STRIKE-SLIP, NORMAL, AND DETACHMENT FAULTS IN THE NORTHERN GILLIS RANGE, WALKER LANE OF WEST-CENTRAL NEVADA

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INTRODUCTION

The northern Gillis Range borders the east side of Walker Lake and lies within the Walker Lane of west-central Nevada, which, in this part of Nevada, is a 30 km. wide zone of northwest-trending right-lateral strike-slip faults. At least five major through-going lateral-slip faults constitute this fault zone, and an additional lateral-slip fault is inferred beneath the alluvial fill of Walker Lake valley, adjacent to the west margin of the Gillis Range (Fig. 1). The combined right-lateral displacement across these faults is at least 48 km. (Hardyman and others, 1975) and may be significantly more. The structural geology of this segment of the Walker Lane is dominated by Cenozoic faults superimposed on folded and thrust

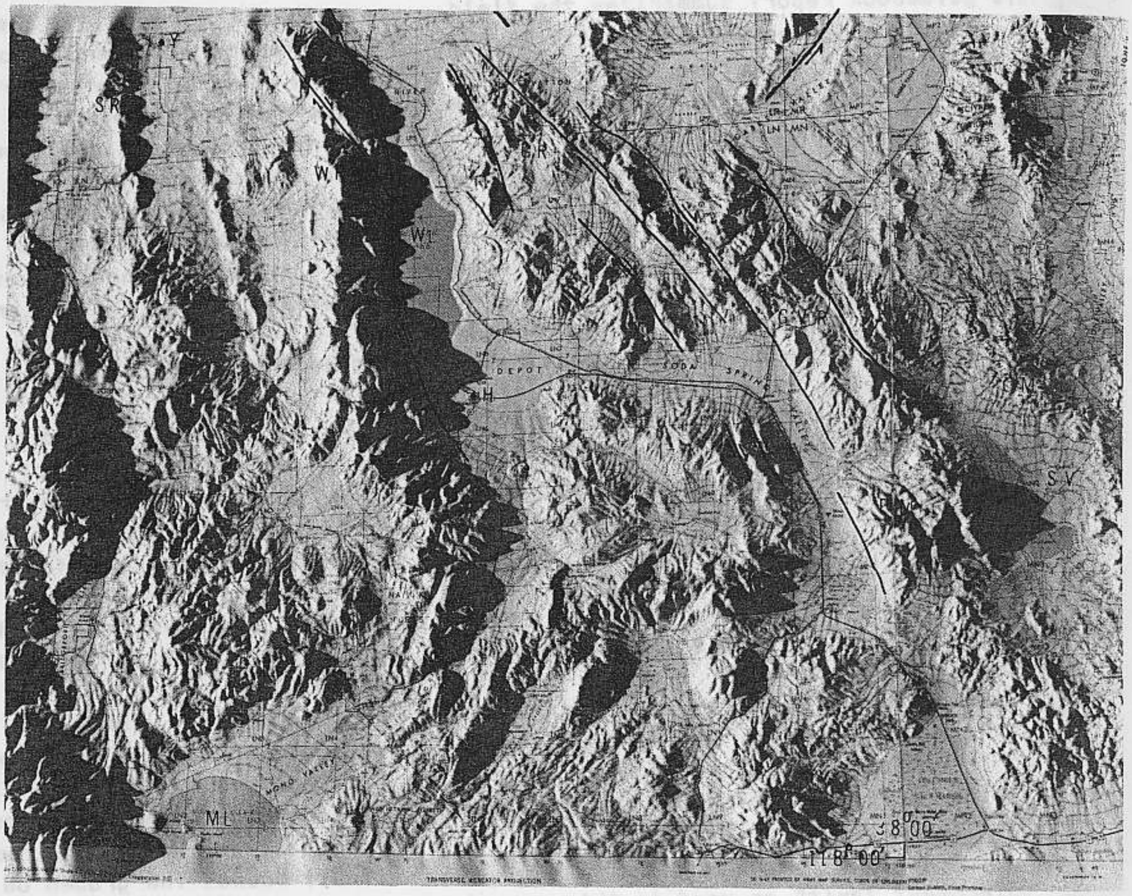

FIGURE 1: Photograph of a relief map of part of eastern California and west-central Nevada showing the major lateral slip faults referred to in this report. The Walker Lane structural zone is inferred to extend from the Wassuk Range on the West (WR) through Cedar Mountain on the east (CM). SR - Singatse Range, WR - Wassuk Range, WL - Walker Lake, GR - Gillis Range, GVR - Gabbs Valley Range, PM - Pilot Mountains, SV - Stewart Valley, CM - Cedar Mountain, ML - Mono Lake, Y - Yerington, H - Hawthorne.

faulted pre-Cenozoic rocks. Faults that cut Tertiary strata in the northern Gillis Range have been grouped into three categories (Hardyman, 1975); strike-slip faults, normal dip and oblique-slip faults, and flat to low-angle "detachment" faults[1].

The detachment faults are particularly well exposed in the northern Gillis Range. They display field relations that contrast with those of low angle faults described in the Singatse Range (Proffett, 1977; and this volume) to the west, and in many aspects, with the detachment faults in the Colorado River country of California, Arizona, and southernmost Nevada (see for example Frost and Martin, editors, 1982; and Frost, Cammeron, and Martin, 1982). This guidebook report summarizes the field relationships of the various faults in the northern Gillis Range and describes particularly the characteristics of the detachment faults.

GEOLOGIC SETTING

Bedrock in the northern Gillis Range consists of Triassic shallow-marine carbonate and clastic rocks along with a package of volcanic and volcaniclastic rocks containing relatively minor intercalated carbonates (Hardyman 1978). Preserved thicknesses of these rocks total more than 900 m. in aggregate thickness and are intruded by Mesozoic plutonic and hypabyssal rocks of diorite to granite compositions. The sedimentary rocks were folded at least twice prior to emplacement of the intrusive rocks (Hardyman and Oldow, in preparation).

The Mesozoic rocks are overlain by a thick section of Tertiary volcanic rocks that is dominated by a sequence of silicic ash-flow tuffs of Oligocene and Miocene age (see Ekren and others, 1980, for a complete description of these units). The lower units of this pyroclastic section, especially the Oligocene Mickey Pass Tuff (including both the Guild Mine and Weed Heights Members) and the Oligocene Singatse Tuff, are of particular importance to the structural geology of this part of west-central Nevada in that these units are regionally extensive (Fig. 2, this report; and Fig. 3 of Proffett, this volume). They occur west of the Walker Lane in the Singatse Range (where they were originally named by Proffett and Proffett, 1976), in the northern Wassuk Range to the east, and, across the Walker Lane fault zone, from the northern Gillis Range, southeast through the Gabbs Valley Range and farther southeast to Cedar Mountain. These units, together with younger ash-flow tuffs (whose distal parts also occur in the Singatse Range) compose the bulk of the rocks exposed in the Gabbs Valley and northern Gillis Ranges and provide excellent chronostratigraphic markers for use in comparing the structural styles of faulting across the Walker Lane.

STRUCTURAL GEOLOGY

The structural framework of the northern Gillis Range is that of a central northwest-trending rift zone or complex graben. It is bounded by two prominent northwest trending high-angle faults that separate the central graben from the structurally higher southwest and northeast flanks of the range (Fig. 3, and see Hardyman, 1980).

The Gumdrop Hills fault, which can be mapped for some 35 km. along strike to the southeast (see Fig. 3, Ekren and Byers, this volume) bounds the central graben on the east-northeast and the Agai-Pah Hills fault bounds the graben on the west-southwest. Exposures of pre-Tertiary basement rock occur in the flanks of the range, outboard of these two major bounding faults. Normal faults in the flanks of the range parallel these major faults, or are at moderate oblique angles to them, and are synthetic to the central graben.

Ash-flow tuffs younger than the Singatse Tuff (dated at about 27 m.y.) are

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[1] "Detachment fault" as used in this report refers to a flat or low-angle bounding surface along which a layer of rock has become separated, "detached", from underlying rock and along which there has been some tectonic transport. No connotation as to the origin of the fault plane or driving mechanism of movement is implied.

