOSUB print.data:
         NEXT
         kk = ko
         PRINT : INPUT "IS THE INFORMATION ENTERED ABOVE CORRECT? <y OR n Enter is y>
-> "; answer$
         IF answer$ = "n" THEN GOTO enter.lengths:
RETURN
REM **********************change.results*************************
change.results:

         CLS
         FOR j = 1 TO 4
        PRINT : PRINT "year of"; j; "th data set", year$(j)
        INPUT "correct <y or n Enter is y>"; answer$
        IF answer$ = "n" THEN INPUT "year"; year$(j)
         NEXT
which.one:
        CLS
        PRINT "Enter 0 to end changes and EXIT."
        INPUT "Which intersection <1....39....70 etc.or 0>"; i
        IF i = 0 THEN GOTO skip22:
        IF i > nn THEN GOTO which.one:
        GOSUB correct.intersection:
another.corner:
        CLS
        GOSUB print.intersection:
        FOR kk = 1 TO 4
                GOSUB print.data:
        NEXT
        PRINT : PRINT "intersection is no."; i, name$(i)
        PRINT "Answer 0 (zero) to do another intersection or exit"
        INPUT "Which corner <1,2,3,4 or 0>"; kk
        IF kk = 0 THEN GOTO which.one:
        IF kk > 4 THEN GOTO another.corner:
        PRINT "Corner is "; Quad$(kk)
another.year:
        PRINT "Answer 0 (zero) to do another corner or intersection or exit"
```

```
        INPUT "Which year <1,2,3,4 or 0>"; j
        IF j = 0 THEN GOTO which.one:
        IF j > 4 THEN GOTO another.year:
        GOSUB enter.lengths:

        PRINT "year is "; year$(j)
        INPUT "Another year <y or n Enter is y>->"; answer$
        IF answer$ <> "n" THEN GOTO another.year:
        INPUT "Another corner <y or n Enter is y>"; answer$
        IF answer$ <> "n" THEN GOTO another.corner:
        INPUT "Another intersection <y or n Enter is y>"; answer$
        IF answer$ <> "n" THEN GOTO which.one:
skip22:
GOSUB save:
RETURN

REM *******************enter.intersection**************************
enter.intersection:
         end$ = "n"
         PRINT "To stop entry of data, push <enter> when asked for name of intersection."
type.in.data:
         PRINT "The previous intersection is:"; name$(i - 1)
         PRINT : PRINT i; "(Name) The intersection of street1/street2": INPUT " ->"; name$(i)
         IF name$(i) = "" THEN nn = i - 1: end$ = "y": RETURN
         PRINT "The type of monumentation is": INPUT "->"; Monumenttype$(i)
         PRINT "The x-coordinate of the intersection": INPUT " ->"; x(i)
         PRINT "The y-coordinate of the intersection": INPUT " ->"; y(i)
         PRINT "datum set"; i; "intersection"; name$(i)
         PRINT : INPUT "IS THE INFORMATION ENTERED ABOVE CORRECT? <y OR n> -> ";
answer$
         IF answer$ = "n" THEN
        GOSUB correct.intersection:
         END IF
RETURN
REM ************************correct.intersection******************
correct.intersection:
         CLS
         PRINT "Note that you can answer yes by simply pushing <Enter>"
         PRINT "but that you must answer no by typing n"
         PRINT : PRINT i; "Intersection of "; name$(i)
         INPUT "Is this name correct <y or n Enter is y>"; answer$
         IF answer$ <> "n" THEN GOTO monuments:
         INPUT "intersection"; name$(i)
         GOTO correct.intersection:
monuments:
         PRINT "Monumentation type is "; Monumenttype$(i)
         INPUT "Is this monument type correct <y or n Enter is y>"; answer$
         IF answer$ <> "n" THEN GOTO positions:
         INPUT "Monument type"; Monumenttype$(i)
         CLS
```

```
        GOTO monuments:
positions:
        PRINT "x–position of the intersection is"; x(i)
        INPUT "Is this position correct <y or n Enter is y>"; answer$
        IF answer$ <> "n" THEN GOTO try.y.then:
        INPUT "x–position ofintersection is"; x(i)
        CLS
        GOTO positions:
try.y.then:
        PRINT "y–position of the intersection is"; y(i)
        INPUT "Is this position correct <y or n Enter is y>"; answer$
        IF answer$ <> "n" THEN GOTO review:
        INPUT "y–position ofintersection is"; y(i)
        CLS
        GOTO try.y.then:
review:
        PRINT : PRINT i; "Intersection of "; name$(i)
        PRINT "Monumentation type is "; Monumenttype$(i)
        PRINT "x–position of the intersection is"; x(i)
        PRINT "y–position of the intersection is"; y(i)
        INPUT "Are these all correct <y or n Enter is y>"; answer$
        IF answer$ <> "n" THEN GOTO jump.out:
        GOTO correct.intersection:
jump.out:
RETURN
' *************correct.quadrants.and.offsets****************
correct.quadrants.and.offsets:
        CLS
        PRINT "Note that you can answer yes by simply pushing <Enter>"
        PRINT "but that you must answer no by typing n"
        PRINT : PRINT i; "Intersection of "; name$(i)
        PRINT "Monumentation type is "; Monumenttype$(i)
        PRINT "x– and y–positions of the intersection are"; x(i), y(i)
try.again:
        INPUT "Quadrant no. NE=1; NW=2; SW=3; SE=4"; kk
        IF kk = 0 OR kk > 4 THEN GOTO try.again:
        PRINT : PRINT "Quadrant is"; Quad$(kk)
        INPUT "Is this quadrant correct <y or n Enter is y>"; answer$
        IF answer$ <> "n" THEN GOTO offsets:
        INPUT "Quadrant number is"; kk
        GOTO try.again:
offsets:
        PRINT "i="; i, "intersection="; name$(i)
        PRINT : PRINT "X– and y–offsets of the shmoo (in cm!) are"; xoffset(kk, i), yoffset(kk, i)
        INPUT "Are these offsets correct <y or n Enter is y>"; answer$
        IF answer$ <> "n" THEN GOTO jump.clear:
       INPUT "X–offset of the shmoo (in cm!) is"; xoffset(kk, i)
       INPUT "y–offset of the shmoo (in cm!) is"; yoffset(kk, i)
        GOTO try.again:
```

```
jump.clear:
RETURN
REM *****************************make.changes*******************************
make.changes:
CLS
PRINT "Note that you can answer yes by simply pushing <Enter>"
        PRINT "but that you must answer no by typing n"
        PRINT : PRINT i; "Intersection of "; name$(i)
        PRINT "Monument type "; Monumenttype$(i)
        INPUT "Is this name correct <y or n>"; answer$
        IF answer$ = "n" THEN INPUT "intersection"; name$(i)
        IF name$(i) = "" THEN n = n – 1: PRINT "A null data set": RETURN
        CLS
        PRINT "Monument type "; Monumenttype$(i)
        INPUT "Is this Monument type correct <y or n>"; answer$
        IF answer$ = "n" THEN INPUT "Monument type"; Monumenttype$(i)
        CLS
        PRINT "x– and y–positions of the intersection are"; x(i), y(i)
        INPUT "Are these positions correct <y or n>"; answer$
        IF answer$ = "n" THEN
       INPUT "x–position ofintersection is"; x(i)
       INPUT "y–position ofintersection is"; y(i)
        END IF
        CLS
        PRINT "i="; i, "intersection="; name$(i)
FOR kk = 1 TO 4
        PRINT : PRINT "x– and y–offsets of the shmoo (in cm!) are"; xoffset(kk, i), yoffset(kk, i)
        INPUT "Are these offsets correct <y or n>"; answer$
        IF answer$ = "n" THEN
       INPUT "X–offset of the shmoo (in cm!) is"; xoffset(kk, i)
       INPUT "y–offset of the shmoo (in cm!) is"; yoffset(kk, i)
        END IF
NEXT
       CLS
RETURN
' **************************examine.pro************************
examine.pro:
       PRINT "As you read the data sets, push <q> to quit or any other key"
       PRINT "to read the next data set. Run option ???3 "
       PRINT "to modify data sets and save data set."
       PRINT
       PRINT "Push any key to continue"

       DO WHILE INKEY$ = "": LOOP
       j = j2
       PRINT "year", year$(j)
       FOR i = 1 TO n
        ' i is number of street corner
```

