CHAPTER 9

RECONNAISSANCE PHOTOGEOLOGIC MAP OF YOUNG (QUATERNARY AND LATE TERTIARY) FAULTS IN NEVADA

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INTRODUCTION

The State of Nevada occupies most of the central and western parts of the Great Basin, the largest tectonically active region within the Basin and Range geomorphic province of North America. The topography of this region is typified by generally north-northwest to northeast trending, subparallel mountain ranges separated by alluvial basins of similar plan and orientation. This classic Basin and Range physiography is the product of at least two phases of middle to late Cenozoic extensional faulting (Zoback and others, 1981; Eaton, 1982; Stewart, 1983), and most of the basins and ranges of the region are at least partly bounded by late Cenozoic faults. The earlier phase of extension was marked by widespread shallow detachment faulting that began at approximately 35 Ma and locally continued into the time of the later phase (Eaton, 1982; Stewart, 1983). The later phase, which was dominated by high-angle, more deeply penetrating block faulting, may have begun locally at about 17 Ma and continues episodically to the present time (Christiansen and McKee, 1978; Eaton, 1982). Plate 9-1 provides a generalized picture of the late Tertiary and Quaternary faulting in Nevada that is associated with this latter extensional phase. These young faults are a primary determinant of the present configuration of ranges and basins across the state; thus their distribution is central to an understanding of the subsurface geometry and stratigraphy of basin areas throughout the region and aid in mineral resource assessments.

MAPPING PROCEDURES

Young faults are herein defined as those faults that have undergone latest Tertiary and/or Quaternary movement. These faults are commonly marked by a variety of diagnostic constructional landforms and other surficial phenomena that can be readily identified and mapped on aerial photographs. These features include (1) scarps on latest Tertiary and/or Quaternary surficial deposits, volcanic strata, or geomorphic surfaces (either erosional or depositional); (2) prominent alignments of linear drainageways, ridges and swales, active springs and/or spring deposits, and linear discontinuities of structure, rock type, and vegetation; and (3) abrupt, steeply sloping range fronts with basal scarps, faceted spurs, 'wineglass valleys', and elongate drainage basins with narrow valley floors (Thornbury, 1969; Bull, 1977; Bull and McFadden, 1977; Wallace, 1977, 1978).

To develop a regionally consistent picture of young faulting in Nevada, a reconnaissance photogeologic analysis was carried out for the entire state. Previous maps of young faults, compiled at scales of 1:125,000 or smaller for several areas within the state (fig. 9-1) were used to calibrate and verify this regional analysis. These maps include 1) fault scarps formed in unconsolidated sediments in the Elko 1° by 2° Quadrangle (Barnhard, 1985), (2) Quaternary faults within the MX siting region (Ertec Western, Inc., 1981), (3) Quaternary faults in the Reno 1° by 2° Quadrangle (Bell, 1984), (4) late Cenozoic faults in the Walker Lake 1° by 2° Quadrangle (Dohrenwend, 1982), and (5) young faults related to earthquakes in north-central Nevada (Wallace, 1979). In aggregate these maps cover nearly 50% of the area of the state; however, they vary significantly in precision, style and scope. Therefore, to insure a high degree of regional consistency, most of this previous mapping was not incorporated directly into plate 9-1.

Three different types and scales of aerial photography were utilized for photogeologic interpretation (fig. 9-2). Nearly 80% of the area of the state was mapped using National High Altitude Program (NHAP), 1:58,000 nominal-scale, color infrared photography, and an additional 14% was mapped using Army Map Service (AMS) 1:60,000 and 1;63,000 nominal-scale, panchromatic photography. The detail of mapping in these areas is judged to be relatively consistent, and it is generally comparable to the previously published maps listed above. Mapping of the remaining areas (primarily within the Goldfield 1° by 2° Quadrangle), using NASA U-2, 1:115,000- to 1:124,000-scale, color infrared transparencies, is somewhat less precise.

This photogeologic mapping was transferred directly to 1/2° by 1° topographic quadrangle maps that were enlarged to the-scale of the photographs. These maps were then reduced to 1:250,000-scale and compiled on 1° by 2° topographic quadrangle maps. For those areas covered by previous mapping, the photogeologic maps were then compared with the previous mapping and substantial differences between maps were resolved. In all cases, the photogeologic analysis successfully identified a large majority (typically 80 to as much as 90%) of previously mapped young faults. (Previous mapping in the MX siting region (fig. 9-1), which was based on photogeologic analysis of 1:24,000-scale color aerial photography and extensive field verification, consistently identified about 15 to 20% more young faults than the present reconnaissance study.) The final 1:250,000-scale maps were manually digitized using a GTCO digitizing board connected to a Macintosh II minicomputer and then further reduced to the 1:1,000,000-scale of this report. The resulting vector files were converted to raster format (cell size = 200 m x 200 m) and analyzed to determine the approximate length and average orientation of each fault segment. These data are summarized in figure 9-3. Because plate 9-1 shows only a highly generalized version of the original mapping, the more detailed 1:250,000-scale maps are being published separately for most of the 1° by 2°