Age (m.y.)	Thickness (meters)				
	0-100	Tcm	TUFF OF COPPER MOUNTAIN (MIOCENE) Quartz latitic ash-flow tuff characterized by abundant accessory sphene. Restricted to area east of Benton Spring fault		
	0-25	Thp	Poinsettia Tuff Member Rhyodacitic ash-flow tuff		HU-PWI RHYODACITE (MIOCENE)
23.3 ± 0.6 (biotite)	0-100	Thg	Ghost Dance Lava Member Rhyodacitic flow breccia and lava		
22.8 ± 0.5 (biotite)	0-70	Thn	Nugent Tuff Member Rhyodacitic ash-flow tuff		
	0-300	Tsp	BLUE SPHINX TUFF (MIOCENE OR OLIGOCENE) Quartz latite ash-flow tuff characterized by extremely resorbed and "wormy" quartz phenocrysts		
25.0 ± 1.0 (sanidine) (lower unit)	67-95	Tgv	TUFFS OF GABBS VALLEY (MIOCENE OR OLIGOCENE) Three ash-flow tuff cooling units of rhyolite and quartz latite compositions		
	0-46	Tbp	Petrified Spring Tuff Rhyodacite ash-flow tuff; only locally present		BENTON SPRING GROU (OLIGOCENE)
	0-305	Tbs	Singatse Tuff Quartz latite ash-flow tuff		
	0-67	Tbmw	Weed Heights Member Ash-flow tuff, zoned from alkali rhyolite near the top to quartz latite at the base	Mickey Pass Tuff	
27.6 ± 0.8 (sanidine)	0-200	Tbmg	Guild Mine Member Ash-flow tuff, zoned from rhyolite at the top to rhyodacite at the bottom.		

Diagram of typical ash-flow tuff coooling unit

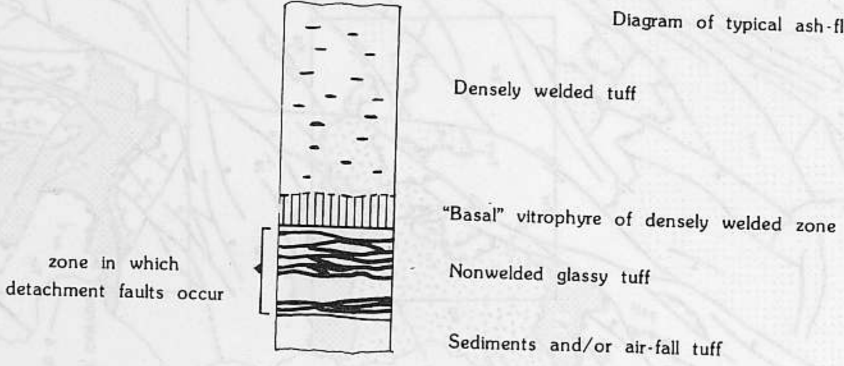

FIGURE 2: Principal volcanic rock units in the Northern Gillis Range.

(MIOCENE)

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PRING GROUP
OCENE)

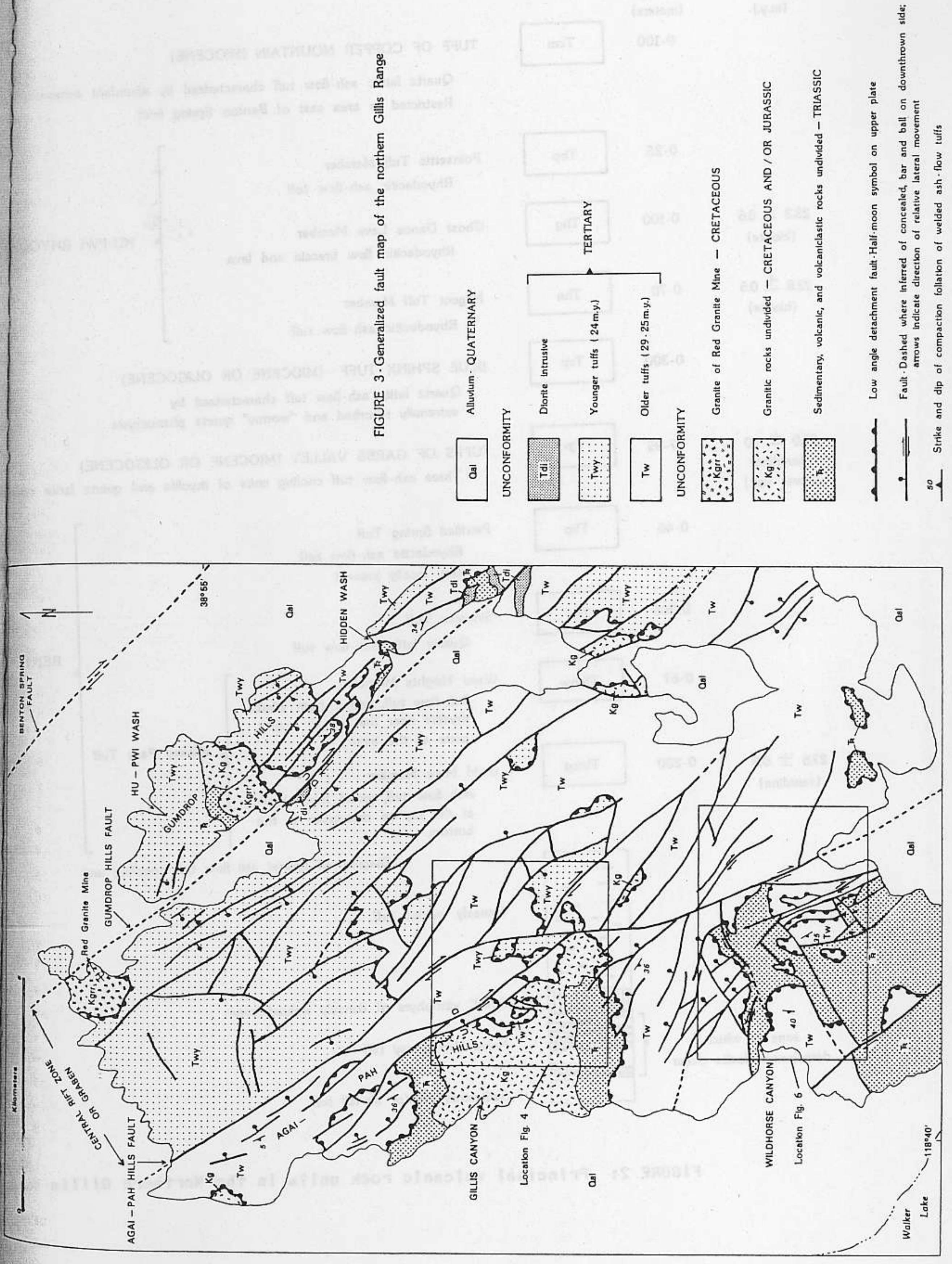

FIGURE 3 Generalized fault map of the northern Gillis Range

nearly absent from the Agai-Pah Hills west of the Agai-Pah Hills fault on the west-southwest but are conspicuous within the central graben; and, locally they form faulted cuestas in the Gumdrop Hills east-northeast of the Gumdrop Hills fault (Fig. 3). The thickest accumulations of post-Singatse tuffs are in the northwestern part of the central graben. These younger tuffs here dip gently to moderately east and are repetiously down faulted to the west. The older Singatse and Mickey Pass Tuffs form most of the outcrops in the medial and southeast parts of the central graben along with scattered outcrops of pre-Tertiary rocks. Directions of dip of these older tuffs and directions of fault displacements are variable in this part of the graben. These relationships, together with elevations of contacts, indicate that the graben is complex and structurally lower in its northwest part.

In addition to the through-going Agai-Pah Hills and Gumdrop Hills faults, rocks within the northern Gillis Range are cut by ubiquitous high-angle faults. Some of these can be shown to be predominantly lateral-slip faults. Others are dip or oblique-slip faults that together impart a strong northwest fabric to the northern Gillis Range. These latter faults trend parallel to the northwest-trending major and minor strike-slip faults or trend obliquely to them. For the most part the normal faults cut the flat to low-angle detachment faults and do not appear to flatten appreciably with depth; however, some minor faults may be of the listric type as observed locally in the Gabbs Valley Range (Ekren and Byers, this volume).

The northern Gillis Range lies between the regionally extensive Benton Spring lateral-slip fault (approximately 90 km. of known strike length) on the east and a right-lateral slip fault that I interpret to exist west of the range, beneath the alluvial fill of Walker Lake valley. In this position, between initially en-echelon left-stepping right-slip faults, the northern Gillis Range with its Tertiary volcanic cover was initially compressively arched and sheared, and was subsequently extended thereby producing a central rift zone with bordering flanks of outward dipping Tertiary strata that are cut by normal faults synthetic to the central graben.

STRIKE-SLIP FAULTS

RIGHT-SLIP FAULTS

Gumdrop Hills Fault

This fault is named after the Gumdrop Hills, a series of prominent domical lava capped hills along the northeast flank of the northern Gillis Range (Fig. 3). A distinct Mesozoic granite, the granite of Red Granite Mine (Hardyman, 1980), exposed east of the fault in the Gumdrop Hills has been displaced 6.4 km. right-laterally along this fault. This is consistent with the apparent right-lateral shift of Tertiary tuffs across the fault farther southeast in the Nugent Wash area (Fig. 3, Ekren and Byers, this volume). It is also compatible with an apparent displacement of about 9 km. for Triassic sedimentary rocks along the south flank of the Gabbs Valley Range (Ekren and Byers, this volume).

