

STRUCTURAL EVOLUTION OF THE WHITE HORSE PASS AREA

SOUTHEAST ELKO COUNTY, NEVADA

by

N.J. Silberling and K.M. Nichols

INTRODUCTION

The White Horse Pass map area includes the White Horse Pass 7.5' Quadrangle and adjacent parts of the White Horse Mountain, Goshute Peak, Ferguson Mountain, and Kinsley Mountains 7.5' Quadrangles (fig. 1). Bedrock within this area crops out in the southern part of the main Goshute Mountains, the White Horse Mountain massif, the Ferguson Hills in the northeast part of the map area, and the Ferber Hills in the southeast part of the map area. These topographically elevated areas surround the White Horse Flat pediment, which covers the central part of the White Horse Pass Quadrangle and the southern part of the Ferguson Mtn. Quadrangle. Along the eastern edge of the map area, lacustrine deposits of Pleistocene Lake Bonneville lap onto older Quaternary gravels covering the pediment surface. Highstand deposits of another Pleistocene lake that occupied the Antelope and Goshute valleys also occur along the west side of the map area.

Pre-Tertiary stratified rocks of the White Horse Pass area range from Late Devonian to Early Triassic in age. The older and younger parts of this succession are separated by a major east-rooted Tertiary extensional detachment fault referred to herein as the Ferguson detachment. In the map area this detachment is located at the stratigraphic level of the Mississippian Chainman Shale. Mississippian and older strata that are mostly gently dipping are exposed in the footwall, and the hanging wall is composed of Pennsylvanian and younger strata, which dip moderately to steeply to the west, or are even overturned. The hanging wall of this detachment—termed here the Ferguson detachment—has been previously referred to as the “Ferguson Mountain terrane” by Ketner (1997; Ketner and others, 1998) and to “structural plates 3 and 4” by Welsh (1994) who regarded these “plates” as Middle Jurassic tectonic features. Strongly tilted Tertiary volcanic and sedimentary rocks are included in the hanging wall of the detachment (fig. 1) and attest to

its Cenozoic age. The hanging wall of the Ferguson detachment is disrupted by numerous faults which are cut by the detachment or merge into it, as well as by post-detachment normal faults. The Ferguson detachment and its hanging wall provide a well-exposed sample of a much larger, east-rooted, Tertiary detachment system (Ketner and others, 1998), that extends at least as far north as the Toano Range and Leppy Hills and as far east as the northern Deep Creek Range in Utah. This fault system appears to be a shallow-level expression and northern continuation of the Snake Range-Deep Creek Range fault system of (Miller and others, 1999), which characterizes ranges farther south in central eastern Nevada.

Folded and faulted Devonian and Mississippian strata intruded by a late Middle or early Late Jurassic pluton—the White Horse pluton—are exposed in the footwall of the Ferguson detachment. Devonian strata surrounding the pluton are isoclinally folded and contact metamorphosed. The geology of the footwall bears on important problems in pre-Tertiary Great Basin geology. Among these, the succession and timing of distinct generations of Mesozoic deformation in this area provide a link between the Mesozoic structural histories of ranges to the east (such as the northern Deep Creek Range) and those farther west (such as the Cherry Creek and Pequop Ranges). Also of importance and exceptionally well displayed in the map area are Mesozoic attenuation faults (Hintze, 1978; Thorman and others, 1994) that can be related to the White Horse pluton and to other Mesozoic structures in the map area (Silberling and Nichols, 1994). Recognition and interpretation of attenuation faulting affecting the Mississippian-Devonian record here is critical to paleogeographic and palinspastic reconstruction of the Devonian-Mississippian Antler foreland (Silberling and others, 1997). The stratigraphic record of foreland strata in the area was previously misinterpreted by Silberling and others (1995) because of the structural omission of strata by attenuation faults.

