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STRUCTURAL TRANSECT ACROSS THE SOUTHERN CARLIN TREND, ELKO AND EUREKA COUNTIES, NEVADA

by

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Abstract

Several outcrops of deformed allochthonous and para-autochthonous Paleozoic sedimentary rocks along Interstate Highway I-80 in the southern Carlin trend were studied to characterize local structures and to compare the geometry in these outcrops to regional structural patterns elsewhere in the Carlin trend area. The outcrop locations are at: (1) Beowawe turnoff, west of the city of Carlin, (2) Vivian Station, in the city of Carlin, and (3) in Carlin Canyon, east of the city of Carlin. These three study areas represent examples of different structural settings from west to east across the Carlin trend. The above outcrops represent, respectively, Ordovician-Devonian strata of the Roberts Mountains allochthon, the Ordovician-Devonian para-autochthonous miogeosynclinal assemblage, and the Mississippian-Permian overlap assemblage. Many deformed rocks in the upper plate of the Roberts Mountains allochthon near the Carlin trend are mélange-like in character.

Data from detailed outcrop studies were coupled with previously collected structural data across the Carlin trend. Fold analysis of these combined data define two structural domains: Domain I, an area of NE–SW-trending, shallow-plunging fold axes, mostly outside the Carlin trend and in the allochthonous rocks; and Domain II, a relatively narrow, NW–trending zone, which contains NW–SE-trending, shallow-plunging fold axes, that is roughly coincident with the Carlin trend.

Introduction

Generally accepted reconstructions of the tectonic history of the region around Carlin, Nev., suggest that early and middle Paleozoic, deep-water sedimentary and igneous rocks were thrust eastward approximately 75 to 200 km during the Late Devonian to Early Mississippian Antler orogeny. These rocks compose the Roberts Mountains allochthon, which lies upon coeval shallow-water rocks of the continental platform (fig. 1). The two packages of rocks, the upper and lower plates, are separated by the Roberts Mountains thrust (Roberts and others, 1958). Emplacement of the allochthon produced a topographic high, which shed sediments, that constitute the overlap assemblage of rocks, to the east and west in the late Paleozoic (Roberts, 1960; Madrid and others, 1992). Other reconstructions of the tectonic history suggest: (1) Early Triassic emplacement of the Roberts Mountains allochthon (Ketner and Alpha, 1992; Ketner and others, 1993); (2) significant tectonism in the region during the late Jurassic Elko orogeny; (3) the Cretaceous to early Tertiary Sevier orogeny, and; (4) large-scale extensional detachment faulting in the late Eocene to early Oligocene (Thorman and others, 1991a, b).

The gold deposits within the Carlin trend are aligned along a northwest-trending belt (Roberts, 1960, 1966; Thorman and Christensen, 1991), but definitive geologic parameters have not been shown to account for this alignment. Previous workers in the Carlin trend (Evans and Theodore, 1978) have documented fold axes in the region of the Carlin trend, which plunge at low angles to the NE and SW. This orientation is consistent with orientations documented by Oldow (1984) who noted a relative consistency to deformation symmetry within the Roberts Mountains allochthon and attributed this symmetry to movement and emplacement of the allochthon. However, fold axes within the trend, particularly near mineralized areas, plunge at shallow angles to the NW (Madrid, 1987; Madrid and Bagby, 1986; Volk and Zimmerman, 1991). The NW-trending fold axes were postulated by Evans and Theodore (1978) to be due to Jurassic tectonism, which is compatible with the timing of other tectonic events proposed by Ketner and Smith (1982), Ketner (1987) and Thorman and others (1991b) in northeastern Nevada.

Fold analysis in the area of the Carlin trend by Peters (1996) confirmed the definition of two structural domains: Domain I, an area of NE–SW-trending, shallow-plunging fold axes; and Domain II, a narrow, NW-trending zone that closely coincides with alignment of mines and prospects and exposed lower plate rocks, which contains NW–SE-trending, shallow-plunging fold axes. These two domains have a structural grain that is relatively consistent throughout the Carlin trend area.

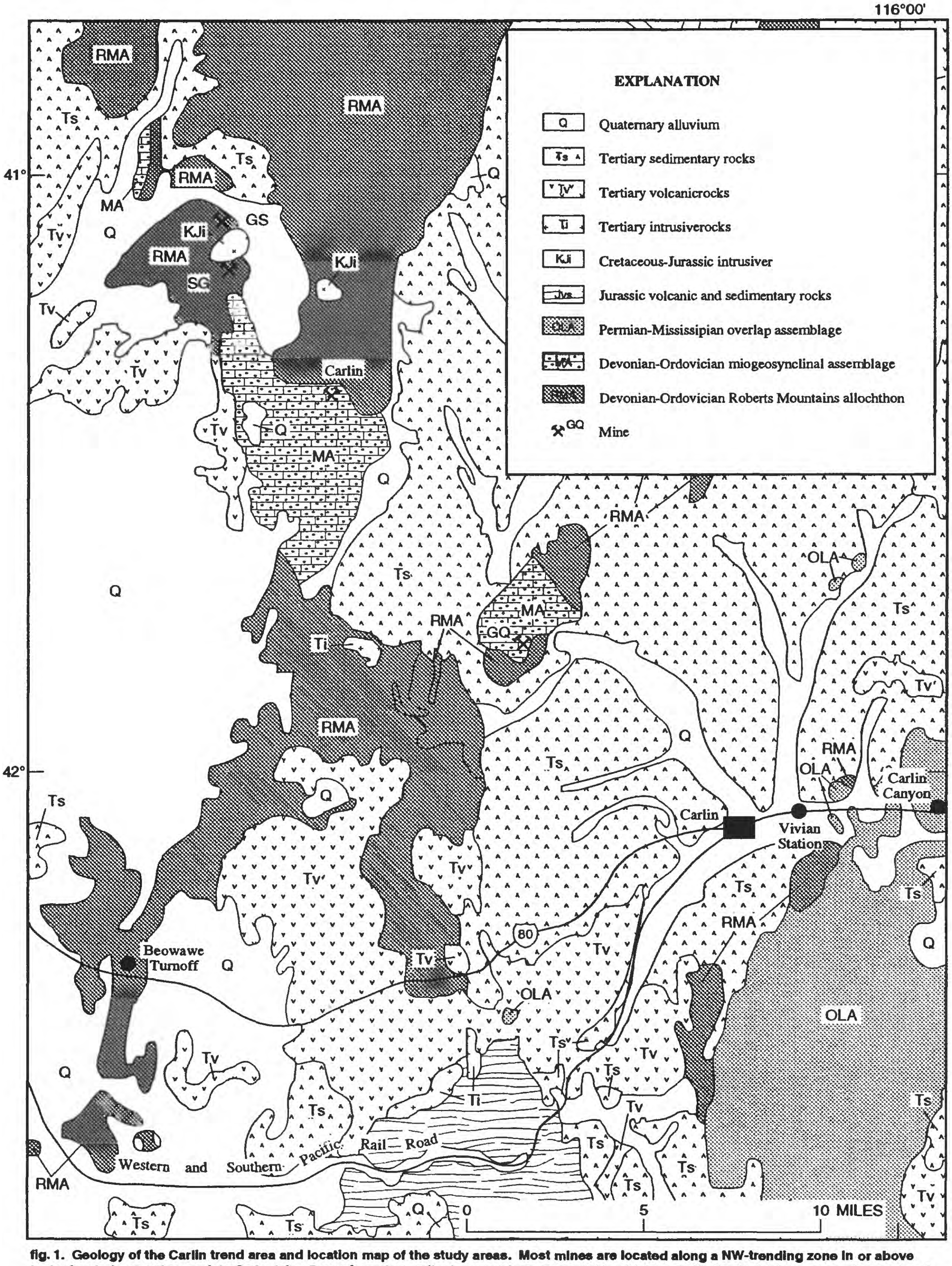

fig. 1. Geology of the Carlin trend area and location map of the study areas. Most mines are located along a NW-trending zone in or above tectonic windows of lower plate Ordovician-Devonian miosynclinal assemblage rocks (MA), which underlie the Ordovician-Devonian rocks of the Roberts Mountains allochthon (RMA). The major unit exposed in the Carlin trend area in the RMA is the Ordovician Vinini Formation. Permian–Mississippian overlap assemblage rocks (OLA) are present in the SE part of the map area. Major mines are noted as follows: GQ = Gold Quarry, SG = Genesis-Blue Star, GS (Goldstrike) Betze–Post. Additional mines noted on figure 9. Geology modified from Stewart and Carlson (1976). Filled circles at Beowawe turnoff, Vivian Station and Carlin Canyon show location of study areas described in this report.