```
            CLS
            PRINT "intersection "; i, name$(i)
            PRINT "x–coord "; x(i), "y–coord "; y(i)
            FOR kk = 1 TO 4
                  PRINT "x–offset "; xoffset(kk, i)
                  PRINT "y–offset "; yoffset(kk, i)
                  PRINT "principal extensions "; E1(kk, i), E2(kk, i)
                  PRINT "Components of displacement gradient"
                  PRINT "dxdX(kk,i), dxdy(kk,i), dydX(kk,i), dydy(kk,i)"
                  PRINT dxdX(kk, i), dxdY(kk, i), dydX(kk, i), dydY(kk, i)
                  PRINT "Orientation of street a "; Alpha(kk, i)
                  PRINT "Angle between streets a and b "; Btheta(j, 1, kk, i);
                  PRINT Btheta(j, 2, kk, i); Btheta(j, 3, kk, i)
                  tp$ = ""
                  DO WHILE tp$ = ""
                  tp$ = INKEY$
                  IF tp$ = "q" THEN GOTO skip7:
                  LOOP
            NEXT
      NEXT
RETURN
' **********************enter.intersection.data*********************
enter.intersection.data:
  i = 1
  CLS
  DO
      PRINT "Starting a new data set (number=)"; i
      GOSUB enter.intersection:
      GOSUB save:
      i = i + 1
      nn = nn + 1
  LOOP UNTIL end$ = "y"
RETURN
'*****************************add.intersections*****************
add.intersections:
      i = nn + 1
      CLS
      DO
            PRINT "Starting a new data set (number=)"; i
            GOSUB enter.intersection:
            IF end$ = "y" THEN GOTO skip24:
            GOSUB lengths.and.angles:
            GOSUB save:
            i = i + 1
            nn = nn + 1
skip24:
      LOOP UNTIL end$ = "y"
RETURN
' ******************add.lengths.angles*******************
add.lengths.angles:
```

```
do.another:
        CLS
        PRINT "To quit, type in <q> when asked a question"
        INPUT "Make a(nother) change <n, y or q Enter is y>"; answer$
        IF answer$ = "q" OR answer$ = "n" THEN GOTO skip13:

try.a.different.one:
        INPUT "Number of intersection"; i
        IF i > nn THEN
                PRINT "there are only "; nn; " intersections "; ""
                GOTO try.a.different.one
        END IF
        PRINT "intersection"; i, name$(i)
        INPUT "Is this the one you wanted <n or y; Enter is y>"; answer$
        IF answer$ = "n" THEN GOTO try.a.different.one:
        GOSUB lengths.and.angles:
        GOSUB save:
        GOTO do.another:
skip13:
RETURN

' **************************examine.data*************************

examine.data:
        CLS
        PRINT "As you read the data sets, push <q> to quit or any other key"
        PRINT "to read the next data set."
        PRINT
        PRINT "Push any key to continue"

        DO WHILE INKEY$ = "": LOOP

        FOR i = 0 TO nn
                '  m = 0
                ' this section strips the prefix
                ' m = INSTR(Name$(i), "NE ")
                ' IF m = 0 THEN m = INSTR(Name$(i), "NW ")
                ' IF m = 0 THEN m = INSTR(Name$(i), "SW ")
                ' IF m = 0 THEN m = INSTR(Name$(i), "SE ")
                ' IF m <> 0 THEN MID$(Name$(i), m, 3) = "   "
                CLS
                PRINT "push <q> to quit"
                FOR kk = 1 TO 4
                        GOSUB print.intersection:
                        GOSUB print.data
                        INPUT "push enter"; tp0
                NEXT
                CLS
                PRINT "push a key <or q to quit>"
                tp$ = ""
```

```
            DO WHILE tp$ = ""
            tp$ = INKEY$
            IF tp$ = "q" THEN GOTO skip15:
            LOOP
        NEXT
skip15:
RETURN
' ******************print.the.data.to.a.file******************************************
print.the.data.to.a.file:
        fileout$ = filename$
        m = INSTR(fileout$, ".")
        IF m <> 0 THEN fileout$ = LEFT$(fileout$, m - 1)
        fileout$ = fileout$ + ".doc"
        OPEN fileout$ FOR OUTPUT AS #3
        PRINT #3, TITLE$
            xst$ = "It is "
            xst1$ = "hours on "
        PRINT #3, xst$, TIME$, xst1$, DATE$
            xstb$ = "Intersection number = "
            xst$ = "Corner "
            xst1$ = "Atheta; Orientation of street a: "
            xst2$ = "x-offset = "
            xst3$ = "y-offset = "
            xst4$ = "year   : "
            xst5$ = "length a       :"
            xst6$ = "length b       :"
            xst7$ = "Angle Btheta: "
            xst8$ = "Monument type: "
            xstc$ = "Location "
            xst1c$ = "x-coord (feet) = "
            xstd$ = "y-coord (feet) = "
            comma$ = ","
jmax = 2                ' number of years
FOR i = 1 TO nn
        PRINT #3, : PRINT #3,
        PRINT #3, xstb$, i
        PRINT #3, xstc$, name$(i)
            PRINT #3, xst8$, Monumenttype$(i)
            PRINT #3, xst1c$, x(i), comma$, xstd$, y(i)
        FOR kk = 1 TO 4
            IF (a(1, kk, i) = 0 OR B(1, kk, i) = 0 OR Btheta(1, 1, kk, i) = 0) THEN GOTO jump99:

            PRINT #3,
            PRINT #3, xst$, Quad$(kk)
            PRINT #3, xst2$, xoffset(kk, i), comma$, xst3$, yoffset(kk, i)
            PRINT #3, xst1$, Alpha(kk, i)
            PRINT #3, xst4$, comma$; : FOR j = 1 TO jmax: PRINT #3, year$(j);
                IF j < jmax THEN PRINT #3, comma$;
            NEXT
            PRINT #3,
```

```
            PRINT #3, xst5$, comma$; : FOR j = 1 TO jmax: PRINT #3, a(j, kk, i);
                IF j < jmax THEN PRINT #3, comma$;
            NEXT
            PRINT #3,
            PRINT #3, xst6$, comma$; : FOR j = 1 TO jmax: PRINT #3, B(j, kk, i);
                IF j < jmax THEN PRINT #3, comma$;
            NEXT
            PRINT #3,
            PRINT #3, xst7$, comma$;
            FOR K = 1 TO 3
                FOR j = 1 TO jmax: PRINT #3, Btheta(j, K, kk, i);
                    IF j < jmax THEN PRINT #3, comma$;
                NEXT
                PRINT #3,
                IF K < 3 THEN PRINT #3, comma$;
            NEXT
jump99:
        NEXT
NEXT
CLOSE #3
RETURN
REM *********************firstpart************************
first.part:
  PRINT "——————————————————————————"
  PRINT " Analysis of Changes of Street Length and Angle Between Streets"
  PRINT "in one–quarter of an intersection. NERDSMOO, VERSION 1.6 (1996)"
  PRINT " extension Analysis, version 1.5, based on an excel program."
  PRINT " Written in 1995 by A.M. Johnson."
  PRINT "——————————————————————————"
  PRINT
  PRINT "It is "; TIME$; " hours  on "; DATE$
  PRINT
  INPUT "Enter descriptive title of run  –> "; TITLE$
  CLS
  PRINT "A *.dat file is a file produced by this program. It contains information about"
  PRINT "intersections, lengths & angles. An existing *.dat file can be manipulated by this program."
  PRINT "A *.pro file is a processed *.dat file that contains extension information."
  PRINT "This program can manipulate an existing *.pro file."
  PRINT "A *.dxf file is a processed *.pro file. It is an AUTOCAD file that DESIGNER can read"
' It can, that is, if you have changed the   mgx.ini   file to include the two lines:

' [Translation]
' EnableAltTrans=1

        PRINT "The *.dxf file contains details of shmoos and nerds and the streets."
        PRINT "Note that information on streets is entered via data statements at end of program."
        PRINT : PRINT
RETURN