The Gumdrop Hills fault is concealed by alluvium for most of its length in the northern Gillis Range. Where exposed in bedrock between the alluvial valleys of Hu-Pwi Wash and Hidden Wash; however, the fault is sharply defined by a deeply weathered zone consisting of cataclastically crushed welded tuff bordering a central zone of clay gouge. Blocks of smashed limestone are present in the gouge zone that, at the closest, were derived from outcrops 1.3 km. to the southeast.

Small intrusive masses of Tertiary diorite are localized along this fault from Hidden Wash in the northern Gillis Range southeast to the Nugent Wash area (Fig. 3; Ekren and Byers, this volume). Southeast of Nugent Wash latite was intruded along this fault. The intrusion of diorite and latite along this fault indicate deep crustal penetration of this structure.

Agai-Pah Hills fault

The Agai-Pah Hills fault can be traced for about 20 km. from the north end of the

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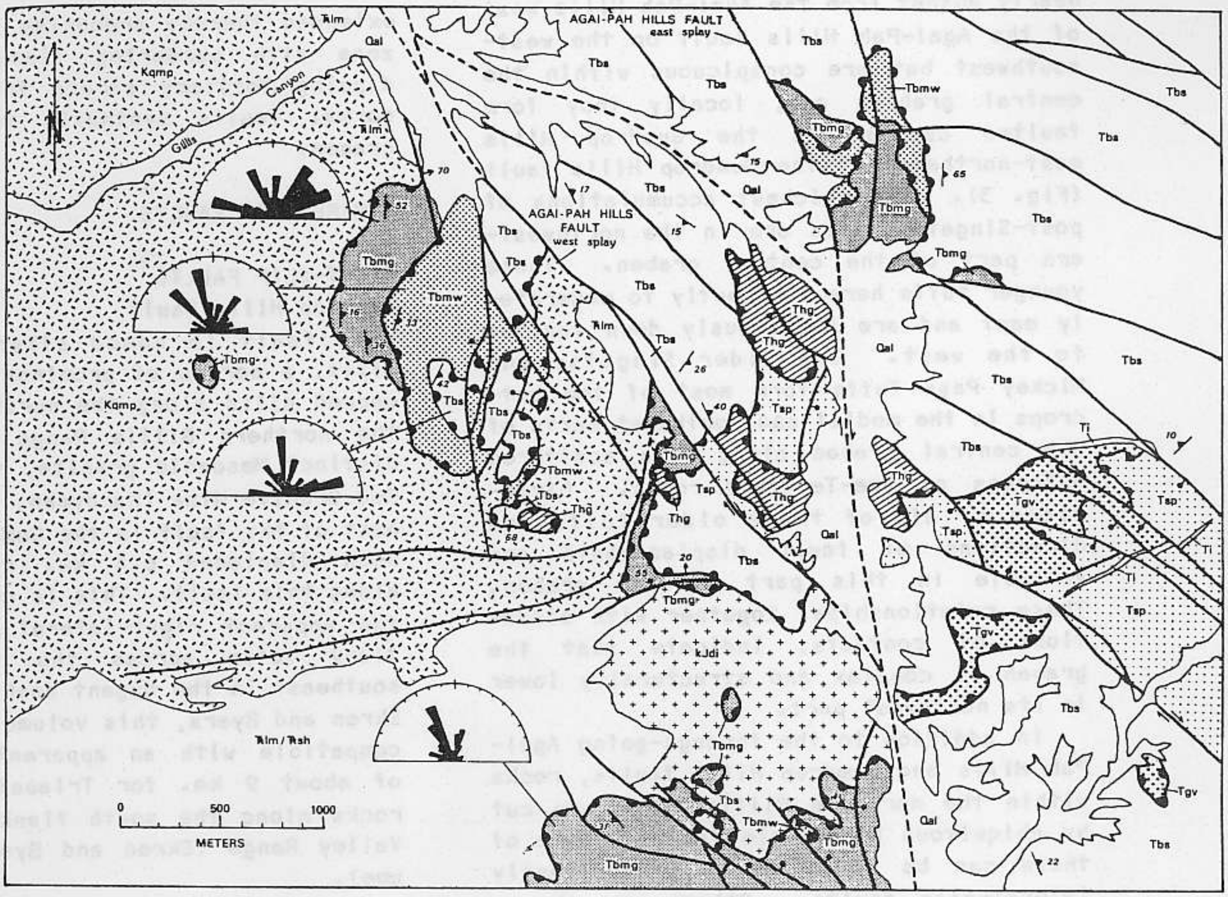
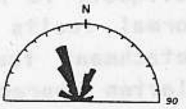


FIGURE 4 · Geologic map of the upper Gillis Canyon area, Agai-Pah Hills, northern Gillis Range

Generalized from Hardyman, 1978

Qal	Alluvium (Quaternary)
Ti	Dike rocks (Miocene?)
Thg	Ghost Dance Lava Member of Hu-Pwi Rhyodacite (Miocene)
Tsp	Blue Sphinx Tuff (Miocene or Oligocene)
Tgv	Tuffs of Gabbs Valley (Miocene)
Tbs	Singatse Tuff
Tbmw	Weed Heights Member — Mickey Pass Tuff — Benton Spring Group (Oligocene)
Tbmg	Guild Mine Member
Kqmp	Gillis Canyon pluton (Cretaceous?)--porphyritic quartz-monzonite
kJdi	Diorite (Cretaceous or Jurassic?)
Tlm / Tsh	Limestone and shale undifferentiated (Triassic)
Tlm	Limestone (Triassic)

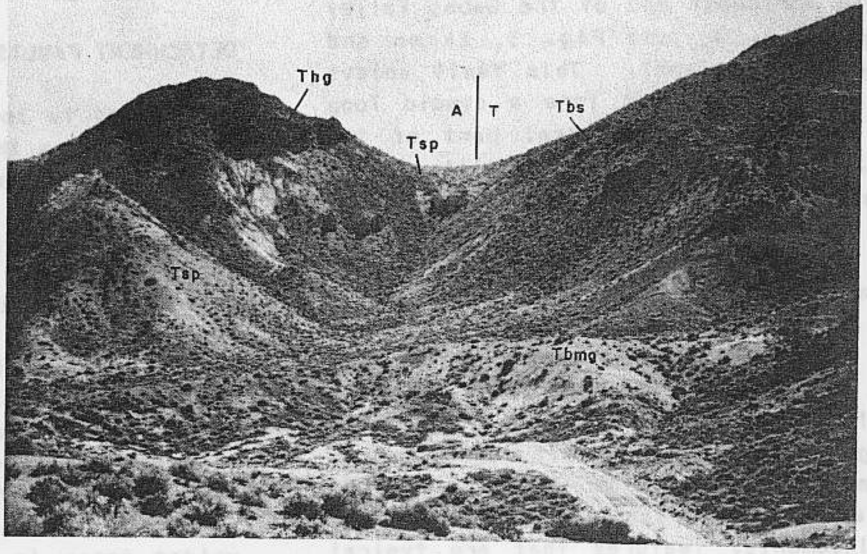


Rose diagram showing strike orientations of high-angle shear planes in detached densely welded tuff sheets

Low angle detachment fault-Half-moon symbol on upper plate

Fault-Dashed where inferred or concealed. Dip shown where known, bar and ball on downthrown side; arrows indicate direction of relative lateral movement

Strike and dip of compaction foliation of welded ash-flow tuffs



a.

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FIGURE 5: a) Upper Gillis Canyon area showing traces of Agai-Pah Hills lateral-slip fault and low-angle detachment faults. b) Brecciated Blue Sphinx Tuff along Agai-Pah Hills fault in saddle of above photograph. End of 4X4" claim post in lower left corner of photograph for scale.

Gillis Range southeast to the alluvial valley that extends east to Nugent Wash, at the northwest end of the Gabbs Valley Range (Fig. 3; and Fig. 3, Ekren and Byers, this volume). This fault splays into two faults that form a cymoid loop map pattern in the central part of the Gillis range. In the upper Gillis Canyon drainage (Fig. 4), the western splay of this cymoid loop juxtaposes Blue Sphinx Tuff against Singatse Tuff and alternately, along strike, the Guild Mine Member of the Mickey Pass Tuff (Fig. 5a). Where this splay fault crosses a low saddle, the Blue Sphinx Tuff along the fault is spectacularly brecciated (Fig. 5b). Elsewhere along strike, this fault displays an inconsistent pattern of juxtaposition of map units and variable apparent vertical displacements; features that are typical of strike-slip faults.

