Structural Geology of the Confusion Range, West-Central Utah

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By Richard K. Hose

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CONTENTS

ILLUSTRATIONS

STRUCTURAL GEOLOGY OF THE CONFUSION RANGE, WEST-CENTRAL UTAH

By Richard K. Hose

ABSTRACT

More than 33,000 feet (10,000 metres) of generally conformable upper Precambrian (present in the subsurface), Paleozoic, and Lower Triassic strata, all overlain in profound unconformity by Oligocene and younger volcanic and sedimentary rock, are present in the Confusion Range of west-central Utah. During the late Mesozoic to early Cenozoic, the pre-Tertiary rocks were deformed into a structural trough or synclinorium concave in map view to the west. The development of the trough generated two décollement-type faults, above which rocks glided toward its axis. This gliding resulted in the formation, in the highest plate, of isoclinal and recumbent folds, the latter with their lobes directed into the axis. After the trough was filled, additional steepening of the west flank caused the development of a lower décollement that died out eastward toward the axis of the trough. Movement of this décollement caused local overturning of the intermediate and upper plates and a more pronounced westward concavity of the trough. Subsequent increase of the slope of the flanks of the trough, whether by uplift or compression, achieved relief of axial stress by thrusting away from the axis of the trough.

INTRODUCTION

The Confusion Range of west-central Utah (fig. 1) is structurally different from ranges to the immediate east and west in that it forms an elongate, curved structural trough or synclinorium (Hose, 1966). The House Range to the east is a block-faulted homoclinal mountain range that dips gently to the east and is made up mainly of Cambrian rocks. To the west, the Snake Range contains intricately faulted allochthonous rocks of Cambrian to Permian age that have moved over a lower plate of Cambrian and older rocks. It has been reasonably well established that the major low-angle fault or fault complex of the Snake Range extends eastward beneath the Confusion Range (Misch, 1960; Hose and Danés, 1967, 1973). Although the Paleozoic section in the Snake Range has been greatly attenuated by low-angle faults that emplaced younger rock or older, the section in the Confusion Range is reasonably intact and is not greatly attenuated. This paper describes the more important structural elements of the Confusion Range structural trough and presents an explanation for their development.

STRUCTURAL HISTORY

The Confusion Range of west-central Utah (fig. 1; pl. 1) contains about 23,000 ft (7,000 m) of exposed Upper Cambrian to Lower Triassic miogeosynclinal strata. On the basis of outcrops in surrounding areas, it is likely that an additional 6,000–8,000 ft (1,800–2,400 m) of Lower and Middle Cambrian strata, plus an indeterminate but great thickness of Precambrian rocks, is present in the subsurface. There is some indirect evidence that Middle and Upper Triassic and Jurassic rocks were also deposited but were removed by post-orogenic erosion. Rocks of this age (Triassic and Jurassic) are present at Blue Mountain in the southern Wah Wah Range where they are overthrust by Cambrian rocks (Miller, 1966). The Wah Wah Range and Confusion Range are in general structurally continuous.

The region was affected by two major tectonic events: the older one took place sometime between Late Jurassic and Oligocene time, and the younger, the Basin and Range orogeny, sometime after Oligocene time. There is some uncertainty as to just when tectonism took place within the older period and whether it was a single or multiple event, representing orogenesis perhaps in both the Cretaceous and the early Tertiary.

Clearly the older event(s) occurred prior to 36.5 m.y. (million years) ago, for gently dipping volcanic rocks of this age (early Oligocene) rest on severely deformed rocks of Permian age just north of the area covered by plate 1.

In the Schell Creek Range of eastern Nevada, which is about 40 mi (64 km) west of the Confusion Range, Drewes (1967) reported clasts of Prospect Mountain Quartzite, which was then considered Early Cambrian, incorporated in what are believed to be equivalents of the Eocene Sheep Pass Formation. Hose and Blake (1976) suggested that unconformable relations at the base of Sheep Pass equivalents elsewhere in eastern Nevada, and the presence of Cambrian-derived material, required significant physiographic and structural relief prior to and during the deposition of the Sheep Pass and its equivalents. Such tectonism was clearly pre-Eocene, and if regionally operative, the episode(s) would be limited to the latest Jurassic to Paleocene.

