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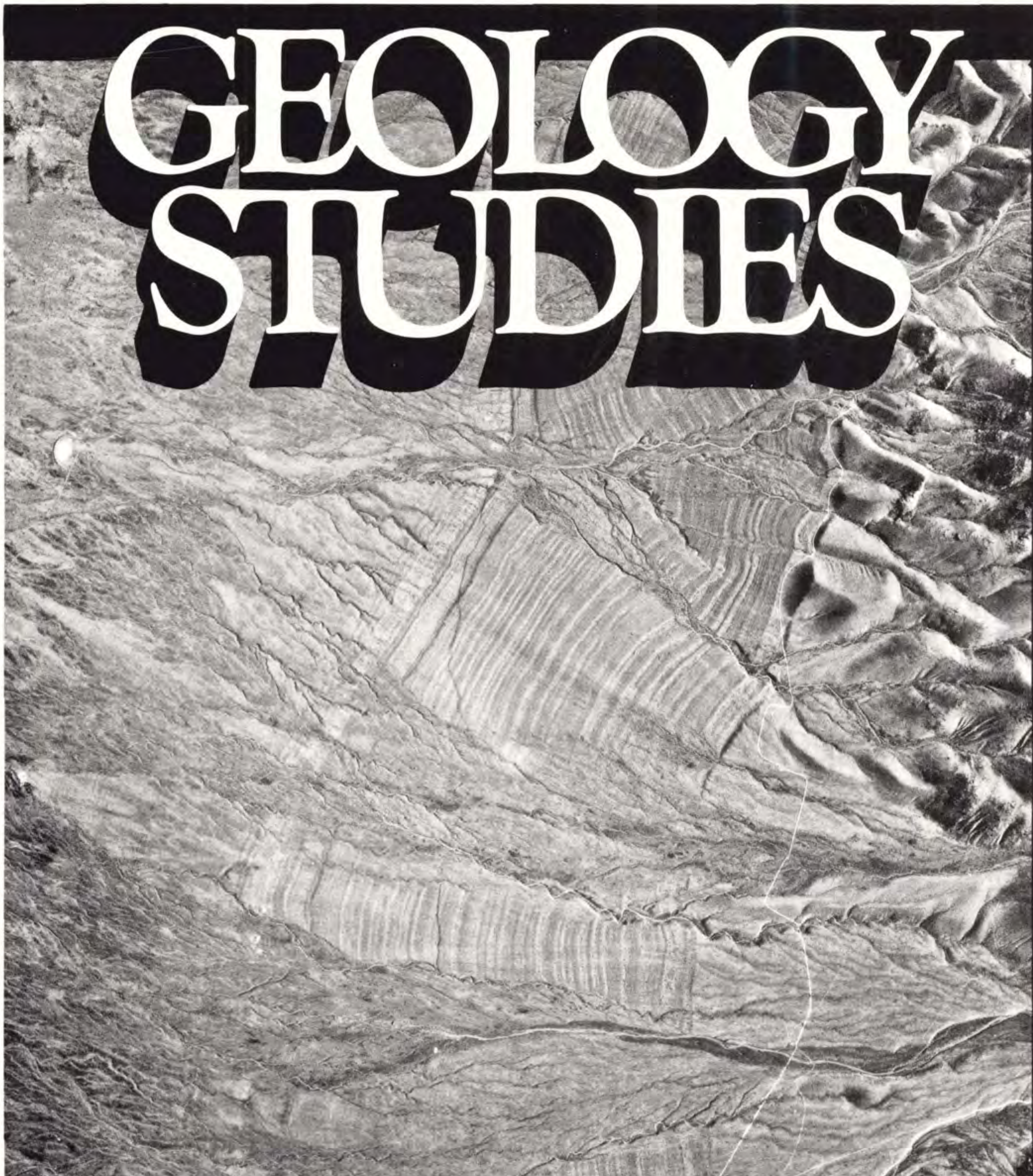
GEOLOGY STUDIES



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THE GLORY OF GOD IS INTELLIGENCE

Cover: Air photo of House Range fault scarp. Courtesy of Lee Piekarski.

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Relative Age Determination of Quaternary Fault Scarps along the Southern Wasatch, Fish Springs, and House Ranges, Utah*

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ABSTRACT.–Identification of the age of faulting is an important task in the evaluation of earthquake hazard areas. The geomorphology of Quaternary fault scarps may be used to categorize them into one of three age categories: recent to 2,000 years old, 2,000 years to 12,000 years, and greater than 12,000 years old but less than one million years old. Three areas in Utah were studied: the Wasatch Front, Alpine area to Nephi; the Fish Springs Range, and the House Range. The Wasatch Front has fault scarps of the first two age categories with evidence of recurring movement and grabens which make this area one of high seismic risk. The Fish Springs fault scarp is of the second age category with no recurring movement along the fault scarp. The House Range fault scarp is of the third age category. The Fish Springs fault scarp and House Range fault scarp are located in remote areas, so environmental concern is at a minimum. The Wasatch Front is becoming increasingly more densely populated. In this particular area, the age of faulting and recurrence intervals derivable from such data are of immediate concern to environmental planning and earthquake risk mitigation studies.

INTRODUCTION

Identification of the age of surface faulting is an important task in the evaluation of earthquake hazard areas. The fault scarps studied transect alluvium and Lake Bonneville deposits of generally late Quaternary age. Displacement of deposits this young places an upper limit on the possible age of surface faulting. Relative ages are estimated by the amount of modification by erosional processes the scarp has suffered, according to the model suggested by Wallace (1977).

Location

Three areas of Utah were studied (fig. 1): the Wasatch Fault zone, from Alpine to Nephi, the fault scarp on the northeastern side of the Fish Springs Range, and the fault scarp on the central western side of the House Range.

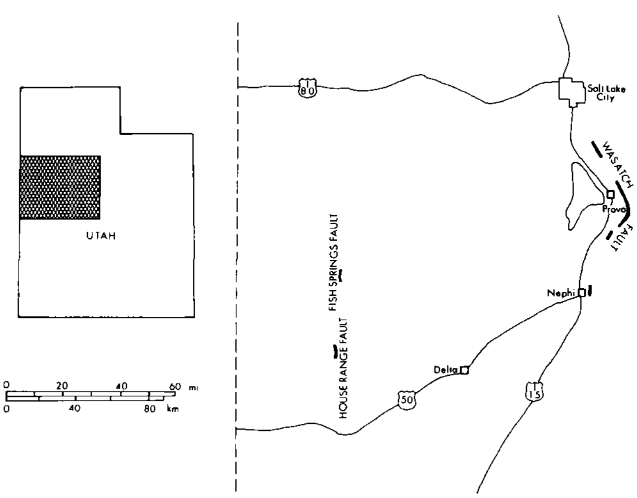

FIGURE 1.–Index map of the study area.

Previous Work

Normal faults were observed in the Wasatch Front near Provo, Utah, a century ago by Emmons (1877). Gilbert (1928) reviewed the structure of the Wasatch Range, and Baker in 1959 discussed the faults in the Wasatch Range near Provo, Utah. Later works by Hintze (1962, 1971, and 1976), Bissell (1964), and Morisawa (1971) made further evaluation of the southern part of the Wasatch fault and its effects on the environment. In 1973, Cluff and others mapped the Wasatch fault with low-sun-angle aerial photos which accentuate the scarp by the effect of shadows. The Fish Springs fault scarp was mapped as an inferred fault on the Geological Map of Utah (Hintze 1963), and the House Range fault scarp was mapped as a fault concealed by alluvium and Lake Bonneville deposits on the same map. The Fish Springs and House Range fault scarps were identified, traced, and then classified in the present study.

Statement and Importance of the Problem

An environmental objective of this study will be recognition of areas which have recurring movement and fault creep in order that land use planning can be more effective. Faults usually break anew where they broke before (Wallace 1977).

The purpose of the study was to establish the characteristics of the fault scarps in the aforementioned areas. These characteristics include slope configuration, slope size, and slope angle (appendix A) (fig. 2). With this knowledge, the fault scarp's relative age and its environmental importance can be evaluated. Such a study is of importance in the identifying of areas where in-depth studies of the faulting might be conducted, such as trenching techniques, etc.

The relative ages of the fault scarps will be estimated by a technique developed by Wallace (1975 and 1977). The fault scarps are placed into one of three categories: (1) recent to 2,000 years old, (2) several thousand to 12,000 years old, and (3) greater than 12,000 years old).

Characteristics of the Fault Scarp

The majority of fault scarps discussed in this study cut Lake Bonneville deposits or range front alluvial material of Quaternary age. A fault scarp is formed by the sudden displacement of the ground surface and immediately begins to change throughout the processes of erosion. Sometimes at the base of the scarp a graben is formed. The shape and configuration of the original scarp is controlled by processes of faulting or fracture mechanics, the stress field, and the properties of the faulted materials. The slope angle of a fresh fault scarp ranges from 45° to overhanging (Wallace 1977). The immediate changes on the fault scarp are two types of erosion, slope replacement and slope decline (Young 1927; fig. 3 taken

*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, December 1979. Thesis chairman: James L. Baer.

from Wallace 1977). In the first stages of erosion, the dominant process is gravity spalling from the free face (Young 1972). As time passes, water erosion or wash becomes the dominant process and continues until the fault becomes part of the original surface. At first, the fault scarp is characterized by two different slopes, the free face and the debris slope, but with time the free face is lost and only the debris slope remains. Slope decline is the main change at the latter stages in the fault scarp's life span.