In the Wildhorse Canyon[2] area (Fig. 6) the Agai-Pah Hills fault strikes N30W, dips 84° east, and the rake of striations in the fault plane is 30° and plunge is towards the south. These fault plane data are consistent with the Agai-Pah Hills block on the west being relatively upthrown compared with the central graben block east of the fault. Lateral displacement on the Agai-Pah Hills fault is uncertain but it is probably at least 1.1 km. and may be as much as 9 km. (Hardyman, 1978).

LEFT-SLIP FAULTS

No major left-slip faults have been recognized within the northern Gillis Range. One high-angle east-striking fault in the lower reaches of Wildhorse Canyon (Fig. 3) displays slip line data indicating left-lateral movement. This fault along with other possible left-slip high-angle faults in the Wildhorse Canyon area are not major through-going faults, however, and are interpreted as complementary shears associated with the through-going northwest trending right-lateral faults.

DETACHMENT FAULTS

Flat lying to low-angle detachment faults are ubiquitous throughout the Gabbs Valley and Gillis Ranges, but are particularly well exposed in several localities in the northern Gillis Range. These faults are an integral part of the Cenozoic deformation in the Walker Lane and appear to be restricted to the zone of pervasive strike-slip faulting. The detachment faults are bedding plane-like faults in that they typically occupy the basal nonwelded parts of ash-flow tuff units or basal contacts of lava units. They do not generally toe-out or cut across densely welded zones in the ash-flow units. In the northern Gillis Range detachment faults rarely cut across section. In two localities a detachment fault in the lower part of the tuffs of Gabbs Valley (consisting of three thin ash-flow tuff cooling units) passes along strike to the base of the overlying Blue Sphinx Tuff or across one ash-flow tuff into a higher unit. The tuffs of Gabbs Valley in the Gillis Range exposures are, for the most part, nonwelded or only moderately welded.

In another example, on the south side of lower Wildhorse Canyon (Fig. 6), a stack of ash-flow tuffs of the Benton Spring Group (Guild Mine and Weed Heights Members of the Mickey Pass and the overlying Singatse), each in normal depositional contact with the other, dips to the west at 35-45°. The lower member, the Guild Mine Member, is in fault contact at its base with pre-Tertiary basement rocks. This fault also dips moderately to the west but apparently cuts across the Guild Mine Member (only moderately welded here) to the base of the Weed Heights Member. This relationship is not unequivocal, however, due to numerous vertical northeast-trending high-angle shear planes through these units. Many of these shear planes display horizontal striations.

The field characteristics of detachment faults in the northern Gillis Range are: 1) they displace younger over older strata, with or without stratigraphic omission

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[2] This is the Wildhorse Canyon of the Gillis Range--not to be confused with the Wildhorse Canyon of the Gabbs Valley Range (Ekren and Byers, this volume).

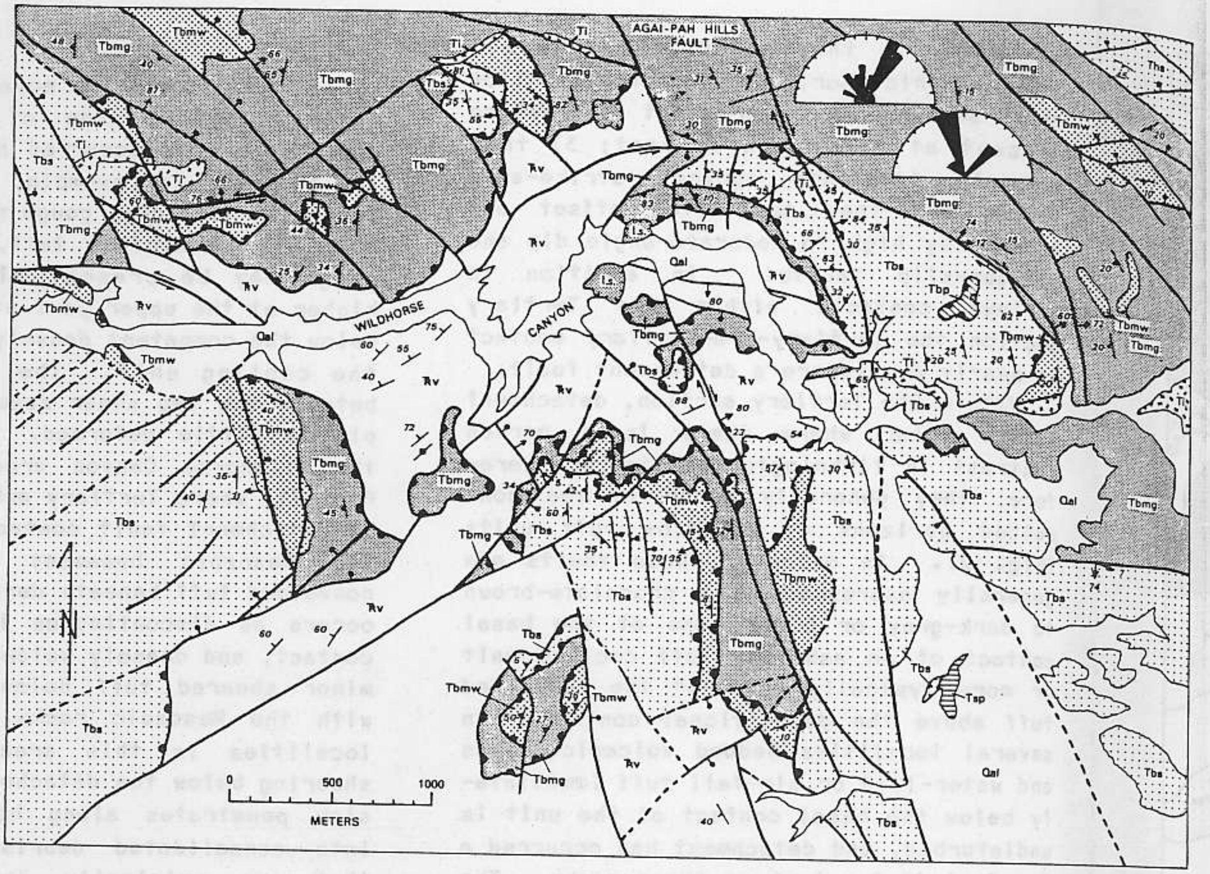

FIGURE 6 - Geologic map of the Wildhorse Canyon area

Generalized from Hardyman, 1978

Rose diagram showing strike orientations of high-angle shear planes in detached densely welded tuff she

Qal Alluvium (Quaternary)

Ti Dike rocks (Miocene?)

Tsp Blue Sphinx Tuff (Miocene or Oligocene)

Tbp Petrified Spring Tuff

Tbs Singatse Tuff

Tbmw Weed Heights Member

Tbmg Guild Mine Member

Mickey Pass Tuff

Benton Spring Group (Oligocene)

TRv Volcanic, volcaniclastic and intrusive rocks undivided (Triassic)

22 Strike and dip of compacton foliation of welded ash-flow tuff

50 Strike and dip of bedding

33 Contact - Dip shown where known

l.s. landslide mass

Low angle detachment fault - Half-moon symbol on upper plate

80 Fault - Dashed where inferred or concealed. Dip shown where known, bar and ball on downthrown side; arrows indicate direction of relative lateral movement

of units; 2) they occur at nearly all stratigraphic horizons in the ash-flow tuff sequence but are not everywhere present at any given contact; 3) they commonly terminate against strike-slip faults and they are often offset and rotated by high to moderate-angle dip and oblique-slip faults. In addition to various contacts within the Tertiary section the Tertiary-pre-Tertiary contact is nearly everywhere a detachment fault.

Within the Tertiary section, detachment faults occur where there is a marked contrast in lithologic competency; therefore, they generally occur in the nonwelded horizons of ash-flow tuff units (Fig. 2). In outcrop, these faults are generally expressed as a chocolate-brown to dark-grey or black zone at the basal contact of an ash-flow tuff cooling unit or more typically "within" the nonwelded tuff above the depositional contact. In several localities bedded volcaniclastics and water-laid or air-fall tuff immediately below the basal contact of the unit is undisturbed, and detachment has occurred a few feet (1-2 m.) above these rocks. The chocolate-brown zones range from as little as 1 or 2 ft. to as much as 20 ft. (7 m.) thick. The clay gouge in these zones displays nearly ubiquitous and often spectacular slickensided surfaces. The general orientation of the most pronounced slickensided surface is generally parallel to the flat lying detachment fault. Chunks or splinters of gouge displaying individual slickensided surfaces one foot or more in length have been observed in some of the clay gouge zones. The clay gouge zones are generally enveloped by cataclastically crushed and sheared non- to moderately-welded tuff. In some places these "sanded" zones are tens of feet (several meters) thick. Thin shear planes or low-angle "shear veinlets" are not uncommon in the more coherent tuff above the sanded zones. Thin sections of tuff from these cataclastically "sanded" and clay gouge zones commonly contain strained quartz grains set in a comminuted matrix of nearly opaque clay and tiny glass fragments. Not uncommonly the sides of lithic fragments in the clay gouge or cataclastic tuff are entirely slickensided.