An additional indirect clue to the age of tectonism

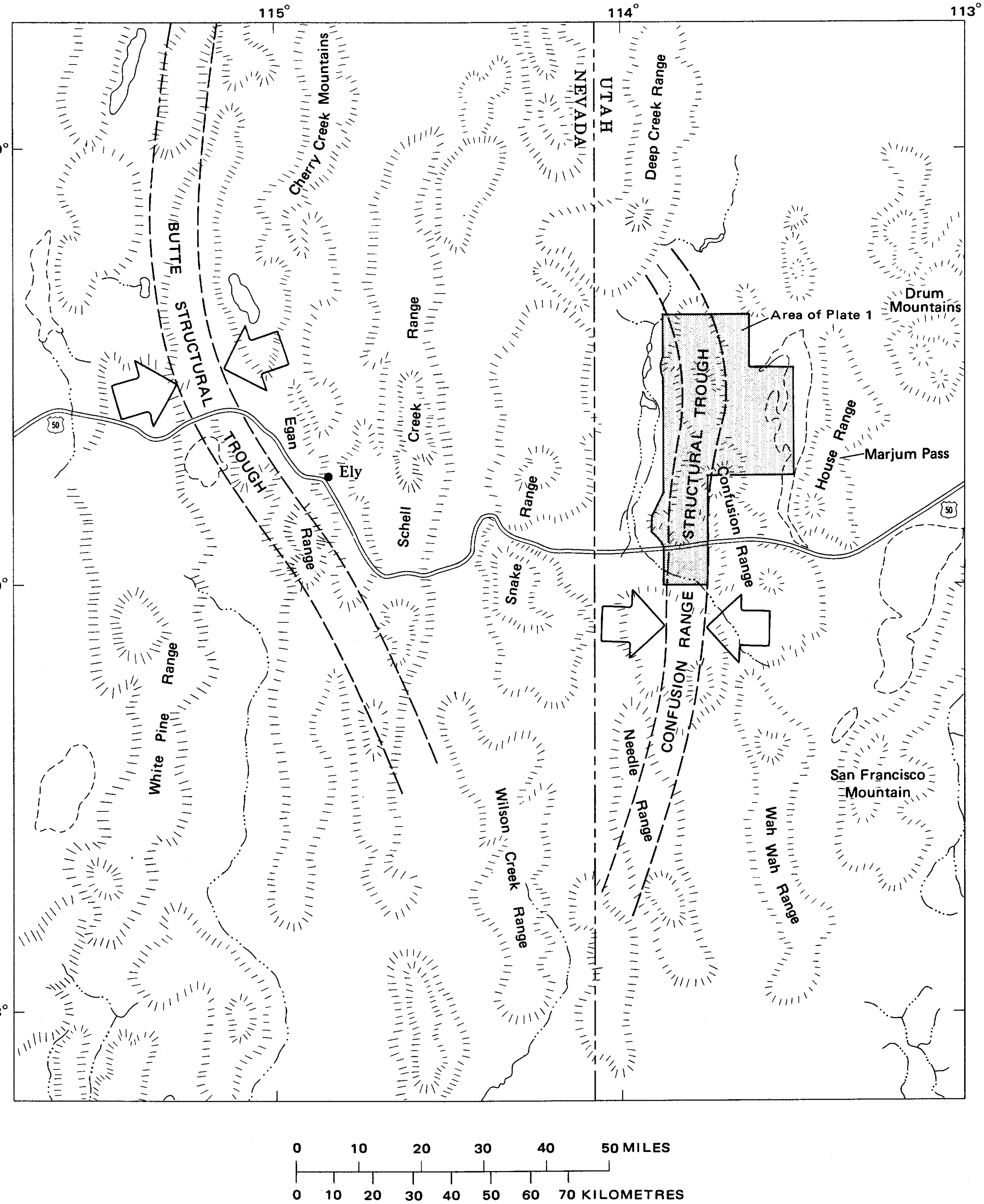

FIGURE 1.—Index map of east-central Nevada and west-central Utah showing location of mountain ranges and position of Butte and Confusion Range structural troughs.

within the former miogeosyncline can be found to the east in the para-autochthonous rocks just east of the Sevier orogenic belt of central Utah. There, the conformable relatively fine grained Triassic and Jurassic rocks are overlain by coarse-grained orogenic boulder conglomerates of Cretaceous age. The amount of relief, both structural and physiographic, indicated by the coarse detritus is believed to define the climax of the older structural events in eastern Nevada and western Utah and thus dates the tectonism as Cretaceous. Admittedly, some or all of these assumptions may be unwarranted, and conclusions on regional correlation and genesis may likewise be unwarranted. Tectonism during the early Tertiary (Laramide) is also known to occur along the eastern part of the Cordillera and may have affected western Utah. In view of the uncertainties of dating, the older tectonism is referred to herein as the late Mesozoic to early Cenozoic orogeny, and the younger as the Basin and Range orogeny.

The younger event reached a climax in east-central Nevada some time after 17 m.y. ago (middle Miocene) and before early Pliocene (Hose and Blake, 1976).