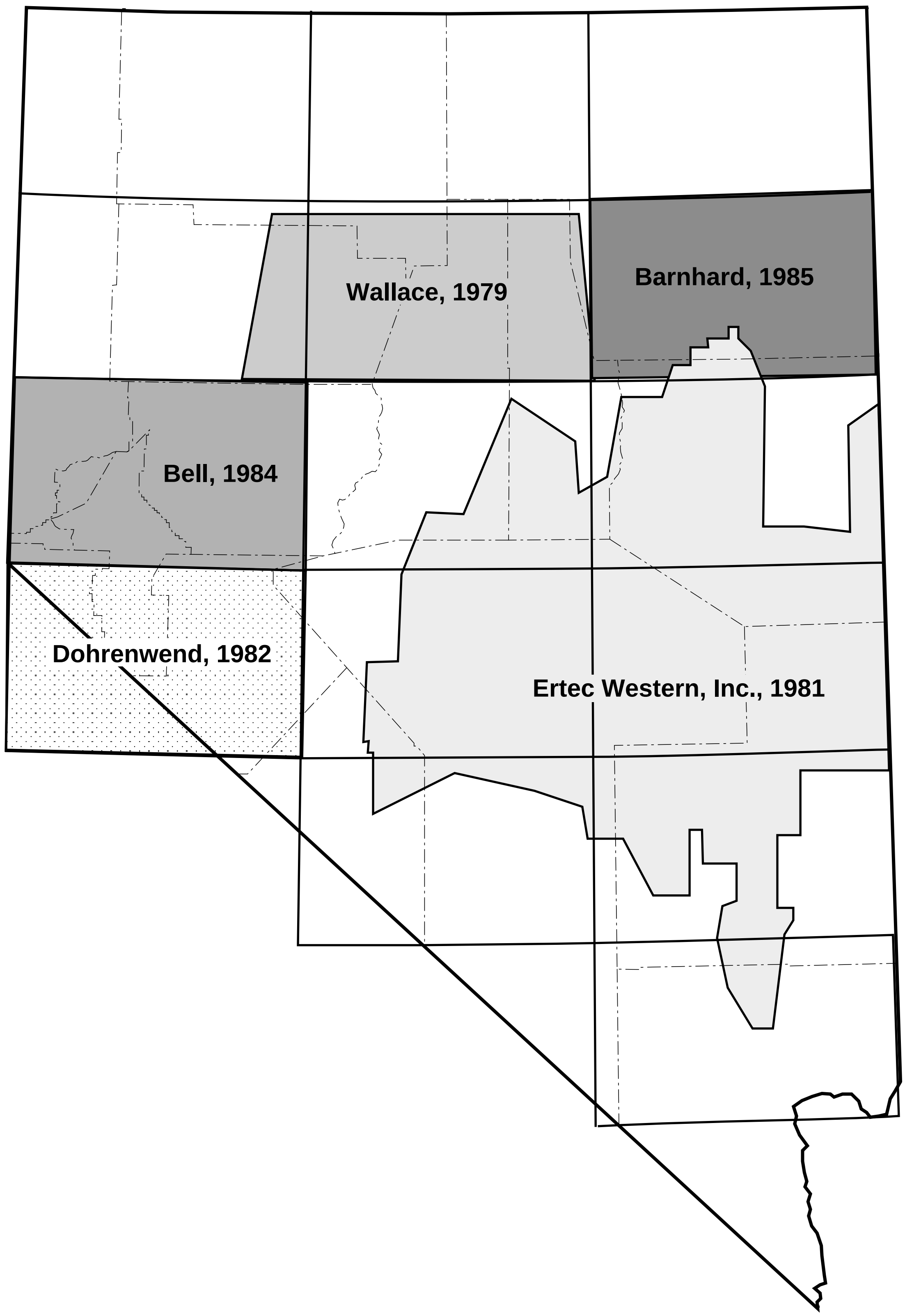

Figure 9-1. Map showing areas of previous mapping of young faults: Elko 1° by 2° Quadrangle (Barnhard, 1985), the MX study region (Ertec Western, Inc., 1981), Reno 1° by 2° Quadrangle (Bell, 1984), Walker Lake 1° by 2° Quadrangle (Dohrenwend, 1982), and the Winnemucca area (Wallace, 1979).