In some localities movement within the basal nonwelded zone of a tuff sheet appears to have occurred along anastomosing planes. For example, a "sanded" tuff zone with some clay gouge may occur at the base of a nonwelded tuff, and good clay gouge may be present also a few feet higher at the upper part of the zone, just below the competent densely welded tuff of the cooling unit. The nonwelded tuff between the two shear zones in this example is little deformed. Locally, as in the Wildhorse Canyon area (Fig. 6, and Fig. 7), where Tertiary ash-flow tuffs are in detachment fault contact with underlying Mesozoic basement rocks, sheared nonwelded tuff beneath densely welded tuff occurs as discontinuous lenses along the contact, and densely welded tuff with only minor sheared tuff below is in contact with the Mesozoic rocks. In scattered localities in this area, the zone of shearing below the detached densely welded slab penetrates along horizontal planes into consolidated debris flow material that was originally deposited on the Mesozoic erosion surface. Here, as in all localities where Tertiary rocks are in detachment fault contact with underlying pre-Tertiary rocks, the detachment faults do not appreciably penetrate the basement rocks and no mylonite zone is present below the Tertiary-pre-Tertiary interface.

Compaction foliation in ash-flow tuff units above detachment faults is locally conformable with the detachment fault but more commonly it is disconformable to the detachment fault (Fig. 6). Attitudes of densely welded tuff above detachment faults may be quite consistent, dipping 30-50° into the detachment faults. Generally, however, the attitudes are highly inconsistent. Within a single detached unit, dips may vary as much as 50° and strikes as much as 60°. Where the detachment fault dips at a low to moderate angle, dips of the overlying detached tuff may be antithetic to the dip of the fault or they may dip in the same direction as the detachment fault.

Likewise, dips of tuffs in detached slabs are highly variable and nonsystematic across high-angle faults, especially

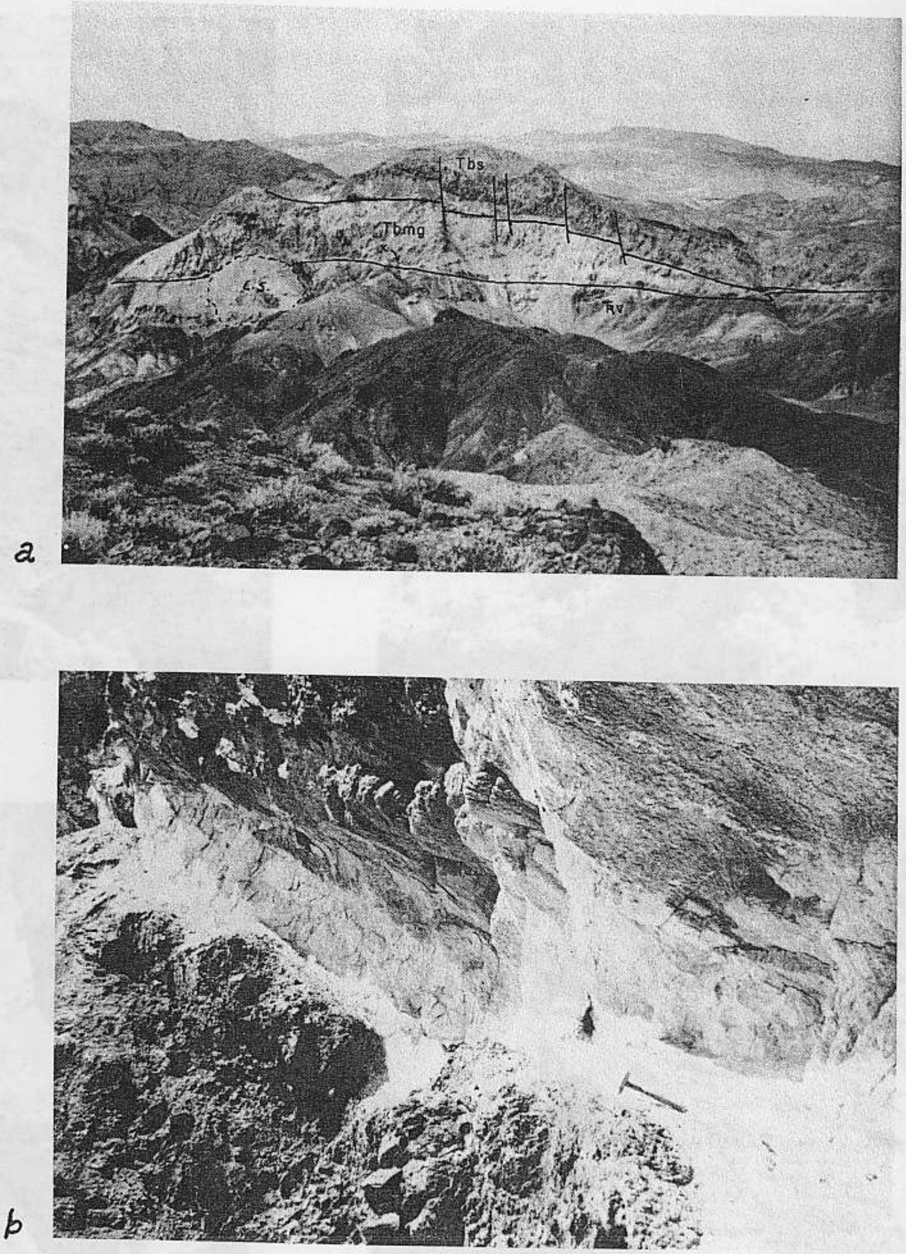

FIGURE 7: a) Tertiary - pre-Tertiary contact relations at bend in canyon of ridge forming north wall of Wildhorse Canyon. View is to the north, across the canyon. Singatse Tuff is detached over Guild Mine Member of the Mickey Pass Tuff, which is in turn in low-angle detachment fault contact with the underlying Mesozoic basement. b) Guild Mine Member in detachment fault contact with underlying Mesozoic volcanic rocks. White zone is pervasively sheared non-welded basal Guild Mine Member. Handle of hammer (lower right) is approximately parallel to compaction foliation in the overlying densely welded tuff at this locality and to the dip of the detachment fault. (Location of this photograph is marked by "X" in photograph a above).