LATE MESOZOIC TO EARLY CENOZOIC OROGENY

At some time during the late Mesozoic to early Cenozoic, the concordant Paleozoic and Triassic sequence of the Confusion Range was downwarped into a structural trough or synclinorium more than 60 mi (97 km) long and at least 8 mi (13 km) wide. More than 40 mi (64 km) of this trough lie within the mapped area (fig. 1; pl. 1). From Cowboy Pass southward through the Conger Range quadrangle and another 20 mi (32 km) beyond the map area, the trend of the trough is N. 10°–15° E., whereas north of Plympton Ridge in the Disappointment Hills the trend is about N. 25° W. Instead of marking a smooth transition between these two trends, the segment between them making up Plympton Ridge shows a sharp accentuation to N. 45° E. at Cowboy Pass at the south end of the segment, to north-south in the central part, to N. 50° W. in the northern part of Plympton Ridge. The southern part of the trough in the Needle Range is overlapped by volcanic rocks, whereas the northwestward extension is truncated against a Basin-Range fault on the east side of the Deep Creek Range (fig. 1). Its pre-Basin and Range extent beyond this fault to the north or northwest is unknown.

The east flank of the structural trough is fairly well defined by dips of 10°–40° W. in the vicinity of Granite Mountain, by west dips in the southern part of the Cowboy Pass quadrangle, and by west dips at intermediate latitudes in the buttes of White Valley (pl. 1). The strikes or contact projections of Devonian units beneath the alluvium of White Valley are mildly concave westward and do not reflect the sharp westward concavity of Plympton Ridge.

The west flank of the trough within the map area is best shown by easterly dips of the pre-Permian Paleozoic rocks in the Conger Range. To the south of the map area, the pre-Permian Paleozoic of the western Burbank Hills also has pronounced easterly dips (Hintze, 1963). A reconstructed cross section expresses the west flank of the trough across the northern part of the map area (Hose, 1975a). The variety of structures along the axis of the trough are of particular significance in that they provide the basis for a hypothesis on their origin.

The original structural relief on the trough can be approximated by removing the effects of the Basin and Range orogeny. The top of the Precambrian Z and Lower Cambrian Prospect Mountain Quartzite should be at a depth of 20,000 ft (6,100 m) below sea level beneath Cowboy Pass along the axis of the trough, assuming no significant repetition or elimination of strata by faulting. To the east, the top of the Prospect Mountain is present at an elevation of 6,000 ft (1,830 m) in Marjum Pass in the House Range, but if the Basin and Range flanking fault had dip slip of about 4,000 ft (1,220 m), it should formerly have been at an elevation of about 2,000 ft (610 m). This would provide about 4 mi (6.4 km) of structural relief between the House Range and Cowboy Pass in 20 mi (32 km), indicating a dip of about 11°.

To the west, the top of the Prospect Mountain is now at an elevation of more than 8,000 ft (2,400 m) in the northern Snake Range, and assuming it was elevated along a Basin and Range fault with about a 2,000 ft (610-m) displacement, its pre-Basin and Range elevation should have been at 6,000 ft (1,800 m) to give a total relief of 26,000 ft (7,900 m) in 20 mi (32 km), or an average slope of more than 15°. Present dips indicate that the west flank was the steeper. It thus seems certain that rather high dips were attained on the flanks of the trough as it developed.

If the Basin and Range orogeny significantly uplifted the northern Confusion Range and accommodations were made for a modest horstlike uplift, then the pre-Basin and Range structural relief would be even greater than cited above.

STRUCTURES WITHIN THE STRUCTURAL TROUGH

LOW-ANGLE FAULTS

Two principal types of low-angle faults characterize the structural trough. The first and most important in terms of structural complexity is the décollement type that emplaces younger rock on older, and the second is the thrust fault that emplaces older rock over younger. The thrust faults, which locally cut the décollements, are of relatively small displacement and are rooted (pl. 1, *D–D′*, *E–E′*, and *G–G′*).

The two décollements in the map area (pl. 1, *D–D′* to *I–I′*) formed within the stratigraphic zones of least competence. The structurally higher of these two faults has its sole in the upper part of the Arcturus Formation, usually close to beds of gypsum. In places, movement on the uppermost décollement placed Arcturus over Arcturus, but locally younger beds, such as the Kaibab Limestone, Plympton Formation, or Gerster Limestone (three units composing the Park City Group), are in fault contact with the Arcturus. Generally the fault cuts the higher parts of the Arcturus, but in places it cuts deeper into the Arcturus, as west of Granite Mountain where virtually the entire upper part of the unit is faulted out. The outline of outcrop of the Park City Group and the Thaynes Formation is approximately coincident with the upper décollement, and so these units are allochthonous everywhere in the map area. This allochthon is referred to informally as the upper plate.