PROCESS CONTROL VERSUS AGE

Wallace (1977) developed a technique to estimate the ages of fault scarps in desert environments. He recognized three age categories. The first category is historic scarps; having two major slopes, the upper slope (free face) ranging from 45° to overhanging, and the lower slope (debris slope) having a maximum angle of about 35° (fig. 3 A and B). These two different slopes persist together for usually not more than 2,000 years. The second category includes scarps estimated to be younger than 12,000 years but more than a few thousand years. These display a single slope with an angle ranging from 15° to 35° (fig. 3 C and D). The third group includes scarps older than 12,000 years; slope angle is from 8° to 25° (fig. 3 E). The upper limit for the third category of fault scarps is around 100,000 years. At 100,000 years slope decline is still in progress, but is difficult to measure. After one million years, almost all scarps, even in bedrock have declined so appreciably in slope angle that wash control and a variety of other processes dominate.

METHOD OF STUDY

Several methods were used to measure the scarp profiles. Most measurements were made by myself, by measuring slope distance with a tape or Jacob's staff and hand leveling with an Abney level or Brunton compass clinometer. To assist in measuring slope angle on an irregular surface, the Jacob's staff was used to help smooth out the irregularities, and then the hand level could be used on the staff. In a few places it was useful to measure a slope from a distance while standing in a position aligned with the plane of the slope. This method also helped smooth out irregularities. After profiles of the scarp were measured, it was then located on topographic maps and air photos. Each profile was then drafted, and the displacement of the fault scarp was calculated by an algebraic relation (fig. 4). The vertical component, the true vertical offset (AC, fig. 4), is an important measurement that is desired in studying most fault scarps. To calculate the true vertical offset, several items are needed. The first is the difference in altitude between the apparent base and crest of the scarp, which may be obtained either by leveling between the base and crest (points A and B) or by measuring slope distance and angle (fig. 4AB and angle b). The apparent offset AH is thus obtained. The actual offset is AC. The principal variables are the original slope (angle a) of the faulted surface, and the slope angle (angle b) between the points at the base and crest of the scarp. Given this data, the algebraic relation between AH and AC is

$$\frac{AH}{AC} = \sin b \quad \frac{\sin (90 + a)}{\sin (\theta - a)}$$

The true vertical offset is then calculated. With each profile classification dating of that particular portion of the fault scarp could be done.

Selection of the proper site to measure is very critical in order to avoid as many complicating factors as possible. An example

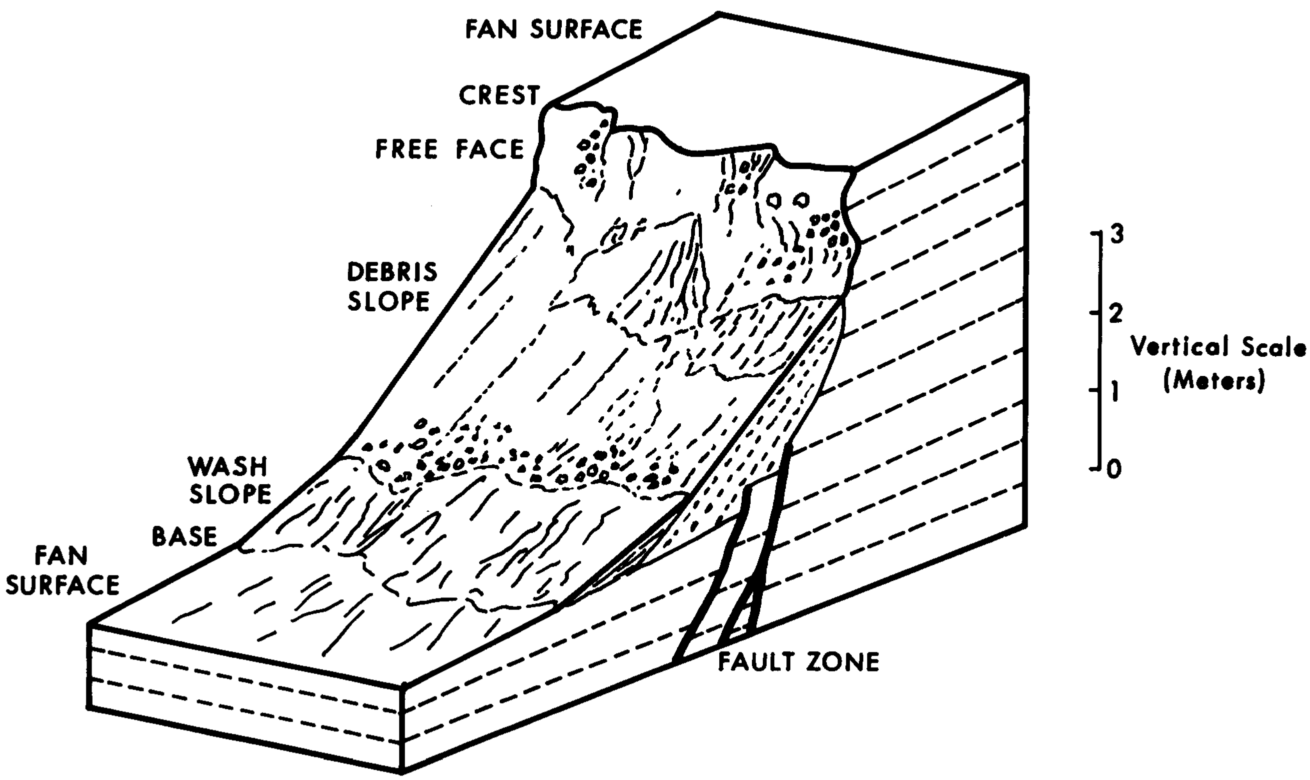

FIGURE 2.–Conceptual model of a fault scarp and terminology used in this study (Wallace 1977).

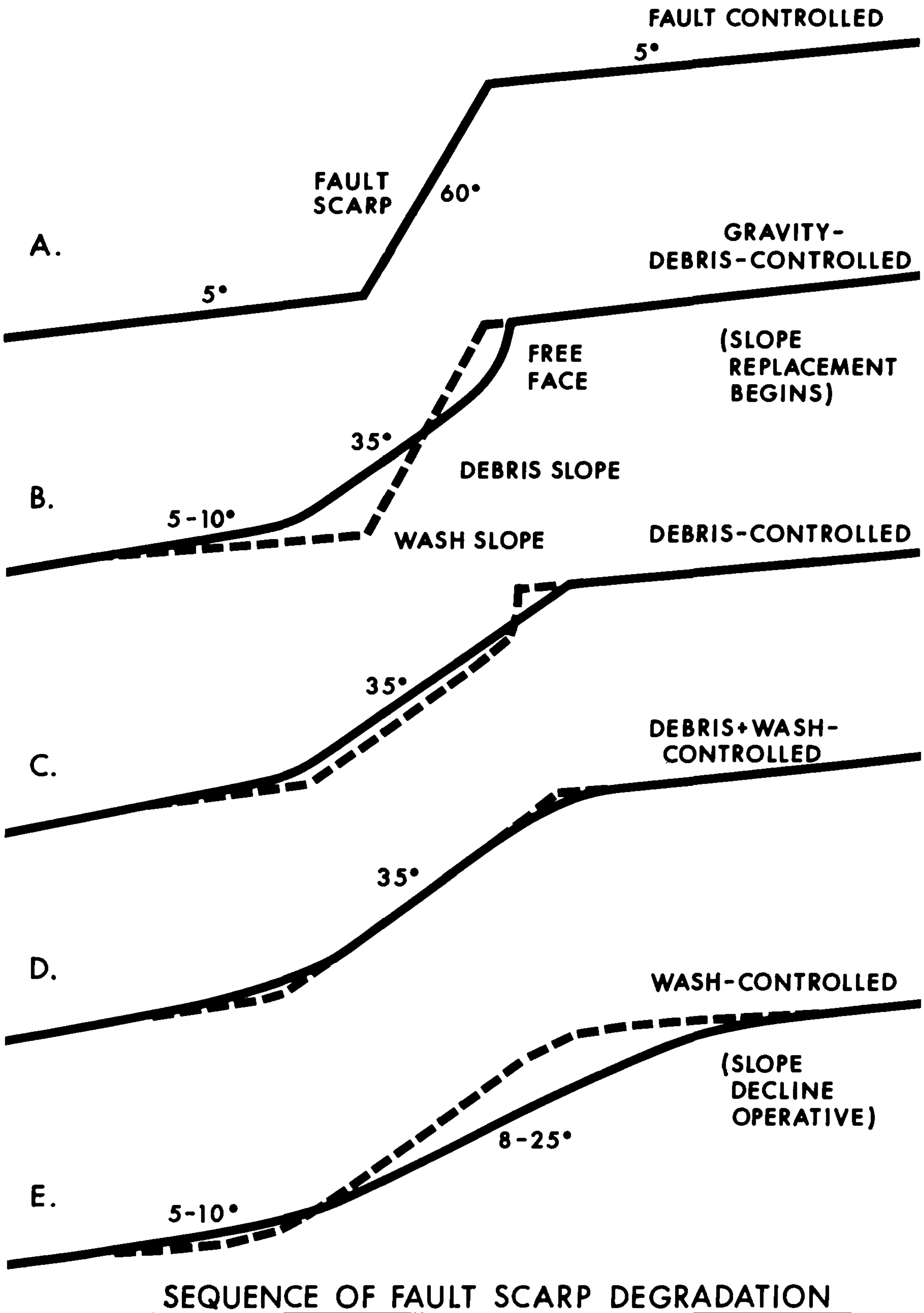

FIGURE 3 – Sequence of fault scarp degradation To show incremental changes, dotted line represents solid line of previous profile (Wallace 1977)

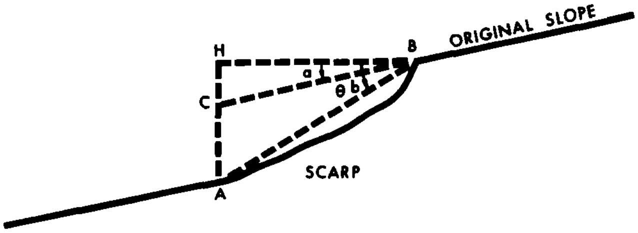

FIGURE 4.–Diagram showing needed measurements to calculate true vertical offset (AC) (Wallace 1977).

of such a complication would be young drainage channels parallel to the scarp base, which greatly accelerate the erosion of the scarp, resulting in an inaccurate scarp profile. Another factor to beware of is drainage channels that run perpendicular to the fault scarp which also accelerate the rate of erosion.