This paper describes outcrop-scale folds and other structures across the southern part of the Carlin trend referred to by Peters (1996), and interprets their structural and geometric relations. In addition, regionally compiled structural data are combined with these data and may partially explain the NW orientation of the Carlin trend. A common rock type in the described deformed outcrops is *clast-in-matrix rock*, typical of mélange zones. Structural data (bedding and foliation attitudes, lineations and fold axes) collected at the outcrops described in this report are tabulated in Appendices I, II, and II.

Character, terms, and genesis of mélange rocks

Many deformed rocks, particularly in the upper plate rocks of the Roberts Mountains allochthon near the Carlin trend, have characteristics that are similar to mélange. Mélange is a general term describing a mappable body of fragmented and mixed blocks, typically contained within a scaly, shaley matrix, commonly called *clast-in-matrix rock* or *brokenite* (Raymond, 1984a; Peters, 1993). Obscure stratigraphic relationships and bedding chaos are developed to such an extent that the laws of lateral continuity and superposition are not generally applicable (Hsu, 1968; Silver and Beutner, 1980), although outcrops usually retain symmetrical fabrics (fig. 2). The chaotic nature of mélange is usually caused by a variety of processes that result in fragmentation, mixing, disruption, and dismemberment. Both sedimentary (Aalto, 1981; Pettinga, 1982; Branden, 1989) and tectonic (Raymond & Terranova 1984) processes of disruption and mixing have been proposed. Polygenetic mélange, including diapirism, has also been reported by Cloos (1982) and Cowan (1985).

Mélange zones are typically interpreted to have formed in either accretionary and compressional settings, such as subduction zones, (Cowan, 1982; Aalto, 1981) or in transform and overthrust settings (Vollmer & Bosworth, 1984; Raymond, 1984b). A variety of origins and types of mélange have been proposed, and therefore the significance of individual mélange units and the interpretation of the causes of fragmentation and mixing, such as tectonic, diapiric or sedimentary processes, is dependent on the regional geologic setting as well as detailed description and analysis. Mélange zones are part of more complex packages of rocks in orogenic belts and recognizing the distribution and extent of these zones is important to understanding the geologic history of a geologic province.

Variations in the fabric of clast-in-matrix rock are due to variations in: (1) precursor rock types or protolith; (2) degree of deformation and cleavage lamellae development; and, (3) the heterogeneous and domainal nature of the deformation. Although prior mixing appears to have occurred locally in some mélanges, movement of clasts usually has not taken place on more than outcrop scale.

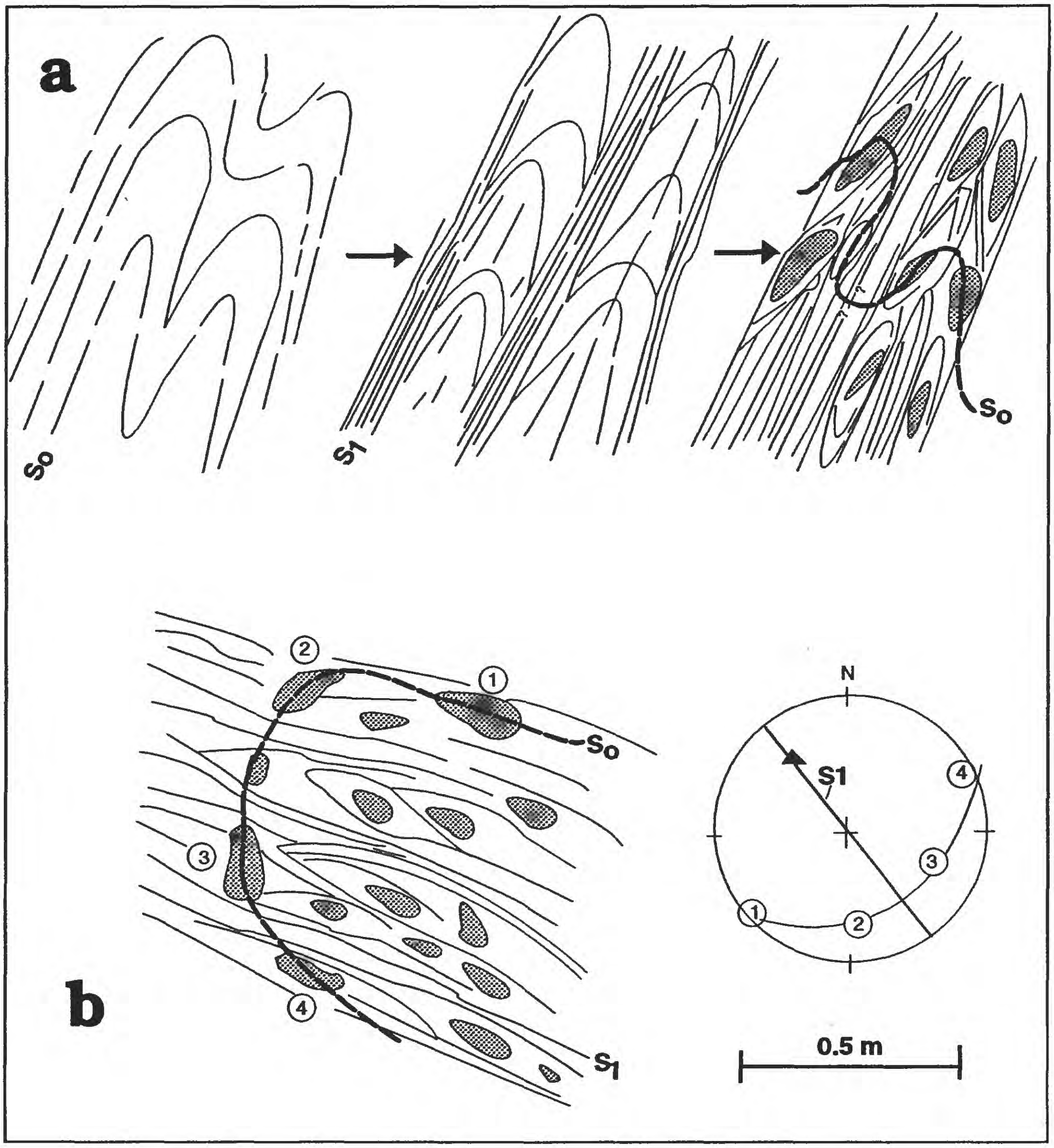

figure 2 (a, b) -- Structures showing remant folds and symmetry preserved inside the zones of intense deformation in clast-in-matrix rock: (a) domainal cleavage formation on fold limbs preserves competent fold hinges as phacoids; (b) limbs and hinges are preserved and So measurements of clasts produce a fold with an axial plane, which is coincident with cleavage in clast-in-matrix rocks. So = bedding S1 = axial plane cleavage. Solid triangle represents fold axis. Remannt folds from flexural slip transposition may also be preserved (adapted from Peters, 1993, 1996).

Classification and definition of the fragments in mélange rocks have standardized the use of clast-in-matrix rock terms. *Clasts* are 4 to 40 cm long, 1 to 15 cm wide, and isolated by scaly cleavage seams. *Phacoid* refers to ellipsoidal, doubly tapered, deformed clasts, which may have asymmetric shapes and are generally elongate, parallel to lineations and streaking on adjacent scaly lamellae (fig. 2). *Block* refers to >0.25–m-diameter, elongate fragments of any shape, surrounded by scaly, anastamosing cleavage or by clast-in-matrix rock, which contains smaller clasts. The dimensions of the blocks may exceed several hundred meters. The original layered or folded fabric of the protolith determines block size and influences the complex relationship between blocks and seams. Blocks may be tapered and phacoidal or they may show rotated, irregular, or rhombohedral shapes. *Megaphacoid* or *megablock* refer to fragments larger than 1 km in size. *Slab* refers to tabular, flat, or elongate blocks.