The lower décollement cut out from 100 to 400 ft (30 to 122 m) of strata and emplaced highest Chainman Shale and lower Ely Limestone over parts of the upper 300 ft (91 m) of the Chainman Shale. The fault underlies virtually all the Ely Limestone along the west flank of the trough except for the Foote Range. The fault is not present at any point on the east side of the trough and is believed to have died out along bedding somewhere beneath the trough or on its west flank. The allochthonous Ely Limestone and most of the Arcturus are interpreted as belonging to the intermediate plate everywhere along the west flank of the trough except in the Foote Range. The Ely Limestone of the Foote Range, along with the Chainman Shale and older units along the remainder of the west flank of the trough, are interpreted as composing the lower plate.

EVIDENCE FOR THE HIGHER DÉCOLLEMENT

The geologic map (pl. 1) has been generalized from detailed maps originally published at a scale of 1:24,000 (pl. 1, index). A consequence of this generalization is removal of much of the detailed data that document the existence of the two décollements. A brief review of the documentation is presented here, for although the fault surfaces, particularly the higher one, crop out at many places, they are mostly inferred.

At Desolation anticline, four rather persistent limestone beds (A to D in ascending order) in an interval from 500 to 600 ft (150 to 180 m) thick were mapped in detail in the upper Arcturus by Hose and Repenning (1963) and Hose and Ziony (1963). Overall, the beds define a smoothly curved anticlinal fold, but high in the section, as the upper plate is approached, the Arcturus is severely deformed. Just west of the Disappointment Hills and north of the Cowboy Pass NW quadrangle, the D bed lies just below the fault surface and is strongly deformed. Nevertheless, it extends nearly as far north as the north end of the Disappointment Hills, as do the A and B beds (C bed was not mapped north of the Cowboy Pass quadrangle).

About 1½ mi (2.4 km) east of the northermost occurrence of the A, B, and D beds, on the east side of the upper plate (Disappointment Hills), the A–D interval is missing altogether from the intermediate plate. It seems unlikely that this disappearance is due to stratigraphic wedging out in view of the fact that some of these beds (A and B) extend nearly the entire length of the map area with only minor changes in lithology. Furthermore, in the position that the limestone beds should have occupied is a severely deformed gypsiferous sandstone sequence of Arcturus that is underlain by lower Arcturus with relatively uniform west dips and overlain by about 30 feet (10 km) of upper Arcturus that conformably underlies the Kaibab and is part of the upper plate.

In the southeastern part of the Desolation anticline, the Gerster Limestone or Plympton Formation are in several places in fault contact with the upper Arcturus. The fault is well exposed and gently dipping in this area.

Figure 2 presents an example of general intermediate-upper plate relations.

The elongate folds in the allochthonous block underlying Plympton Ridge are terminated by a high-angle fault at the northwest end (fig. 2). Abutting that fault on the northwest is a synclinal block of Kaibab Limestone which is an offset element of a syncline that extends virtually the entire length of Plympton Ridge. This small offset element in effect demonstrates the relations between the upper plate and the intermediate plate for all of Plympton Ridge. Beds A–D are continuous across the syncline on the west of Desolation anticline. The A and B beds also continue around the southwest side of the offset element, but the C and D beds are overturned and were cut off by the décollement so that as much as 400 ft (120 m) of strata was removed along the southwest side of the offset and southward along the entire west side of Plympton Ridge. To account for the removal of the C and D beds, a fault must be inferred above the B bed and below the upper 30 ft (10 m) or so of Arcturus, which is part of the