PRECIPITATION, CLIMATE, AND EROSION

The amount and types of precipitation and runoff can be important factors in scarp erosion. It should be noted that this study was done in a semiarid environment where the rate of erosion would be similar to Wallace's study area (1977). The House and the Fish Springs Ranges are very similar, and the Wasatch area does receive more precipitation but is still classified as a semiarid environment. The rates and processes of scarp degradation must have changed with changing climate, and the climate surely has changed a few times (Lake Bonneville, etc.) since some of the fault scarps were first formed. Such change provides a reason for using a broad time range in classification of fault scarps. It should be noted that the average precipitation in the House and Fish Springs Ranges is about 20 cm annually as compared to 35.6 cm along the Wasatch Front. In order to narrow the time of faulting, analysis of vegetation types and soil profiles and trenching of the faults need to be accomplished–not the intent or the purpose of this study.

STUDY AREAS ALONG THE WASATCH FRONT

The Wasatch Front was separated into eight areas of study (fig. 5). The eight are the Alpine area marked A in figure 5 and mapped with B and C in figure 6, American Fork area (B), Provo (C), Springville (D), Mapleton (E), Spanish Fork (F), Payson (G), and Nephi (H), and selected fault scarp profiles from within them are found in figures 7–10. There are several reasons why the Wasatch Front was separated into eight areas: (1) these locations are still visible, and buildings and other forms of development have not destroyed them; (2) significant geological examples of the different stages of faulting are present; (3) in these locations in the alluvium and Lake Bonneville sediments the faulting has occurred which is needed to classify them according to Wallace's (1977) technique.

Alpine Area

The Alpine area is marked as area A in figure 5. A map of the faulting and location of the measured profile of the Alpine area can be found in figure 6A. Diagrams of the measured profiles are present in figure 7, profiles 1–5. The average slope angle is 28.4°, and the average length of the fault scarp is 12 m with an average displacement of 4.3 m. The relative age of faulting in the Alpine area falls into the second age category of

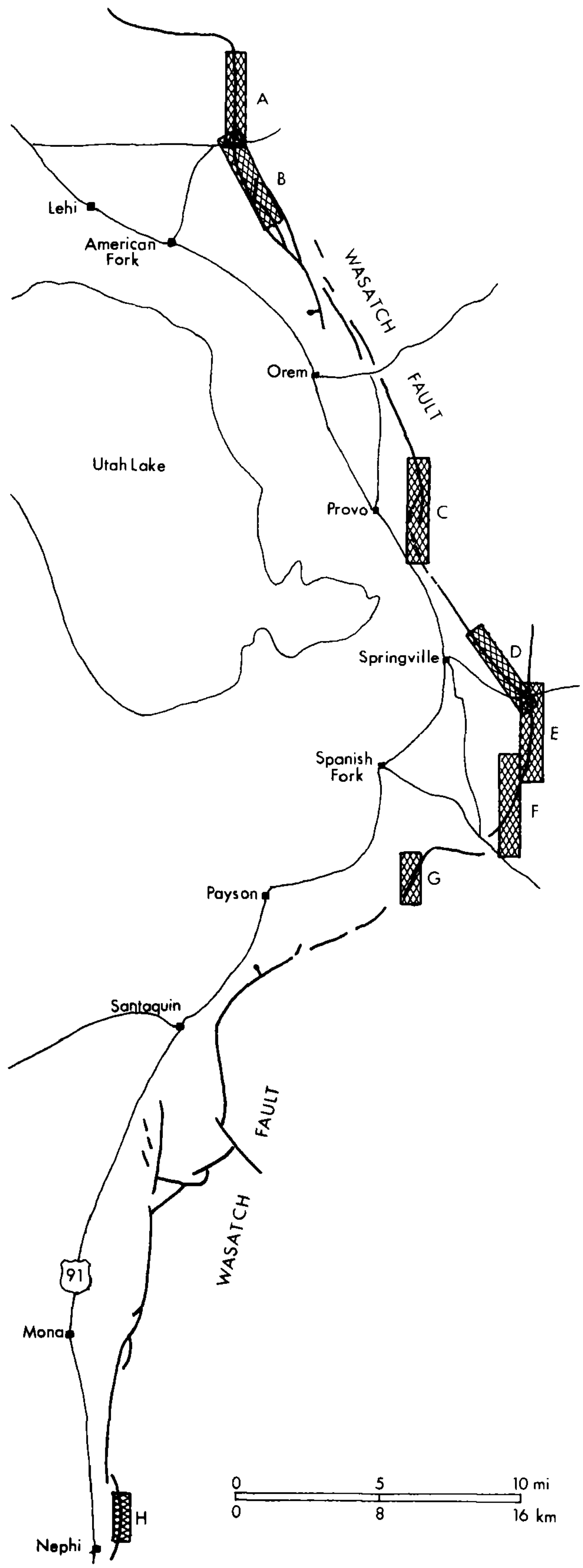

FIGURE 5.–Index map of study areas along Wasatch Front.

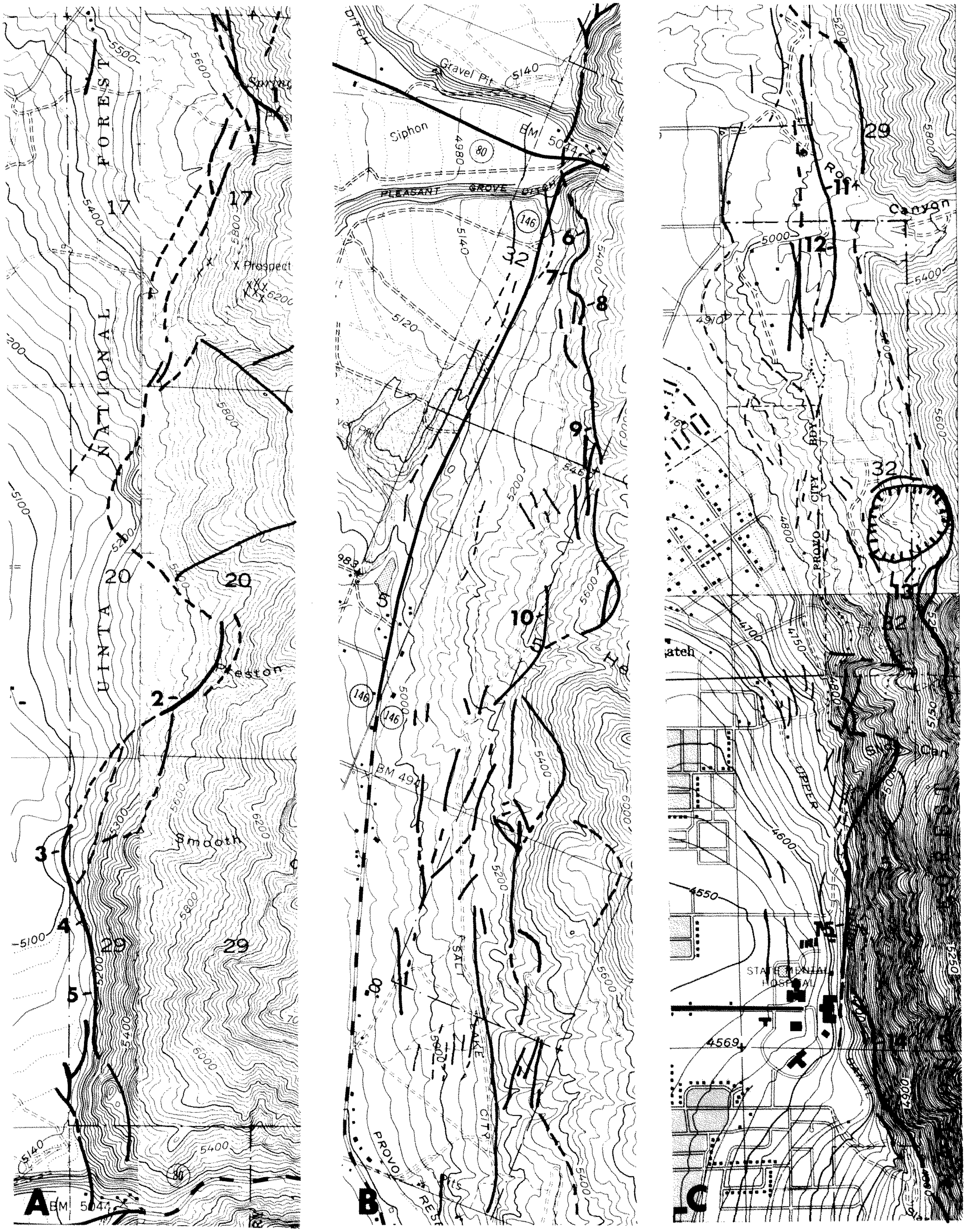

FIGURE 6.—Maps of study areas A, B, and C along Wasatch Front, showing existing faults and location of measured fault scarps.