Generation of clast-in-matrix rock can be accomplished by several mechanisms. Figure 3a shows an example of idealized deformation from normal strain due to *progressive bulk inhomogeneous shortening* (Bell, 1981), where deformation and dissolution are concentrated at the margins of lesser deformed phacoids. Anastamosing or conjugate shear zones (see Lamouroux and others, 1991) also partition strain around undeformed phacoidal-shaped zones and such zones are characterized by complex intersections where shear zones meet. In the southern Carlin trend area, mélange-type rocks have developed in upper plate rocks at Beowawe turnoff, and at Vivian Station (pls. 1 and 2), and are represented by clast-in-matrix fabrics.

Another mechanism that generates phacoidal-shaped rocks is cuspate folding, which involves different responses to deformation between competent rocks (*i.e.* quartzite, granodiorite, or limestone-marble) and incompetent rocks (*i.e.* shale or argillite), as illustrated in figure 3b. The more pointed apexes of folds point to the competent rocks, whereas the round parts of the folds are competent rocks, which point toward the incompetent rocks. This boudinage-style of deformation is important at all scales in the Carlin trend area. In the upper plate rocks of the Roberts Mountains allochthon, this style of deformation may account for the early-stage development of mesoscopic phacoids in clast-in-matrix rock. In the lower plate rocks, this style of deformation produced steep-sided limbs of paired anticlines and synclines with areas of intense deformation occurring within the incompetent rocks in the synclinal hinges.

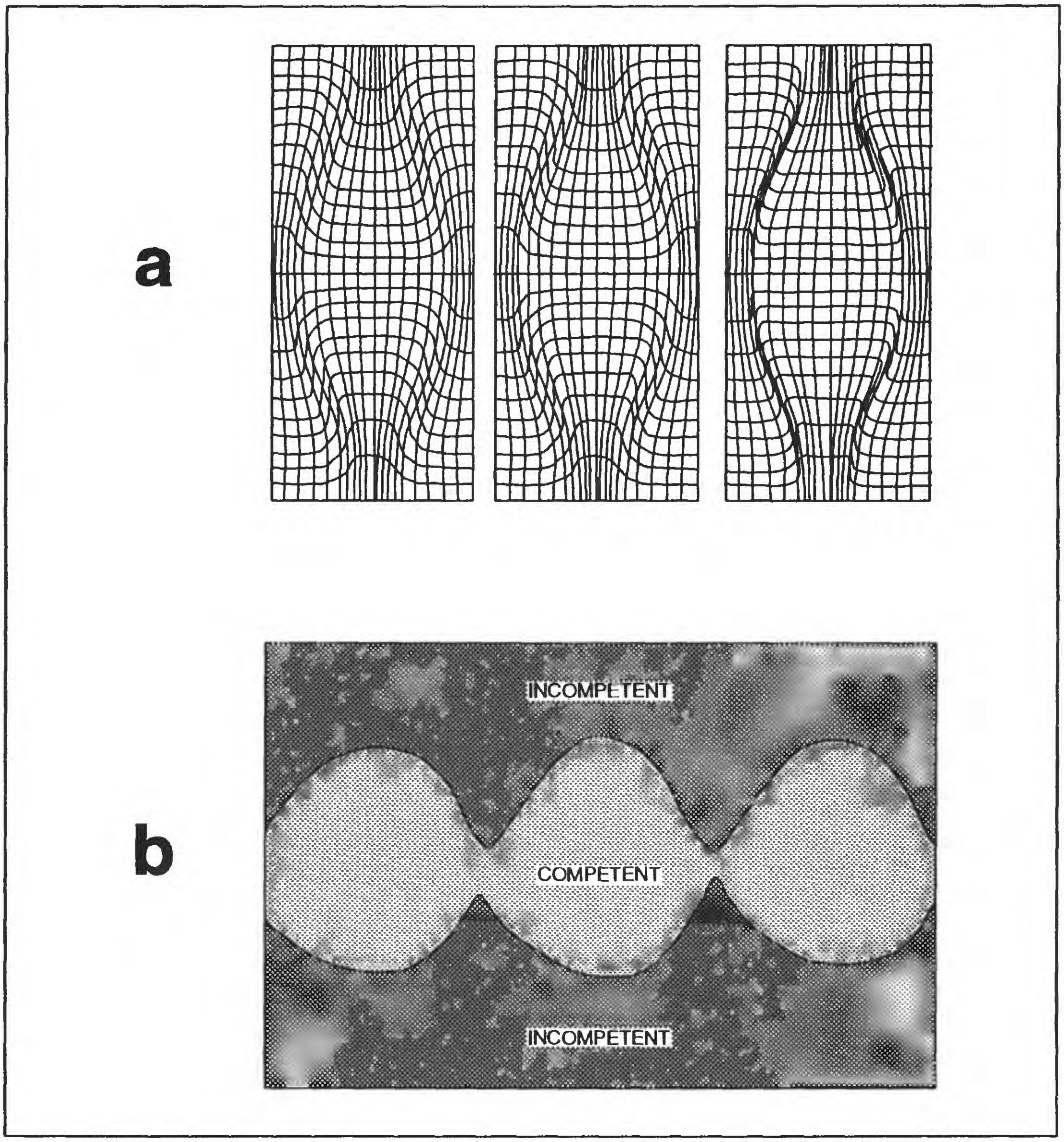

fig. 3 (a, b) –Mechanisms of formation of clast–in–matrix rock. (a) Diagram of idealized deformation under normal strain due to progressive bulk inhomogeneous shortening. This style of deformation is present within the melange-type rocks exposed at or near Beowawe Turnoff (plate 1), the Vivian Station rocks (plate 2) and in other rocks of the Vinini Formation. The seams form in the deformed parts of the rocks and leave mesoscopic partially deformed phacoids. Fluid movement and dissolution is predicted by Bell (1981) to occur in the seams. (b) Diagram of cuspate folding between competent and incompetent rocks.

Structural Studies

Outcrops of deformed allochthonous and para-autochthonous Paleozoic sedimentary rocks were studied to characterize the local structure and to compare the geometry in these outcrops to regional structural patterns in the Carlin trend. Investigations were made in the upper plate rocks of the Ordovician Vinini Formation at the Beowawe turnoff (pl. 1), and at Vivian Station (pl. 2), and in overlap sequence rocks in Carlin Canyon (fig. 1). These data were combined with regional fold axis data of other workers from the Roberts Mountains allochthon, and from the miogeoclinal rocks of the lower plate.

Beowawe turnoff

The Beowawe turnoff, about 40 km west of the city of Carlin (fig. 1), is the location of a 500–m-long road cut, along the west-bound lane of Interstate Highway I-80, in intensely deformed rocks of the Ordovician Vinini Formation (pl. 1). Rock types include laminated pelitic chert, massive chert, silty and calcareous sandstone, and massive dolomitic, fine-grained sandstone. Bedding has been dismembered and transposed such that competent layers, which are 1 to 100 cm thick, have been broken or deformed into phacoids in a matrix of irregularly cleaved shale or clast-in-matrix rock.

Strain in the outcrop is concentrated in the incompetent, pelitic matrix of the clast-in-matrix rock, which contains up to m–long blocks of undeformed, thick-bedded chert and massive dolomitic sandstone. Although the deformed bedding, form line patterns, and broken appearance in this outcrop suggest chaotic, random symmetry, a consistent SW–NE shallow-plunging, linear fabric is present as shown by calculated fold axes plotted on stereographic nets (fig. 4; Appendix I). This linear symmetry is present in almost every part of the outcrop.

Deformation of this type in upper plate rocks is commonly interpreted to be the result of the Antler orogeny, and directly related to the emplacement of the Roberts Mountains allochthon. Folding and transposition of bedding and shearing along cleavage of the clast-in-matrix rock reflect local NW–SE shortening, internal strain and bulk transport within the allochthon. These features could have been produced during, but also before or after allochthon emplacement.