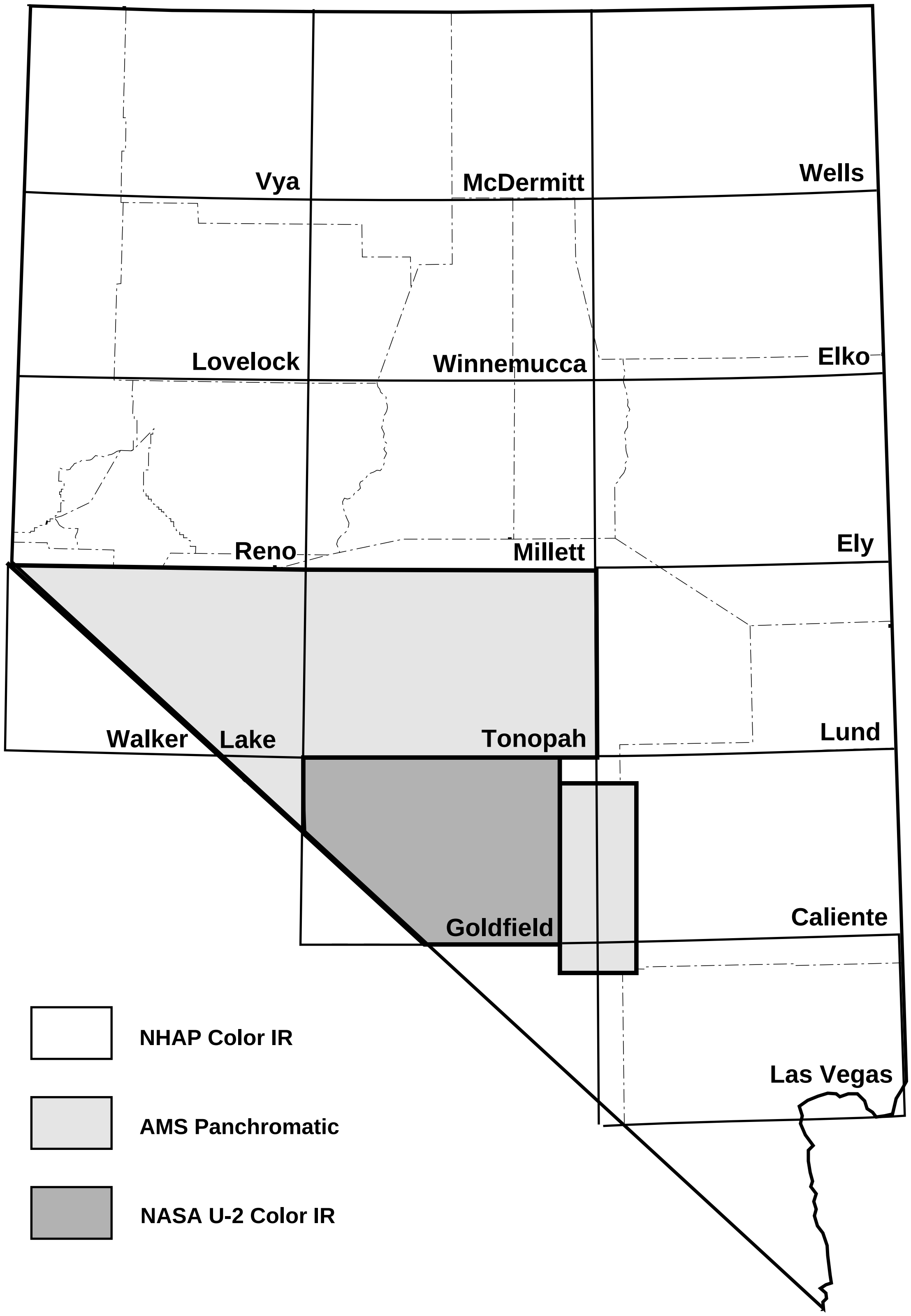

Figure 9-2. Areas covered by the three types of aerial photography used for preparation of this map: unshaded areas indicate coverage by National High Altitude Program (NHAP) 1:58,000 scale (nominal) color infra-red photography; light gray areas indicate coverage by Army Map Service 1:60,000 scale (nominal) panchromatic photography; and dark gray areas indicate coverage by NASA U2 1:115,000 to 1:124,000 scale color infra-red photography.

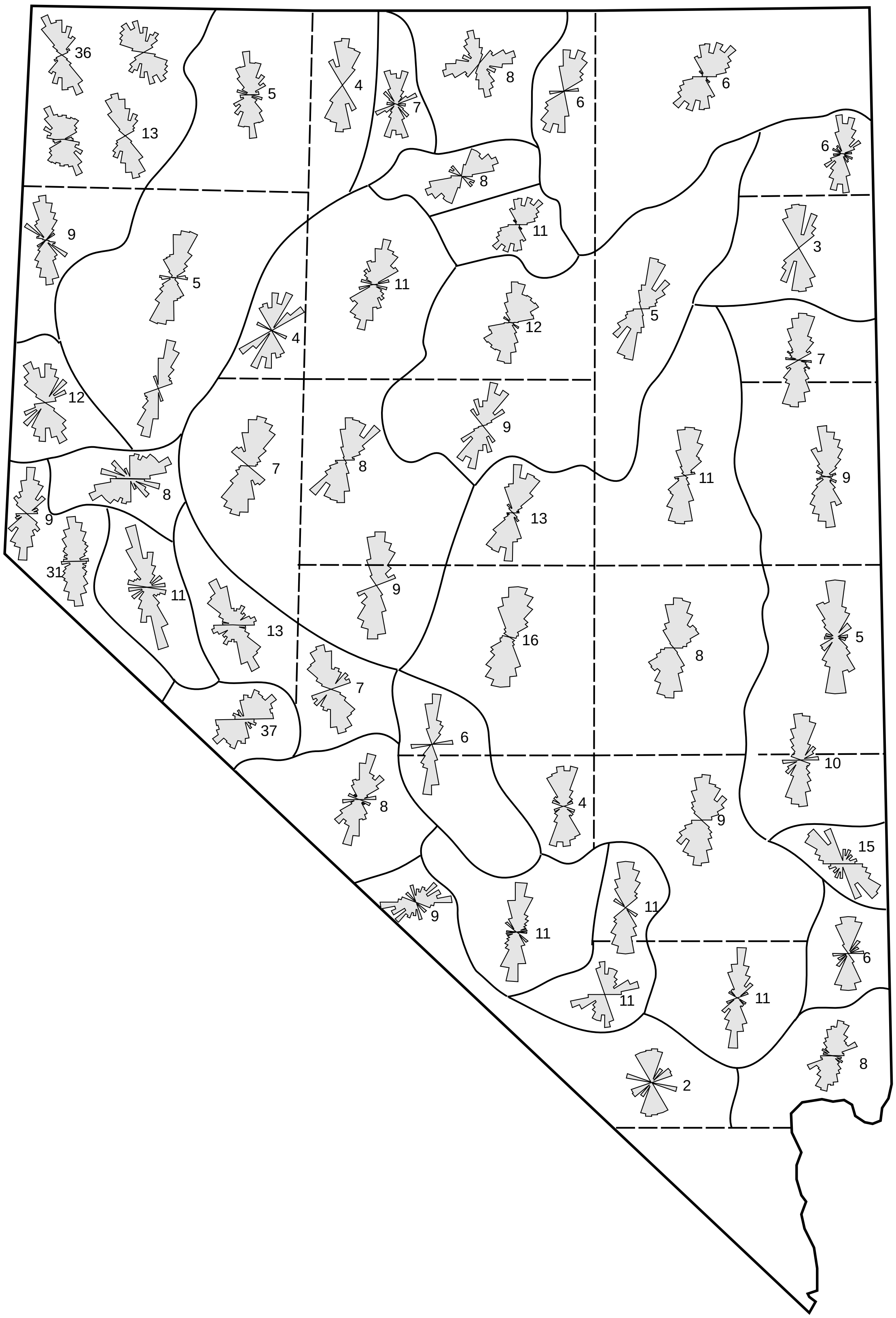

Figure 9-3. Map of Nevada showing general variations in the density and orientation of young faulting in neotectonic domains. Numbers indicate the mean density of young faulting (km/km^2).

topographic quadrangles within the state (e.g. Dohrenwend and others, 1991).

General ages of surficial deposits and erosion surfaces cut by young faults were estimated using a variety of photo-geologic and geomorphic criteria (table 9-1). Although these age estimates provide a general indication of the approximate timing of young faulting, they do not necessarily reflect the age of most recent surface rupture along any particular fault segment. Rather, they provide only maximum age constraints on this surface faulting. Moreover, age estimates based on photogeologic analysis of surficial deposits and erosion surfaces are, at best, both tentative and imprecise; and the distribution of these deposits and surfaces is inherently biased by geomorphic process and environment. For example, in those areas of the Great Basin where range uplift rates are low to moderate, remnants of older geomorphic surfaces tend to be concentrated in proximal piedmont areas, whereas younger surficial deposits tend to accumulate on distal piedmonts and basin flats. Consequently, young faults located in intrabasin areas are more likely to offset younger surface deposits then are faults located along range fronts or in proximal piedmont areas. Therefore, inferences based on these data regarding the temporal distribution of young fault activity should be used with caution.