' ************************lprint.the.data************************
```

```
lprint.the.data:
IF print$ <> "y" THEN RETURN
FOR i = 0 TO nn
CLS
        LPRINT : LPRINT "Intersection number= "; i, "Location "; name$(i)
                LPRINT "x-coord "; x(i), "y-coord "; y(i)
        FOR kk = 1 TO 4
                LPRINT : LPRINT Quad$(kk); " corner"
                LPRINT "x-offset "; xoffset(kk, i), "y-offset "; yoffset(kk, i)
                LPRINT "Atheta; Orientation of street a:"; Alpha(kk, i)
                LPRINT "year            :"
                LPRINT "                                 "; year$(1); "     "; year$(2); "          "; year$(3); "
"; year$(4)
                LPRINT "length a      :"; : LPRINT USING format1$; a(1, kk, i); a(2, kk, i); a(3, kk, i);
a(4, kk, i)
                LPRINT "length b      :"; : LPRINT USING format1$; B(1, kk, i); B(2, kk, i); B(3, kk, i);
B(4, kk, i)

                LPRINT "Angle Btheta:";
                LPRINT USING format2$; Btheta(1,1,kk,i); Btheta(2,1,kk,i); \
                                Btheta(3,1,kk,i); Btheta(4,1,kk,i)
                LPRINT "                          ";
                LPRINT USING format2$; Btheta(1,2,kk,i); Btheta(2,2,kk,i); \
                                Btheta(3,2,kk,i); Btheta(4,2,kk,i)
                LPRINT "                          ";
                LPRINT USING format2$; Btheta(1,3,kk,i); Btheta(2,3,kk,i); \
                                Btheta(3,3,kk,i); Btheta(4,3,kk,i)
        NEXT
NEXT
LPRINT CHR$(27) + CHR$(69)
RETURN
' **************fix.another.intersection*****************
fix.another.intersection:
        CLS
        PRINT "To quit, type in <q> when asked a question"
        INPUT "Make a(nother) change <n, y or q Enter is y>"; answer$
        IF answer$ = "q" OR answer$ = "n" THEN RETURN
which.intersection:
        INPUT "Number of intersection"; i
        IF i > nn THEN
                PRINT "there are only "; nn; " intersections "; ""
                GOTO which.intersection:
        END IF
        PRINT "intersection"; i, name$(i)
        INPUT "Is this the one you wanted <n or y; Enter is y>"; answer$
        IF answer$ = "n" THEN GOTO which.intersection:
        GOSUB correct.intersection:
        GOTO fix.another.intersection:
'***********************return is above**************
' **************add.some (intersection data)*******************
```

```
add.some:
        CLS
        i = nn
increment.id:
        PRINT "To quit, type in <q> when asked a question"
        INPUT "Want to add an intersection <n, y or q Enter is y>"; answer$
        IF answer$ = "q" OR answer$ = "n" THEN RETURN
        i = i + 1
        GOSUB enter.intersection:
        GOTO increment.id:
' *********return is above*******************

'——————————END————————————
 ' _—————————data on streets at Balboa—————

' the pair of numers 999,999 signifies end of polyline
DATA 0,0,–25.1,0,–25.1,6.2,–25.9,9.8,–25.9,29.9,–26.5,33.9,–26.5,38.5,999,999
DATA –11,8.4,–11,24.9,999,999
DATA 60,65,51,65,51,42,60,42,999,999
DATA 59,41,51,41,51,40
' the pair of numers 9999,9999 defines the end of the data set
DATA 9999,9999

' —————————END——————————
```

DIFFLENG.BAS

```
REM  Saved as <DIFFLENG.bas>
        ' This version of progeram is customized for Winnetka area.
        ' July 1996
        CLS
        nMax = 200: PRINT
        ' set nMax to 100 to run conversion subroutine.

        'x and y are coordinates of intersection,AA,a are lengths in x–direction
        ' BB, b are lengths in other street direction, xoffset and yoffset determine
        ' where shmoo is to be plotted. Atheta(i) is orientation of a relative to east
        ' counterclockwise angles positive.
        ' Four sets of data, 1, 2 3,4  for three times.
        DIM x(nMax), y(nMax), name$(nMax)
        DIM E1(nMax), ang(nMax)
        DIM c(nMax), d(nMax)

        ' the following are needed only for option 1
        ' DIM Monumenttype$(nMax), Btheta(4, 4, 4, nMax), a(4, 4, nMax), b(4, 4, nMax)
        ' DIM xoffset(4, nMax), yoffset(4, nMax), Alpha(4, nMax)

        CLS
        Quad$(1) = "NE": Quad$(2) = "NW": Quad$(3) = "SW": Quad$(4) = "SE"
        pi = 4 * ATN(1)
        co = pi / 180
        format1$ = "#####.##"
```

```
        format2$ = "########"
        GOSUB first.part:
n = 0
PRINT "To proceed, you need to select an option:"
        PRINT "If there is no file, do <1>. Else, do another option"
        PRINT
        PRINT
options:
        PRINT "Type <1> to CONVERT data on intersections to data on street segments."
        PRINT "Type <2> to ADD data to a .len file."
        PRINT "Type <3> to CHANGE some data in .len file."
        PRINT "Type <4> to READ a *.len file, PROCESS the data"
        PRINT " and CREATE a *.dxf file for an autocad map."
        PRINT "Type <5> to SCREEN some data in .len file. Then make autocad map."

INPUT "Which is it, <1 OR 2 OR 3 OR 4> –>"; ans
        IF ans > 5 OR ans < 1 THEN GOTO options:



'***********************START THE OPTIONS*********************
' *******
IF ans <> 1 THEN GOTO skip1:
        IF nMax = 200 THEN
                PRINT "You need to change nMax to 100 and restart program."
                PRINT "Be sure last two Dim statements are executed."
                STOP
        END IF
' Read a *.dat file and MAKE a *.len file.
        GOSUB name.of.file:
        ' read a *.dat file
        GOSUB file:
        ' change name and save a *.len file
        GOSUB convert.file:
        STOP
skip1:
        IF nMax = 100 THEN
                PRINT "You need to change nMax to 200 and restart program."
                PRINT "Be sure last two dimension statements are commented out."
                STOP
        END IF
'**********
IF ans <> 2 THEN GOTO skip2:
'         ADD some data to .len file.
        GOSUB name.of.file:
        GOSUB xfile:
        ' this brings up data on name$, nn, x(ii), y(ii), c(ii),d(ii), ang(ii)
        GOSUB add.len.data:
skip2:
'********
```

```
IF ans <> 3 THEN GOTO skip3:
'         CHANGE some data in .len file
        GOSUB name.of.file:
        GOSUB xfile:
        GOSUB change.results:
        GOSUB save.len.data:
skip3:
'*******
IF ans <> 4 THEN GOTO skip4:
'         READ a *.len file, PROCESS the data
'         and CREATE a *.dxf file for an autocad map.
        CLS
        GOSUB name.of.file:
        GOSUB xfile:
        INPUT "Have you checked for duplicates <no=n;yes=y or Return>"; ans$
        IF ans$ = "n" THEN
                GOSUB check.for.duplicates:
                GOSUB xfile:
        END IF
        GOSUB make.autocad.file:
skip4:
IF ans <> 5 THEN GOTO skip5:
'         SCREEN some data to .len file. This routine is to be customized.
        GOSUB name.of.file:
        GOSUB xfile:
        ' this brings up data on name$, nn, x(ii), y(ii), E1(ii), ang(ii),E1(ii)
        GOSUB Screen.file:
        GOSUB chgname.of.file:
        GOSUB save.len.data:
        GOSUB xfile:
        GOSUB make.autocad.file:
skip5:

' *****Send a carriage return and end program.
LPRINT CHR$(27) + CHR$(69)        ' this ejects paper.
END
' **********************END OF MAIN PROGRAM**************************
' ******************************************************************
'**********************BEGIN SUBROUTINES***************************
' ******************************************************************
' ****************check.for.duplicates******************************
check.for.duplicates:
dup$ = "no"
FOR i = 0 TO nn
        CLS
        PRINT "I = "; i; E1(i)
        PRINT "Checking for duplicates"
        FOR j = i + 1 TO nn
                PRINT "j= "; j;
                IF E1(j) * E1(i) = 0 THEN GOTO skip.check:
```