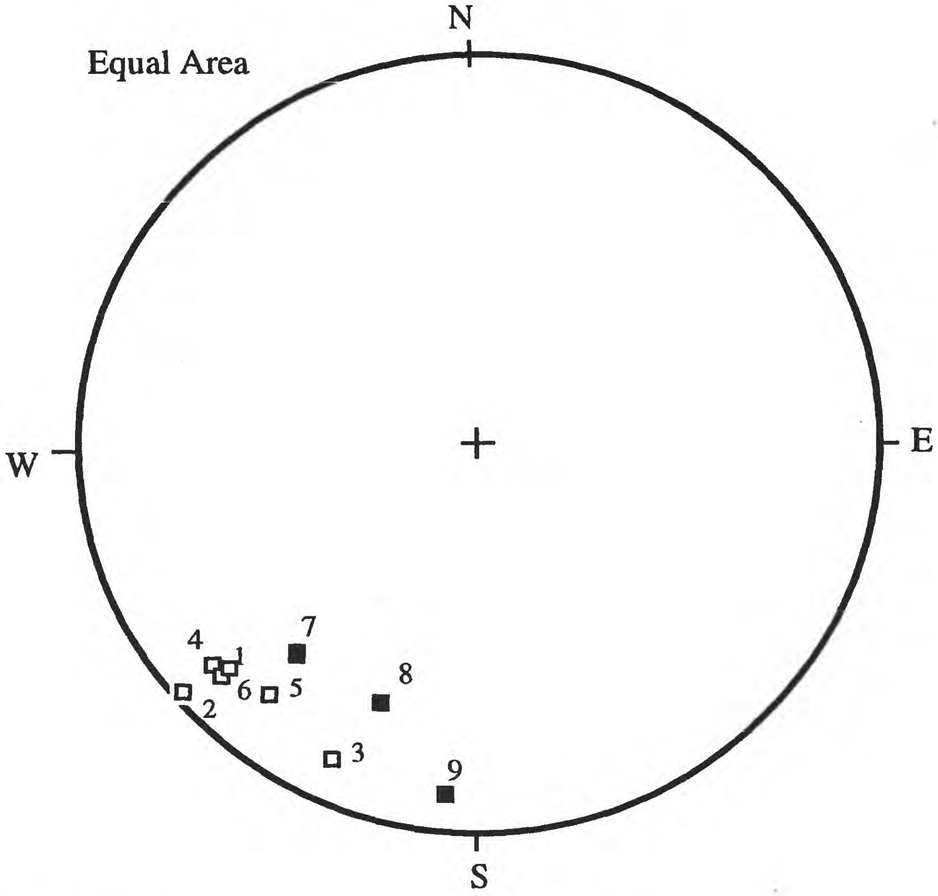

fig. 4. Summary of linear structural features in the Beowawe turnoff area (see fig. 1 for location). Open squares represent fold axes from areas in the outcrop (pl. 1, Appendix I) resolved by stereographic net from bedding attitudes. Solid squares represent rodded or streaking lineations on bedding plane surfaces. Numbers keyed to boxes in stereographic net.

no.	**strike**	**plunge**	**description**
1.	229.0	14.0	Fold axis west side of sketch
2.	229.0	3.0	Fold axis center of sketch
3.	204.0	12.0	Fold axis east side of sketch
4.	227.0	14.0	Fold axis total sketch
5.	219.0	18.0	Fold axis in chert folds
6.	227.0	17.0	Fold axis W and center of sketch
7.	220.0	30.0	lineation
8.	200.0	30.0	lineation
9.	185.0	10.0	lineation

Vivian Station

At Vivian Station, 1 km east of the city of Carlin (S part of Sec. 19, T. 33 N., R. 53 E.), four railroad cuts expose rocks interpreted by Stewart and Carlson (1976) as allochthonous rocks of the Ordovician Vinini Formation (fig. 1). Rock types present include laminated and banded cherty shale, pelitic shale, argillite, and clast-in-matrix rock. Deformation at the mesoscopic scale is intense (pl. 2). Most folds plunge at low angles to the NW; a few plunge to the W (fig. 5; Appendix II). The rocks are cut by NW- and W-trending, 0.25- to 0.5–m-thick fault zones that dip at low angles to the W, and by steep faults that strike N.

Fold axes lie along a great circle that approximates the average orientation of the low-angle, west-dipping faults (fig. 5). Clast-in-matrix rock in this outcrop is similar to that in rocks of the Vinini Formation at the Beowawe turnoff, and is similar to that found in many mélanges. The Vivian Station railroad cuts have both NW-trending and local NE-trending folds in the same outcrop. These two fold orientations are interpreted as local remnants of refolded, SW-plunging, older folds preserved in an otherwise rotated NW-trending set of folds (see Peters, 1996).

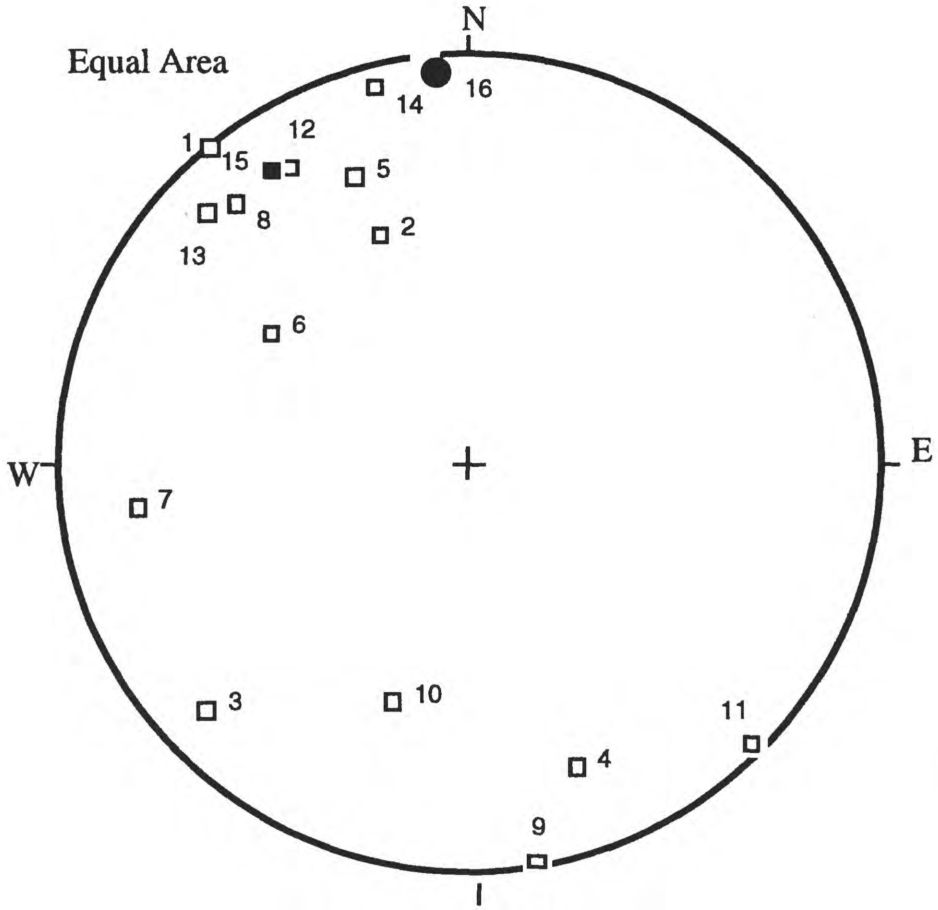

fig. 5. Summary of linear features in the Vivian Station area (see fig. 1 for location). Open squares represent fold axes of individual folds or resolved by stereographic net in folded, deformed areas. Solid square represents fold axis of all areas (A to N) in the four railroad cuts, resolved by stereographic net. Larger solid circle represents fold axis resolved by stereographic net for combined foliation fabrics in the several clast-in-matrix rock outcrops (see pl. 2, and Appendix II). Areas coded to boxes on stereographic net:

no.	**strike**	**plunge**	**description**
1.	321.0	1.0	Area A
2.	339.0	40.0	Area B
3.	226.0	13.0	Area C
4.	338.0	26.0	Area E
6.	303.0	42.0	Area F
7.	262.0	20.0	Area G
8.	318.0	16.0	Area H
9.	170.0	1.0	Area I
10.	197.0	38.0	Area J
11.	135.0	2.0	Area K
12.	329.0	17.0	Area L
13.	314.0	13.0	Area M
14.	346.0	6.0	Area N
15.	326.0	15.0	Combination of Areas A to N
16.	354.0	3.0	Clast-in-matrix rock foliations

Carlin Canyon

In Carlin Canyon (Secs. 26 and 27, T. 33 N., R. 53 E.), between the cities of Carlin and Elko, adjacent and north of Highway I-80 (fig. 1), exposures of conglomerate and cherty limestone of the Lower and Middle Pennsylvanian Moleen Formation are cut by many faults that strike NNE, dip less than 40°E, and have a reverse-slip sense of movement to the W (figs. 6-8). The fault zones contain chaotic geometries and develop truncated monoclines in the hanging walls of the fault zones. These mesoscopic folds contain fold axes that are commonly coplanar with the fault planes, and plunge across them 6° to 13° NE (fig. 8). The fold linear symmetry from this study is similar to that discussed by Jansma and Speed (1990) in a study area approximately 3 to 4 km to the west in Carlin Canyon.