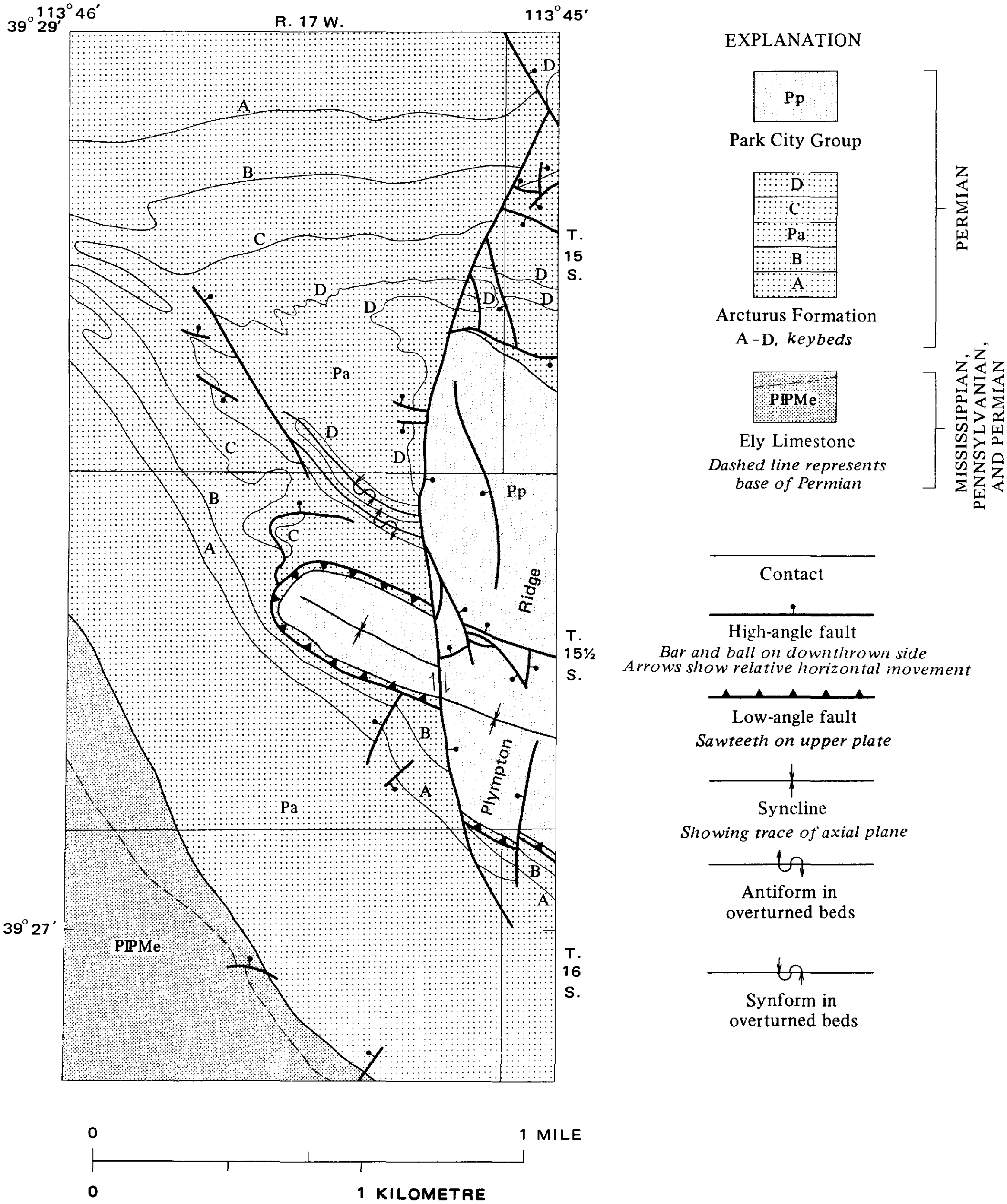

FIGURE 2.—Generalized geologic map of northwest end of Plympton Ridge (Modified from Hose and Ziony, 1963).

upper plate. The position of the fault in the missing C–D interval requires that the fault be subparallel to the bedding in the Arcturus of the intermediate plate and coincidentally subparallel to the bedding in the lower part of the upper plate, or that the fault originally had about the same strike as the bedding. The bedding in the upper and intermediate plates locally is overturned along the west side of Plympton Ridge, as so must be the upper décollement. Near Cowboy Pass the C–D interval is present, thus further precluding any possibility that the missing interval resulted from some stratigraphic phenomenon. Furthermore, a deformed gouge zone is present in some places at the upper-intermediate plate boundary around the offset, and if the fault underlies the offset, it must also underlie the rest of Plympton Ridge. Elsewhere the presence of the upper décollement is demonstrated by severe deformation in the higher parts of the intermediate plate.

EVIDENCE FOR THE LOWER DÉCOLLEMENT

Evidence for the lower décollement is based mainly on the absence of strata at various places northwest, north, and east of the Bishop Spring anticline. The upper Chainman Shale and lower Ely Limestone of the northern Foote Range are well exposed and the sequence is clear, so there is little doubt that strata are removed along the trace of the fault in the area east of the Foote Range (pl. 1, *F–F′*). The concealed position of the trace southward from the latitude of Bishop Spring anticline, however, is uncertain because of the depth of Tertiary and Quaternary cover.

A relation comparable to that east of Bishop Spring anticline exists in the Conger Range where missing upper Chainman and lower Ely indicate faulting. Additional evidence appears in a fenster close to the west side of the Buckskin Hills (pl. 1, *H–H′*, and *I–I′*). A geologic map of White Pine County, Nev. (Hose and Blake, 1970), to the west, also shows several areas where the upper Chainman Shale–lower Ely Limestone is the locus of low-angle décollement faulting.