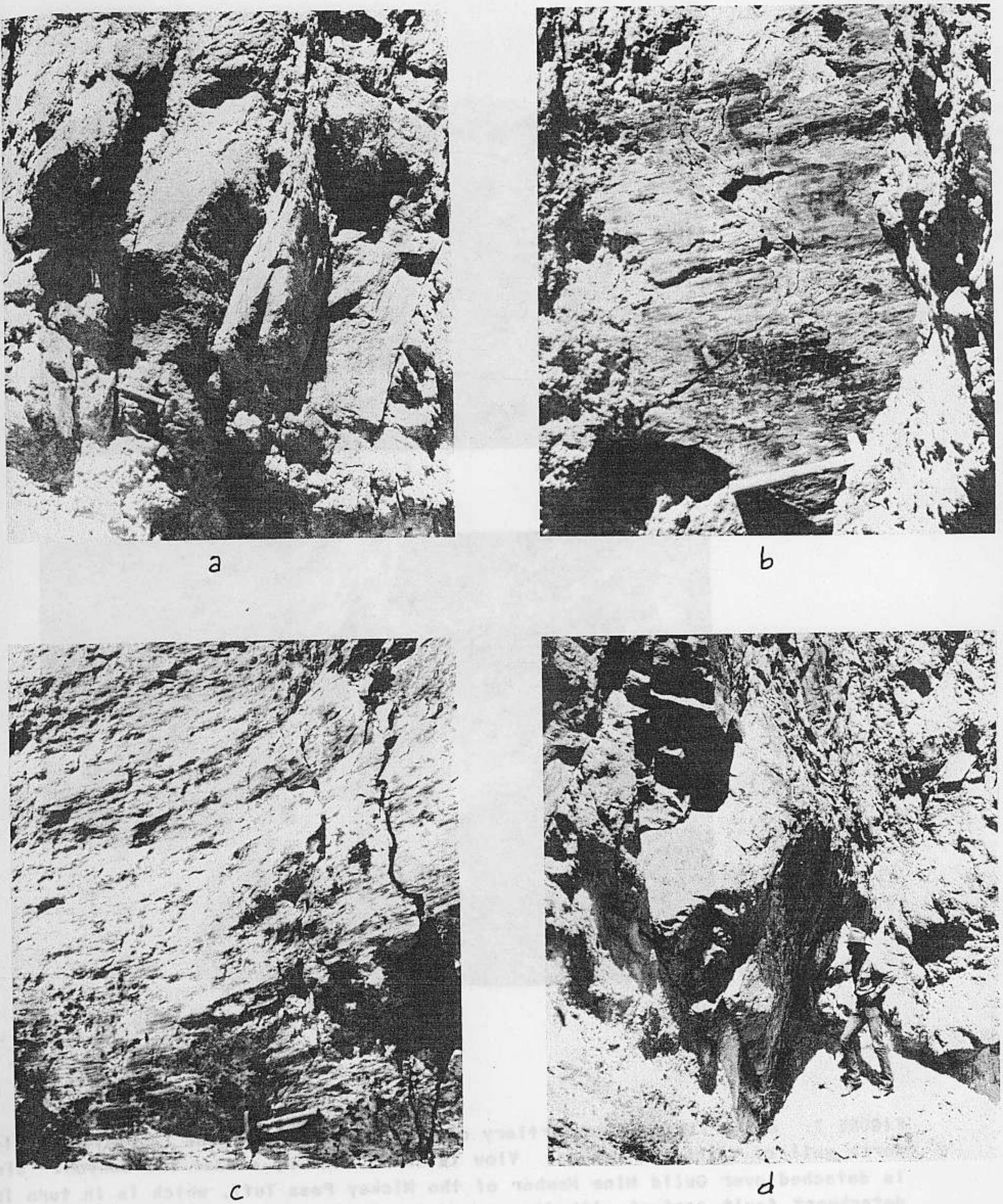

FIGURE 8: a) High-angle shear planes in densely welded Guild Mine Member above the basal low-angle detachment fault, Wildhorse Canyon area (lower detachment fault in Fig. 7). b,c) Subhorizontal striations on slickensided shear planes in densely welded Guild Mine Member. d) Shear plane displaying mullion structure.

adjacent to strike-slip faults (Fig. 6). Where tuff attitudes are discordant to underlying or overlying detachment faults, in a stack of detached tuff units, compaction foliation in one unit may be quite discordant (dips varying as much as 60°, strikes varying as much as 90° from that of tuffs in the underlying or overlying detached slabs (Fig. 6), even though the detachment fault planes may have very nearly the same attitudes. There is no apparent systematic variation in the above discordant relationships across the structural grain of the northern Gillis Range, except that tuff units and their basal detachment faults in the Agai-Pah Hills and the Gumdrop Hills generally tend to dip away from the relatively down dropped but anticlinal core of the range.

Although some variability of compaction foliation attitudes in ash-flow tuff are to be expected, especially if the tuff sheet is laid down on a faulted terrain of locally quite variable topographic relief, much of the complexities in tuff attitudes observed are interpreted to result from fault disruption.

Another important characteristic of the detached ash-flow tuff sheets is ubiquitous high-angle shear planes within densely welded tuffs above the detachment faults. These shear planes "bottom out" in the more or less flat lying detachment fault zones and do not cut across the zones (Fig. 8a). Densities of the high-angle shear planes range from one per meter to as many as several per meter laterally along a densely welded tuff slab above a detachment fault.

Where a stack of detached slabs is exposed, high-angle shear planes within each slab are unique to that unit. High-angle shear planes in one competent slab bottom out in the detachment fault at the base of that unit and are not continuous with the high-angle shear planes in the next lower competent slab. Shear planes in detached rock units dip at high angles (generally nearly perpendicular) to the detachment faults regardless of variations in attitude of compaction foliation in the tuff cut by the shear planes. Shear planes do not asymptotically converge into the detachment faults. Commonly these shear planes, where well exposed, displ horizontal or near horizontal striatio on their surface (Fig. 8b,c). Not uncom monly, the better developed shear plane display horizontal or subhorizontal mul lion structures (Fig. 8d).

Orientation data for the shear plane within detached structural lithic plates collected above detachment faults expose throughout the northern Gillis Range an regardless of stratigraphic position o the detachment faults, show that th strain experienced through brittle defor mation of the plates is systematic (se rose diagrams in Figs. 4 and 6). The dat show that the high-angle shear plane occur in conjugate sets that displa orientation maxima which are essentiall coincidental with first-order primary an complementary or second order shear orien tations predicted for strike-slip faul deformation (see for example Moody an Hill, 1956) (Fig. 9).

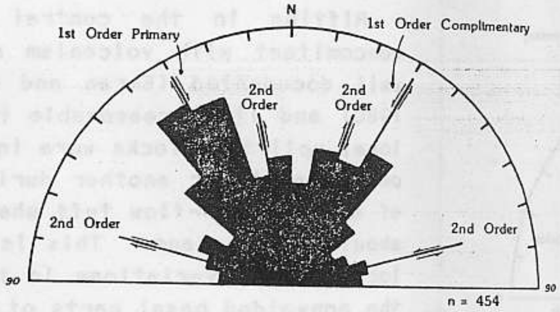

FIGURE 9: Rose diagram showing strik orientations of high-angle shear planes i detached densely welded tuff sheets Agai-Pah Hills, northern Gillis Range Predicted first and second order latera shear planes (modified from Moody an Hill, 1956) for a N-S directed primar stress are also shown.

Detachment faults always displace younger over older strata. Where a succession of ash-flow sheets comprises a continuous stack, a detachment fault may exist only at the base of the entire stack or these faults may exist at every contact between units in the stack. The basal contact of a given unit may be a detachment fault in one structural block or it may be a normal depositional contact in a nearby structural block across a high-angle fault. Detachment faults appear to be localized solely by zones of maximum horizontal stress.

Stratigraphic omissions do occur in terranes affected by detachment faults. In most localities only one unit is omitted but in a few places as many as five units are omitted. Locally, as in the Gillis Canyon area, along the Agai-Pah Hills fault, a "stack" of ash-flow tuff sheets appears to be "shingled" onto the Mesozoic basement (Fig. 4). Here, each younger unit is detached and apparently displaced farther southward than the next older unit so that the younger overlaps that unit, and in turn rests directly on the granite. The direction of overlap, however, coincides with the direction of increasing elevation of the granite erosion surface so that the overlap may be partly due to filling of a depression as eruptions proceeded.

Rifting in the central Walker Lane concomitant with volcanism appears to be well documented (Ekren and others, 1971; 1980) and it is reasonable to assume that local uplifted blocks were in existence in one locality or another during deposition of all the ash-flow tuff sheets beginning about 27 m.y. ago. This is supported by local abrupt variations in thicknesses of the nonwelded basal parts of ash-flow tuff units, and the local occurrences of thick zones of breccia and debris at several stratigraphic horizons and between high-angle faults. Local deposits of coarse epiclastic sediments between ash-flow tuff cooling units and the presence of petrified wood at a couple of horizons indicates erosional hiatuses between the major pyroclastic eruptions. Therefore, it seems likely that in most localities where stratigraphic omissions occur they are due to pre-detachment fault nondeposition of units or local removal of strata by erosion.

NORMAL FAULTS

Together with the through-going Agai-Pah Hills and Gumdrop Hills lateral slip faults many of the other shorter high-angle faults that are parallel or subparallel to the major faults within the northern Gillis Range have probably experienced predominantly lateral-slip movement. These faults give rise to patterns typical of lateral-slip fault zones (Tchalenko, 1970; and discussions in Hardyman, 1978). Certainly, some of these high-angle lateral-slip faults have experienced additional vertical readjustments. Other high-angle faults of diverse strikes are probably primarily dip-slip or oblique-slip faults. These faults cut the low-angle detachment faults and locally can be mapped into the pre-Tertiary basement rocks. In the Agai-Pah Hills, these faults mostly dip to the east-northeast and are down to the east. The strata within the blocks dip to the west in a manner similar to listric faulted blocks described by Ekren and Byers (this volume). In the Gumdrop Hills on the east side of the central rift zone, in contrast, the normal faults generally dip west, step units down to the west, and tilt strata to the east-northeast.

Within the central rift zone, normal faults trend northwest parallel to the major bounding faults, or they trend at high angles to the northwest bounding faults. These geometries result in various rhomb-shaped blocks. Many of these rhomb-bounding faults undoubtedly formed as second order normal faults in response to movement on first order strike-slip faults in the basement rocks. Locally, particularly in the northern part of the central graben, the high-angle normal faults have served as conduits for emplacement of dike rocks of intermediate compositions. In other places in the range hydrothermal fluids have migrated along the faults, depositing quartz vein material and silicifying the adjacent volcanic wall rocks.