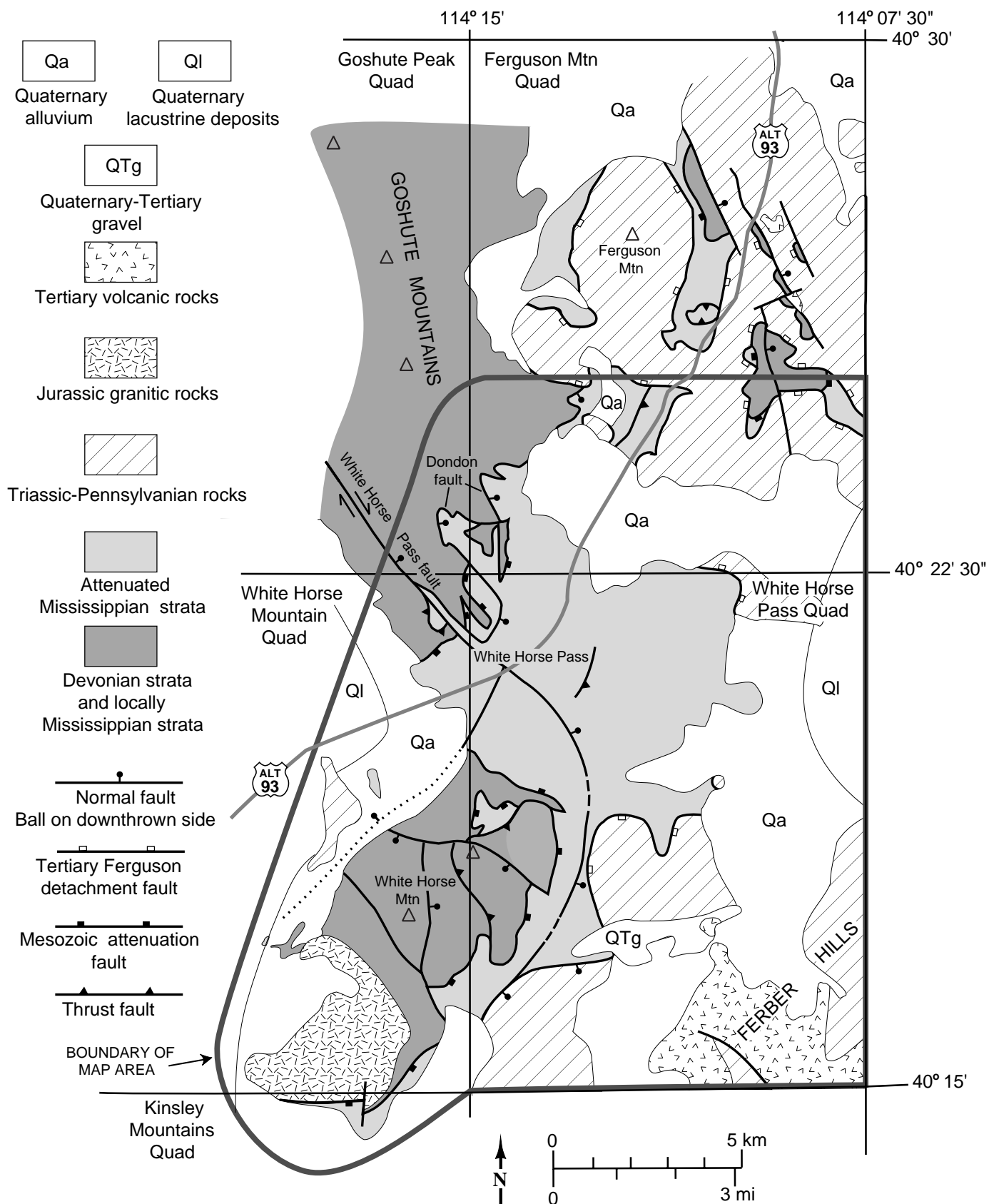


Figure 1. Index map locating the map area in relation to the White Horse Pass 7.5' Quadrangle and adjoining quadrangles and showing some of the principal geographic and geologic features. Geology within Ferguson Mtn. Quadrangle modified after Welsh (1994).

MESOZOIC STRUCTURE

Structural features, including folds and thrust faults, that deform the pre-Tertiary strata of the White Horse Pass area belong to three generations of deformation, D_1 , D_2 , and D_3 . Each phase of deformation is represented by a unique set of structures and is discussed sequentially below.

D_1 Structures

D_1 structures include attenuation faults and the isoclinal folds that are geometrically associated with the margin of the ca. 160 Ma (Armstrong, 1970; Miller and Hoisch, 1995) White Horse pluton and are interpreted to be syn-plutonic. In addition, widespread bedding-parallel solution(?) cleavage within the White Horse Pass limestone member of the Chainman Shale (Mcw) is folded and faulted by D_2 structures and is thus also interpreted as a D_1 feature resulting in part from regional heating during pluton emplacement. At the outset of Mesozoic deformation the maximum stratigraphic depth to the top of the Devonian in the area is estimated at only about 4 to 5 km, but conodont alteration indices (CAI's) in Mississippian strata from the vicinity of White Horse Pass are about 5 (Karklins and others, 1989; R.G. Stamm, written commun., 1994), interpreted to represent heating to temperatures of ca. 300° C (Epstein and others, 1977). This would have far exceeded heating resulting from the normal geothermal gradient and thus is ascribed to the late Middle to early Late Jurassic period of regional magmatism in the northeastern Great Basin (Miller, 1990) that included intrusion of the White Horse pluton.

The Guilmette Formation (Dg) in the metamorphic aureole of the White Horse pluton contains spectacular tight to isoclinal map-scale (F_1) folds, attention to which was first drawn by Misch (1960). The pluton intrudes the upright limb of a largely overturned, inward-facing syncline whose axis wraps around and conforms to the roughly circular pluton margin. This fold and the more outward, coordinate, major anticline can be traced for more than a third of the way around the pluton; metamorphic lineations, defined by stretching of mineral grains and fossils parallel to the foliation within the sheared F_1 fold limbs, are crudely radial to the pluton margin. These F_1 folds and the

associated metamorphic fabrics are thus clearly the localized result of ascending pluton emplacement, as pointed out by Allmendinger and Miller (1991). Although intrusion of this pluton profoundly deformed its wall rocks, internally it lacks structural fabric other than a spaced cleavage along its southwest edge, which may be related to subsequent (F_3 ?) folding.