In addition to the limitations imposed by photo and publication scales, at least one other factor also significantly constrains the resolution of plate 9-1. The photography used in this analysis, which was acquired under high sun angle conditions, is not well suited for the discrimination and mapping of subtle topographic features. Consequently, reexamination of any of the fault systems shown on plate 9-1, using larger-scale and/or lower-sun-angle aerial photography, would very likely reveal a substantial number of additional young fault segments.

PATTERNS OF LATEST TERTIARY AND QUATERNARY FAULTING

Several factors significantly influence the preservation of fault-related landforms and, therefore, the apparent distribution of young faults as indicated by the distribution of these landforms can be significantly biased. These factors include (1) composition, induration, and structural integrity of the rock or sediment type(s) underlying fault scarps; (2) local geomorphic environment of the scarp or other fault-related landforms; (3) regional climatic conditions and paleoclimatic variations; and (4) magnitude and recurrence of fault movement (Wallace, 1977; Bucknam and Anderson, 1979; Nash, 1980, 1984; Hanks and others, 1984; Mayer, 1984; Pierce and Coleman, 1986; Machette, 1986, 1988, 1989). Therefore, the distribution of young faults shown on plate 9-1 provides, at best, only an approximate picture of late Tertiary and Quaternary faulting. Specifically, faults having a long history of recurrent movement, juxtaposing bedrock and alluvium, or cutting late Cenozoic lava flows and/or welded ash-flow tuffs tend to be overrepresented whereas faults of pre-late Pleistocene age cutting unconsolidated surficial deposits and having either short histories of recurrent movement or long recurrence intervals tend to be underrepresented. Scarps developed on volcanic rocks may be preserved for periods of as much as 10 million years. By comparison, scarps on the fluvially active parts of piedmont surfaces would likely be completely destroyed within a few thousand years at most, and even on inactive piedmont surfaces, fault scarps on unconsolidated alluvial fill are significantly rounded within 10,000 years (Wallace, 1977), and low scarps would be sufficiently degraded to be unrecognizable on standard aerial photography within a few hundred thousand years (Wallace, 1977; Hanks and others, 1984; Machette, 1989). Moreover, scarps on active piedmont surfaces would likely be completely destroyed within a few thousand years at most.

Thus, low densities of young faulting in many areas underlain by unconsolidated alluvium (relative to adjacent areas underlain by late Tertiary volcanic rocks) very likely are more apparent than real. A particularly striking example of this bias occurs along the west flank of the Reveille Range in the south-central part of the state (Dohrenwend and others, 1985). Here, conspicuously-faulted, late Miocene basaltic lava flows extend from the range crest to the axis of the adjacent basin documenting extensive and widely distributed post-late-Miocene faulting across the intervening piedmont; however, no evidence of faulting is visible on the adjacent piedmont surface. This faulting, which is clearly defined by prominent scarps across the surfaces of the basalt flows, is sufficiently old and short-lived to have been completely obscured by subsequent fluvial erosion and/or alluviation on the piedmont. Similar relations in a number of other areas scattered across the Great Basin indicate that many piedmont areas are probably much more intensely faulted than surviving surficial expressions of this faulting would suggest.

These inherent biases notwithstanding, faults that juxtapose unconsolidated surficial deposits against bedrock or form prominent scarps in unconsolidated surficial deposits are more likely to be significant range and/or basin bounding structures than other faults. The overall correspondence between young fault zones and major range fronts is very high throughout most of the state, particularly across the central part between 38° and 41°N latitude. However, this overall perspective also reveals substantial variations in the density and orientation of young faults from one area of the state to another (fig. 9-3). The Great Basin is composed of an irregular mosaic of neotectonic domains, each domain being characterized by its own neotectonic history and style. Young fault densities and orientations, which are very likely related to variations in the timing, intensity and style of neotectonic activity, differ significantly and often abruptly from one neotectonic domain to the next. These differences are particularly striking within and adjacent to the Walker Lane belt, which subparallels the southwest boundary of the state, but they are also apparent in other areas as well.

Within areas that are largely underlain by middle to late Tertiary volcanic rocks (in the extreme northwest, north-central and southeast parts of the state and in several separate areas within the Walker Lane belt along the state's southwest margin), young fault orientations and densities are substantially different from other areas of the state. Within these diverse and widely separated areas, mean fault trace orientations are, for the most part, confined to two narrow fields (east-northeast to northeast and north-northwest to northwest) and mean young fault densities are typically high (averaging approximately 0.16 km/km^2). Elsewhere within

Table 9-1. General photogeologic and geomorphic criteria used to estimate general ages of piedmont surfaces.

Age	Depth of dissection	Drainage net morphology	Interfluve morphology	Geomorphic relations	Typical geomorphic environments	General field criteria
Holocene (O to 10 ka)	Shallow to none; generally < 3m	Predominantly radial from fan apex; channels typically poorly to moderately well defined	Typically poorly defined; bar and swale micro-topography common on most surfaces	Surfaces cut pluvial shorelines and (or) late Pleistocene glacial moraines	Distal piedmont surfaces; channels and terraces in proximal areas; (proximal surfaces along some highly active range fronts)	Unweathered to slightly weathered; very weak to weak soil development
Late Pleistocene (10 to 130 ka)	Shallow to moderate; typically 2-6 m	Predominantly distributary; however, some channels head on piedmont; well-defined channels	Typically well defined; surfaces broad and flat with abrupt margins	Surfaces overlain by pluvial shore-lines and (or) latest Pleistocene glacial moraines	Proximal to distal piedmont surfaces; some inset terraces	Weakly to moderately well developed soils; interlocking stone pavements
Early to middle Pleistocene (0.13 to 1.5 Ma)	Moderate to deep; commonly >10 m	Predominantly subparallel; well-defined channels	Well defined; older interfluve surfaces (ballenas) commonly narrow and irregular	Surfaces overlain by pluvial shore-lines and (or) latest Pleistocene glacial moraines	Generally confined to intermediate and proximal piedmont areas	Moderately to very well developed soils; interlocking to highly degraded stone pavements

the Walker Lane belt , young faulting is widely variable from one neotectonic domain to the next; indeed substantially more variable than in most other areas of the state. Mean fault trace orientations range between east-northeast and north-northwest, and fault densities vary from 0.02 to 0.31 km/km^2. Throughout the remainder of Nevada (large areas within the central and eastern parts of the state), the overall geomorphic expression of young faulting is much more consistent. Mean fault orientations are confined to a limited range between north and north-northeast, and they shift gradually from north-northeast-trending in western areas to north-trending in eastern areas. Mean fault densities, which range between 0.03 and 0.16 km/km^2, tend to be somewhat higher near the center of this region than around its periphery.