Fold axes throughout the Carlin Canyon study area plunge at shallow angles to the NE, similar to fold axes in Beowawe turnoff and throughout most of the Roberts Mountains allochthon. Figure 7 shows a detailed sketch of one fault zone, which contains folding with fold axes that plunge to the NE at shallow angles (fig. 8; Appendix III). This localized analysis of the overlap assemblage does not resolve controversies concerning tectonics and sedimentation (see Fails, 1960; Smith and Ketner, 1968, 1978; and Jansma and Speed, 1990), but demonstrates that the stratigraphic sequence at this location has been shortened from the east to the west by multiple, east-dipping reverse faults. Coincidence of similar fold axis orientations in the underlying Roberts Mountains allochthon and in rocks of the overlap assemblage may imply that the NE-SW fold axial trend in both these rock stratigraphic packages are coeval and may be the result of post-Paleozoic, regional strain that post-dated Antler age deformation.

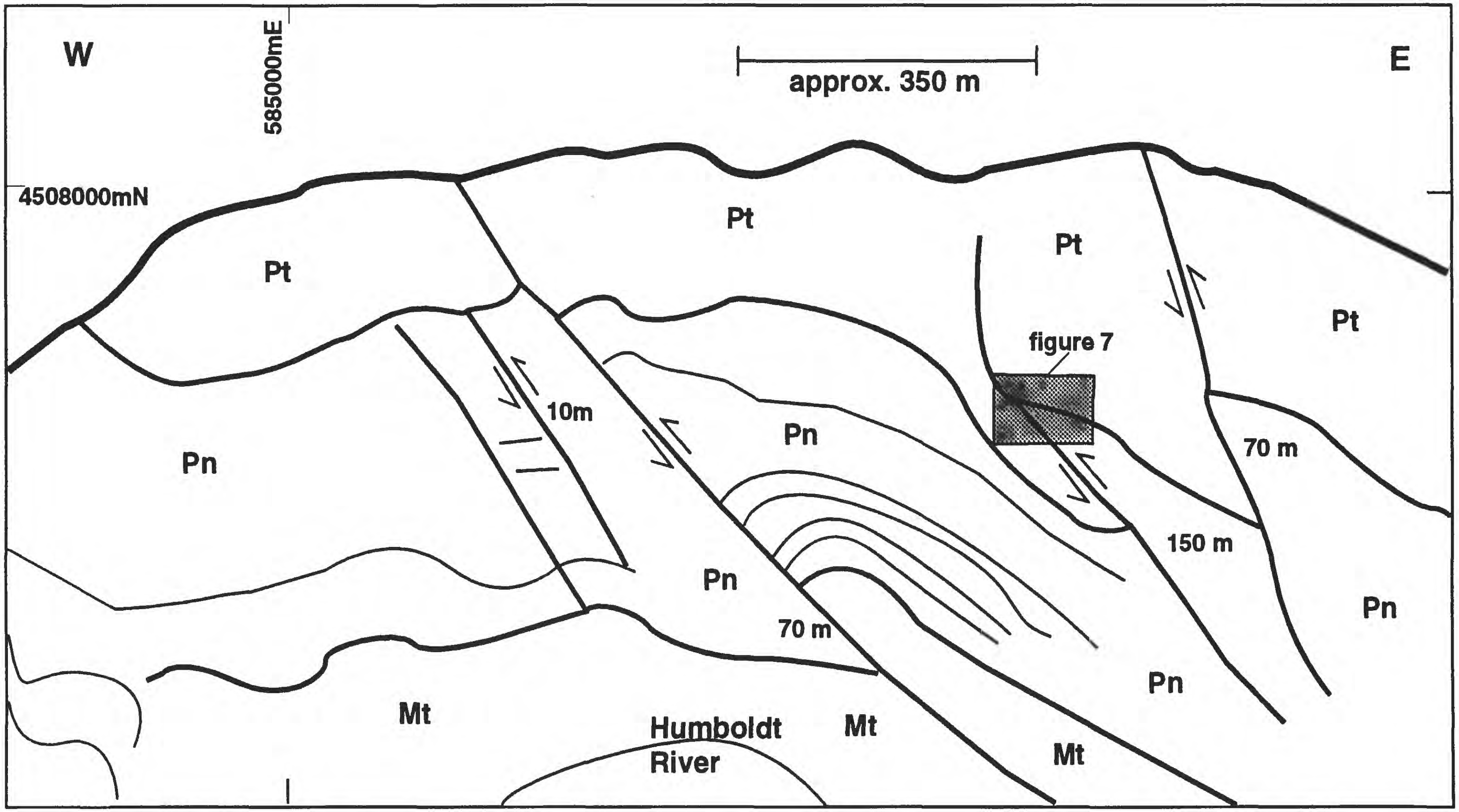

fig. 6. Longitudinal projected section sketch of Carlin Canyon area, looking north from bridge over Interstate Highway I–80. The stratigraphic section in this area has been shortened from the east to the west by a similar series of E-dipping reverse faults. Some of the faults produce monoclines and other disturbances. Geologic units modified from Fails (1960) and Smith and Ketner (1978). Pt = Middle Pennsylvanian Tomera Formation, interbedded interfingering limestone and siliceous-clast conglomerate. Pn = Middle and Lower Pennsylvanian Moleen Formation, gray limestone with interbedded silty and sandy limestone and pods of layers of chert. Mt = Lower Pennsylvanian and Upper and Lower Mississippian Conglomerate, composed of mostly siliceous-clast conglomerate and sandstone of the lower Moleen Formation or Upper Diamond Peak Formation. Arrows indicate fault movement direction with approximate offset (shortening) in meters. Note location of figure 7.