Attenuation faults within the Mississippian succession can also be related to the time of emplacement of the White Horse pluton. Approaching the pluton, the structurally and stratigraphically lowest attenuation fault gradually cuts down section from a level in the basal part of the Needle Siltstone Member of the Chainman Shale (Mcn) to a level within the upper member of the Joana Limestone (Mju)—a stratigraphic separation of only a few tens of meters—from north to south along the east flanks of the White Horse Mountain massif and the main Goshute Range over a distance of about 13 km. A higher attenuation fault separates the White Horse Pass limestone member of the Chainman Shale (Mcw) from underlying units near the White Horse pluton and also in the northern part of map area. In proximity to the pluton the higher of these attenuation faults truncates the hanging wall of the lower attenuation fault. The highest of the recognized attenuation faults has as its hanging wall throughout the map area the argillite member of the Chainman Shale (Mca), which in different places is separated by this fault from various underlying units ranging from the siltstone member of the Chainman (Mcs) down to the Guilmette Formation (Dg). A swarm of sills, usually much altered but originally of granitic texture and intermediate composition, occurs in the lowest part of the Chainman argillite (Mca), following the attenuation fault from the vicinity of the White Horse pluton to as far as several kilometers northeast of White Horse Pass. Some of these sills also intrude the structurally highest footwall rocks of this attenuation fault. These isotopically undated sills range from less than a meter to several meters in thickness, and most of them are too thin to be shown individually on the geologic map. Like the attenuation fault with which they are associated, they are apparently folded and faulted by D_2 structures.

As portrayed diagrammatically in figure 2, upon approaching the White Horse pluton from the north, the attenuation faults overstep one another so that the Chainman

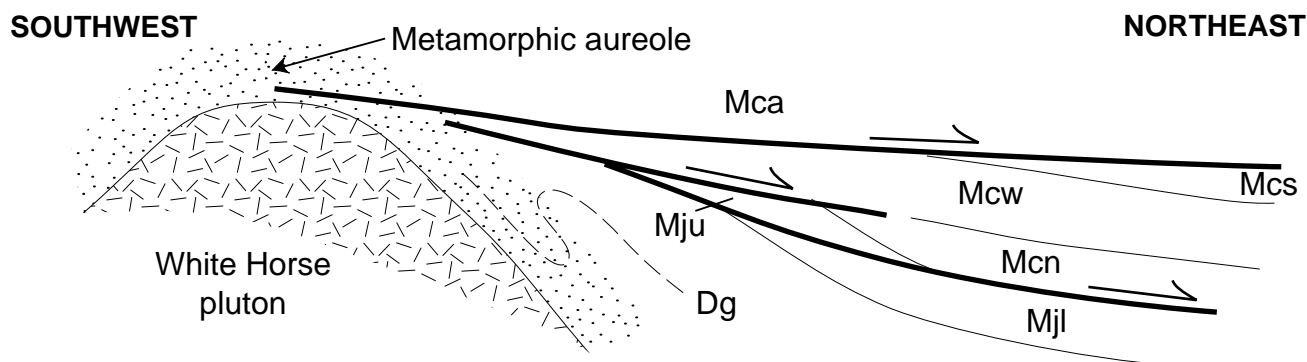


Figure 2. Schematic cross section showing the relationships among the attenuation faults and stratigraphic units as they are traced southwestward toward the White Horse pluton. This pattern is interpreted to be the result of progressive tilting of strata and gravity-driven faulting in response to thermal uplift associated with pluton emplacement.

argillite eventually comes in contact, or nearly so, with the pluton and is contact metamorphosed by it. The White Horse pluton crops out at the southeast end of a pronounced broad, linear, positive magnetic anomaly extending west-northwestward for about 40 km (Ponce, 1994). Another late Middle Jurassic pluton, the Melrose pluton, for which a discordant U-Pb age of ca. 165 Ma is reported by Zamudio and Atkinson (1992), crops out in the Dolly Varden Mountains near the western end of this anomaly. Although no kinematic indicators are associated with the attenuation faults, the pattern of attenuation faulting in relation to the aeromagnetically delineated plutonic trend suggests sliding off of the flanks of a growing thermal uplift. As a generalization, widespread attenuation faulting in the eastern Great Basin (Hintze, 1978; Thorman and others, 1994) may have resulted from thermal doming of relatively flat-lying strata prior to regional compressional deformation.