```
            ratio = ABS(E1(j) / E1(i)) * 1000
            IF ratio > 999 AND ratio < 1001 THEN
                CLS
                PRINT "Checking for duplicates"
                PRINT "Points"; i; " and"; j; " have about the same strain magnitude"
                PRINT
                PRINT "Point"; i; " The strain is"; E1(i)
                PRINT "Point"; j; " The strain is"; E1(j)
                PRINT "Point"; i; "The street orientation is"; ang(i)
                PRINT "Point"; j; "The street orientation is"; ang(j)
                PRINT "Point"; i; "The x-position is"; x(i)
                PRINT "Point"; j; "The x-position is"; x(j)
                PRINT "Point"; i; "The y-position is"; y(i)
                PRINT "Point"; j; "The y-position is"; y(j)
                PRINT
                PRINT "If the strains are duplicates, answer <d>. Otherwise <Enter>."
                INPUT "Delete the duplicate strain value <d deletes Enter keeps>"; ans$
                IF ans$ = "d" THEN
                    INPUT "Are you sure <n or Enter>"; ans$
                    IF ans$ <> "n" THEN
                        E1(i) = 0
                        x(i) = 9999
                        y(i) = 9999
                        dup$ = "yes"
                    END IF
                END IF
            END IF
skip.check:
        NEXT
NEXT

INPUT "push <Enter> key to continue."; ans$
        IF dup$ = "yes" THEN
            CLS
            PRINT "Duplicates found, so file being re-saved"
            GOSUB name.of.file:
            GOSUB save.len.data:
        END IF
RETURN

' ****************Custom Modification of *.len data**********************
Screen.file:
CLS
' The following lines need to be customized.
PRINT "Elimination of Data"
INPUT "Eliminate data with x-values less than minX"; minX
INPUT "Also, eliminate data with y-values less than minY"; minY
j = -1
PRINT "nn is now="; nn; "push <Enter> to go"
INPUT ans$
```

```
FOR i = 0 TO nn
PRINT "I = "; i;
        IF x(i) > minX AND y(i) > minY THEN
          PRINT "Saving data"
          PRINT
          j = j + 1
          PRINT "j is"; j; "The position is x,y"; x(i), y(i);
          x(j) = x(i)
          y(j) = y(i)
          c(j) = c(i)
          d(j) = d(i)
          ang(j) = ang(i)
          E1(j) = E1(i)
          nm = j
        END IF
NEXT
nn = nm
PRINT "nn is now="; nn; "push <Enter> to go"
INPUT ans$
RETURN
' *************convert .dat to .len data*****************************
' Make a *.len file from a *.dat file.
convert.file:
        sf = 8.5 / 3240 ' (feet per cm)
        PRINT
        GOSUB chgname.of.file:
        fileout$ = filename$
        m = INSTR(fileout$, ".")
        IF m <> 0 THEN fileout$ = LEFT$(fileout$, m – 1)
        fileout$ = fileout$ + ".len"
        CLS
        OPEN fileout$ FOR OUTPUT AS #2
        WRITE #2, Title$
        FOR i = 0 TO nn
          '  i is number of street intersection

                        acount = 0
                        bcount = 0
                        '1st quadrant
                        IF a(1, 1, i) * a(2, 1, i) <> 0 THEN
                                acount = 1
                                angle = 0
                                xxx = x(i) + sf * a(1, 1, i) / 2
                                yyy = y(i)
                                ext = (a(2, 1, i) – a(1, 1, i)) / a(1, 1, i)
                                WRITE #2, xxx, yyy, a(1, 1, i), a(2, 1, i), angle, ext
                        END IF
                        IF b(1, 1, i) * b(2, 1, i) <> 0 THEN
                                bcount = 1
                                angle = 90
                                xxx = x(i)
```

```
        yyy = y(i) + sf * b(1, 1, i) / 2
        ext = (b(2, 1, i) – b(1, 1, i)) / b(1, 1, i)
        WRITE #2, xxx, yyy, b(1, 1, i), b(2, 1, i), angle, ext
END IF
' 2nd quadrant
IF a(1, 2, i) * a(2, 2, i) <> 0 THEN
        IF acount = 1 THEN
                acount = 3
        ELSE
                acount = 2
        END IF
        angle = 180
        xxx = x(i) – sf * a(1, 2, i) / 2
        yyy = y(i)
        ext = (a(2, 2, i) – a(1, 2, i)) / a(1, 2, i)
        WRITE #2, xxx, yyy, a(1, 2, i), a(2, 2, i), angle, ext
END IF
IF b(1, 2, i) * b(2, 2, i) <> 0 AND bcount <> 1 THEN
        bcount = 1
        angle = 90
        xxx = x(i)
        yyy = y(i) + sf * b(1, 2, i) / 2
        ext = (b(2, 2, i) – b(1, 2, i)) / b(1, 2, i)
        WRITE #2, xxx, yyy, b(1, 2, i), b(2, 2, i), angle, ext
END IF
' 3rd corner
IF a(1, 3, i) * a(2, 3, i) <> 0 AND acount < 2 THEN
        IF acount = 1 THEN
                acount = 3
        ELSE
                acount = 2
        END IF
        angle = 180
        xxx = x(i) – sf * a(1, 3, i) / 2
        yyy = y(i)
        ext = (a(2, 3, i) – a(1, 3, i)) / a(1, 3, i)
        WRITE #2, xxx, yyy, a(1, 3, i), a(2, 3, i), angle, ext
END IF
IF b(1, 3, i) * b(2, 3, i) <> 0 THEN
        bcount = 2
        angle = 270
        xxx = x(i)
        yyy = y(i) – sf * b(1, 3, i) / 2
        ext = (b(2, 3, i) – b(1, 3, i)) / b(1, 3, i)
        WRITE #2, xxx, yyy, b(1, 3, i), b(2, 3, i), angle, ext
END IF
' 4th corner
        IF a(1, 4, i) * a(2, 4, i) <> 0 AND acount = 2 THEN
        angle = 0
        xxx = x(i) + sf * a(1, 4, i) / 2
        yyy = y(i)
```

```
                        ext = (a(2, 4, i) – a(1, 4, i)) / a(1, 4, i)
                        WRITE #2, xxx, yyy, a(1, 4, i), a(2, 4, i), angle, ext
                END IF
                        IF b(1, 4, i) * b(2, 4, i) <> 0 AND bcount <> 2 THEN
                        angle = 270
                        xxx = x(i)
                        yyy = y(i) – sf * b(1, 4, i) / 2
                        ext = (b(2, 4, i) – b(1, 4, i)) / b(1, 4, i)
                        WRITE #2, xxx, yyy, b(1, 4, i), b(2, 4, i), angle, ext
                END IF
        NEXT
        CLOSE #2
RETURN

' *************add len data**************
' Add data to a *.len file

add.len.data:
        street$ = "a"
        sf = 8.5 / 3240 ' (feet per cm)
        PRINT
        fileout$ = filename$
        m = INSTR(fileout$, ".")
        IF m <> 0 THEN fileout$ = LEFT$(fileout$, m – 1)
        fileout$ = fileout$ + ".len"
        CLS
        OPEN fileout$ FOR OUTPUT AS #2
        WRITE #2, Title$
        FOR i = 0 TO nn
             WRITE #2, x(i), y(i), c(i), d(i), ang(i), E1(i)
        NEXT
        i = nn
INPUT "add data <a> or extend data to other areas <e>"; answ$
         ' get another data set
IF answ$ = "e" THEN GOTO extend.data:
next.data.set:
          PRINT "Last entry was"; "i="; i, x(i), y(i), c(i), d(i), ang(i)
          INPUT "Is this correct.<n or y; Enter is y>. If not, delete the datum."; ans$
          IF ans$ = "n" THEN
        i = i – 1
        GOTO next.data.set:
          END IF
          i = i + 1
which.street:
          INPUT "a or b street <to stop, enter q"; street$
          IF street$ <> "a" AND street$ <> "b" AND street$ <> "q" THEN
               CLS
               PRINT : PRINT
               PRINT "LET'S GET SERIOUS!"
               GOTO which.street:
          END IF
```