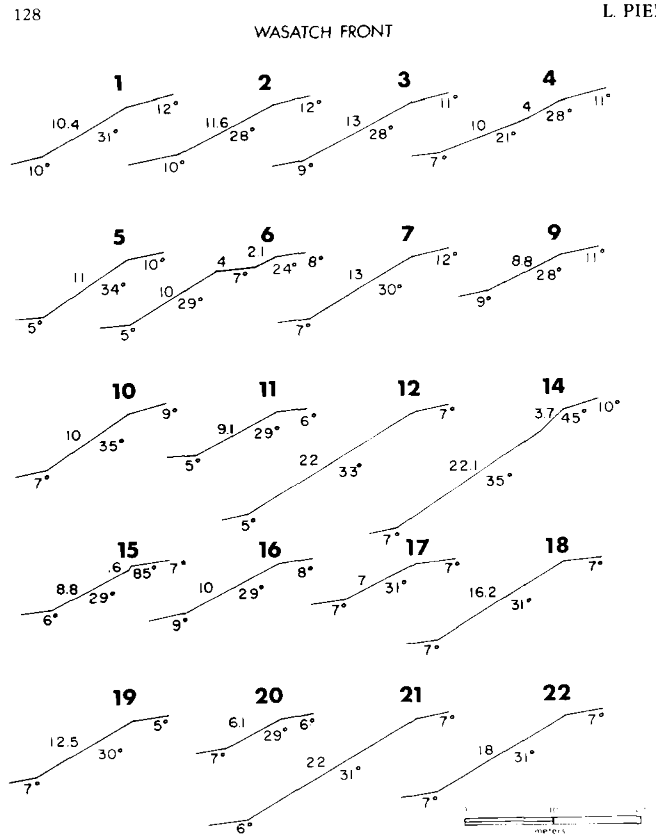

FIGURE 7.–Diagram of profiles 1–22, excluding profiles 8 and 13, along Wasatch Front.

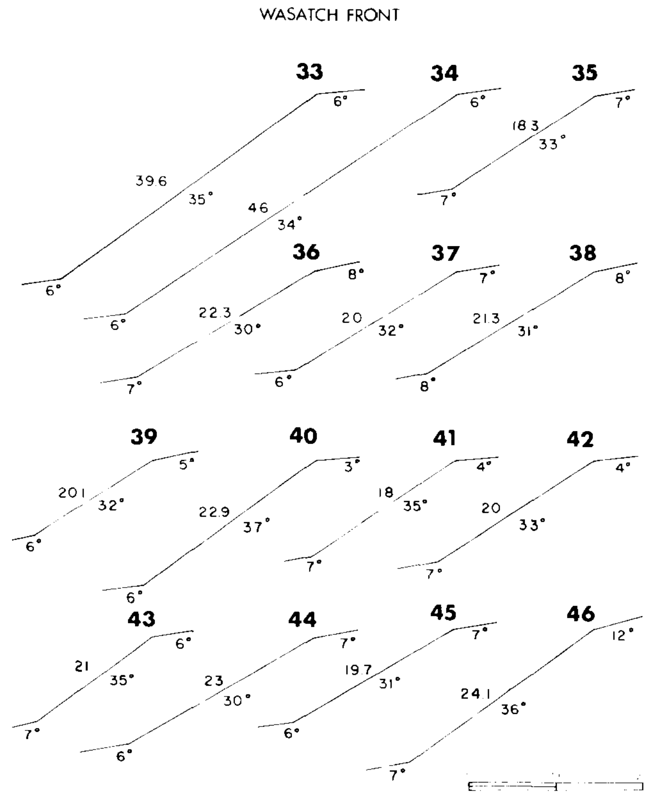

FIGURE 9.–Diagram of profiles 33–46 along Wasatch Front.

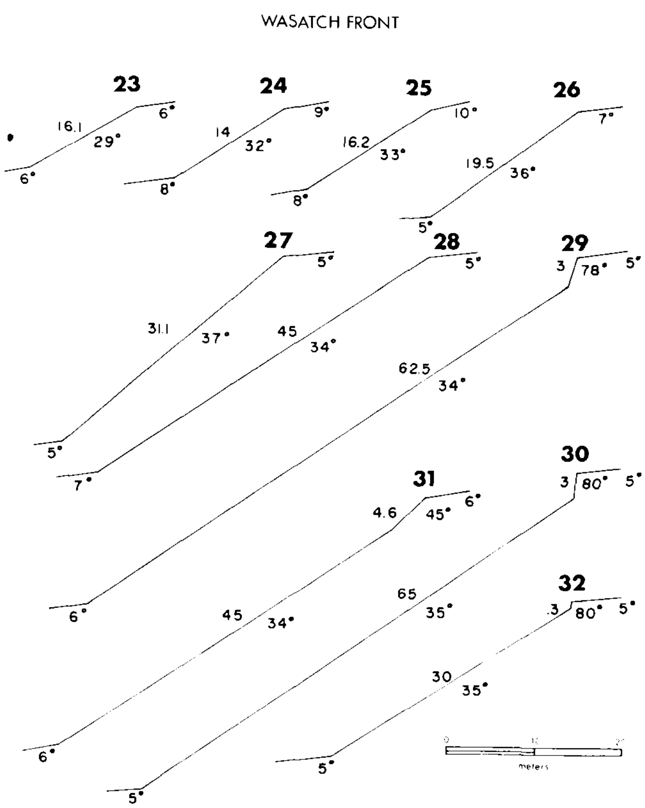

FIGURE 8.–Diagram of profiles 23–32 along Wasatch Front.

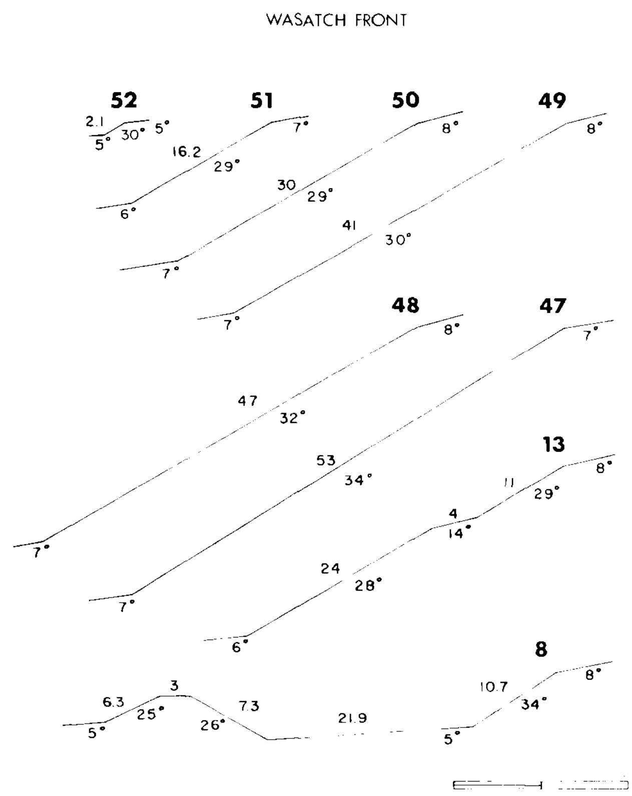

FIGURE 10.–Diagram of profiles 8, 13, and 47–52 along Wasatch Front.

2,000 to 12,000 years old. Faulting occurs mainly in a mixture of alluvium and Lake Bonneville sediments located near the base of the Wasatch Front. The fault scarps are still preserved across the intermittent stream channels, which would indicate that the faulting is on the younger side of the second age category. Vegetation cover on the slopes of the fault scarps is approximately 60 percent as much as the surrounding vegetation cover. The majority of the faulting occurs next to the base of the Wasatch Front and has not progressed so far into the alluvium as in other areas along the Wasatch Front–for example, the Springville and Provo areas. Profile 4 is evidence of recurring faulting, and the change of the slope angle should be noted. The fault (profile 4 area) has recurred near the original fault bank. Close field examination of the area shows that it is a recurring fault and not a remnant of the free face of a single fault movement. Profiles 1-5 were measured on three fault scarps of similar age and characteristics. Numerous housing developments are being built near the base of faulting and will create environmental problems at a later date.

American Fork Area

The area south of American Fork Canyon is marked as area B (fig. 6B) and includes profiles 6 through 10 (figs. 7 and 10). The average slope angle is 31° while the average length of the fault scarps is 10.5 m with an average displacement of 4.6 m. The relative age of faulting in this area is 2,000 years to 12,000 years, but most likely on the younger side of this age category because of the preservation of a graben in this area. The profiles were measured on the major surface fault scarps in this area. Profile 8 is a profile across the graben found in this area (figs. 10, 11, 12), and profile 6 is a profile of a fault scarp with recurring movement on it. An aerial view of the area (fig. 13) shows the faulting with the related graben and the recurring faulting. Vegetation cover on the fault scarp is 7 percent as much as on the surrounding area. The faulting occurred in the alluvium and the Lake Bonneville sediments of the area. No housing development of any great extent is being done on the area, but as figure 32 indicates, the area will most likely be developed in the future.

Provo Area

The Provo area is marked as area C on figure 4, and a map of faults can be found in figure 6C. Profiles 11–15 (fig. 7) are the measured profiles of this area. The faulting occurs mainly in the alluvium and Lake Bonneville sediments with numerous surface expressions of faulting. Faulting occurs over a wider area as compared with the Alpine area. The relative age of faulting in this area falls into the first two categories. Profiles 11–13 are of the second age category of 2,000 to 12,000 years old, and profiles 14 and 15 are of the first age category of recent to 2,000 years old. The average slope angle, average length, and average displacement were not calculated because of the two different age categories present in this area. The profiles were measured in areas where surface expression has not been destroyed by nature or man. Profile 13 is again evidence for re curring movement along the fault zone. Notice the two slope angles. Vegetation cover on the fault scarps ranges from 50 to 80 percent as much as the surrounding area. Figure 32 is

FIGURE 13.–Oblique aerial photograph of American Fork area.