For interpreting the stratigraphic record of the Antler foreland, one effect of attenuation faulting in the map area is to partly eradicate the Joana Limestone from the stratigraphic succession. The resulting stratigraphic omission, and the extensive, nearly bedding-parallel, cryptic nature of the fault responsible for this, produces a pattern easily misinterpreted as the primary result of syndepositional uplift such as by a flexural peripheral bulge in the foreland. Other stratigraphic omissions produced by attenuation faulting within the Mississippian strata of the Antler foreland in the map area are also apparent from the map pattern. Nevertheless, the absence in the stratigraphic section of the Late Devonian Pilot Shale is evidently not structurally controlled, because the contact between the Joana Limestone and the Guilmette Formation, the units that bracket the Pilot in ranges to the north and to the south and southwest, is clearly depositional where well exposed in the map area (see map explanation).

The different effects of D_1 in the White Horse Pass area generally conform to the characterizations of Jurassic tectonism and magmatism in the northeastern Great Basin by Ellison (1995) and Miller and Hoisch (1995) whereby superimposed extensional and compressive structures resulted from the intrusion of discrete plutons through a crust that was undergoing little tectonic thickening.

D₂ Structures

D_2 contractional structures of mesoscopic to kilometeric scales are pervasive in the pre-Tertiary strata of the White Horse Pass area, and they control the general map pattern of the footwall of the Ferguson detachment. F_2 folds associated with D_2 deformation range from open and upright to close and oversteepened, or even overturned, verging to the east-northeast. Axes of minor F_2 folds plunge shallowly to about N20°W or S20°E, and the general F_2 fold axis derived from bedding attitudes within the White Horse Pass limestone member of the Chainman Shale (Mcw), lower member of the Joana Limestone (Mjl), and Guilmette Formation (Dg) in the 20 km² area surrounding White Horse Pass is nearly horizontal and trends about N20°W (fig. 3). In summary, F_2

fold axes in the footwall of the Ferguson detachment trend about N20°W and have shallow to negligible plunges.

Minor D_2 thrust faults include those involving the White Horse limestone (Mcw) and Needle Siltstone (Mcn) members of the Chainman Shale in the axial part of the major F_2 syncline in the S $\frac{1}{2}$ sec. 31, T29N,R69E and that carrying the Guilmette Limestone over the Needle Siltstone in the NE $\frac{1}{4}$ sec. 26, T29N,R68E. Another style of D_2 faulting within the evenly bedded White Horse limestone might be prevalent but can only be observed in exceptional cut-bank exposures such as in the W $\frac{1}{2}$ sec. 33, T29N,R69E. Here, an eastward-overturned anticline overlies a west-dipping thrust that ramps up to a regionally bedding-parallel roof thrust. In a similar, smaller scale example in the SE $\frac{1}{4}$ sec. 18, T29N,R69E, the ramp fault is limited by both floor and roof, bedding-parallel faults. Bedding-parallel D_2 shearing of this kind may be widespread.

Subparallel, roughly planar, steeply dipping calcite veins are conspicuous in Mcw and older carbonate units, particularly in the Mcw where they occur locally in swarms. In most places they strike about N20°W and are axial planar to the F_2 folds. In a few places they bisect the extension direction within conjugate en echelon calcite gash arrays, showing that the planar veins are extensional features (fig. 4). Consequently, the axial-planar veins are interpreted to be the result of flexural extension during folding.

D₃ Structures

D_3 contractional structures are more localized than D_2 structures and involve east-dipping faults such as the Sugar Loaf thrust, near Sugar Loaf Peak in the White Horse Mountain massif, and other well-exposed or inferred minor thrust or reverse faults, as in the W $\frac{1}{2}$ sec. 4 and E $\frac{1}{2}$ sec. 5, T29N,R69E (cross section A-A') and the S $\frac{1}{2}$ sec. 29, T29N,R69E. Associated with these faults are west-northwest-vergent folds whose axes trend about N30°E. (fig. 5). The relationship between D_3 structures having this orientation and the more ubiquitous D_2 contractional structures is difficult to demonstrate in these generally low-strain rocks. However, the Sugar Loaf thrust truncates a map-scale F_2 anticline about 2 km northeast of Sugar Loaf Peak. Where a localized well-developed foliation cuts across bedding, as in sec. 27, T29N,R69E, both bedding and the crosscutting foliation are folded around an apparent F_3 axis (fig. 6), but the structural generation of this foliation is uncertain.

Locally, planar veins and related gash arrays like those associated with F_2 folds, but oriented so as to express flexural extension related to F_3 folds, are found in Mcw and still older carbonate rocks in the vicinity of F_3 folds (fig. 7)

Dondon Fault

The Dondon¹ low-angle fault north of Wild Horse Pass offsets D_1 attenuation faults. In addition, it carries a down-to-the-west, partly east-dipping fault in its hanging wall. The geometry of this fault within the hanging wall of the Dondon fault suggests that it could be a D_3 structure, and thus the Dondon may be a late or post- D_3 structure. On the

¹ "Dondon Pass" is the name used in the King Survey (Hague and Emmons, 1877, Folio Map IV) for White Horse Pass.