```
        IF street$ = "q" THEN GOTO end.of.additional.data:
        ang(i) = 0
        IF street$ = "b" THEN ang(i) = 90
        INPUT "x–positon of street (cm)"; x(i)
        INPUT "y–positon of street (cm)"; y(i)
        INPUT "initial length of street(feet)"; c(i)
        INPUT "final length of street(feet)"; d(i)
      ' look over the data
        CLS
        PRINT "The type of street is"; street$
        PRINT "The x– and y–positions are"; x(i), y(i)
        PRINT "The lengths are"; c(i), d(i)
        INPUT "Are these o.k.<n or y, Enter is yes ==>>"; ans$
        IF ans$ = "n" THEN
      i = i – 1
      GOTO next.data.set:
        END IF
        E1(i) = (d(i) – c(i)) / c(i)
        WRITE #2, x(i), y(i), c(i), d(i), ang(i), E1(i)
        GOTO next.data.set:
end.of.additional.data:
GOTO end.of.extended.data:
extend.data:
        PRINT "Last entry was"; "i="; i, x(i), y(i), c(i), d(i), ang(i)
        INPUT "Is this correct.<n or y; Enter is y>. If not, delete the datum."; ans$
        IF ans$ = "n" THEN
              i = i – 1
              GOTO extend.data:
        END IF
        i = i + 1
you.must.be.kidding:
        PRINT "Is street type "; street$
        INPUT ans$
        IF ans$ = "n" THEN
              INPUT "a or b street <to stop, enter q"; street$
              IF street$ <> "a" AND street$ <> "b" AND street$ <> "q" THEN
                      CLS
                      PRINT : PRINT
                      PRINT "YOU MUST BE KIDDING!"
                      PRINT : PRINT
                      GOTO you.must.be.kidding:
              END IF
              IF street$ = "q" THEN GOTO end.of.extended.data:
        END IF
        ang(i) = 0
        IF street$ = "b" THEN ang(i) = 90
        INPUT "x–positon of street (cm)"; x(i)
        INPUT "y–positon of street (cm)"; y(i)
        INPUT "initial length of street(cm)"; lenor
        c(i) = lenor / sf
        INPUT "change in length street(feet)"; deltalen
```

```
          d(i) = c(i) + deltalen
          CLS

          PRINT "The type of street is"; street$
          PRINT "The x– and y–positions are"; x(i), y(i)
          PRINT "The lengths are"; c(i), d(i)
          INPUT "Are these o.k.<n or y, Enter is yes ==>>"; ans$
          IF ans$ = "n" THEN
        i = i – 1
        GOTO extend.data:
          END IF
          E1(i) = sf * deltalen / lenor
          WRITE #2, x(i), y(i), c(i), d(i), ang(i), E1(i)
          GOTO extend.data:
end.of.extended.data:
        CLOSE #2
RETURN

'********************enter name of files**************************
name.of.file:

        PRINT "Enter only first part of name. <.dat> or <.len> will be added automatically"
        PRINT "Name must be 7 or fewer letters and numbers"
        CLS
        INPUT "Data are in file with name"; filename$

RETURN
'********************change name of files**************************
chgname.of.file:
        CLS
        PRINT : PRINT
        PRINT "Full set of data is under name  +===>"; filename$
        PRINT : PRINT
        PRINT "You must change name of file. Otherwise you will destroy your original data."
        PRINT "Enter only first part of name. <.len> will be added automatically"
        PRINT "New name must be 7 or fewer letters and numbers"
        PRINT : PRINT
        INPUT "Data are to be in file with name"; filenm$
        IF filenm$ = filename$ OR filenm$ = "" THEN
        IF try > 3 THEN
                PRINT "You need help!!! RUN IS BEING ABORTED"
                PRINT "Push <Enter or any key> to STOP <Ctrl C will abort>"
                INPUT ans$
                STOP
        END IF
        PRINT "No, you cannot use the same name! Push <Enter> to continue."
        INPUT ans$
        try = try + 1
        GOTO chgname.of.file:
        END IF
```

```
        filename$ = filenm$
        try = 0
RETURN

REM ***********************change.results**************************
change.results:
         FOR i = 0 TO nn
         CLS
         PRINT : PRINT i; "Intersection of "; name$(i)
         PRINT "x- and y-positions of the intersection are"; x(i), y(i)
         PRINT "The street lengths are -before"; c(i); " after="; d(i)
         PRINT "the direction of the street is"; ang(i)
         INPUT "Are these all o.k. <y or n Yes is Enter>"; ans$
         IF ans$ <> "n" THEN GOTO next.one:
         CLS
         PRINT "x- and y-positions of the intersection are"; x(i), y(i)
         INPUT "Are these positions correct <y or n Yes is Enter>"; answer$
         IF answer$ = "n" THEN
        INPUT "x-position ofintersection is(cm)"; x(i)
        INPUT "y-position ofintersection is(cm)"; y(i)
         END IF
        CLS
        PRINT : PRINT "the direction of the street is"; ang(i)
        INPUT "Is this correct <y or n yes is Enter>"; answer$
         IF answer$ = "n" THEN
        INPUT "The angle is (0 or 90)"; ang(i)
         END IF
         CLS
        PRINT : PRINT "The lengths of the street segment are"; c(i), d(i)
        INPUT "Is this correct <y or n yest is Enter>"; answer$
         IF answer$ = "n" THEN
        INPUT "The original length was (ft)"; c(i)
        INPUT "The final length was(ft)"; d(i)
         END IF
next.one:
NEXT
RETURN
' ****************save the *.len data to a file******************
save.len.data:
        fileout$ = filename$
        m = INSTR(fileout$, ".")
        IF m <> 0 THEN fileout$ = LEFT$(fileout$, m - 1)
        fileout$ = fileout$ + ".len"
        ' Warning***######****zero strain data are removed***********

        CLS
        PRINT "Now we are saving the data"
        PRINT "Name of file is"; fileout$
        PRINT "Number of data is"; nn; "to continue, push <Enter>"
        INPUT ans$
```

```
        OPEN fileout$ FOR OUTPUT AS #2
        WRITE #2, name$
        FOR i = 0 TO nn
                IF (x(i) + y(i) = 2 * 9999) THEN GOTO jump.save:
                E1(i) = (d(i) – c(i)) / c(i)
                WRITE #2, x(i), y(i), c(i), d(i), ang(i), E1(i)
jump.save:
        NEXT
CLOSE #2
RETURN

' ****************** Open the data *.dat file*************************.
file:
        filein$ = filename$
        m = INSTR(filein$, ".")
        IF m <> 0 THEN filein$ = LEFT$(filein$, m – 1)
        filein$ = filein$ + ".dat"
        CLS
        OPEN filein$ FOR INPUT AS #2
        FOR j = 1 TO 4                  ' j is no of year
                INPUT #2, year$(j)
        NEXT
ii = 0
DO UNTIL EOF(2)
         ' ii is number of street intersection
                INPUT #2, name$(ii), x(ii), y(ii)
                INPUT #2, Monumenttype$(ii)
                FOR kk = 1 TO 4
                        INPUT #2, xoffset(kk, ii), yoffset(kk, ii), Alpha(kk, ii)
                        ' j is the year
                        FOR j = 1 TO 4
                                INPUT #2, a(j, kk, ii), b(j, kk, ii)
                                FOR k = 1 TO 3   ' k is degr, min or sec
                                        INPUT #2, Btheta(j, k, kk, ii)
                                NEXT
                        NEXT
                NEXT
ii = ii + 1
LOOP
CLOSE #2
nn = ii – 1
RETURN

' ******************Open the data *.len file****************************
' this routine loads a *.len file.
xfile:
        filein$ = filename$
        m = INSTR(filein$, ".")
        IF m <> 0 THEN filein$ = LEFT$(filein$, m – 1)
        filein$ = filein$ + ".len"
```

```
        OPEN filein$ FOR INPUT AS #2
ii = 0
INPUT #2, name$
DO UNTIL EOF(2)
         ' ii is number of street intersection
                 INPUT #2, x(ii), y(ii), c(ii), d(ii), ang(ii), E1(ii)
ii = ii + 1
LOOP
CLOSE #2
nn = ii – 1
        CLS
        PRINT "File name is "; filein$
        PRINT "File name is also "; filename$
        PRINT "Number of data read in is"; nn; "push <Enter> to continue."
        INPUT ans$

RETURN

REM *************************make.autocad.file*******************

make.autocad.file:
        CLS
        PRINT "Making autocad file"
        PRINT "The data set is"; filename$
        PRINT "The numer of data is"; nn; " push <Enter> to continue"
        PRINT : PRINT : PRINT : PRINT :
        PRINT "Please be patient. This takes a little time."
        PRINT "I will ask you to push a key when I am finished."