Caliente 1° by 2° Quadrangle

The distribution of young faulting in the Caliente Quadrangle is complex; fault densities range from 0.08 to 0.15 km/km^2 and fault orientations are widely variable. Within the Clover Mountains - Clover Valley area in the east-central part of the quadrangle, northwest-trending faults in Miocene volcanic rocks occur with an average density of approximately 0.15 km/km^2. Across the remainder of the quadrangle, four widely-spaced, northeast-trending fault systems of variable dimension and complexity disrupt an otherwise consistent pattern of relatively short, generally north-trending young faults. Major range-front faulting is limited to the south-central part of the quadrangle, along west and east flanks of the Sheep Range and the northwest flank of the Meadow Valley Mountains. Continuous zones of intrabasin faulting occur along the southeast flank of Sand Springs Valley and the east flank of Dry Lake Valley, and large clusters of intrabasin faults occupy the east side of Emigrant Valley and the north end of Pahranagat Valley. Faults displaying evidence of Late Quaternary offsets are mostly limited to the western two-thirds of the quadrangle. Fault systems with evidence of Late Pleistocene offset include the intrabasin faults of Sand Spring, Emigrant, and Pahranagat Valleys and the range-front faults of the Sheep Range; faults with Late Pleistocene and/or Holocene offset are limited to the east side of Dry Lake Valley and the northwest flank of the Meadow Valley Mountains.

Elko 1° by 2° Quadrangle

The density and orientation of young faults in the Elko Quadrangle are typical of the central Great Basin. Fault trace orientations are predominantly north-northeasterly in the west part of the quadrangle (areas to the west of Ruby Valley), whereas they are predominantly northerly in areas to the east of that valley. This change in orientation is part of a general west-to-east change across the central Great Basin from central Nevada to central Utah. Relatively little young faulting occurs in the east central and extreme northwest parts of the quadrangle. However, young faults are relatively uniformly distributed across the remainder of the map area where average young fault densities range between 0.05 and 0.07 km/km^2.

Nearly continuous range-front faults bound (1) the west flanks of the East Humboldt Range, Spruce Mountain Ridge, the Pequop Mountains, and the Maverick Springs Range, (2) both the east and northwest flanks of the Ruby Mountains, and (3) the east flank of the Cherry Creek Range. However, young range-front faulting is conspicuously absent along most of the length of the Goshute Range in the east central part of the quadrangle. The fault along the Cherry Creek Range is the northern continuation of a major range-front fault zone which bounds the east side of the Egan Range in the Ely 1° by 2° Quadrangle to the south. Nearly 160 km long, this fault zone is one of the longest in the central Great Basin. Major range-front fault zones showing evidence of substantial late Pleistocene (10-30 ka) and/or Holocene (0-10 ka) movement define the northwest margin of the Ruby Mountains and western margin of the East Humboldt Range. Other fault zones with evidence of late Pleistocene and/or Holocene movement are located along the northwest flank of the Maverick Springs Range just east of Ruby Lake and along the east flank of the Antelope Range and the Kinsley Mountains in the southeast corner of the quadrangle. Faults of probable Holocene age are located in the south end of Huntington Valley, the west central part of Ruby Valley, and the north end of Steptoe Valley.

Ely 1° by 2° Quadrangle

Young faults are distributed more or less uniformly across the western and central parts of the Ely Quadrangle (however, they are conspicuously less abundant along the quadrangle's eastern margin). Average young fault densities range between 0.09 and 0.11 km/km^2 and fault trace orientations are concentrated between N20°W and N30°E. Major fault zones showing evidence of late Pleistocene and/or Holocene displacement define most range fronts within the western 80% of the quadrangle. These major faults have predominantly northerly trends which contrast with the more northeasterly orientations of major fault zones in adjacent areas to the west.

Major faults along the east sides of the Egan and Schell Creek ranges extend almost continuously across the entire quadrangle from north to south. These faults, ranging from 130 to 160 km long, are among the longest in the Great Basin. Another nearly continuous zone of young faulting occurs along the west side of the Butte Mountains and appears to continue southward along the eastern side of Moorman Ridge in the eastern part of the White Pine Range. However, this zone is composed of two separate systems, the former down-faulted on the west and the latter down-faulted on the east. In the extreme southwest corner of the quadrangle, the predominant orientation of young faulting changes abruptly to a more northeasterly trend along the east side of the Diamond Mountains and the west side of the Pancake Range.

Holocene faulting is widely scattered across the quadrangle (although generally, faulting of this age can only be interpreted with confidence in the central parts of the intermontane basins which are occupied by modern playa and latest Pleistocene pluvial lake deposits). Small clusters of short, small-displacement faults and lineaments occur in Newark, Jakes, Butte, Steptoe and Spring valleys. In addition, faulting in southern Spring Valley includes a major fault with a large multiple-displacement scarp up to 20 m high. The latest displacement along this fault cuts latest Pleistocene pluvial lake shorelines and, therefore, probably represents a major Holocene earthquake event. Many of the lineaments in these central basin areas may represent cracks and fissures formed by seismically induced liquefaction and lateral spreading (Schell, 1985, 1987). It is noteworthy that most of these minor Holocene features have northeasterly orientations in contrast to the more northerly trends of the major range-bounding fault zones.