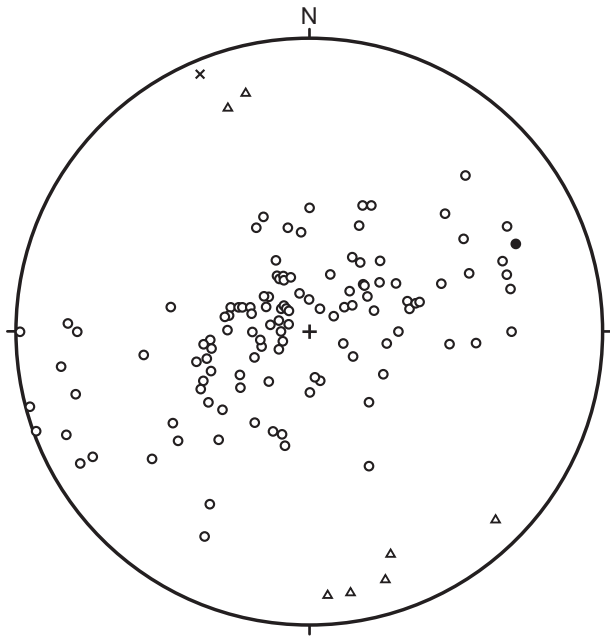


Figure 3. Stereographic projection of bedding attitudes and fold axes associated with northeast-vergent F_2 minor folds in the White Horse Pass limestone member of the Chainman Shale, the lower member of the Joana Limestone, and the Guilmette Formation in the roughly 20 km² area centered on White Horse Pass. *Open circles*, poles to upright bedding; *filled circle*, pole to overturned bedding; *triangles*, measured fold axes; *x*, fold axis computed from bedding.

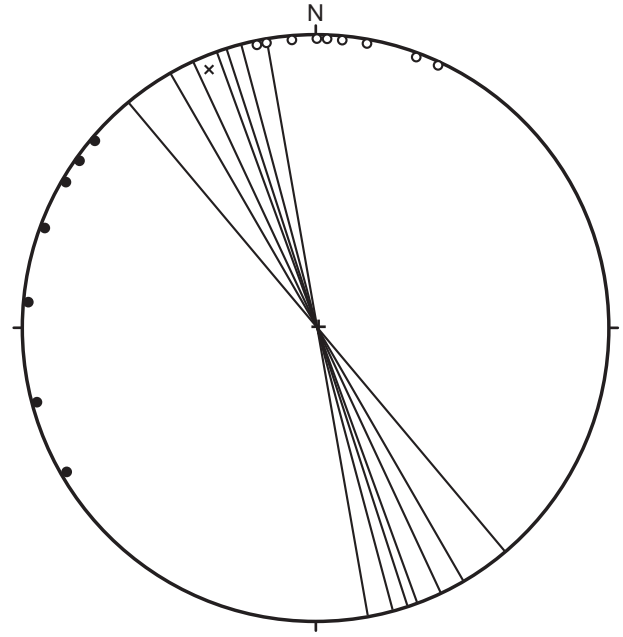


Figure 4. Two-dimensional plot showing the trends on bedding surfaces of planar calcite veins and vein sets (lines) associated with F_2 minor folds and the azimuths on bedding surfaces of associated left-slip (open circles) and right-slip (filled circles) en-echelon calcite gash arrays in the White Horse Pass limestone member of the Chainman Shale in the area immediately north of White Horse Pass. The F_2 axis computed from bedding is plotted stereographically as an *x*. The planar veins are approximately axial planar to F_2 folds, and the extension direction derived from the associated en-echelon gash arrays is perpendicular to the axial-planar veins. Both the axial-planar veins and gash arrays are therefore interpreted as flexural-extension features.

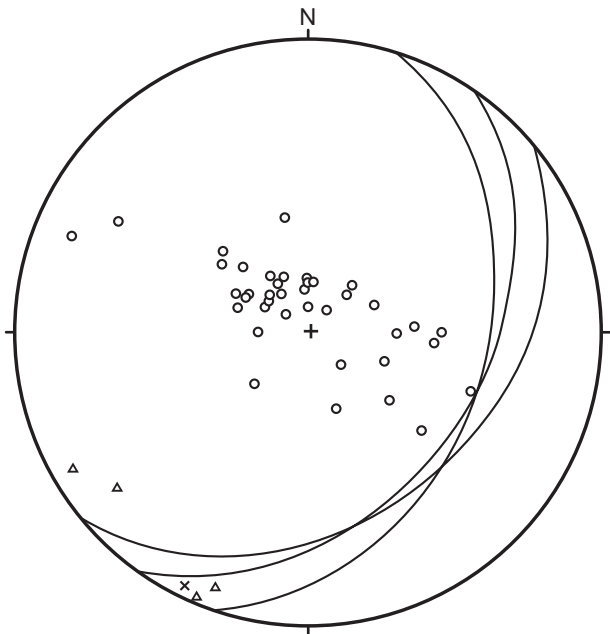


Figure 5. Stereographic projection of bedding attitudes and structural features associated with northwest-vergent F_3 minor folds in the White Horse Pass limestone member of the Chainman Shale, the lower member of the Joana Limestone, and the Guilmette Formation, which in part are directly associated with observed or inferred east-dipping thrust faults. *Open circles*, poles to bedding; *triangles*, measured fold axes; *x*, fold axis computed from bedding; *great circles*, axial-planar fracture cleavage.