STRUCTURES OF THE UPPER PLATE

Cross sections accompanying maps of the Confusion Range (Hose, 1963a, b; 1965a, b; 1966, 1975a, b; Hose and Repenning, 1963) show that the upper plate is synclinal and forms the core of the Confusion Range structural trough at least from Rattlesnake Bench northward to the north end of the map area as well as a few outliers in the area just northwest of the Conger Range. Within this synclinally folded allochthon, there are two common fold types: those that are nearly isoclinal with vertical to recumbent axes and those that are broad and open. The isoclinal folds characterize the northern part of the Disappointment Hills; the more open folds, the southern part from the southern Disappointment Hills to the south end of the upper plate near Rattlesnake Bench. Plympton Ridge, which is also part of the upper plate, contains tight folds that are overturned to the east. Plympton Ridge also has a much more pronounced bend in it than the contiguous area of more open folds on the east with which it is in fault contact.

Displacement on the thrust within the upper plate in the Disappointment Hills (pl. 1, *D–D′* and *E–E′*) moved units as old as the Arcturus Formation and the Kaibab Limestone relatively westward over units as young as Triassic. The thrust becomes vertical just north of the latitude of the central part of Plympton Ridge, and in places the relative displacement of the high-angle extension suggests a throw that is down on the east rather than up, as it is to the north where clearly low angle. Such a contrast in throw could be resolved if there were an element of left-transcurrent motion on the fault or later vertical movement.

Displacement on a second thrust cutting the upper plate southeast of Cowboy Pass (pl. 1) moved Permian beds, the Kaibab and Plympton, over Triassic units; here, the movement of the hanging wall of the thrust is clearly to the southeast. This thrust dies out just north of Rattlesnake Bench, but to the northeast it effects a contrast in trends of about N. 45°–55° E. in the upper plate to about north-south to N. 35° E. on the average in the lower plate. It seems likely that the broad open syncline just north of Cowboy Pass (pl. 1, *F–F′* and *G–G′*), which is certainly a part of the upper plate of the thrust southeast of Cowboy Pass, is continuous northward to the southern Disappointment Hills where it is also part of the upper plate of the thrust of the western part of Disappointment Hills. This synclinal unit then is the upper plate of two rooted thrusts, one to the north that moved rocks relatively west and the other in the south that moved rocks relatively southeast (pl. 1, Disappointment Hills–Plympton Ridge and northeast of Rattlesnake Bench; *D–D′*, *E–E′*, and *G–G′*).

Two additional details of the upper plate structures are cited here because of their bearing on interpretations of the genesis of the entire upper plate. Along the west edge of and within the upper plate in the northern part of the Disappointment Hills is a flaplike recumbent fold with its lobe directed eastward into the axis of the structural trough (pl. 1, *A–A′*, *B–B′*, and *C–C′*). The south end of the flap has a steep southerly plunge and is believed to die out in a short distance beneath right-side-up beds. A second flaplike fold is present 4–5 mi (6–8 km) south of the north end of the map area on the east side of the upper plate (*D–D′*, *E–E′*). The lobe of this flap is directed westward into the axis of the structural trough.

STRUCTURE OF THE INTERMEDIATE PLATE

The intermediate plate in part outlines the west flank of the Confusion Range structural trough. The west edge of the plate is defined by the trace of a near bedding plane fault that is cut in the upper Chainman Shale and lower Ely Limestone. Since no fault at a comparable stratigraphic position is present on the east side of the trough, it is believed that the fault died out somewhere in the subsurface beneath the trough. Accordingly, the intermediate and lower plates merge into a single plate on the east side of the trough. The fault surfaces that mark the base of both the intermediate and upper plates have the same synclinal form as the structural trough.

Beds in the higher parts of the intermediate plate where they are close to the upper décollement are severely compressed into tight, small-amplitude folds. In the area directly northwest of Plympton Ridge, the D bed of the Arcturus Formation (Hose and Ziony, 1963) is overturned and upside down for a distance of half a mile. The beds in this flaplike upside-down element are locally sharply folded. The direction of overturn suggests that the upper plate moved in an easterly direction. Except for this severe deformation high in the intermediate plate, the folds of the intermediate plate are much broader and of larger amplitude than those of the upper plate.