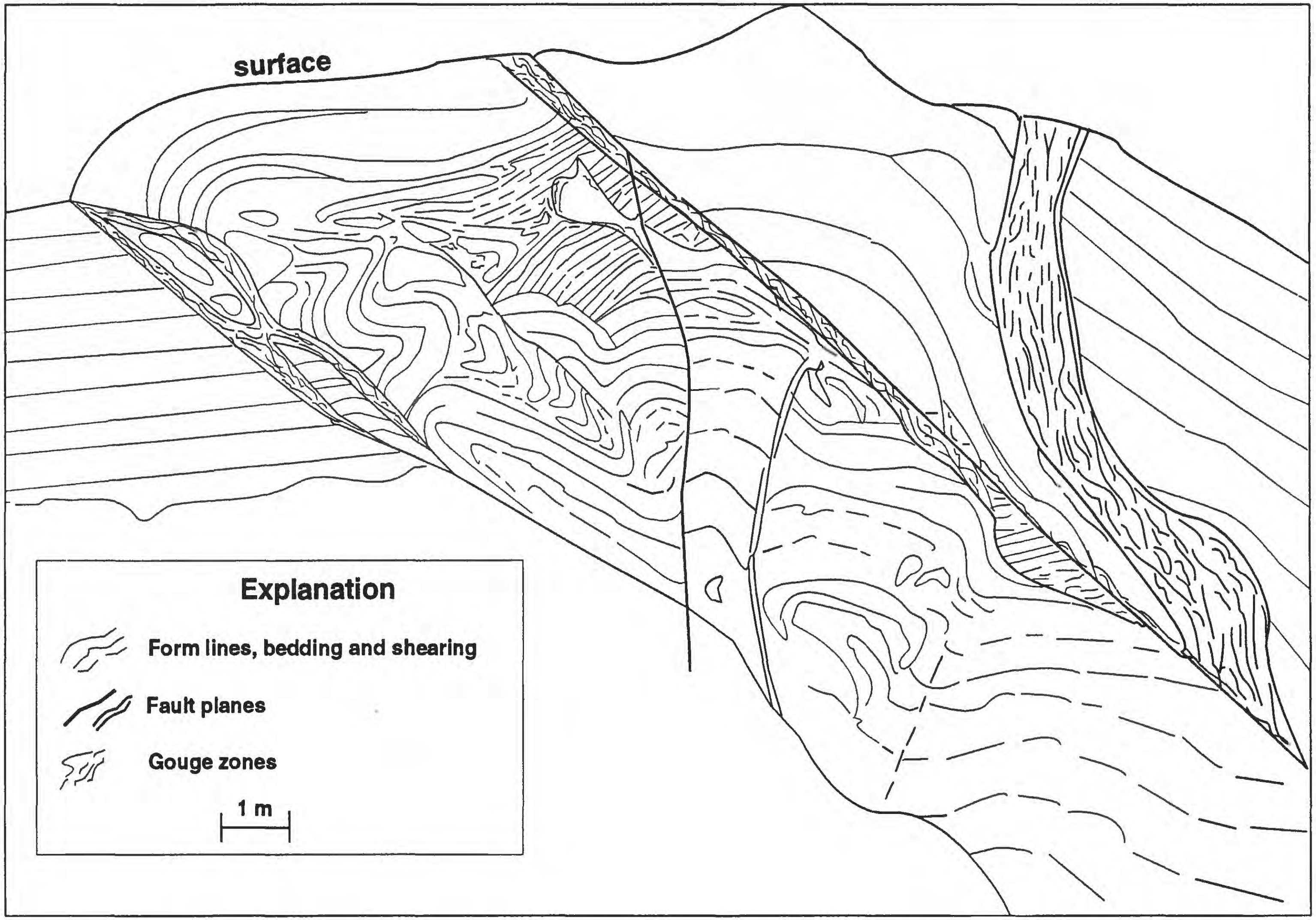

fig 7. Sketch map of faulted out crop of Middle and Lower Pennsylvanian Moleen Formation in Carlin Canyon, looking approximately NE. Folds within the fault zone and local warping in the adjacent area have NE-trending fold axes (fig. 8 and Appendix III) that are coplanar with the fault zones. The area lies within cliffs to the north of the oxbow formed by the Humboldt River on Interstate Highway I–80. See figure 6 for approximate location.

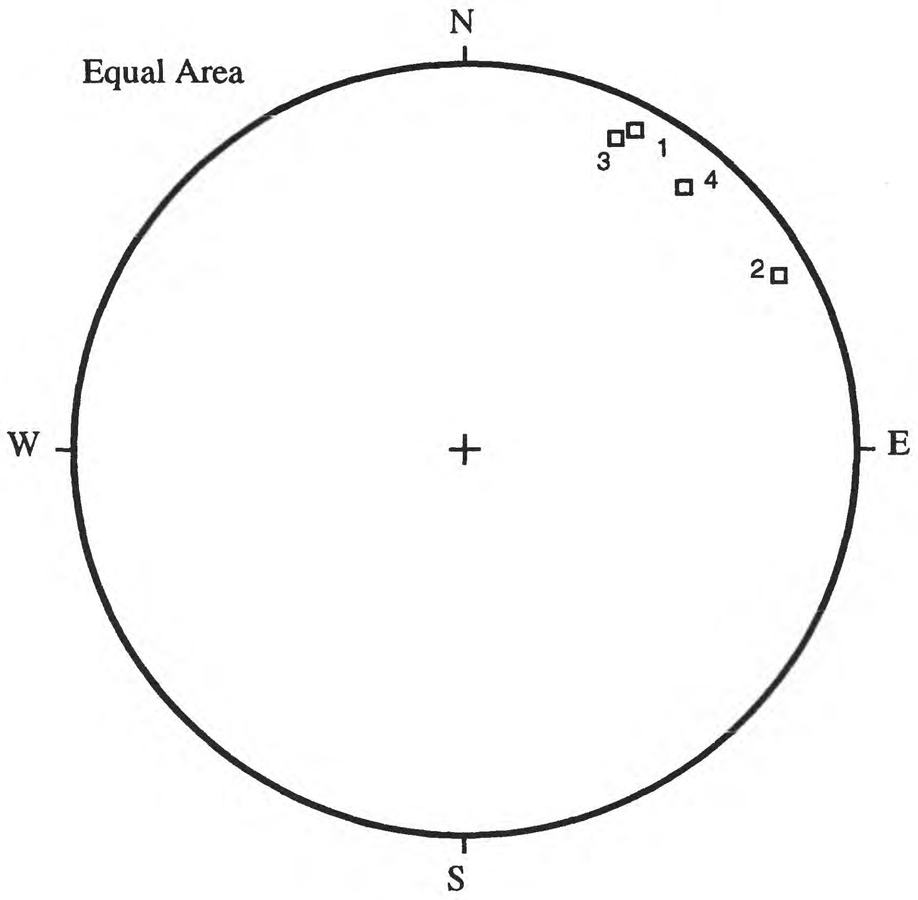

fig. 8. Summary of linear structural features in the Carlin Canyon area. Squares represent fold axes resolved by stereographic net for different areas on figures 6 and 7. Areas coded to boxes on stereographic net:

no.	strike	plunge	description
1.	28.0	8.0	East of fault zone
2.	61.0	9.0	First traverse in road cut
3.	26.0	12.0	Fault zone (fig. 7)
4.	40.0	13.0	Total bedding collected in Carlin Canyon

Definition of the Carlin trend by distribution of fold axes

Results of this study and data from other workers (see fig. 9) suggest that shallow-plunging, NE- and SW-plunging fold axes are widespread in the Roberts Mountains allochthon, peripheral to the NW-trending zone of mines along the Carlin trend (Evans and Theodore, 1978; Madrid, 1987; Madrid and Bagby, 1986; Volk and Zimmerman, 1991; Peters and Evans, 1995; Peters, 1996). Zones of intensely deformed tectonic mélange in the allochthon also contain NE-striking mesoscopic and megascopic folds that consistently plunge at low angles to the NE and SW. In Carlin Canyon, rocks of the overlap assemblage also contain deformation with NE- and SW-trending fold axes. The Carlin trend, by contrast, coincides with a NW-striking, approximately 15–km-wide zone in which shallow-plunging, NW- and SW-trending folds, mostly in the lower plate para-autochthonous miogeoclinal assemblage, are present but not ubiquitous.

Two orientations of fold axes are separated into two structural domains (fig. 9): Domain I, a series of NE- and SW-plunging fold axes, and Domain II, a narrow NW-trending belt of NW–SE-trending fold axes, roughly coincident with much of the Carlin trend. Domain II also roughly coincides with the belt of "windows," that expose lower plate rocks. Some upper plate rocks of the Roberts Mountains allochthon, such as those as Vivian Station (fig. 9), also are deformed into NW-trending folds. A model of the structural formation and development of the Carlin trend is proposed by Peters (1996), who suggests that NE-trending fold axes in both the upper and lower plates of the Roberts Mountains thrust system may have been rotated (refolded) by left-lateral shearing to a NW-trending orientation.

The spatial coincidence of the consistent NW- and SE-trending fabrics, with the lower plate windows in the Roberts Mountains allochthon (figs. 1 and 9), suggests that the deformation that created this fabric may also have contained a vertical component that could have elevated the allochthon and exposed the tectonic windows (see Prihar and others, 1996). This would explain why the windows are most common where the NW- and SE-plunging fold axes are present—because the same mechanisms that produced them may have also elevated the lower plate and the allochthon above them. Alternative explanations involve doming during emplacement of Jurassic plutons and uplift of the windows by late Basin and Range boundary faults.