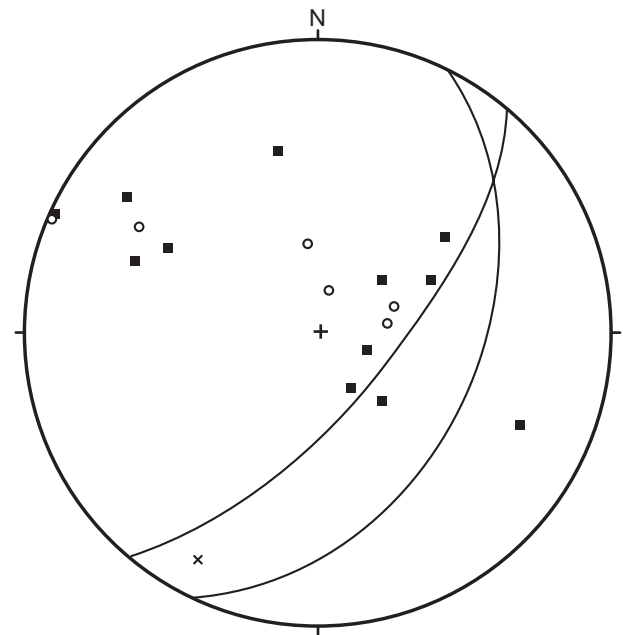


Figure 6. Stereographic projection of bedding attitudes and structural features associated with northwest-vergent F_3 folds in the limestone of White Horse Pass 5 to 6 km east of White Horse Pass (sec. 27, T29N,R69E). *Open circles*, poles to bedding; *filled squares*, poles to foliation; *x*, fold axis computed from bedding and foliation; *great circles*, spaced fracture cleavage.

other hand, the map trace of the Dondon fault suggests that it is folded by northwest-trending F_2 folds, making it a D_1 structure. In any case, the Dondon fault is younger than the structurally lower of the D_1 attenuation faults and older than the Tertiary Ferguson detachment, which cuts across it at the north margin of the map area. Granitic dikes of unknown age intermittently parallel and locally intrude the trace of the Dondon fault on the east flank of the main Goshute Range 4 to 7 km north of White Horse Pass. The transport direction on the Dondon fault is uncertain, but the outcrop pattern in its hanging wall in secs. 13 and 24, T29N,R68E suggests down-to-the-southwest tilting corresponding to northeastward transport. Strata in the hanging wall of the Dondon fault are more obviously discordant with their footwall rocks than are those associated with D_1 attenuation faults. However, map relations are inadequate to show whether or not the upper attenuation fault carrying the Chainman argillite (Mca) is cut by the Dondon fault. If this fault is a D_1 structure, the upper attenuation fault could conceivably carry the Chainman argillite over both the footwall and hanging wall of the Dondon low-angle fault, all of these structures being part of a continuum of thermal uplift and gravitational sliding.

Summary

In summary, the oldest Mesozoic deformation, D_1 is associated with emplacement of the ca. 160 Ma (Armstrong, 1970; Miller and Hoisch, 1995) White Horse pluton. Isoclinal F_1 folds in the wall rocks of the pluton are related to its emplacement. Thermal doming along a plutonic trend, of which the White Horse pluton is a part, resulted in D_1 gravity-

driven attenuation faulting concomitant with the metamorphism and folding around the pluton margin. Widespread bedding-parallel foliation in the White Horse limestone also formed at this time, because east-northeast-vergent F_2 folds and thrust faults deform both this foliation as well as the attenuation faults. East-directed thrusting and related structures in the Gold Hill district, about 35 km east of White Horse Pass, in the northern Deep Creek Range predate a granodiorite having K-Ar ages from biotite of about 152 Ma (Robinson, 1993; Stacey and Zartman, 1978), and these structures may be an expression of D_2 deformation in the White Horse Pass area. Comparing this K-Ar date for the pluton at Gold Hill with that of ca. 158 Ma for the White Horse Pluton, D_2 structures may be bracketed in age by the Gold Hill and White Horse plutons and thus could be a late episode of a really extensive, east-vergent contraction along the southeast margin of the late Middle to early Late Jurassic magmatic belt in the northeastern Great Basin. However, the ages of the relevant plutons need reaffirmation using now-available isotopic methods more applicable to plutonic rocks.