The intermediate plate occupies the axial region of the structural trough. Throughout the northern two-thirds of the map area, the intermediate plate is partly overlain by the upper plate, and so a complete view of the axial structures is not available. In the southern third of the map area, where erosion has exposed most of the intermediate plate, the most conspicuous feature is a faulted anticlinal fold along the very axis of the structural trough. Interpretive cross sections (pl. 1, *H–H'* and *I–I'*) show both flanks of the faulted anticline to be overturned in the southern Conger Range but overturned only to the west in the northern part. The overturns plus complex faulting give the fold a mushroom shape in cross section in the southern part of the Conger Range. In the southern part of the Conger Range (pl. 1, *I–I'*), the anticline is flanked on both sides by synclines, but the syncline on the east in the northern part of the Conger Range is partly cut out by a reverse fault. This fault and the precise anticline-syncline relation are obscured by Quaternary cover in the vicinity of Brown's Wash. The slight northerly plunge of about 15° of the anticline suggests that it may die out beneath the upper plate, and so the intermediate plate may be wholly synclinal beneath the upper plate.

At the latitude of Plympton Ridge, both the upper and intermediate plates are more concave to the west than either the lower plate or the axis of the structural trough. The area where the concavity is greatest is the area of greatest overturn of the upper décollement as well as the intermediate plate.

OTHER STRUCTURES

CONGER RANGE FAULT

Two large faults have had a profound effect on the structure and thus deserve mention. Of these two, the larger is the Conger Range fault, which offsets both of the décollement faults and therefore is younger. It is overlapped by Tertiary sedimentary and volcanic rocks as young as 29 m.y., and also it is older than the Basin and Range orogeny. The fault is composite, arcuate, and high angle. It borders the lower and middle Paleozoic rocks of the western part of the Conger Range and where it trends easterly, cuts directly across the structural trough; on the east it trends south beneath Tertiary sedimentary and volcanic rocks. The maximum stratigraphic displacement is more than 2 mi (3.2 km) at the southwest end, diminishing to perhaps 1,000 ft (305 m) at the east terminus of exposure. The apparent offset of the anticline in the axis of the intermediate plate is more than a mile (1.6 km).

SALT MARSH RANGE FAULT

The Salt Marsh Range fault flanks the range on the southeast and trends northerly. The attitude of the fault surface is unknown, but it is probably steep and up on the west. The fault has moved Middle Devonian strata on the west against the Ely Limestone, indicating a stratigraphic displacement of more than 4,000 ft (1,200 m). The areas to the north and south of the Salt Marsh Range are covered by Quaternary deposits, and the continuation of the fault is unknown. However, the scattered outcrops east of the northern part of the Salt Marsh Range suggest that the trend changes to nearly due north; the fault may die out to the north and also to the southwest. Although the age of this fault is uncertain, it may have formed during the Basin and Range orogeny, but direct evidence is lacking.

BASIN AND RANGE OROGENY

A large measure of the present physiography of the Basin and Range province was imposed by the Basin and Range orogeny. This event was extensional and produced steep fault scarps and high relief on one or both flanks of most of the ranges of the province. The total extension across the province has been estimated by Thompson and Burke (1973) to be about 62 mi (100 km), on the basis of careful geologic and geophysical work in Dixie Valley, Nev. To account for the relatively uniform array of mountain ranges and basins across the province, Stewart (1971) attributed the structures to deep-seated extension of a plastic substrate.

It is fairly certain that the development of the basins and ranges occurred over a long period, probably starting as early as Oligocene and continuing to the present (Nolan, 1943, p. 183). It is also possible that the event climaxed at different times in different places. In east-central Nevada it is believed to have reached a climax in the late Miocene (Hose and Blake, 1976).

Precise dating of a tectonic event requires the presence of a sequence of datable rock whose age closely brackets the event. In the Confusion Range the Basin and Range orogeny can be dated no closer than post-28–29 m.y. (the late Oligocene age of welded ash flows at Toms Knoll in the Conger Range quadrangle and at Cowboy Pass and other places) and pre-late Tertiary.

Block faulting is negligible or at least uncharacteristic in the northern Confusion Range, inasmuch as the prominent range-front scarps so common elsewhere are here uncommon and relief is low. A Basin and Range fault may have produced the scarp on the west flank of the Salt Marsh Range, however, and may extend a considerable distance to the north and south, buried beneath Quaternary pediment veneer. The large Conger Range fault complex that produces the prominent scarp along the west to north margin of the Conger Range, however, is overlapped depositionally by the limestone that underlies the 28–29-m.y.-old welded ash flows. The southern part of the Confusion Range beyond the map area to the east and southeast is somewhat more typical, as it does have steep scarps. No doubt Basin and Range faults cut the older faulted terrane, but differentiation of these, where Tertiary rocks are absent, is impossible. The sharp contrast in the abundance of faults in the Paleozoic and Triassic terrane with the sparsity of faults cutting the Oligocene rocks in the Conger Range is probably representative of the whole Confusion Range. Oligocene volcanic rocks and limestone are cut by a fault along the west side of Toms Knoll.