FIGURES 11 and 12.–Photograph of fault scarp and associated graben located in American Fork area (area B), profile 8 is measured secton of fault scarp.

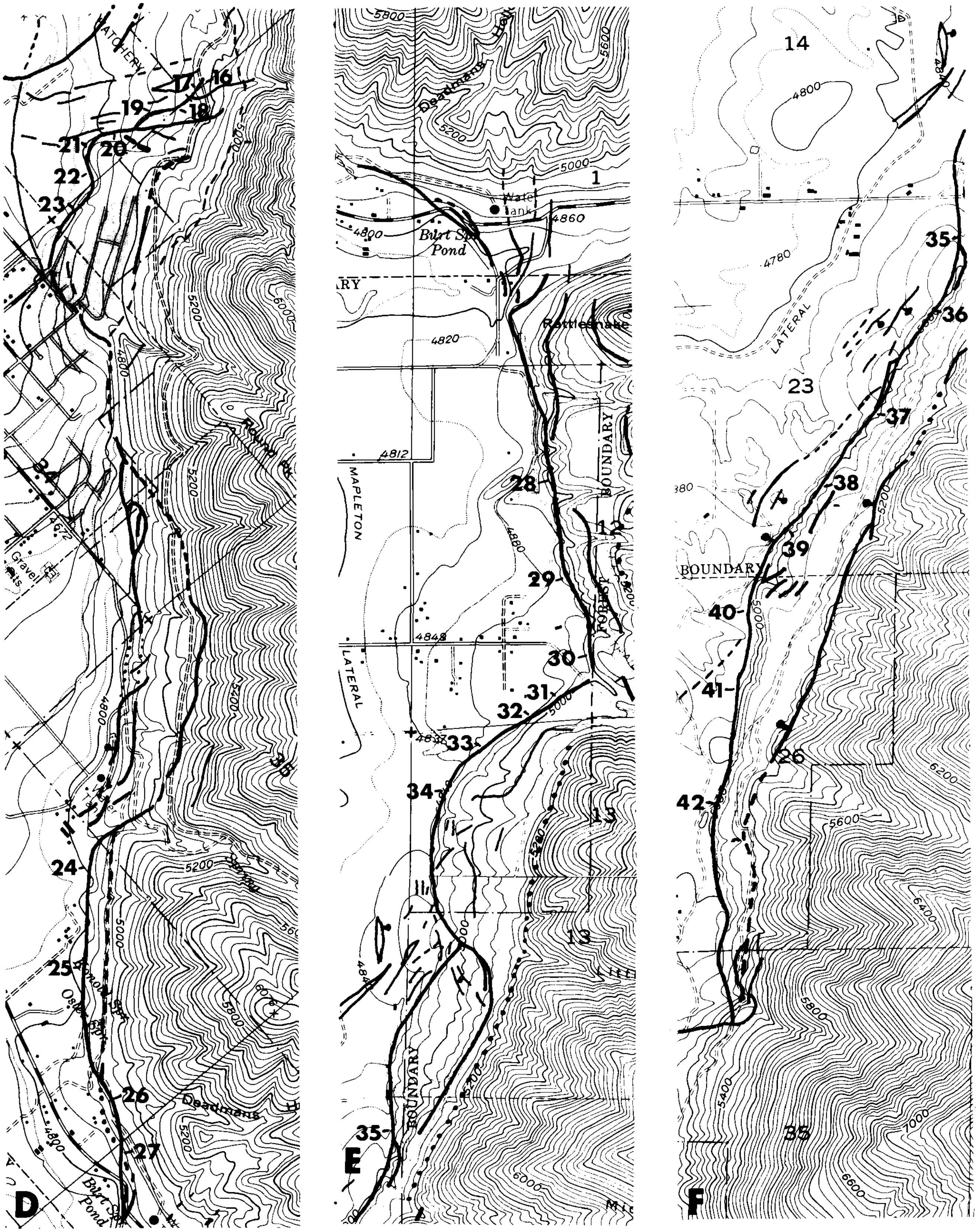

FIGURE 14.–Maps of study areas D, E, and F along the Wasatch Front, showing existing faults and location of measured fault scarps.

located near profile 12, and it can be easily seen that there are numerous buildings located in this area. Probably within the next few years many of the fault scarps will not be visible because of rapid construction.

Springville Area

The area east of Springville is marked as area D (fig. 5). A map of the faulting and location of the measure profiles can be seen in figure 14D. Profiles 16 through 27 (figs. 7 and 8) are in the Springville area. The average slope angle of the area is 31.6°. The average length of the fault scarps in this area is 15.7 m with an average displacement of 6.4 m. The majority of faulting occurs in alluvium and Lake Bonneville sediments over a wide area extending from the bedrock into the town of Springville. Figure 15 and 16 is a photograph of the area where profiles 16 through 21 were measured. With the early morning shadows of a summer day, this photograph highlights the faulting in detail. The relative age of profiles 16 through 23 falls into the second age category of 2,000 to 12,000 years old. There are found near this fault zone numerous springs related to the faulting in the area. South of profile 23 several houses are built on or near the faulting. Profiles 24 through 27 are located north of the mouth of Springville Canyon and fall into the second age category. Profiles 24 and 25 are located nearr Springville city water storage tanks with some housing nearby. Several springs are found near the mouth of Springville Canyon and are related to the faulting. Vegetation cover on the fault scarps is about 50 to 70 percent as much as the surrounding area. In years to come, construction in progress on the faulting in this area will become an even bigger problem, as the area is rapidly growing.

Mapleton Area

The Mapleton area is marked as area E on figure 5 and a map of the faults can be seen on figure 14E. Profiles 28 through 35 (fig. 8) are the measured profiles located in this area. All the measured fault scarps have occurred in alluvium and Lake Bonneville sediment. The area has heavy vegetation cover, even on part of the fault scarps, making measurements difficult. Vegetation cover on the fault scarps is about 70 to 90 percent as much as the surrounding area. Profiles 29 through 32 are located near the mouth of Mapleton Canyon and fall into the first age category, whereas the other profiles in this area fall into the second age category of 2,000 years old to 12,000 years old. Figure 17 is an aerial view of the area. Profiles 28 and 33 through 35 have an average slope angle of 34° with an average length of 37 m and an average displacement of 17.4 m. Profiles 29 through 32 have an average lower slope angle of 35° and an average upper slope angle of 68°. The average length of the fault scarp is 53.6 m with an average displacement of 30.4 m. Mapleton Canyon has cut through part of the fault scarp; therefore, care was taken with profiles made near the canyon mouth. The Mapleton area has some of the largest fault scarps in the Wasatch study area. There are not many buildings located at or on the fault scarps in this area, but it is also growing fast.

Spanish Fork Area

The Spanish Fork area is marked on area F (figs. 5 and 14F) and includes profiles 35 through 42. Notice there is an overlap of areas E and F which is the reason for having two profiles numbered 35. Actually, profile 35 resembles the fault scarps in area F more closely than in area E but is part of this area

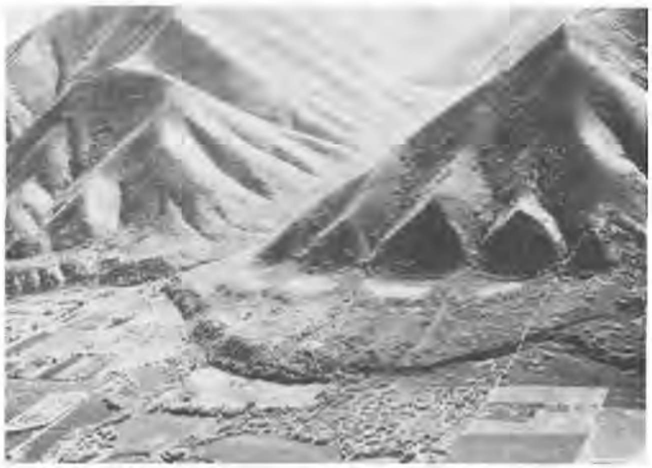

FIGURE 17.–Oblique aerial photograph of Mapleton area (area E).

FIGURES 15 and 16.–Photograph of fault scarps in Springville area (area D). Profiles 16–22 were measured in this area. Low-sun-angle technique was used to highlight fault scarps. This photograph was taken at approximately 9:00 a.m. during the summer.