        PRINT : PRINT : PRINT : PRINT :
        PRINT "Thank you, oh patient master!"

        section$ = "SECTION"
        polyline$ = "POLYLINE"
        entities$ = "ENTITIES"
        vertex$ = "VERTEX"
        seqend$ = "SEQEND"
        endsec$ = "ENDSEC"
        eof$ = "EOF"
        fileout$ = filename$
        m = INSTR(fileout$, ".")
        IF m <> 0 THEN fileout$ = LEFT$(fileout$, m – 1)
        filout1$ = fileout$ + "1.dxf"
        filout2$ = fileout$ + "2.dxf"
        filout3$ = fileout$ + "3.dxf"
        nMin = 4.9
        blank$ = CHR$(0)
OPEN filout1$ FOR OUTPUT AS #3
        PRINT #3, 0
        PRINT #3, section$
```

```
        PRINT #3, 2
        PRINT #3, entities$
        PRINT #3, 0
OPEN filout2$ FOR OUTPUT AS #4
        PRINT #4, 0
        PRINT #4, section$
        PRINT #4, 2
        PRINT #4, entities$
        PRINT #4, 0
scale.strain.figures:
        CLS
        PRINT "You need to scale the figures"
        PRINT "What is the largest magnitude of strain you expect?"
        INPUT "What is exponent, n, in 10^–n"; nX
        IF n < 0 THEN
                PRINT "You jest, presumably. Try again or change program."
                GOTO scale.strain.figures:
        END IF
        PRINT "Now you need to know how big you want the largest strain figures to be."
        PRINT "The data are plotted in centimeters as now set up."
        PRINT "How large (cm) do you want the radius of the largest strain figure to be?"
        PRINT "If in doubt, select 1 cm. You can experiment."
        PRINT "Note that each reference strain figure will be 1/sqr(10) that of"
        PRINT "the next larger one. That is, if 10^–1 is the largest and is one"
        PRINT "cm, then 10^–2 will be about 1/3 cm and 10^–3 will be 1/9 cm etc."
        PRINT : PRINT :
        INPUT "Radius of largest strain figure (cm)"; r

        G = pi * (r ^ 2) / (10 ^ –nX)

        PRINT "G is"; G
        PRINT "The largest strain figure, for a strain of +,– 10^–"; nX; " is"; r; " cm"
        r1 = SQR(G * (10 ^ –(nX + 1)) / pi)
        r2 = SQR(G * (10 ^ –(nX + 2)) / pi)
        PRINT "This implies that the radius for a strain figure of 10^–"; nX + 1; " is"; r1; " cm"
        PRINT "and that the radius for a strain figure of 10^–"; nX + 2; " is"; r2; " cm"
        PRINT "If you wish to revise, answer <n>.    <y or Return> is yes"
        INPUT "Are these values satisfactory"; ans$
        IF ans$ = "n" THEN GOTO scale.strain.figures:
          co = pi / 180
          FOR i = 0 TO nn
                IF i = 0 THEN PRINT "Determining arrow figures. i="; i
                trans = 0
                angle = ang(i) * co
                refstr = ABS(E1(i))
                IF refstr < (10 ^ (–nMin)) THEN
                        ' if strain is too small, draw circle with diag. line.
                        radius = .5 * SQR(G * (10 ^ –nX) / pi)
                        x0 = 0
                        y0 = 0
```

```
        PRINT "Strain is too small to plot for point"; i
        angle = 45 * co
ELSE
        radius = SQR((G * refstr) / pi)
        x0 = radius / 3
        y0 = radius / 9
        IF E1(i) < 0 THEN trans = –1
        ' define the arrow
END IF
cox = ABS(COS(angle))
sox = ABS(SIN(angle))
PRINT #3, polyline$
PRINT #3, 8
PRINT #3, 0
PRINT #3, 66
PRINT #3, 1
PRINT #3, 0
xx(1) = 0
yy(1) = 0
xx(2) = radius * cox
yy(2) = radius * sox
xx(3) = xx(2) – (x0 * cox + y0 * sox)
yy(3) = yy(2) + (y0 * cox – x0 * sox)
xx(4) = xx(2) – (x0 * cox – y0 * sox)
yy(4) = yy(2) – (y0 * cox + x0 * sox)
xx(5) = xx(2)
yy(5) = yy(2)
FOR j = 1 TO 5
        PRINT #3, vertex$
        PRINT #3, 8
        PRINT #3, 0
        PRINT #3, 10
        PRINT #3, xx(j) + x(i) + trans * radius * cox
        PRINT #3, 20
        PRINT #3, yy(j) + y(i) + trans * radius * sox
        PRINT #3, 0
NEXT
PRINT #3, seqend$
PRINT #3, 8
PRINT #3, 0
PRINT #3, 0

PRINT #3, polyline$
PRINT #3, 8
PRINT #3, 0
PRINT #3, 66
PRINT #3, 1
PRINT #3, 0

xx(2) = –radius * cox
```

```
            yy(2) = –radius * sox
            xx(3) = xx(2) + (x0 * cox + y0 * sox)
            yy(3) = yy(2) – (y0 * cox – x0 * sox)
            xx(4) = xx(2) + (x0 * cox – y0 * sox)
            yy(4) = yy(2) + (y0 * cox + x0 * sox)
            xx(5) = xx(2)
            yy(5) = yy(2)
            FOR j = 1 TO 5
                PRINT #3, vertex$
                PRINT #3, 8
                PRINT #3, 0
                PRINT #3, 10
                PRINT #3, xx(j) + x(i) – trans * radius * cox
                PRINT #3, 20
                PRINT #3, yy(j) + y(i) – trans * radius * sox
                PRINT #3, 0
            NEXT
            PRINT #3, seqend$
            PRINT #3, 8
            PRINT #3, 0
            PRINT #3, 0

            ' start a new image–plot the circle
            PRINT #4, polyline$
            PRINT #4, 8
            PRINT #4, 0
            PRINT #4, 66
            PRINT #4, 1
            PRINT #4, 0
            FOR thet = 0 TO 360 STEP 5
                th = thet * co
                xxc = x(i) + radius * COS(th)
                yyc = y(i) + radius * SIN(th)
                PRINT #4, vertex$
                PRINT #4, 8
                PRINT #4, 0
                PRINT #4, 10
                PRINT #4, xxc
                PRINT #4, 20
                PRINT #4, yyc
                PRINT #4, 0
            NEXT
            PRINT #4, seqend$
            PRINT #4, 8
            PRINT #4, 0
            PRINT #4, 0
jump51:
        NEXT

        PRINT "Determining scales for shmoos"
        ' The following routine provides data for scales of shmoos
```

```
        PRINT : PRINT : PRINT : PRINT :
        PRINT "Please be patient. This takes a little time."
        PRINT "I will ask you to push a key when I am finished."
        nLow = INT(nX – 1)
        nHigh = 5
        FOR ra = nLow TO nHigh STEP .5
                radius = SQR((G * 10 ^ (–ra)) / pi)
                xx = –5
                yy = 45 + 4 * ra
                ' start a new image
                PRINT #4, polyline$
                PRINT #4, 8
                PRINT #4, 0
                PRINT #4, 66
                PRINT #4, 1
                PRINT #4, 0
                FOR thet = 0 TO 360 STEP 5
                        th = thet * co
                        xxc = xx + radius * COS(th)
                        yyc = yy + radius * SIN(th)
                        PRINT #4, vertex$
                        PRINT #4, 8
                        PRINT #4, 0
                        PRINT #4, 10
                        PRINT #4, xxc
                        PRINT #4, 20
                        PRINT #4, yyc
                        PRINT #4, 0
                NEXT
                PRINT #4, seqend$
                PRINT #4, 8
                PRINT #4, 0
                PRINT #4, 0
        NEXT