Locally, as in the Agai-Pah Hills, densities of normal faults are greater in the Tertiary volcanic rocks than in adjacent pre-Tertiary outcrops suggesting that some of the normal faulting is not deeply penetrating and restricted to the Tertiary strata. In some localities these faults may be of the listric type as documented locally in the northern Gabbs Valley Range (Ekren and Byers, this volume). Numerous faults that cut the Nugent Tuff Member of the Hu-Pwi Rhyodacite in the Hu-Pwi wash area in the northeastern part of the northern Gillis Range (Fig. 3) are probably of this type. In this area these faults trend northwest, parallel to the Gumdrop Hills lateral-slip fault, and dip to the west. These faults have quite linear traces and repetitiously cut the Nugent Tuff Member but the erosional relief in this area is insufficient to allow interpretation of the attitudes of the faults at depth. Faults in this area may once have been contiguous with the package of listric faults cutting the same section in the Nugent Wash area to the southeast along the Gumdrop Hills fault, described by Ekren and Byers. The amount of lateral shift (about 6.1 km.) on the Gumdrop Hills fault necessary to restore these two areas of repetitious normal faulting is comparable with other estimates of displacement on the Gumdrop Hills fault.

As discussed earlier, lateral-slip and associated normal faults were active at the time of earliest ash-flow deposition (27-28 m.y.) in the northern Gillis Range. Normal faults cut the youngest tuff unit in the range (Nugent Tuff Member, 22-23 m.y.) and younger aphanitic intermediate lavas in Gumdrop Hills that are undated but which may be as young as 15 m.y. In at least two localities, dissected fault scarps can be mapped in alluvium indicating normal faulting has continued to recent times.

DISCUSSION

The northern Gillis Range is a highly faulted terrain lying within the central Walker Lane lateral-slip fault zone. Two major and several minor lateral-slip faults cut pre-Tertiary rocks and Tertiary volcanic rocks exposed in the range. Most of the high-angle normal faults are inferred to cut the low-angle detachment faults that are an integral part of the fault deformation.

The salient aspects of the low-angle detachment faults exposed in the northern Gillis Range and the Gabbs Valley Range that must be considered in any interpretation of their mode of origin are: (1) Detachment faults are present at the Tertiary-pre-Tertiary interface and at most contacts throughout the Tertiary section. Basement rocks below the Tertiary-pre-Tertiary detachment fault are not mylonitized or pervasively sheared; (2) Contacts between Tertiary volcanic units are not everywhere faulted and a given contact may be a detachment fault in one structural block and not in an adjacent structural block; (3) Attitudes of compaction foliation in detached tuff sheets may be concordant or discordant to detachment faults and tuff attitudes may vary considerably within one detached unit or between units in a stack of detached tuffs. Detachment faults within a stack of detached tuffs are generally concordant with one another; (4) Detachment faults do not toe-out or cut across densely welded zones; (5) Detached ash-flow tuff units in the northern Gillis Range display ubiquitous high-angle shear planes that bottom out in the detachment fault zones. This deformation is systematic and conforms with shear strain predicted for strike-slip fault deformation.

Detachment faults in the central Walker Lane are thin skinned tectonic features and occur where there is a marked contrast in the competency of rock units. They occur in the incompetent, easily disaggregated, nonwelded basal zones of ash-flow tuff cooling units or basal flow breccias of lava units. The presence of these incompetent stratigraphic horizons and an underlying faulted basement terrain experiencing dominant lateral shearing appear to be two factors intimately associated with the detachment faults in the central Walker Lane.

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STRIKE-SLIP, NORMAL, AND DETACHMENT FAULTS IN THE NORTHERN GILLIS RANGE, WALKER LAKE OF WEST-CENTRAL NEVADA

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(See Hardyman, R. F., 1980, Geologic Map of the Gillis Canyon quadrangle, Nevada: U.S. Geological Survey Map I-1237, 1:48,000; for reference to the geology of the northern Gillis Range)

ROADLOG

DAY 2

Mileage

0.0 Start at the post office in Shurz, Nevada, on Highway 95. You are now in the Shurz quadrangle, 15 minute topographic map. Turn southeast on paved road adjacent to the south side of the post office building. Follow road along the Southern Pacific Railroad line.

.25 Cross bridge over the Walker River. View ahead is of the northwest end of the Agai-Pah Hills that border the west side of the northern Gillis Range. Note moderate west tilt of the contact between the Weed Heights Member of the Mickey Pass Tuff (dark reddish-brown rocks) and the underlying lighter colored Guild Mine Member of the Mickey Pass Tuff.

2.3 Bend in road, pass under telephone line. Leave pavement and follow gravel road to the southeast (telephone line along west side of road). You are now nearly off the Shurz 15 minute map.

3.6 Cross irrigation canal, ranches on your right.

4.15 Corner of fenced field on right, bear left. You are now in the Gillis Canyon 15 min. topographic map. Sign a few yards ahead reads, "Travel at own risk, sandy roads."

6.95 Pass under east-west power line, railroad tracks are a few yards to your left.

8.0 Road passes along bluff composed of rounded to subrounded conglomerate, conglomeratic sandstone, and coarse sandstone interbeds of probable alluvial fan/deltaic deposition. The inclined beds in this sequence are underlain and overlain by subhorizontal beds of the same material. The dip of the inclined beds (15-30°, strike approximately N80°W) is interpreted to be primary-depositional and not tectonic. One high-angle normal fault trending approximately N10°E, displaces the prominent horizontal strata (exposed about 2/3 of the way up bluff) about 4 m., down to the west. This fault does not offset the overlying flat-lying conglomeratic sequence.

The age of these conglomeratic beds is uncertain but they are thought to be pre-Lake Lahonton (Pleistocene) in age. The clasts in the conglomerates here consist of abundant dark metavolcanic rocks, a variety of fine- to medium-grained leucocratic granitic rocks, diorite, and Tertiary pyroclastic rocks. The granitic rocks are dissimilar from the granitic rocks exposed in the northern Gillis Range. The source of these conglomerates was apparently not the Gillis Range but the Wassuk Range to the west. If this is the case, it is possible that these beds have been transported right-laterally several kilometers from a position originally near the northeastern flank of the Wassuk Range. Continue on road to the south; for a couple of hundred yards this will be a critical part of the road.

10.3 Entrance to Gillis Canyon road (unmarked), turn left, road heads southeast, then east, towards range front.

12.0 View directly ahead at range front. Varicolored rocks forming high ridge are ash-flow tuffs of the Guild Mine Member of the Mickey Pass Tuff. Dark outcrops in the notch are of bedded, folded, Triassic carbonate and clastic rocks. Somber gray-brown hills to the right of the folded sediments consist of porphyritic quartz monzonite of Gillis Canyon, capped by more Mickey Pass Tuff to the right.

13.5 Outcrops on the left are of porphyritic quartz monzonite of the Gillis Canyon pluton.

15.0 Dark outcrops on your left and extending uphill to the left are of foliated metasedimentary rocks, with local diorite outcrops adjacent to wash, cut by apophyses of quartz monzonite and aplite. Reddish cap rock on hill to the south consists of Guild Mine Member of the Mickey Pass Tuff in fault contact with the underlying Gillis Canyon pluton.

15.3 Fork in Gillis Canyon drainage. Brick red outcrops directly ahead are of ash-flow tuff of the Tuffs of Gabbs Valley sequence. The western splay of the Agai-Pah Hills fault passes along the front of these outcrops. All outcrops to the east of this location are of Tertiary ash-flow tuffs. The dark-brown outcrops forming the skyline (Ghost Dance Ridge) consist of Singatse Tuff. Proceed on right fork of drainage.

15.55 Headframe visible on the hillside off to your right is at the Gentry Mine. Here, calc-silicate rock (garnet, epidote rock primarily) occurs adjacent to granodioritic rock that is locally present near the margins of the Gillis Canyon quartz-monzonite intrusive. Limited scheelite was taken from this mine. Uphill from the mine area is the Guild Mine Member of the Mickey Pass Tuff that rests in low-angle fault contact on the pre-Tertiary granitic rocks. In this fault block the Guild Mine Member dips generally 42° to 52° (with dips locally as low as 16°) to the east. The fault at the base of this tuff is poorly exposed but is marked by a zone of "sanded" and locally gouged tuff. This fault contact also dips east but at only about 10°-20°.

The next ridge to the south is composed of Weed Heights Member of the Mickey Pass Tuff that rests in low-angle fault contact on the Guild Mine Member and, on the back side of the ridge, on granite. This tuff also dips 30°-40° east, but the fault at its base dips east only about 15°-20°.