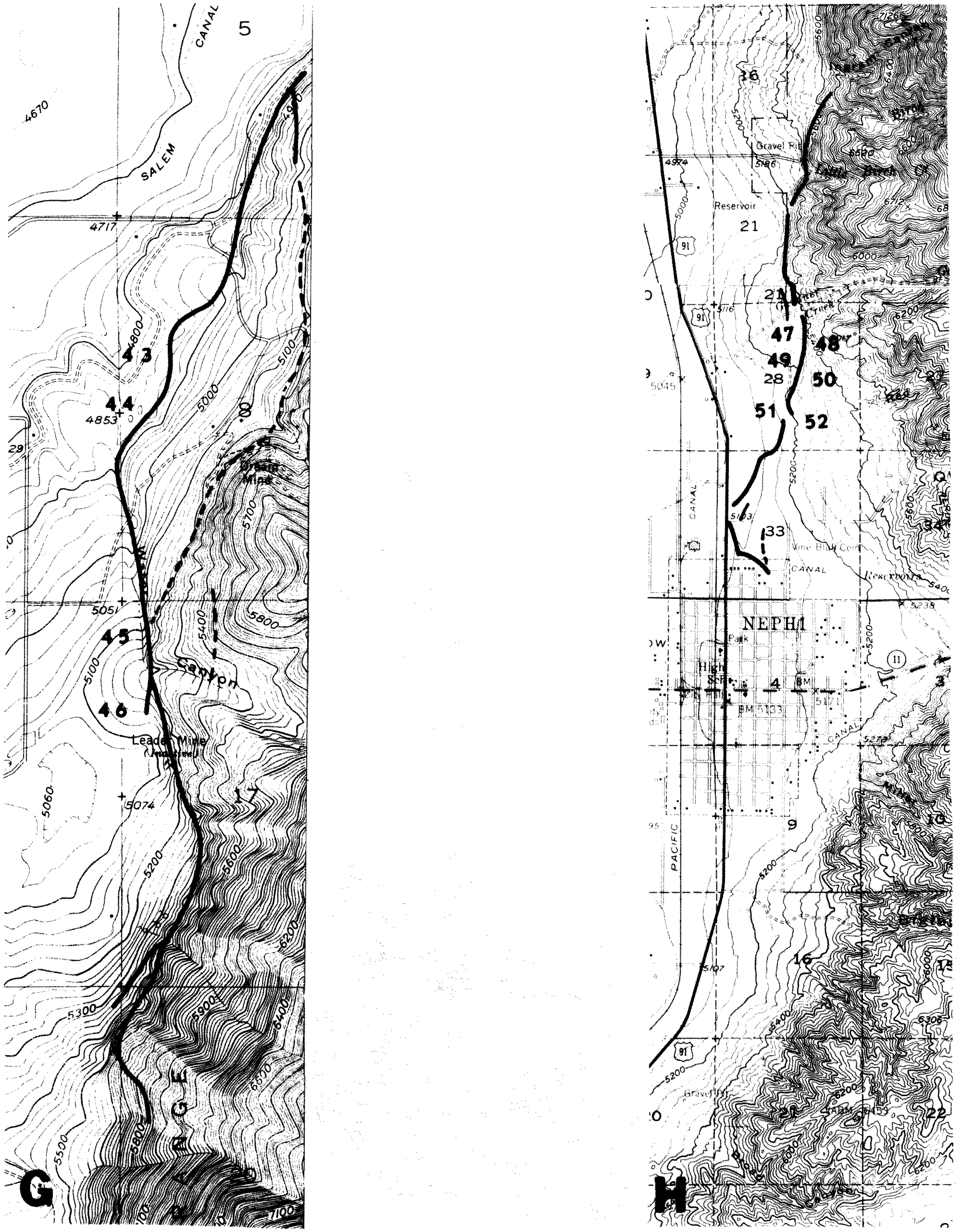

FIGURE 18.—Maps of study areas G and H along Wasatch Front, showing existing faults and location of measured fault scarps. On H the map scale is 1:62,500.

because it is near profiles 36 through 42. The average slope angle is 33° with an average length of the fault scarps of 20.4 m and an average displacement of 11.1 m. The relative age of faulting in this area is 2,000 years to 12,000 years old. All the measured fault scarps have occurred in alluvium and Lake Bonneville sediments. Vegetation cover is heavy over most of the area, estimated on the fault scarps at 70 to 90 percent as much as the surrounding area. The fault scarps are best seen in the winter, when the vegetation is dead and no snow is on the ground. The faulting can be seen across the intermittent stream channels in the area but is not well defined across the mouth of the Spanish Fork Canyon. Around the base of profiles 38 and 39 a graben or slump area appears to be present, but it is difficult to see because of erosion. Buildings are at a minimum in this area, but there is an explosives factory at the mouth of Spanish Fork Canyon, located near the faulting. This area is also continually growing, and there will be more construction.

Payson Area

The Payson area is marked as area G (figs. 5 and 18G) and includes profiles 43 through 46 (fig. 9). The average slope angle is 33°, and the average length of the fault scarps is 22 m with an average displacement of 9.6 m. The relative age of the fault scarps in this area is 2,000 to 12,000 years old. The faulting occurs mainly in the Lake Bonneville sediments and alluvium. Faulting is still preserved across the intermittent stream channels but has been modified to a degree. There is heavy vegetation cover in most of this area, and the fault scarps are most visible in the winter when vegetation is dead and no snow is present. Vegetation cover is estimated at 70 to 80 percent of that of the surrounding area. There are only a few buildings located close to the faulting, but population is expanding rapidly into this area.

Nephi Area

Area H (figs. 5 and 18H), the Nephi area, is located just north of the town of Nephi and includes profiles 47 through 52 (fig. 10). The faulting can be traced coming from the bedrock into the alluvium, wherein it becomes smaller and smaller until it cannot be seen on the surface. The relative age of faulting in this area is 2,000 years to 12,000 years old. The length of the fault scarps is from 53 m to 2.1 m with a displacement ranging from 24 m to .9 m. The average slope angle of the area is 31°. Vegetation cover on the fault scarps is about 50 to 80 percent as much as the surrounding area. The fault scarp can be seen cutting across the intermittent stream channels. Figure 19 is a view of the fault scarp, where the development of faceted spurs and the presence of a graben at the base of the fault scarp can be seen. Figure 20, a closer view of the area, provides

FIGURE 19.–Distance photograph of Nephi area (area H). Note development of faceted spurs on fault scarp.

FIGURE 20.–Closer view of Nephi area. Compare figure 19.

a better view of the faceted spurs. There is little construction in the area, but as can be seen in figures 19 and 20, there are power lines crossing the fault scarp.

WASATCH AREA

Most of the faulting in this area is of the relative age of 2,000 years to 12,000 years old, but, as stated earlier, there are areas of recent faulting. Figure 21 is an illustration of the principal slope angles of the three study areas, showing that the majority of the faulting is of the second age category. There are also several areas along the Wasatch with grabens and recurring movement giving evidence of recent faulting. Most of the faulting occurs in the alluvium and Lake Bonneville sediments. Vegetation cover on the fault scarps ranges from 30 to 90 percent as much as the surrounding area. Many of the fault scarps are still preserved across the intermittent stream channels but are not so well defined across the mouth of the several canyons in the area.

FISH SPRINGS AREA

The Fish Springs area is located in western Utah (fig. 1). The measured fault scarps occur in the alluvium on the northeast side of the Fish Springs Mountain Range (figs. 5, 22, 23). Profiles of the measured fault scarp can be seen in figure 24. The average slope angle is 27°, with the fault scarp length ranging from 6 to 14.4 m. The average displacement of the fault scarp is 3.1 m. The relative age of the faulting is 2,000 to 12,000 years old. Vegetation cover on the fault scarps is about 40 to 80 percent as much as the surrounding area. Figure 25 shows vegetation growing on the fault scarps, but in figures 26 and 27 the fault scarp can be clearly seen from a distance. In figure 26 the fault scarp has been preserved over the alluvium fan at the left of the photo. Profiles 15 through 17 reflect the existence of the fault scarp over the alluvium fan. The slope angle over the alluvium fan is not as great as it is over the other areas. The remoteness of the area gives very little concern with the environmental aspects of buildings or population on or near the fault scarp.

HOUSE RANGE AREA

The House Range is located in western Utah (fig. 1) just south of the Fish Springs Range. The measured fault scarp has occurred in the alluvium and Lake Bonneville sediments on the west side of the House Range (figs. 22, 28). The average slope angle (fig. 29) of the area is 12° (fig. 21), with the average length of fault scarps at 13.4 m and an average displacement of 1.4 m. The relative age of the fault scarp would be greater than 12,000 years old and less than when the Lake Bonneville sediments were deposited. Vegetation cover on the fault scarps is estimated at 80 to 100 percent as much as the surrounding

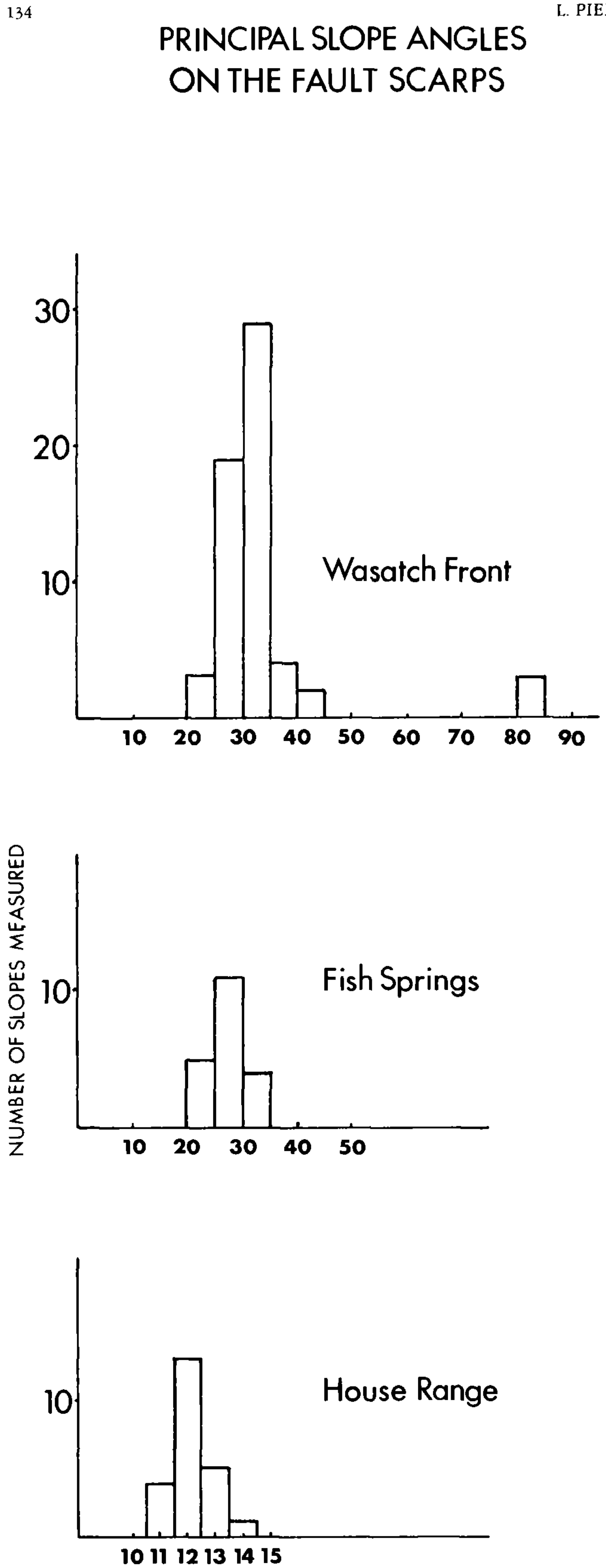

FIGURE 21.–Chart, plotting number of slopes measured vs. principal slope angles on fault scarps, places age of faulting of an area in one of three categories.