        PRINT #4, seqend$
        PRINT #4, 8
        PRINT #4, 0
        PRINT #4, 0
        PRINT #4, endsec$
        PRINT #4, 0
        PRINT #4, eof$
        PRINT #4,
CLOSE #4
        PRINT #3, seqend$
        PRINT #3, 8
        PRINT #3, 0
        PRINT #3, 0
        PRINT #3, endsec$
        PRINT #3, 0
        PRINT #3, eof$
```

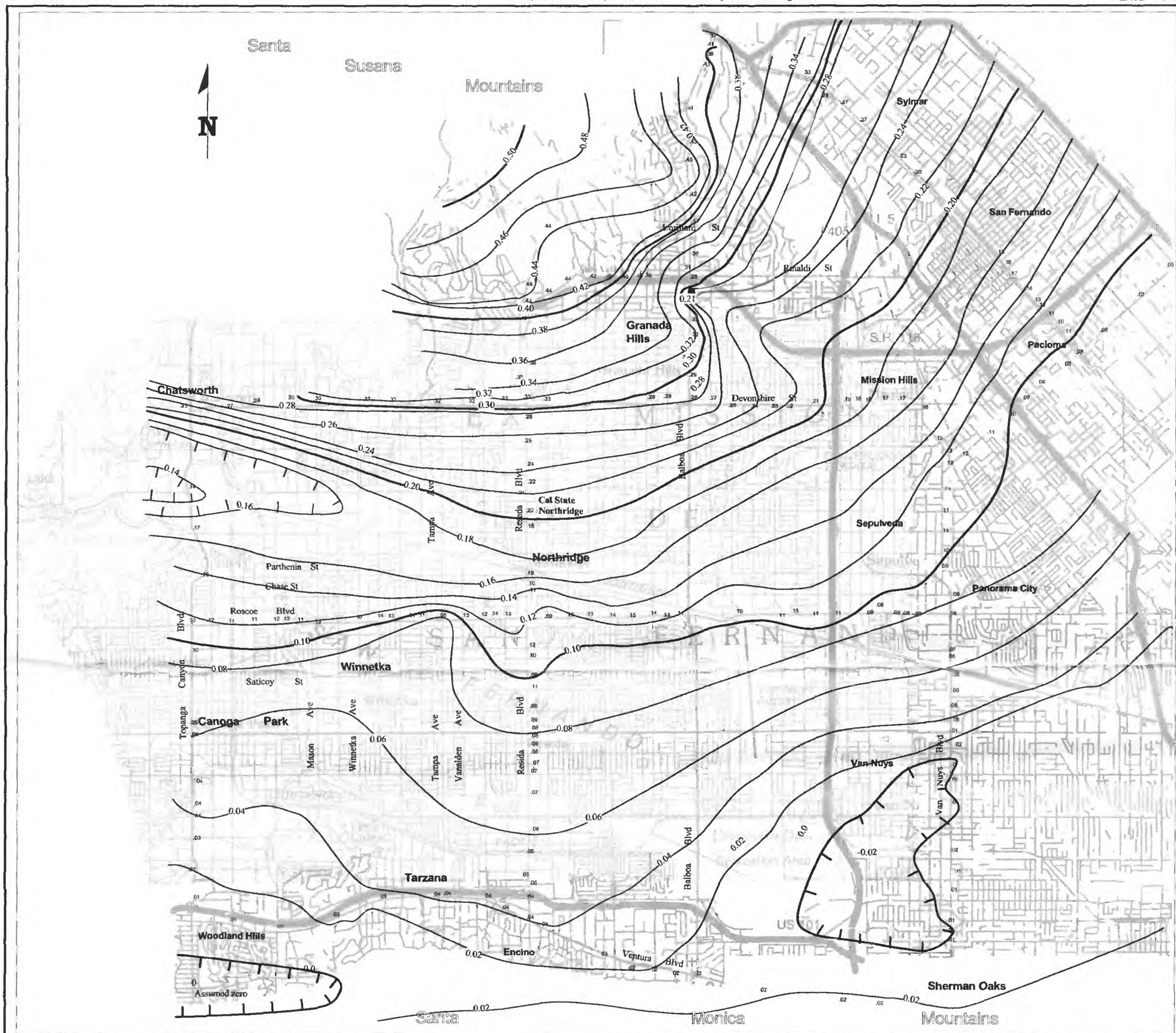
```
        PRINT #3,
CLOSE #3

                ' start lines for streets
OPEN filout3$ FOR OUTPUT AS #5
        PRINT #5, 0
        PRINT #5, section$
        PRINT #5, 2
        PRINT #5, entities$
        PRINT #5, 0
                CLS
read.next.line:
                PRINT #5, polyline$
                PRINT #5, 8
                PRINT #5, 0
                PRINT #5, 66
                PRINT #5, 1
                PRINT #5, 0
read.next.point:
                READ xxc, yyc
                IF xxc = 9999 THEN GOTO no.more.streets:
                IF xxc = 999 THEN GOTO end.of.line:
                        PRINT #5, vertex$
                        PRINT #5, 8
                        PRINT #5, 0
                        PRINT #5, 10
                        PRINT #5, xxc
                        PRINT #5, 20
                        PRINT #5, yyc
                        PRINT #5, 0
                        GOTO read.next.point:
end.of.line:
                PRINT #5, seqend$
                PRINT #5, 8
                PRINT #5, 0
                PRINT #5, 0
                GOTO read.next.line:
no.more.streets:
        PRINT #5, seqend$
        PRINT #5, 8
        PRINT #5, 0
        PRINT #5, 0
        PRINT #5, endsec$
        PRINT #5, 0
        PRINT #5, eof$
        PRINT #5,
CLOSE #5
RETURN

'******************************print.intersection**********************
print.intersection:
```

```
PRINT "Intersection number= "; i, "Location "; name$(i), "x= "; x(i), "y= "; y(i)
RETURN
' *********************print data**********************
print.data:
PRINT Quad$(kk); " corner(no."; kk; ")"; "xo= "; xoffset(kk, i), "yo= "; yoffset(kk, i); "  Alpha; Orientation
of street a:"; Alpha(kk, i)
PRINT "                              "; year$(1); "            "; year$(2); "            "; year$(3); "
"; year$(4)
PRINT "length a       :"; : PRINT USING format1$; a(1, kk, i); a(2, kk, i); a(3, kk, i); a(4, kk, i)
PRINT "length b       :"; : PRINT USING format1$; b(1, kk, i); b(2, kk, i); b(3, kk, i); b(4, kk, i)
PRINT "Angle Btheta:";
PRINT USING format2$; Btheta(1, 1, kk, i); Btheta(1, 2, kk, i); Btheta(1, 3, kk, i);
PRINT "_";
PRINT USING format2$; Btheta(2, 1, kk, i); Btheta(2, 2, kk, i); Btheta(2, 3, kk, i);
PRINT "_";
PRINT USING format2$; Btheta(3, 1, kk, i); Btheta(3, 2, kk, i); Btheta(3, 3, kk, i);
PRINT "_";
PRINT USING format2$; Btheta(4, 1, kk, i); Btheta(4, 2, kk, i); Btheta(4, 3, kk, i)
RETURN

REM *********************firstpart************************
first.part:
  PRINT "————————————————————————"
  PRINT " Analysis of Changes of Street Length and Angle Between Streets"
  PRINT "in one–quarter of an intersection. NERDSMOO, VERSION 1.6 (1996)"
  PRINT " extension Analysis, version 1.5, based on an excel program."
  PRINT " Written in 1995 by A.M. Johnson."
  PRINT "————————————————————————"
  PRINT
  PRINT "It is "; TIME$; " hours  on "; DATE$
  PRINT
  INPUT "Enter descriptive title of run  –> "; Title$
  CLS
  PRINT "A *.dat file is a file produced by this program. It contains information about"
  PRINT "intersections, lengths & angles. An existing *.dat file can be manipulated by this program."
  PRINT "A *.pro file is a processed *.dat file that contains extension information."
  PRINT "This program can manipulate an existing *.pro file."
  PRINT "A *.dxf file is a processed *.pro file. It is an AUTOCAD file that DESIGNER can read"
' It can, that is, if you have changed the   mgx.ini   file to include the two lines:

' [Translation]
' EnableAltTrans=1
      PRINT "The *.dxf file contains details of shmoos and nerds and the streets."
PRINT : PRINT
RETURN