Subsequent D_3 west-directed thrusting and associated F_3 folds in the White Horse Pass area may relate to west-vergent structures in ranges to the west of the Goshute Range such as the Spruce Mountain syncline about 40 km northwest of White Horse Pass (Coats, 1987) and the conspicuous, approximately N30°E-trending, minor folds in Mississippian strata of the Cherry Creek Range about 55 km southwest of White Horse Pass (N.J. Silberling and K.M. Nichols, unpublished data). The ages of these structures are unconstrained within the late Mesozoic.

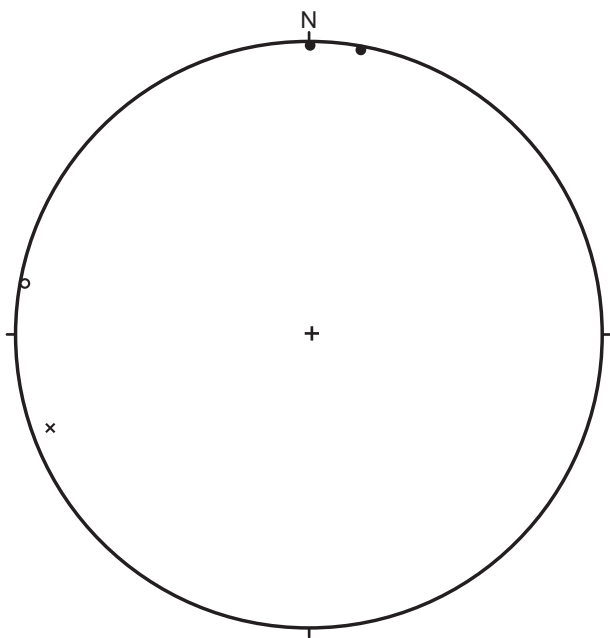


Figure 7. Two-dimensional plot showing the azimuths on bedding surfaces of left-slip (*open circle*) and right-slip (*filled circles*) en-echelon calcite gash arrays associated with a F_3 minor fold in the Guilmette Formation about 3 km west-northwest of White Horse Pass. The F_3 axis computed from bedding is plotted stereographically as an x.

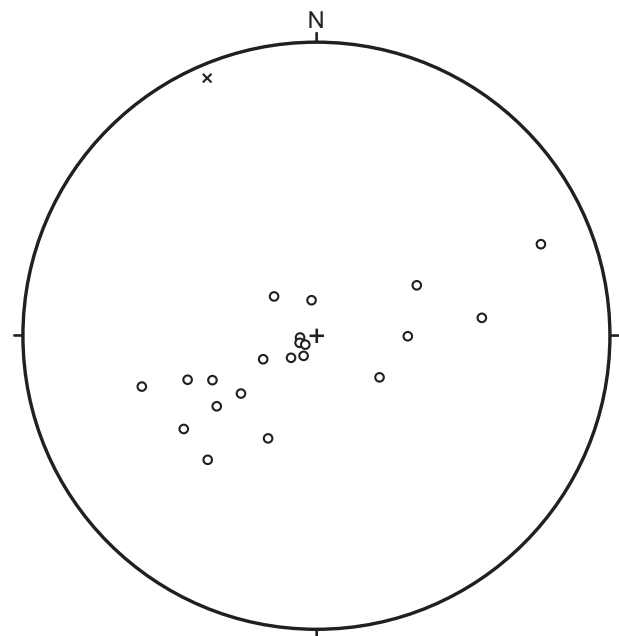


Figure 8. Stereographic projection of restored bedding attitudes (*open circles*) of the Ely Limestone and Permian unit A east of Sugar Loaf Peak (in the SE¼ sec. 8, SW¼ sec. 9, and NE¼ sec. 17, T28N,R69E). Corrected for Tertiary tilt using a rotation of 90° around a horizontal tilt axis trending 350°. x, fold axis computed from these restored bedding attitudes.

The low-angle Dondon fault in the White Horse Pass area could be an early Tertiary structure but more likely resulted from extensional collapse of orogenic highlands produced by late Mesozoic deformation. Unfortunately, isotopic ages are not available for the granitic dike rocks that follow the trace of the Dondon fault.

CENOZOIC STRUCTURE

Cenozoic structural features of the White Horse Pass area include the Ferguson detachment and subsequent basin-and-range normal faults. The hanging wall of the Ferguson detachment originally blanketed the entire map area. Pre-Tertiary rocks forming the hanging wall are mainly Permian strata along with more limited exposures of the Pennsylvanian Ely Limestone and one small occurrence (in north-central sec. 4, T29N,R69E) of the Lower Triassic Thaynes Formation. Within the map area, Tertiary rocks are found only in the hanging wall of the Ferguson detachment in the Ferber Hills in the southeast corner of the map where they unconformably overlie Permian strata.