Goldfield 1° by 2° Quadrangle

The Goldfield Quadrangle extends across the Walker Lane Belt of the western Great Basin. The Walker Lane Belt, a complex zone of strike-slip displacement from 80 to 150 km wide, extends northwestward from the eastern Mojave Desert for approximately 700 km along the western margin of the Great Basin. This complex neotectonic zone is made up of several major structural blocks each of which has acted more or less independently of adjacent blocks during late Cenozoic Basin and Range extension (Carr, 1984; Stewart, 1987; Dohrenwend, 1987). The central part of the quadrangle includes four physiographically (and neotectonically) distinct areas within the Goldfield block, and the eastern part extends across the transitional boundary between the Walker Lane Belt and the central and southeast Great Basin (Dohrenwend, 1987). Consequently, the density and orientation of young faulting varies substantially from one area of the quadrangle to another.

Across the southern half of the quadrangle, large groups of short, bifurcating to cross-cutting, normal faults cut extensive areas of late Tertiary volcanic rocks. Fault densities in these areas range from 0.09 to 0.20 km/km^2; however these faults display little evidence of Quaternary activity and may be partly synvolcanic in origin. To the north, major range-bounding fault zones form the dominant mode of young faulting in the northwest part of the quadrangle (along the west flanks of the Silver Peak Range, Clayton Ridge, and the Montezuma Range and the east flank of the Weepah Hills) and in the northeast part (along the Kawich, Reveille, and Belted ranges). These areas of conspicuous Quaternary fault movement (with young fault densities of 0.04 to 0.08 km/km^2) are separated by a region, nearly 80 km across, of low ranges and extensive pediments that is almost entirely devoid of young faults This inactive region bears a strong geomorphic resemblance to areas in the northeastern part of the Mojave Desert.

All of the major range-bounding fault systems within the quadrangle display evidence of Quaternary activity. Several lesser range-front systems and four areas of extensive intrabasinal faulting (in Clayton Valley, Stonewall Flat, Yucca Flat and northern Death Valley) also display evidence of late Pleistocene movement. However, only one area of likely Holocene activity was identified by this photogeologic reconnaissance. This apparent lack of Holocene faulting may be due to the limited resolution of the small-scale NASA U-2 photography that was used to map the western 80% of the quadrangle.

Las Vegas 1° by 2° Quadrangle

The density and orientation of young faulting varies widely within the Las Vegas quadrangle. Young fault densities are moderately high (about 0.10 km/km^2) in northwest and north central areas and relatively low (0.022 km/km^2) in the southwest part of the quadrangle. Fault orientations are variable but are predominantly northerly in the northeast and north-central parts of the quadrangle and north-northeasterly to northeasterly elsewhere. These variations likely reflect substantial variations in neotectonic activity and style across southern Nevada. Major, northerly-trending range-front faults characterize most of the young faulting within the north-central part of the quadrangle. Within this area, fault zones showing evidence of Quaternary displacement bound both the west and east flanks of the Pintwater and Sheep ranges, and the west flanks of the Arrow Canyon Range, Meadow Valley Mountains, East Mormon Mountains, Muddy Mountains, and North Muddy Mountains. Young range-front faulting is present but considerably less prominent in other areas.

Areas of intrabasin faulting of Quaternary age include Frenchman Flat, Pahrump Valley, Las Vegas Valley, and the valley of California Wash. In the northeastern part of the quadrangle, three northerly trending fault clusters extend across broad, deeply dissected surfaces (including Mormon and Flat Top mesas) north and west of the Virgin River. For the most part, these fault clusters are well removed from surrounding uplands. Although many of the faults are marked by prominent scarps, the scarps are developed on extremely well-indurated pedogenic caprock. Consequently, these scarps may have been produced by surface faulting of early Quaternary and/or Pliocene age.

No faults of unequivocal Holocene age were identified in the Las Vegas Quadrangle. The youngest faults mapped by this study are short segments which displace deposits or surfaces of latest Pleistocene and/or Holocene age along the west and east flanks of the Sheep Range and the west flanks of the Northern Muddy Mountains, Meadow Valley Mountains and Arrow Canyon Range in the north-central part of the quadrangle.

Lovelock 1° by 2° Quadrangle

Young faulting within the Lovelock Quadrangle is also widely variable. West and northwest of the Black Rock and Simpson Creek Deserts (an area largely underlain by late Miocene volcanic rocks), young fault densities average approximately 0.09 km/km^2 and fault trace orientations average N349°W. In contrast, young faults are almost completely absent from a 20- to 25-km-wide, north-northeast-trending zone of extensive pediments which extends westward from and roughly parallels the valley of the Humboldt River in the east central part of the quadrangle. In all other areas of the quadrangle, major range-bounding fault zones are almost uniformly distributed with young fault densities averaging approximately 0.05 km/km^2 and fault trace orientations averaging about N15°E. All of these fault zones have been active during Quaternary (and quite possibly late Pleistocene) time, and at least five of them display abundant evidence of latest Pleistocene and/or Holocene movement (e.g., the west flanks of the Fox Range and Lake Ranges, southwest flank of the Granite Range, east flank of the Shawave Mountains, and west flank of the Humboldt

Range). Late Pleistocene and/or Holocene movement also has occurred within three NNE-trending systems of distributed intrabasinal faulting located in the central part of the quadrangle. The most significant of these is the southward extension of the fault zone which bounds the western flank of the Black Rock Range. This system is manifested as a continuous trend of prominent scarps that extends about 20 km across the Black Rock Desert (and transverse to its generally east-west trend in this area).

Lund 1° by 2° Quadrangle

Young faulting within the Lund quadrangle is fairly typical of the central Great Basin. Fault orientations are predominantly north-northeasterly in areas along and to the west of the Egan Range (which nearly bisects the quadrangle from north to south) whereas they are predominantly northerly in areas to the east of that range. Moreover, the density of young faults also changes from west to east across the quadrangle. Average young fault densities in the western part of the quadrangle are nearly twice as high as average densities in the eastern part (0.08 km/km^2 and 0.05 km/km^2 respectively).