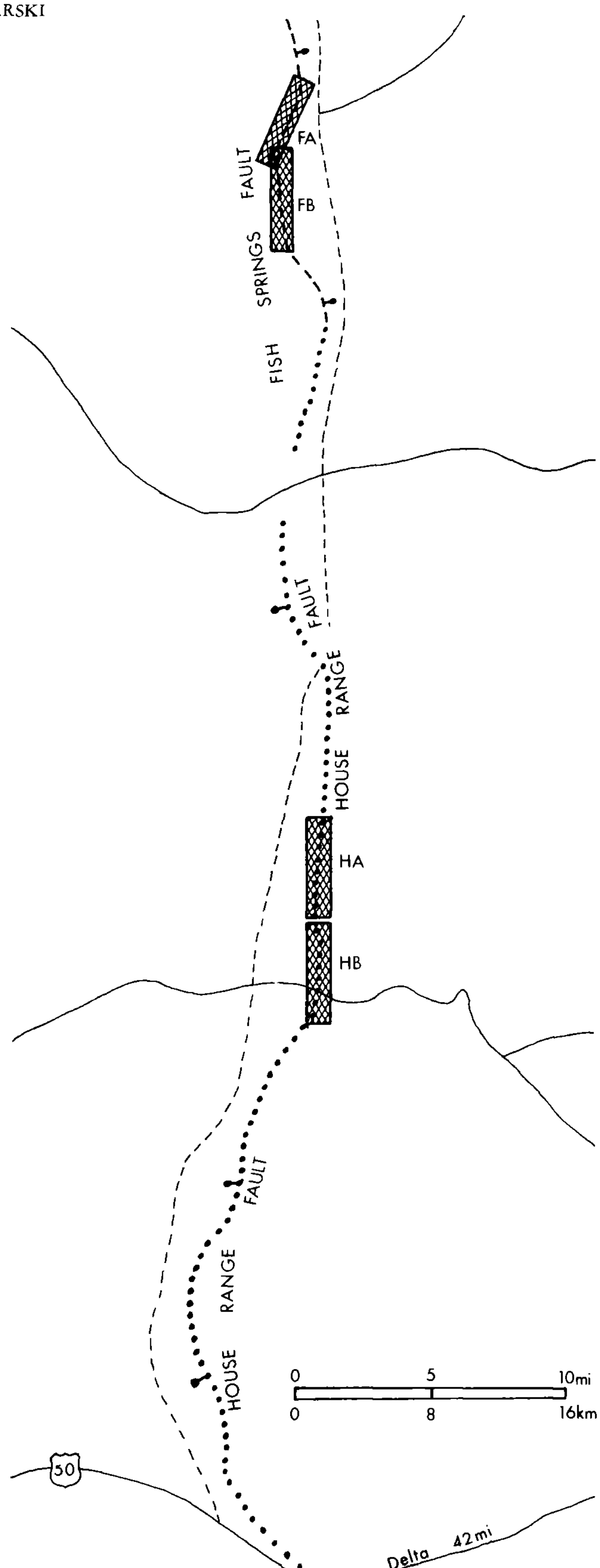

FIGURE 22.–Index map of study areas in Fish Springs and House Ranges.

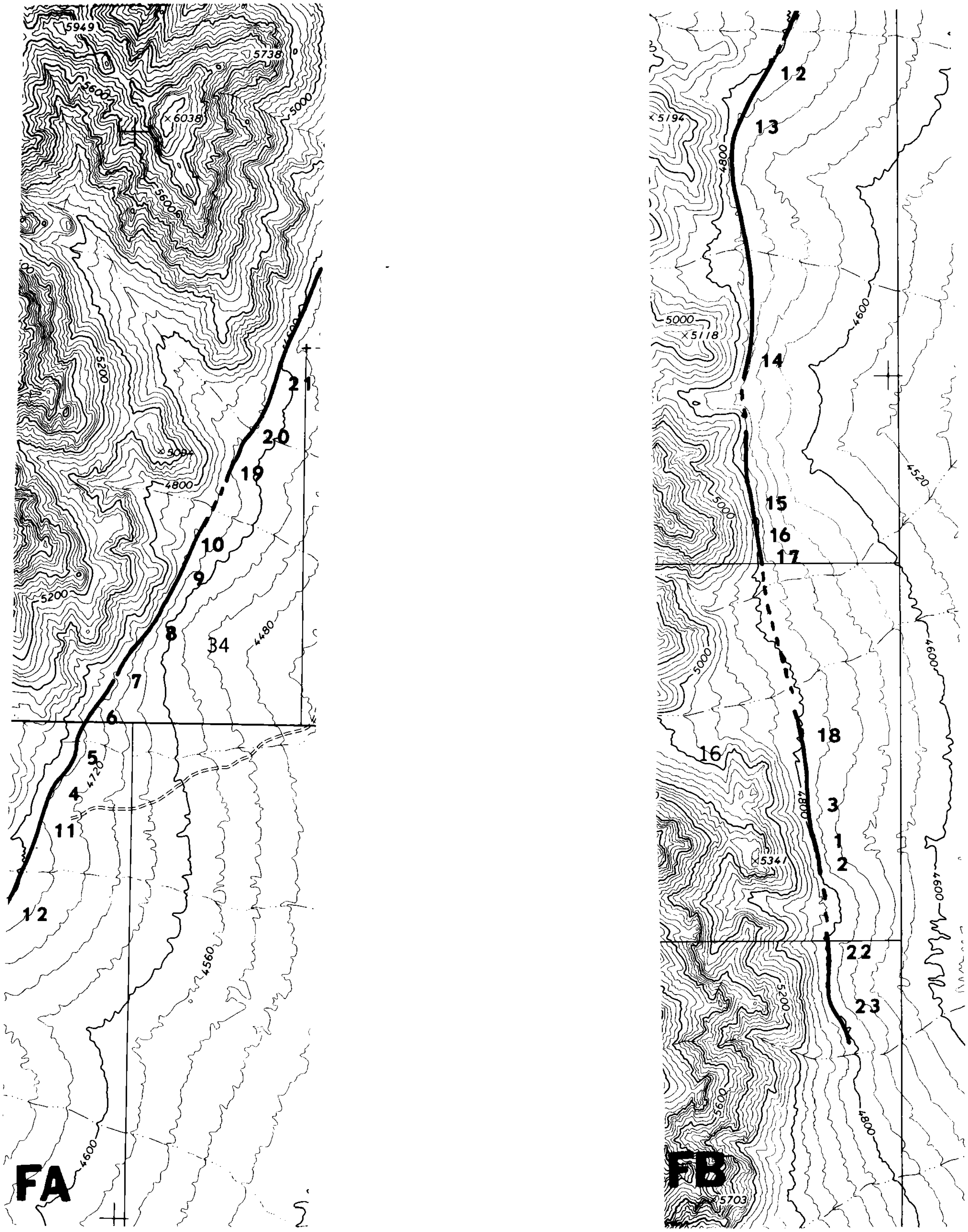

FIGURE 23.—Maps of study areas FA and FB along the Fish Springs Range showing existing faults and location of measured fault scarps.

area. The surface expression of the fault scarp (fig. 30) is difficult to locate, but can be readily seen in air photos (fig. 31). Therefore, the best way to locate the faulting is on air photos, and then location can be made on the surface. The House Range fault scarp is located in a remote area which makes surface identification not so complex. If the faulting were present in a populated area, detection would have been difficult or near impossible. The low-sun-angle technique would be a good method of detection of these types of faults.

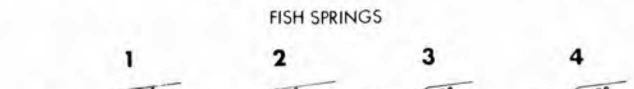

FIGURE 24.–Diagram of profiles 1-23 along Fish Springs Range.

ENVIRONMENTAL ASPECTS

The purpose of this thesis is to identify areas where relatively young faulting has occurred. Its purpose is not to recommend where to construct homes or businesses, but to identify possible hazard areas. There is a great amount of construction on the Wasatch Front. In that light, it is difficult not to be concerned about the possible dangers to people and buildings in the area if an earthquake does occur. Figure 32 shows a fault scarp in the Provo area with homes located above and below it, and there is a strong possibility that the families who live near it do not realize they are located near a fault and its possible hazards. Figure 33 shows an example of land which could be purchased on a fault, without the seller or the buyer recogniz-

FIGURE 25.–Photograph of fault scarp along Fish Springs Range which shows amount of vegetation.