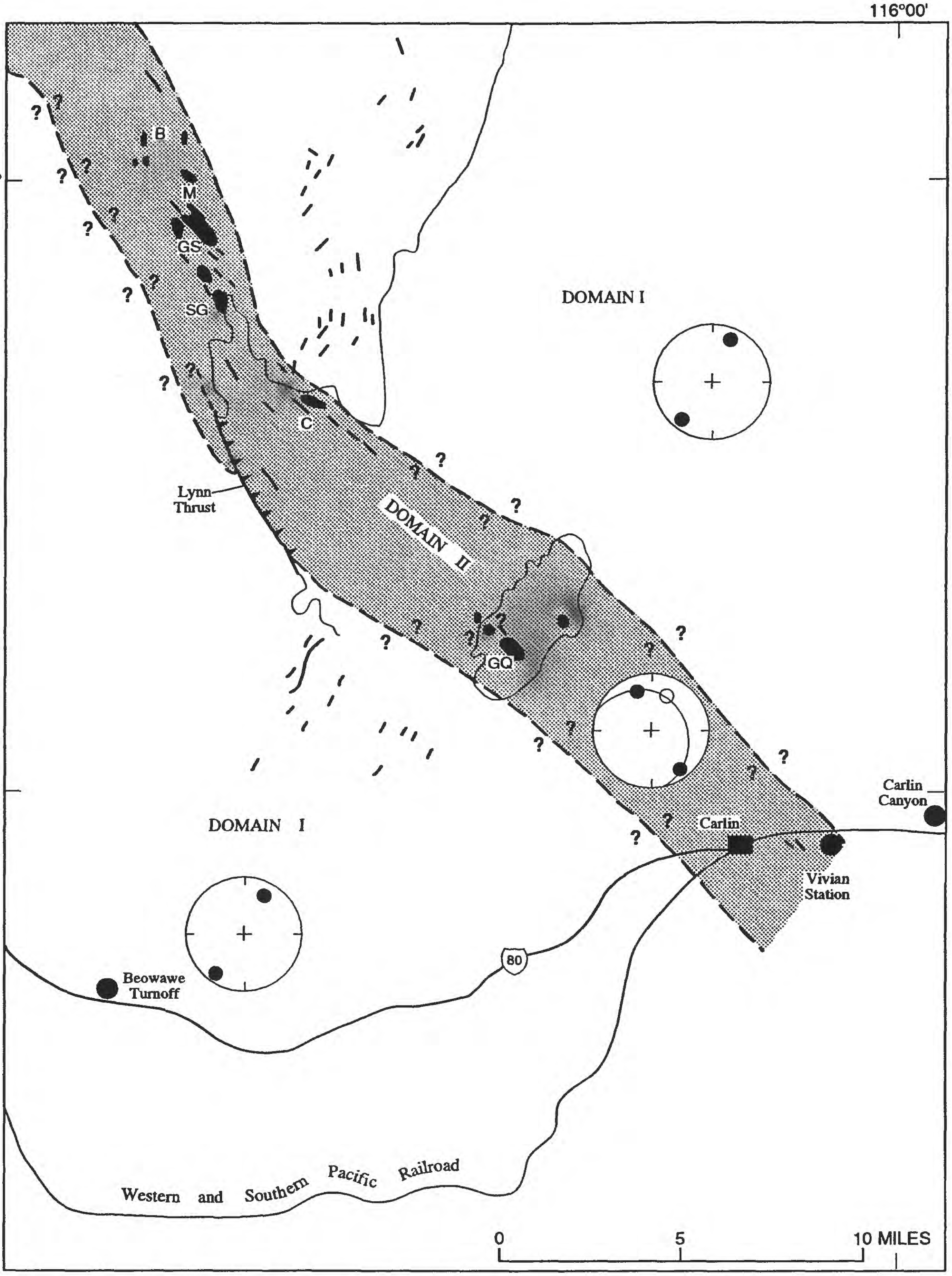

figure 9. Structural domain map of the Carlin trend area, based on fold axes, outlining the Carlin trend. Strikes of the shallow-plunging fold axes define two Domains: Domain I contains a series of NE–SW-plunging fold axes; Domain II, a local NW-trending belt of NW-trending fold axes. Domain II roughly coincides with the lower plate "windows", but some of the upper plate rocks are also deformed. Small, short lines on map are fold axes from Evans and Theodore (1978). Other data (from S to N) from Dave Cole (oral communication), Evans and Cress (1972), Radtke (1973, and 1985), Volk and Lauha (oral communication), Sampson (1993), and Evans and Mullens (1976). GQ = Gold Quarry mine; C = Carlin mine; SG = Star-Genesis mine; GS = Goldstrike mine; M = Meikle mine; B = Bootstrap mine. Adapted from Peters (1996).

Because most of the lower plate rocks outside the Carlin trend have NE- and SW-plunging fold axes, and lower plate rocks are not exposed outside the windows, the possibility of NW- and SE-plunging folds in lower plate rocks outside the Carlin trend cannot be ruled out. Similarly, not all fold orientations within the Carlin trend have NW- and SE-plunging orientations. However, if deformation along the Carlin trend were heterogeneous, it is likely that shear strain would have been partitioned into several strands, which would anastamose along strike and dip and contain undeformed or partially rotated megaphacoids and megaslabs between them (fig. 3a). New folds would be most common near the major shear strands, whereas the megaphacoids would contain partially rotated folds. This mechanism would account for different fold orientations within the Carlin trend corridor.

Conclusions

Strong linear NE–SW structural grain—defined by fold axes in the Roberts Mountains allochthon and in the overlap assemblage—may be the result of post-Paleozoic, regional deformation and may not be related to emplacement of the allochthon.

Many deformed rocks in the upper plate of the Roberts Mountains allochthon near the Carlin trend, have characteristics that are similar to mélange.

Two structural domains are present in the area of the Carlin trend area: Domain I, an area of NE–SW-trending folds with shallow-plunging axial planes, mostly present in the Ordovician Vinini Formation, and Domain II, a narrow, NW-trending zone (including the Carlin trend proper), which contains NW–SE-trending, shallow-plunging folds—mainly involving "lower plate" rocks, but also some upper plate rocks of the Roberts Mountains allochthon. A relatively consistent structural grain is present within the NW-trending Carlin trend.

Acknowledgments

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Appendix I—Bedding attitudes and structural linear features from Beowawe turnoff (pl. 1)

1. Beowawe turnoff
Total bedding attitudes

200.0	26.0	W
205.0	40.0	W
330.0	20.0	E
188.0	36.0	W
180.0	40.0	W
318.0	8.0	N
120.0	48.0	W
173.0	23.0	W
4.0	37.0	E
150.0	20.0	W
93.0	55.0	W
173.0	15.0	W
85.0	23.0	S
80.0	23.0	S
190.0	19.0	W
168.0	25.0	W
225.0	22.0	N
260.0	52.0	N
90.0	40.0	W
230.0	11.0	N
195.0	30.0	N
260.0	65.0	N
200.0	80.0	N
240.0	25.0	N
100.0	30.0	S
205.0	45.0	W
45.0	75.0	E
215.0	75.0	W
95.0	44.0	S
75.0	55.0	E
200.0	30.0	W
340.0	60.0	E
35.0	90.0	E
205.0	58.0	W
185.0	38.0	W
205.0	20.0	W

2. Beowawe turnoff
west side of sketch
bedding attitudes

190.0	19.0	W
168.0	25.0	W
225.0	22.0	N
260.0	52.0	N
90.0	40.0	W
230.0	11.0	N
195.0	30.0	N
260.0	65.0	N
200.0	80.0	N
240.0	25.0	N
100.0	30.0	S
205.0	45.0	W
45.0	75.0	E
215.0	75.0	W
95.0	44.0	S
75.0	55.0	E
200.0	30.0	W
340.0	60.0	E
35.0	90.0	E
205.0	58.0	W
185.0	38.0	W
205.0	20.0	W

3. Beowawe turnoff
folds in chert on
west side of sketch

205.0	45.0	W
45.0	75.0	E
95.0	44.0	S
215.0	75.0	W
75.0	55.0	E
200.0	30.0	W
340.0	60.0	E
35.0	90.0	E
205.0	58.0	W
185.0	38.0	W
205.0	20.0	W