Two major range bounding fault zones, each showing evidence of late Pleistocene and/or Holocene movement, form the most prominent young fault features in this quadrangle. These major fault zones define the western edge of the Quinn Canyon Range-Grant Range-White Pine Mountains and the western edge of the Egan Range. Other areas with evidence of late Pleistocene and/or Holocene movement are located on distal piedmonts and basin flats in southern Railroad Valley, central White River Valley, along the western margin of Lake Valley, and at the southern end of Snake Valley (in the extreme northeast corner of the quadrangle). One of these areas, the central part of White River Valley, contains the largest cluster of young intrabasin faults in the west central part of the Great Basin. The predominant north-northeasterly to northeasterly trend of these faults is typical of young intrabasin faults throughout the region.

McDermitt 1° by 2° Quadrangle

Faults of late Tertiary (?) age are locally abundant along or near the margins of a late Miocene volcanic tableland that occupies the north-central part of the McDermitt Quadrangle. Although little photogeologic evidence of Quaternary movement is apparent along any of these faults, some Pleistocene movement may have occurred locally. Major range-bounding fault systems are limited to the east and west margins of the quadrangle. Extensive and complex fault systems, with abundant wide-spread evidence of Pleistocene movement bound the west flank of the Santa Rosa Range near the western edge of the quadrangle and a northerly trending zone of distributed Pleistocene faulting has formed a chain of three small isolated basins along the eastern edge of the quadrangle. Latest Pleistocene and Holocene faulting is limited to the south-central part of the quadrangle where a complex zone of range-bounding and intrabasin faults, from 5 to 15 km wide, extends east-northeastward for about 60 km from the southeast flank of the Osgood Mountains to the west flank of the Tuscarora Mountains.

Millett 1° by 2° Quadrangle

The uniform distribution and high average densities (0.08 to 0.13 km/km^2) of young faults in the Millett quadrangle indicate that it is one the more tectonically active areas of Nevada. Areas of historic surface faulting, associated with the 1915 Pleasant Valley and 1954 Dixie Valley and Fairview Peak earthquakes, are located immediately west and north of the quadrangle (Slemmons, 1957; Wallace, 1979; Bell, 1984) Major range-bounding faults are distributed across the entire quadrangle. These include some of the largest and most continuous fault zones in Nevada. The largest of these, which defines the west flank of the Toiyabe Range, exceeds 120 km in aggregate length. Nearly all of these range-bounding systems display at least some evidence of latest Pleistocene and/or Holocene movement. Several complex areas of distributed intrabasinal faulting are also present, and all of these display at least some evidence of latest Pleistocene and/or Holocene movement. Some of these areas of distributed faulting occur along the trend of, or immediately adjacent to, major range-bounding faults (e.g., southern part of Reese River Valley, Monitor Valley, Antelope Valley (east)); however, others show no clear relationship to any particular range-front system (e.g., Antelope Valley (west) and Carico Lake Valley).

Reno 1° by 2° Quadrangle

Young faulting within the eastern part of the Reno Quadrangle is dominated by historic surface ruptures associated with four large (magnitude 6.6 to 7.1) earthquakes that occurred during 1954 (Slemmons, 1957; Bell, 1984). Two contiguous, generally north-trending zones of distributed surface rupture formed as a result of these earthquakes. One of these zones extends for more than 60 km along the west flank of the Stillwater Range and out into the central part of the Carson Sink; the other zone extends for more than 100 km from the area of Fairview Peak along the west flanks of the Clan Alpine and Louderback Mountains on the east side of Dixie Valley and along the east flank of the Stillwater Mountains on the west side of Dixie Valley. Areas of earlier Holocene faulting also are present within these zones along both flanks of the Stillwater Range and along the east flank of the Sand Spring Range to the south. Other major areas of Holocene faulting are present within a north-trending zone along the west side of Carson Valley and within a north-northwest-trending zone that extends from the southern part of Dodge Flat to the south end of Pyramid Lake. Most Pleistocene faulting is widely distributed across the quadrangle as relatively short faults and fault segments that vary widely in both orientation and spacing.

Tonopah 1° by 2° Quadrangle

Young faulting in the north and east parts of the Tonopah Quadrangle is highly typical of the central Great Basin. Young faulting is dominated by major range-front systems. Extensive young fault systems bound one or both flanks of all major ranges, and essentially all of these systems display at least some evidence of late Pleistocene movement. Intrabasin faulting is locally extensive (within Little Fish

Lake Valley and along the west flank of Ione Valley) and small clusters of intrabasin faults are scattered across the quadrangle. Young fault densities are high (0.09 to 0.16 km/km^2) and fault trace orientations are predominantly north to north-northeast trending. In contrast, young faulting in the southwest part of the quadrangle (which extends across the transition between the Walker Lane belt and the central Great Basin) differs substantially from the remainder of the area. Fault densities are moderate (about 0.6 km/km^2), fault trace orientations are widely variable, and major range-front faulting is limited to the northwest flank of Lone Mountain and the west flank of the San Antonio Mountains. Also within this area, surface ruptures associated with the 1932 Cedar Mountain earthquake occurred within a northwest-trending zone of oblique slip that extends along the quadrangle's west margin from Dry Lake through Stewart Valley (Gianella and Callaghan, 1934).

Vya 1° by 2° Quadrangle

Quaternary faulting is concentrated in the central and eastern parts of the Vya Quadrangle. The western half of the quadrangle, an area largely underlain by late Tertiary volcanic rocks, is characterized by widely distributed and locally pervasive swarms of northwest and/or northeast trending faults. These faults appear to be mainly of pre-Quaternary age. Major range-bounding fault systems are largely limited to the central and eastern parts of the quadrangle. Range-bounding fault zones bound the west flank of the Black Rock Range, the east flanks of Rock Spring Table, Pueblo Mountain, and the Bilk Creek Mountains, and both the east and west flanks of the Jackson Mountains and the Pine Forest Range. Most of these range-bounding systems show evidence of latest Pleistocene and/or Holocene movement. Other areas of significant late Pleistocene and/or Holocene faulting include the southern end of Long Valley (on the western edge of the quadrangle) and several areas in the eastern part of the quadrangle (the east side of Desert Valley, Thousand Creek/Pueblo Valley, and the west flank of the Montana Mountains). Prominent fault scarps in unconsolidated alluvium are largely limited to these areas.