In general, rocks in the hanging wall of the Ferguson detachment dip moderately to steeply west, suggesting top-to-the-east structural transport. However, much local variation in dip exists owing to pre-Tertiary folding and to dismembering of the hanging wall by high-angle faults that are confined to the detachment plate. North- to northwest-striking subsidiary normal faults in the hanging wall are mainly down-to-the-east, although some have the opposite sense of displacement. "Structural plates 3 and 4" of Welsh (1994) apparently correspond respectively to the hanging wall and footwall of these normal faults that root into the Ferguson detachment, so that either the Pennsylvanian Ely Limestone or the younger strata of Permian age may be floored by the Ferguson detachment (cross section B-B'). Still other faults confined to the hanging wall of the Ferguson detachment are orthogonal to the northerly trending normal faults and both intersect and are cut by them. Some of these generally northeast- to east-trending structures may be tear faults paralleling the principal transport direction of the Ferguson detachment. Others, however, have moderate to low dips and may be normal faults responsible in part for abrupt, but small changes in bedding strikes within adjoining fault blocks, resulting from relatively minor northward or southward tilt of previously west-tilted fault blocks.

Broad pre-Tertiary folds are a more important cause of variation in the attitude of bedding in upper Paleozoic rocks in the hanging wall of the Ferguson detachment. For example, in the two coherent blocks of Ely Limestone and Permian unit A to the east of Sugar Loaf Peak in secs. 8 and 9, T28N,R69E bedding has the peculiar aspect of varying about vertical, from upright and dipping moderately west to overturned and dipping east (cross section B-B'). Although the trend of the Tertiary axis of tilt and the amount of tilt are both uncertain, restored to their pre-tilt orientation using the average attitude of Tertiary strata on the Ferguson detachment plate farther to the southeast, these upper

Paleozoic rocks appear to be gently folded around a F_2 fold axis (fig. 8). Restoring original bedding attitudes of other tilt blocks of upper Paleozoic strata that lack close association with depositionally overlying tilted Tertiary rocks is even more uncertain. However, the folded Permian unit A-Ely Limestone contact near the northeast corner of sec. 30, T28N,R69E, southeast of White Horse Mountain, describes an east-dipping axial surface, which restored for steep westward tilting becomes west dipping, again suggesting east-vergent F_2 folding. Still other blocks, such as that west of the White Horse Mountain massif, when restored about a northerly tilt axis, have northeast-trending fold axes that may represent F_3 folds.

The time of displacement on the Ferguson detachment is not well constrained in the White Horse Pass area. However, the older Tertiary volcanic and clastic rocks in the hanging wall of the detachment in the southeast corner of the map area are steeply tilted, whereas horizontal rhyolite flows that have a fission-track age of 10.7 ± 1.4 Ma and overlie near-vertical, tilted Pennsylvanian strata about 8 km north of Ferguson Mountain (see fig. 1) are reported by Ketner and others (1998). The Ferguson detachment is thus permissibly part of the widespread ~17 Ma extension event in east-central Nevada described by Miller and others (1999).

The Ferguson detachment is offset by high-angle basin-and-range normal faults that produced the modern topography in the region. One of these faults offsets the detachment in sec. 2, T29N,R69E and resembles the several similar north-northwest-trending high-angle faults mapped by Welsh (1994, fig. 1) farther to the north in the hills east of Ferguson Mountain. The White Horse Mountain massif is surrounded by exposed or inferred basin-and-range normal faults whose relatively downthrown sides face away from the mountain. One of these is the White Horse Pass fault that trends northwest through the pass. Down drop on this fault is to the northeast—uplifting the White Horse Mountain massif relative to the main Goshute Mountains. To the northwest of White Horse Pass, however, canyons draining the southwest flank of the main Goshute Mountains are conspicuously offset right laterally by about one-third of a kilometer across this fault. The northwest segment of the White Horse Pass fault thus was reactivated as a basin-and-range transform that accommodated the horizontal component of subsequent west-northwest dip-slip on the mountain-front faults along the northwest flank of the White Horse Mountain massif and those along the west side of the north-trending main Goshute Mountains farther to the northwest.

Followed south-southeast and then south from White Horse Pass, the trace of the White Horse Pass normal fault becomes obscure where it lies within the poorly exposed argillite member of the Chainman Shale (Mca) or is covered by older Quaternary gravels (Qo). When active, however, this poorly exposed to unexposed segment of the White Horse Pass fault east of the White Horse Mountain massif evidently produced a prominent scarp from which the coarse debris—including megabreccias—that characterize the more

western exposures of the Quaternary-Tertiary gravel (QTg) were derived. The apparent absence in this gravel of clasts representing units older than the Chainman argillite evidently results from the prevailing easterly dip of the footwall strata coupled with the extraordinary local thickness of the preserved Chainman argillite (cross section B-B'); only the Chainman argillite and the younger rocks in the hanging wall of the Ferguson detachment would have been exposed on the scarp despite its considerable (as much as 1 km) height.

Some basin-and-range normal faults postdate the White Horse Pass fault, but Holocene scarps are not apparent where these faults project through alluviated parts of the area or across the highstand shorelines of Pleistocene lakes in the area.

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