'——————————END——————————
```

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the City of Los Angeles

OPEN-FILE REPORT 96-698
PLATE 1 of 3



Base from Topographic Map of Los Angeles, 1:100,000 Scale, U.S. Geological Survey, 1979.
Level Data from Engineer of Surveys, Survey Division, Bureau of Engineering, Department of Public Works, City of Los Angeles.

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0 1 2 3 MILES

0 1 2 3 KILOMETERS

Contour Interval of Differential Vertical Displacements = 0.02 meter

Arbitrary Datum of Zero Differential Displacement Selected in Woodland Hills, along Topanga Canyon Road

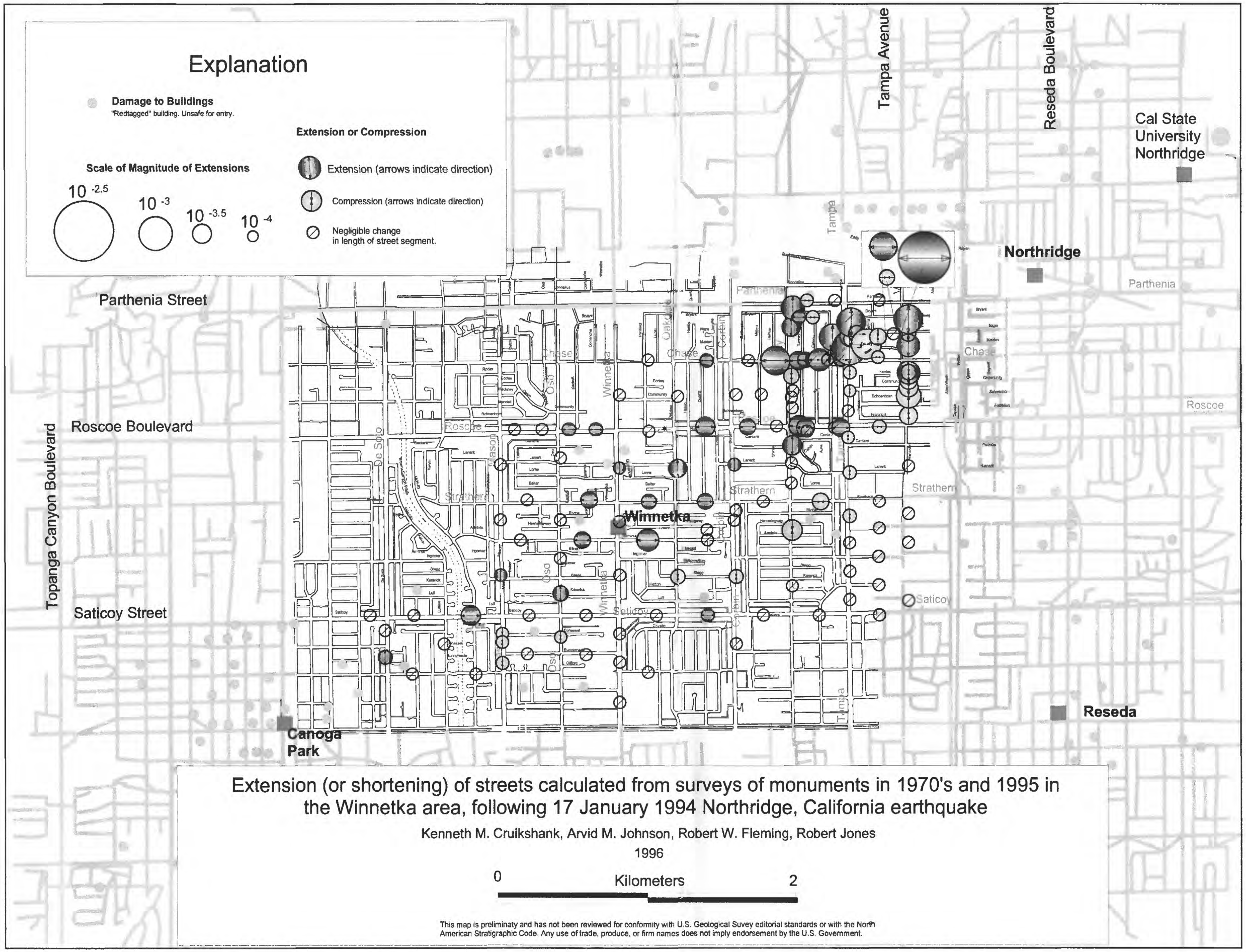
Differential Vertical Displacements Between 1980 and 1994 in San Fernando Valley, Los Angeles, California

By

Kenneth M. Cruikshank, Arvid M. Johnson, Robert W. Fleming and Robert Jones

Drafted by: Nils A. Johnson

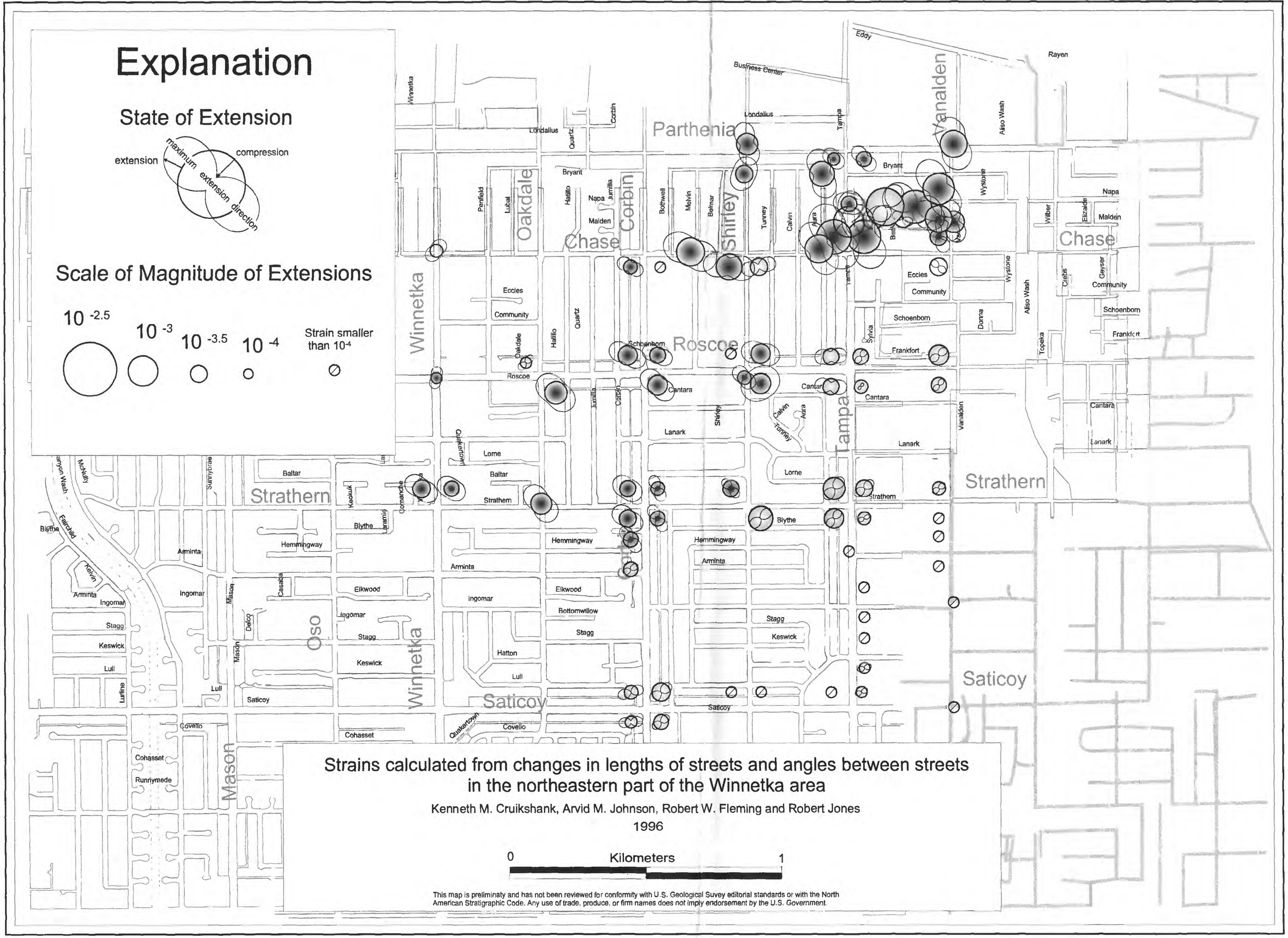
1996



Extension (or shortening) of streets calculated from surveys of monuments in 1970's and 1995 in the Winnetka area, following 17 January 1994 Northridge, California earthquake

Kenneth M. Cruikshank, Arvid M. Johnson, Robert W. Fleming, Robert Jones

1996



Strains calculated from changes in lengths of streets and angles between streets in the northeastern part of the Winnetka area

Kenneth M. Cruikshank, Arvid M. Johnson, Robert W. Fleming and Robert Jones

1996

0 Kilometers 1

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