FIGURES 26 and 27.–Distance photograph of the fault scarp along Fish Springs Range. Fault scarp is more visible when photographed at a distance.

ing the danger. It must be remembered that the Wasatch Front is classified as a high seismic risk area, and that faults usually break anew where they broke before (Wallace 1977). Therefore, it is of the utmost importance that individuals are aware of these high seismic risks and of the possible dangers of building in these areas. This type of information should be made public through the federal or state government and concerned citizen groups.

SUMMARY

Utah is classified as an area of high seismic risk. To pinpoint the high-risk areas where faulting has recently taken place was the purpose of this study. First, the recent faulting of the study area was mapped, and then profiles were measured of the recent faulting (fault scarps). From these profiles, fault scarps were placed in one of three age categories: recent through 2,000 years, 2,000 to 12,000 years, and greater than 12,000 years old but less than one million years. After this data was compiled and categorized, the areas whose recent faulting was the greatest can be located.

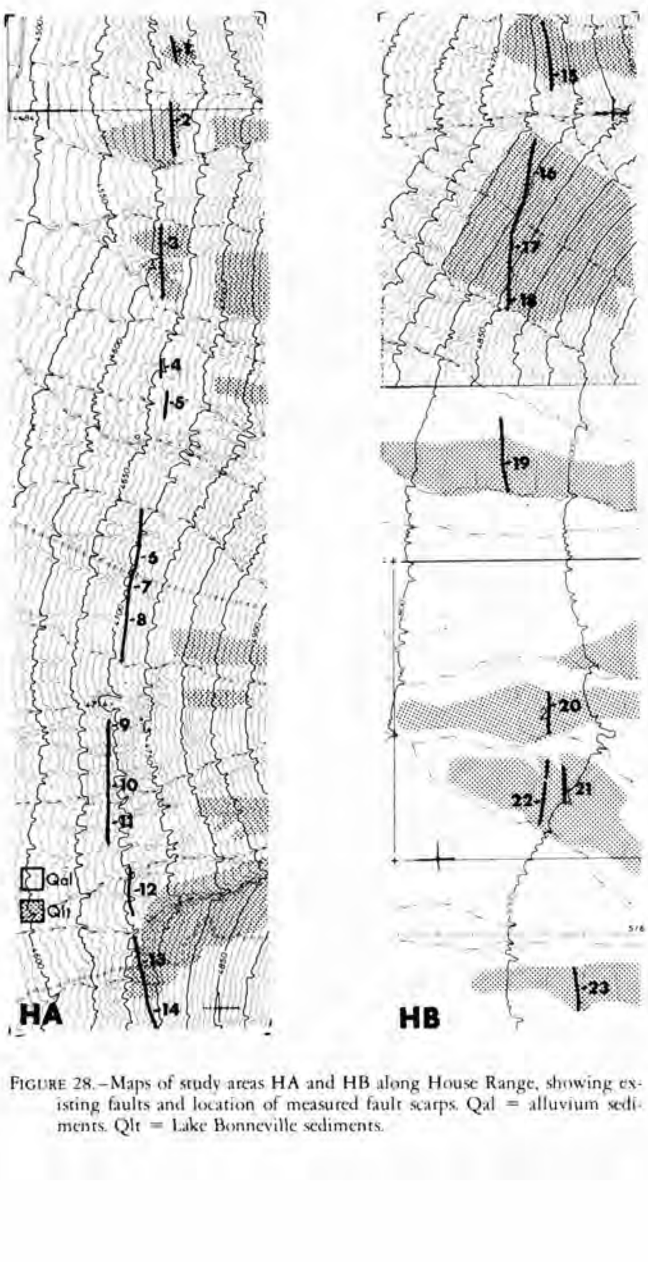

FIGURE 28.–Maps of study areas HA and HB along House Range, showing existing faults and location of measured fault scarps. Qal = alluvium sediments. Qlt = Lake Bonneville sediments.

The Wasatch Front from Alpine to Nephi has recent faulting, as well as older faulting. Care therefore must be taken when building near the Wasatch Front. The House Range and Fish Springs areas are good examples of the third and second age categories, respectively. These two areas have excellent examples of fault scarps which have not been destroyed by construction because of their remoteness.

There are several weaknesses in a study of this type: (1) the three age categories are very broad and need to be more clearly delineated, especially the second and third age categories. Secondly, there remains the question of how much of an effect the

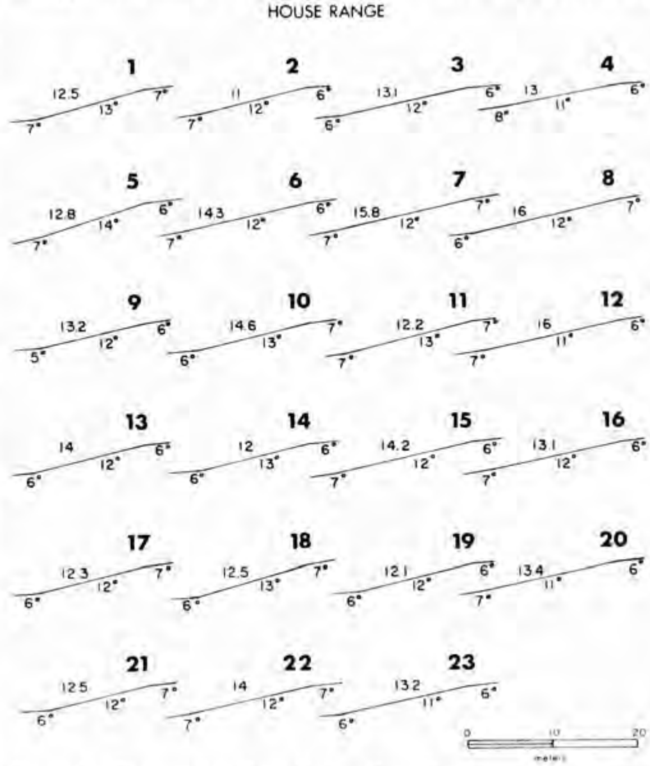

FIGURE 29.–Diagram of profiles 1–23 along House Range.

FIGURE 30.–Profile of fault scarp along House Range. Scarp is believed to be more than 12,000 years old.

climatic differences have on the erosion rate in comparing the Wasatch Front to the Fish Springs and House Ranges.

There are also several strong points in a study such as this: (1) the study is relatively inexpensive to conduct, (2) the study gives a broad range of ages of the faulting in an area, and (3) such a study can quickly and inexpensively locate areas where there are possible environmental hazards.

FIGURE 31.—Aerial photograph of House Range area. Faulting cuts both alluvium and Lake Bonneville sediments.

Future recommendations of extension to this study are (1) identification of the different soil horizons to narrow the age categories. Techniques such as trenching can be done to narrow the age categories. Such a project is expensive and well beyond the scope of this study. (2) A study of climatic conditions in comparison to rates of erosion is needed to narrow the age categories. It should be noted that such a study would be very extensive and also beyond the scope of this study. This study was done to evaluate high risk areas where faulting has taken place and to locate areas with possible environmental hazards.

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APPENDIX A

Nomenclature

Terms used in this paper to refer to different parts of a fault scarp are from Wallace (1977) and myself.

The *upper* and *lower original surfaces* are the segments of the original surface that have been separated by faulting.
The *base* of the scarp is its lower extreme.
The *crest* of the scarp is its upper extreme.
The *free face* is the exposed surface resulting from faulting or succeeding gravity spalling.

FIGURE 32.—Photograph of faulting near mouth of Provo Canyon (profiles 11 and 12).

FIGURE 33.—Photograph of faulting in American Fork area (profile 9).

The *slope* is the vertical angle between a horizontal plane and any planed surface, the fault scarp in this case

The *debris slope* is the talus slope accumulated by gravity fall below the free face

The *wash slope* is any part of the scarp controlled by fluvial erosion or deposition

The *fault scarp length* is the combination of the debris slope and wash slope that was measured and that helped to categorize the relative age of faulting

REFERENCES

Algermissen, S T, 1969, Seismic risk map for conterminous U S U S Department of Commerce News Release ES 69-1

Baker, A A, 1959, Faults in the Wasatch Range near Provo, Utah Intermountain Association of Petroleum Geologists Guidebook 10, p 153-58

Bissell, H J, 1964, Wasatch Fault of the south-central Wasatch Mountains Utah Geological Guidebook 10, p 15-30

Cluff, L S, Brogan, G E, and Glass, C E, 1973, Wasatch fault, southern portion, earthquake fault investigation and evaluation Woodward-Lundgren and Associates, Oakland, Calif

Emmons, S F, and Hague, A, 1877, Descriptive geology U S Geological Exploration of the 40th Parallel, v 2

Gilbert, G K, 1928, Studies of basin-range structure U S Geological Survey Professional Paper 153, 92p.

Hintze, L F, 1962, Structure of the southern Wasatch Mountains and vicinity, Utah. Brigham Young University Geology Studies, v 9, pt 1, p 70-79

____________, 1963, Geological map of the state of Utah.

____________, 1971, Wasatch fault zone east of Provo, Utah Utah Geological Association Publication 1, p F1-F10

____________, 1976, Attenuation faulting in the Fish Springs and House Ranges, western Utah [abs]: Geological Society of America Abstracts with Programs, v 8, no 6, p 918-19

Lowell, H S., 1971, Environmental geology of the Wasatch Front Utah Geological Association Publication 1, 246p

Morisawa, M, 1971, The Wasatch Fault zone general aspects. Utah Geological Association Publication 1, p. D1-D16

Wallace, R E, 1975, Fault scarp geomorphology and seismic history, north central Nevada· (abs) Geological Society of America Abstracts, v. 7, (Cordilleran Section) p 385

____________, 1977, Profiles and ages of young fault scarps, north-central Nevada Geological Society of America Bulletin, v 88, p 1267-81

Young, A, 1972, Slopes Oliver and Boyd, Edinburgh, 288p