16.3 STOP 1.
Gully to your right.

Singatse Tuff here is in low-angle fault contact over pre-Tertiary granodioritic rock. Attitudes of the Singatse above the fault here are variable, ranging from N45°E, dip 37°SE, to N10°W, 29°NE, to N15°W, 68°NE. I interpret the Tertiary-pre-Tertiary contact here to be a fault that strikes about N10°E and dips about 12°NW. Locally along this fault there are a couple of thin slivers of Mickey Pass Tuff less than 4 meters thick that are essentially within the fault zone. In contrast, the Mickey Pass Tuff in the fault bounded ridges just to the west is in excess of 122 m. thick. Return to vehicles and proceed up wash.

16.5 The outcrop to the right of the wash is composed of metamorphosed pre-Tertiary carbonate rock. The outcrops to the left of the wash are of Singatse Tuff. A high-angle fault trending along the wash separates these rock units.

16.8 STOP 2.
(Brief stop).

Cat cut to right of wash is in red-brown gouge along the high-angle fault separating Singatse Tuff to the east from pre-Tertiary rocks in the hill to the west. The gouge here is typical of many of the faults cutting the Tertiary rocks in the northern Gillis Range, regardless if they are high-angle or low-angle faults. Return to vehicles, proceed up wash and up road over hill ahead.

17.1 STOP 3.

The saddle directly ahead to the south contains the trace of one splay of the high-angle, Agai-Pah Hills fault (Fig. 4 of guidebook report). Singatse Tuff forms the ridge to the right (west) of this saddle; brecciated Blue Sphinx Tuff forms outcrops in the fault zone in the saddle, and Ghost Dance Lava Member of the Hu-Pwi Rhyodacite forms the prominent knob east of the saddle and is in low-angle detachment fault contact over Blue Sphinx Tuff. We will proceed to the conspicuous brick red zone at the base of the Singatse Tuff about 100 yds. west of the saddle and traverse this zone to the saddle. This zone is interpreted to be a detachment fault at the base of the Singatse Tuff that maps to the high-angle fault through the saddle. Examine the brecciated Blue Sphinx Tuff in the saddle (Fig. 5 of guidebook report) and the detachment fault zone at the base of the Ghost Dance Lava to the east of the saddle. Traverse through saddle and meet vehicles. Vehicles only: Retrace route to Gillis Canyon Wash.

18.3 Turn right into Gillis Canyon Wash and proceed south-southeast up wash.

20.55 Do not take dirt road that intersects wash here, stay in wash. A few yards farther another road exits wash, but do not take it; stay in wash. The road will exit on right (west) side of wash a few yards ahead.

21.05 Take intersecting road to right and drive to end of road (about .4 mi.) and pick up people. Proceed back to main road and turn right (south).

22.0 Road pases through narrow gully. Immediate outcrops on both sides are Singatse Tuff, dark outcrops adjacent to these are of pre-Tertiary diorite.

22.3 STOP 4.

At saddle, with view of Walker Lake and Wassuk Range across valley to the west, leave vehicles and walk back on road to brick red outcrops. Here, Guild Mine Member of the Mickey Pass Tuff is in low-angle detachment fault contact over pre-Tertiary diorite and in the gully to the north the Singatse Tuff is in detachment fault contact over the Guild Mine Member. Farther to the east, the Singatse Tuff rests in fault contact on the pre-Tertiary diorite.

The low-angle fault at the base of the Singatse is believed to be the same fault plane as observed at the last stop. Attitudes of the Singatse Tuff above this fault here are variable and locally range from N20°-40°W, 80°E dip to N20°E, essentially vertical. The low-angle detachment fault here dips 20°-30° to the north.

Between the Singatse Tuff and the underlying Guild Mine Member is a thin ash-flow tuff that is mapped with the Guild Mine Member, but this tuff may be the distal part of one of a couple of thin cooling units that exist between the Guild Mine Member and the Singatse Tuff farther south in the southern Gabbs Valley Range. A high-angle fault with minor displacement may separate this discontinuous ash-flow tuff from the underlying Guild Mine Member. This thin ash-flow tuff and the Guild Mine Member, however, are conformable and have an attitude of about N50°-60°W, 30°40°NE. The fault contact between the Guild Mine Member and the pre-Tertiary diorite also has this attitude. Return to vehicles and retrace route down Gillis Canyon wash to the railroad west of the range front.

30.4 Junction of Gillis Canyon road and road along railroad grade. Turn south and proceed to the Wildhorse Canyon road.

32.1 Road crosses under an east-west-trending power line. Dark outcrops along west flank of the range, along trend of power poles, consist of pre-Tertiary carbonate and clastic rocks intruded by diorite on the skyline (diorite at the last stop). Varicolored Tertiary rocks to the south are primarily Guild Mine Member of the Mickey Pass Tuff.

34.85 Cattle guard in east-west fence line. You are now leaving the Walker Lake Paiute Indian Reservation. Proceed to the railroad crossing (former railroad maintenance station on west side of tracks) and turn left (east) on road leading to Wildhorse Canyon. White rock on cement slab to your right is barite ore mined along two high-angle faults in dark outcrops near crest of range directly ahead.

36.95 Road enters Wildhorse Canyon wash. Outcrops of highly sheared Singatse Tuff are to the left (north) and in the ridge to the right (south). "Tortured" pre-Singatse tuffs make up the hills directly ahead.

If time permits, we will stop and examine these outcrops of Singatse Tuff. The Singatse here strikes about N20°W and dips 30°-40°SW.

Proceed up the wash to the east. The dark outcrops on your right are of pre-Tertiary metavolcanic, volcaniclastic and thin bedded carbonate rocks that strike northeast and dip moderately to steeply to the northwest. On the left (north) side of the canyon the highly bleached, sheared and fractured, hydrothermally altered pre-Tertiary rocks are overlain in detachment fault contact by Guild Mine Member of the Mickey Pass Tuff.

38.4 On your left, Mickey Pass Tuff is in detachment fault contact over dark-gray pre-Tertiary rocks.

39.1 Directly ahead is another good view of the Tertiary ash-flow tuffs in detachment fault contact over the pre-Tertiary rocks. On your right (south side of wash) you will pass a landslide mass of Guild Mine Member of the Mickey Pass Tuff.

40.15 STOP 5.

Guild Mine Member of the Mickey Pass Tuff in detachment fault contact over pre-Tertiary rocks. The Singatse Tuff, forming the ridge crest, is in detachment fault contact over the Guild Mine Member. To the east in this canyon wall, the Guild Mine Member wedges out.

Climb hill on the north side of the wash to whitish outcrop along the pre-Tertiary-Tertiary contact. Return to vehicles.

40.45 STOP 6.
(Time permitting). Just around bend in Wildhorse Canyon at reentrant in canyon wall (gully to the east). Climb to exposures at head of gully to view the detachment fault at the base of the Singatse Tuff.

Return to vehicles and retrace route back down Wildhorse Canyon to railroad line.

45.5 At railroad crossing. Follow road on west side of tracks to the south.

60.2 Railroad crossing at Thorne (former railroad depot site). Turn right (west) on blacktop road. Pass through ordnance facility.

64.0 Junction of Bonanza Rd. (chain-link fenced compound on the right). Turn left, cross railroad tracks, and proceed to Hawthorne.

65.45 Major intersection just past cemetery on right (west) side of road. Proceed straight ahead through intersection and straight ahead at next stop sign onto F Street. Proceed about 3 blocks to the El Capitan Lodge (Best Western Motel) and Casino.

66.0 END OF SECOND DAY ROAD LOG.

THE GABBS VALLEY RANGE--A WELL-EXPOSED SEGMENT OF THE WALKER LANE IN WEST-CENTRAL NEVADA

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ABSTRACT

Four northwest-striking, en echelon right-slip faults are exposed in and adjacent to the Gabbs Valley Range in west-central Nevada. These faults, together with northwest-striking faults exposed in the Gillis Range and Walker Valley to the west, lie within the Walker Lane structural zone and have a combined displacement of 48-60 km. The four faults in and adjacent to the Gabbs Valley Range probably have a minimum of 4 km. displacement each, and the two easternmost faults may have displacements as great as 10-15 km. each. In addition to the four northwest-striking right-slip faults, several northeast-striking conjugate left-slip faults are present. The most important of these conjugate wrench-system faults lies just east of the Monte Christo Range and is the only fault in the region that shows extensive associated drag folding. This fault drags beds of cobble conglomerate from northeast strikes in exposures several kilometers east of the fault zone to northwest and west strikes adjacent to the fault zone. This major fault probably has at least 10-15 km. of left-slip displacement.

Listric normal faults are abundant in several localities along the Gabbs Valley Range. These strike northwest--parallel to the range-bounding right-slip faults--and are principally down to the west. Tertiary volcanic rocks appear to be detached from the underlying Mesozoic basement rocks in most localities. The detachment faulting, wrench faulting, and listric-normal faulting were synchronal and recurrent. Strike-slip faulting along northwest trends commenced about 25 m.y. ago and has persisted into recent times.