Walker Lake 1° by 2° Quadrangle

The Walker Lake Quadrangle extends across the central part of the Walker Lane belt from the Sierra Nevada to the central Great Basin; consequently, several neotectonic domains, clearly defined by contrasting orientations and densities of young faulting, occur within this area. These include: (1) Four major range-front fault systems dominate the northwest and north-central parts of the quadrangle. These high-angle, dip-slip fault systems trend generally north to north-northwest along the east flanks of the ranges they bound (the Pine Nut Mountains, Wellington Hills, Singatse Range and Wassuk Range). Intrabasin and intrarange faulting is also common within this area and typically occurs as north-trending subparallel groups of short, closely spaced faults. (2) Five northwest-trending dextral strike-slip faults of the Walker Lane dominate young faulting in the northeast part of the quadrangle. These faults are characterized by relatively straight, continuous traces as much as 20 km long and by subsidiary faults that branch and splay from these main traces. (3) Farther to the northeast, in the extreme northeast corner of the quadrangle, north-northeast trending faults mark the southwest margin of the central Great Basin. All of these faults display evidence of Quaternary movement, and a few short traces experienced surface rupture during the Cedar Mountain earthquake of 1932 and the Dixie Valley-Fairview Peak earthquakes of 1954 (Gianella and Callaghan, 1934; Slemmons, 1957). (4) A broad zone of northeast to east trending faults extends eastward from Mono Lake, across the Adobe and Anchorite Hills and along the Excelsior Mountains. Young faulting within this zone is dominated by two contrasting styles: short, closely spaced, subparallel, dip-slip faults forming prominent fault scarps in Pliocene and Quaternary volcanic rocks and widely separated, east-trending faults with some left-oblique Quaternary displacement.

Wells 1° by 2° Quadrangle

Young faults in the Wells Quadrangle are less abundant and less well defined than in most other areas of Nevada. Young fault densities are relatively low, averaging about 0.06 km/km^2 throughout most areas of the quadrangle. Major range-bounding faults are limited to three general areas: the east flank of the Independence Mountains on the extreme western edge of the quadrangle, the east flank of the Granite Range in the east-central part of the quadrangle, and a general northerly trending alignment of three fault zones which nearly bisect the quadrangle just west of 115°W longitude. Only those major range-bounding fault zones along the Granite and East Humboldt ranges show evidence of possible late Pleistocene (10-130 ka) faulting. Other areas of possible late Quaternary movement occur on the east flank of the Adobe Range, along the northwest margin of Goshute Valley and along the northeast and northwest margins of Pilot Creek Valley. All of these areas lie in the southern half of the quadrangle and most are located in the south-central to southeastern part. Evidence of possible Holocene faulting is restricted to the northwest flank of the East Humboldt Range.

Winnemucca 1° by 2° Quadrangle

The Winnemucca Quadrangle lies across the northern end of the Central Nevada Seismic Zone, one of the most tectonically active areas in the Great Basin (Wallace, 1977; Thenhaus and Barnhard, 1989). This zone trends generally northward into the southwestern part of the quadrangle where historic fault scarps, formed during the 1915 Pleasant Valley earthquake, score the west flanks of the Tobin Range and the Sou Hills. Young fault densities are uniformly high across most of the quadrangle, ranging between 0.11 and 0.12 km/km^2. Widespread range-bounding fault systems, displaying evidence of latest Pleistocene and/or Holocene movement, bound the west or northwest flanks of essentially all of the major ranges within the quadrangle. Intrabasinal swarms of young faults, most notably within Dixie, Grass, Dry Lake, Antelope, Reese River, Boulder, and Crescent Valleys, also show evidence of latest Pleistocene and/or Holocene activity. With the exception of the area northeast of the Humboldt River where the incidence of late Quaternary faulting is somewhat less than elsewhere in the quadrangle, no regional trends of changes in young fault density or orientation are apparent.

GENERAL CONCLUSIONS

Late Cenozoic faulting is a primary determinant of basin geometry throughout the Great Basin. Young fault density, orientation and activity vary widely across the region and commonly differ significantly from one basin to the next. Consequently, basin configurations are also widely variable and subsurface basin geometry must be analyzed on a case by case basis.

General characteristics of young faulting within the state of Nevada include:

1. a close similarity of young fault orientation and density within most areas (a) north and east of the Walker Lane belt and (b) not underlain by late Tertiary volcanic rocks,
2. substantial variations in young fault orientation, density and activity among the various domains of the Walker Lane belt,
3. pervasive, dip-slip faulting in areas underlain by late Miocene and Pliocene volcanic rocks. (Young fault densities in these areas are substantially higher than in most other areas of the state and fault scarp orientations are more northeasterly or northwesterly trending.),
4. a predominance of dip-slip faulting (The most conspicuous areas of strike-slip faulting are confined to portions of the Walker Lane belt which subparallels the California-Nevada boundary.),
5. a strong genetic association between young faulting and major range fronts (The great majority of major range fronts within the state have undergone at least some fault offset during Quaternary time, and the longest, most continuous fault systems are typically associated with the tallest, most continuous range fronts.),
6. a tendency for the segmentation of the longer fault systems (Even the limited resolution afforded by this photogeologic reconnaissance indicates that many range-front fault systems are composed of several segments with conspicuously different ages of latest surface offset.),
7. a wide variability in intrabasin faulting ranging from small isolated fault scarps and lineaments to large clusters of scarps and lineaments as much as 30 km long and 10 km wide (Many of these larger fault clusters trend obliquely across basin axes and across the general trend of most major range- and/or basin-bounding faults.).

Although young fault density, orientation and activity vary widely across the state, a few general regional trends can be discerned. These include:

1. a conspicuous concentration of historic and Holocene faulting within the area of the central Nevada seismic belt,
2. a concentration of the longer, more continuous young faults in the central part of the state (Major range-front fault systems are conspicuously less abundant within large areas of the Walker Lane belt and in the extreme northern and southern parts of the state.),
3. a regional shift in fault trace orientation within the central part of the Great Basin (central and eastern Nevada) from north-northeast trends in western areas to north-trends in eastern areas, and
4. a tendency for higher young fault densities in the central part of the central Great Basin than around the periphery of that region.

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