4. Beowawe turnoff
center of sketch
bedding attitudes

240.0	29.0	W
210.0	25.0	W
205.0	2.0	W
180.0	19.0	W
80.0	30.0	S
130.0	8.0	S
7.0	30.0	E
245.0	28.0	N
255.0	25.0	N
240.0	40.0	N
125.0	10.0	S
220.0	20.0	N
40.0	35.0	S
5.0	10.0	S
195.0	32.0	W
20.0	14.0	E
75.0	22.0	S
143.0	23.0	S

5. Beowawe turnoff
east side of sketch
bedding attitudes

240.0	29.0	W
210.0	25.0	W

205.0	2.0	W
180.0	19.0	W
80.0	30.0	S
130.0	8.0	S
7.0	30.0	E
245.0	28.0	N
255.0	25.0	N
240.0	40.0	N
125.0	10.0	S
220.0	20.0	N
40.0	35.0	S
5.0	10.0	S
195.0	32.0	W
20.0	14.0	E
75.0	22.0	S
143.0	23.0	S

6. Beowawe turnoff linear features (number keyed to boxes in stereonet, fig. 2)

1. 229.0 14.0 Fold axis west side of sketch
2. 229.0 3.0 Fold axis center of sketch
3. 204.0 12.0 Fold axis east side of sketch
4. 227.0 14.0 Fold axis total sketch
5. 219.0 18.0 Fold axis in chert folds
6. 227.0 17.0 Fold axis west and center of sketch
7. 220.0 30.0 lineation
8. 200.0 30.0 lineation
9. 185.0 10.0 lineation

Appendix II—Bedding attitudes, foliations, and structural linear features from Vivian Station (pl. 2)

1. Vivian Station poles to bedding combination of areas A to N

142.0	60.0	W
142.0	40.0	W
142.0	65.0	W
142.0	80.0	W
315.0	80.0	E
325.0	65.0	E
345.0	76.0	E
175.0	75.0	W
300.0	55.0	E
150.0	80.0	W
210.0	40.0	W
70.0	30.0	E
120.0	10.0	W
120.0	60.0	W
350.0	83.0	E
160.0	76.0	W
230.0	30.0	W
320.0	40.0	E
350.0	85.0	E
310.0	45.0	E
150.0	58.0	W
262.0	42.0	N
260.0	55.0	N
170.0	55.0	W
100.0	15.0	W
180.0	40.0	W
150.0	80.0	W
140.0	70.0	S
210.0	70.0	N
210.0	35.0	W
130.0	50.0	W
90.0	30.0	S
110.0	30.0	S
225.0	21.0	W
210.0	35.0	W
130.0	50.0	W
90.0	30.0	S
110.0	30.0	S
225.0	21.0	W
175.0	25.0	W
170.0	60.0	W
260.0	20.0	W
140.0	40.0	W
140.0	60.0	W
140.0	50.0	W
140.0	60.0	W
0.0	20.0	E
10.0	90.0	E
205.0	30.0	W
205.0	30.0	W
135.0	40.0	W
195.0	85.0	W
165.0	60.0	W
130.0	90.0	X
350.0	20.0	E
165.0	15.0	W
180.0	60.0	W
265.0	35.0	W
90.0	0.0	W
150.0	50.0	W
142.0	60.0	W
142.0	40.0	W
142.0	65.0	W
142.0	80.0	W
315.0	80.0	E
325.0	65.0	E
330.0	50.0	E
155.0	20.0	W
340.0	30.0	E
180.0	65.0	W
290.0	45.0	E
245.0	10.0	W
140.0	45.0	W
145.0	80.0	W

2. Area A

142.0	60.0	W
142.0	40.0	W
142.0	65.0	W
142.0	80.0	W
315.0	80.0	E
325.0	65.0	E

3. Area B

345.0	76.0	E
175.0	75.0	W
300.0	55.0	E
150.0	80.0	W

4. Area C

210.0	40.0	W
70.0	30.0	E

5. Area D

120.0	10.0	W
120.0	60.0	W
350.0	83.0	E
160.0	76.0	W

6. Area E

230.0 30.0 W
320.0 40.0 E
350.0 85.0 E
310.0 45.0 E
150.0 58.0 W
262.0 42.0 N

7. Area F

260.0 55.0 N
170.0 55.0 W
100.0 15.0 W
180.0 40.0 W
150.0 80.0 W
140.0 70.0 S
210.0 70.0 N

8. Area G

210.0 35.0 W
130.0 50.0 W
90.0 30.0 S
110.0 30.0 S
225.0 21.0 W

9. Area H

175.0 25.0 W
170.0 60.0 W
260.0 20.0 W
140.0 40.0 W
140.0 60.0 W

10. Area I

140.0 50.0 W
140.0 60.0 W
0.0 20.0 E
10.0 90.0 E
205.0 30.0 W
205.0 30.0 W

11. Area J

135.0 40.0 W
195.0 85.0 W
165.0 60.0 W

12. Area K

130.0 90.0 X
350.0 20.0 E
165.0 15.0 W

13. Area L

180.0 60.0 W
265.0 35.0 W
90.0 0.0 W
150.0 50.0 W

14. Area M

330.0 50.0 E
155.0 20.0 W
340.0 30.0 E
180.0 65.0 W

15. Area N

290.0 45.0 E
245.0 10.0 W
140.0 45.0 W
145.0 80.0 W

16. Clast-in-matrix rock foliations

180.0 50.0 S
0.0 52.0 E
205.0 35.0 W
135.0 35.0 W
260.0 35.0 N
101.0 35.0 W
249.0 15.0 N

17. Fold Axes, Areas A to N strike and plunge

1. 321.0 1.0 Area A
2. 339.0 40.0 Area B
3. 226.0 13.0 Area C
4. 160.0 21.0 Area D
5. 338.0 26.0 Area E
6. 303.0 42.0 Area F
7. 262.0 20.0 Area G
8. 318.0 16.0 Area H
9. 170.0 1.0 Area I
10. 197.0 38.0 Area J
11. 135.0 2.0 Area K
12. 329.0 17.0 Area L
13. 314.0 13.0 Area M
14. 346.0 6.0 Area N
15. 326.0 15.0 Combination of Areas A to N
16. 354.0 3.0 Clast-in-matrix rock foliations

Appendix III—Bedding attitudes and structural linear features from Carlin Canyon area (figs. 6-8)

1. Total bedding attitudes Carlin Canyon

5.0	40.0	E
5.0	55.0	E
355.0	5.0	E
5.0	32.0	E
13.0	45.0	E
0.0	40.0	E
25.0	45.0	E
20.0	35.0	E
20.0	35.0	E
40.0	35.0	E
320.0	45.0	E
45.0	30.0	E
205.0	30.0	N
30.0	40.0	E
45.0	30.0	E
15.0	45.0	E
25.0	35.0	E
25.0	40.0	E
230.0	45.0	W
40.0	42.0	E
50.0	40.0	E
55.0	50.0	E
75.0	60.0	E
50.0	80.0	E
35.0	32.0	E
60.0	35.0	E
305.0	25.0	E
200.0	65.0	W
215.0	55.0	N
20.0	30.0	E
1 5.0	40.0	E
325.0	50.0	E
10.0	50.0	E
350.0	30.0	E

2. East of fault, bedding attitudes

5.0	40.0	E
5.0	55.0	E
355.0	5.0	E
5.0	32.0	E
13.0	45.0	E
0.0	40.0	E
25.0	45.0	E
20.0	35.0	E
20.0	35.0	E
40.0	35.0	E
320.0	45.0	E
225.0	30.0	E
25.0	30.0	N
30.0	40.0	E
45.0	30.0	E
15.0	45.0	E
25.0	35.0	E
205.0	40.0	E
50.0	45.0	W

3. Road cut area, bedding attitudes

40.0	42.0	E
50.0	40.0	E
55.0	50.0	E
75.0	60.0	E
50.0	80.0	E

4. Near fault zone, bedding attitudes

35.0	32.0	E
60.0	35.0	E
305.0	25.0	E
200.0	65.0	W
215.0	55.0	N
20.0	30.0	E
1 5.0	40.0	E
325.0	50.0	E
10.0	50.0	E
350.0	30.0	E

5. Linear structural features Carlin Canyon

1.	28.0	8.0	East of Fault Zone
2.	61.0	9.0	First Traverse in road cut
3.	26.0	12.0	Fault Zone (fig. 7)
4.	40.0	13.0	Total bedding collected in Carlin Canyon