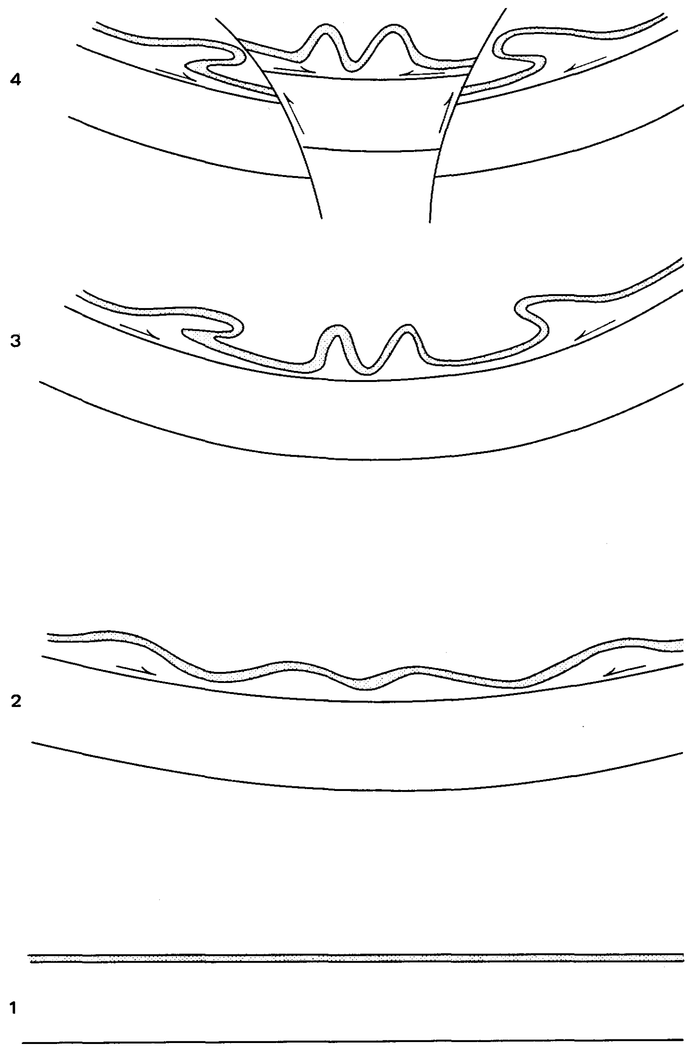

FIGURE 3.—Schematic cross sections showing stages of development (1–4) of décollement and thrust faults and folds in axial part of Confusion Range structural trough. Arrows show movement direction on faults; datum formation (such as the Kaibab Limestone) is shaded.

SUMMARY AND CONCLUSIONS

As the Confusion Range structural trough developed, the flanks became steeper. When some unknown critical slope was reached, competent units high in the section sheared loose from weak gypsiferous zones of the upper Arcturus Formation and moved in a quasi-viscous manner toward the axis of the trough. The inward-directed movement of this upper plate produced isoclinal and recumbent folds whose basal disharmonic surfaces became coincident with the major glide surface, or décollement. The occurrence of recumbent folds with opposing directions of overturn toward the axis of the Confusion Range structural trough is best explained by gravity sliding and would have evolved as shown schematically in figure 3. The present configuration of the structural trough (pl. 1, *A–A′* to *E–E′*) shows some isoclinal and recumbent folds. Significantly the lobes of the recumbent folds are directed toward the axis or direction of movement. In sections *B–B′* and *C–C′* the lobe is directed to the east and suggests eastward movement of the upper plate; sections *D–D′* and *E–E′* show the lobe of the east flank directed toward the west.

The intermediate plate formed in a similar way to the upper plate, but it developed on a lower stratigraphic level and was confined to the west flank. It played an important role in the present configuration of the structural trough. Although it is believed to extend nearly the whole length of the map area (pl. 1, *D–D′* to *I–I′*), it seems to have had its maximum relative eastward movement at the latitude of Plympton Ridge. At this latitude (pl. 1, *F–F′*) its movement produced an overturn of the upper and intermediate plates and accentuated the westward concavity of the structural trough.

As a result of the two episodes of axially directed gliding and flowage, the structural trough was filled with folded rock. The presence of rooted thrust faults that later cut this body of rock suggests that there was a continued buildup of stress in the axial part of the trough that was relieved by thrusting away from the axis (to the west in pl. 1, *D–D′* and *E–E′* and to the east in *G–G′*). The nature of this stress is unknown but could have been regionally compressive and quite different from the local compressive stress that produced the axial folds.

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