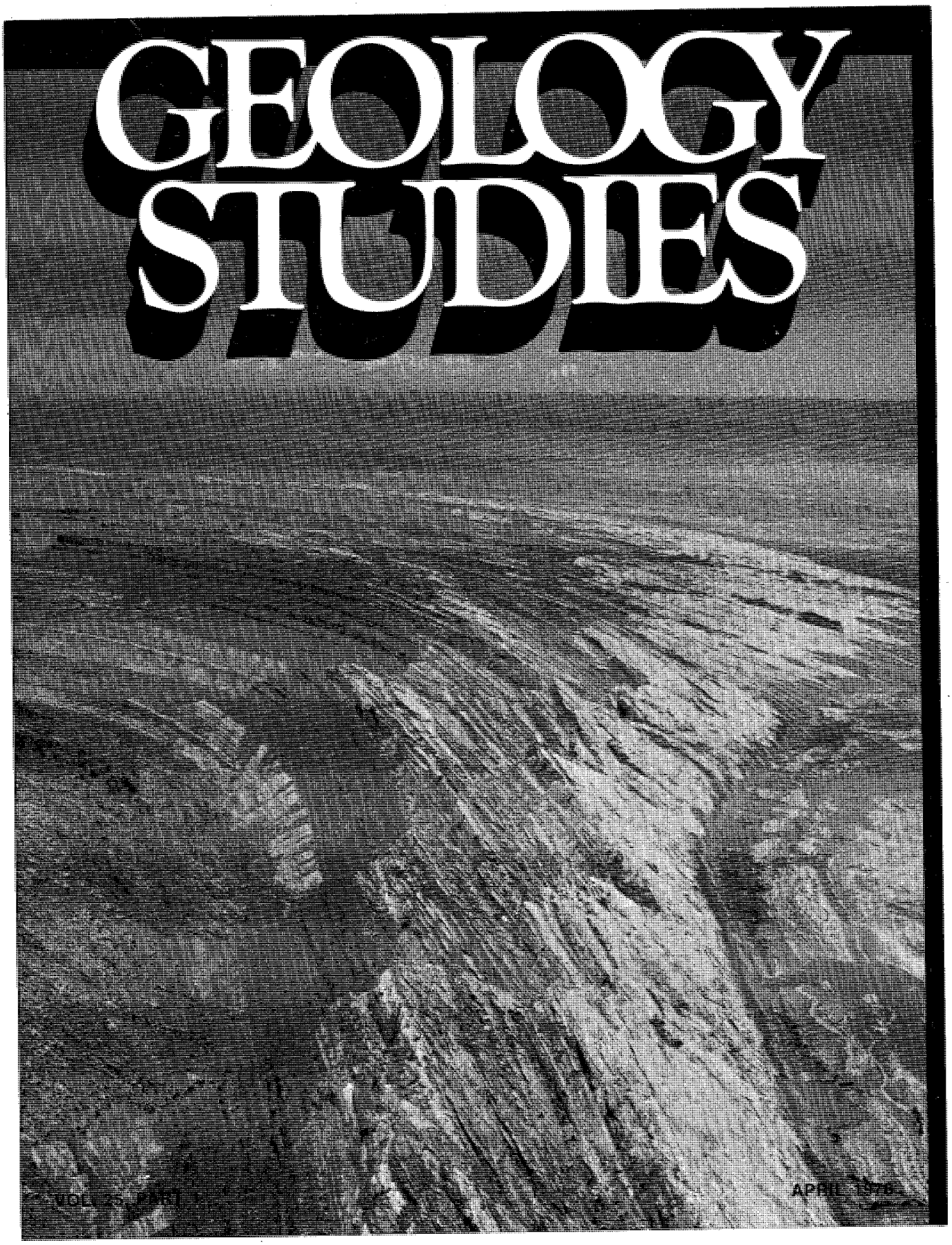
BRIGHAM YOUNG UNIVERSITY

GEOLOGY STUDIES



VOL. 25, PART 1

APRIL 1978

BRIGHAM YOUNG UNIVERSITY GEOLOGY STUDIES

Volume 25, Part 1

Papers reviewing geology of field trip areas, 31st annual meeting, Rocky Mountain Section, Geological Society of America, April 28-29, 1978, at Brigham Young University, Provo, Utah.

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Cover: East flank of San Rafael Swell, Emery County, Utah; looking north. Photo by W. K. Hamblin.

A publication of the
Department of Geology
Brigham Young University
Provo, Utah 84602

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Brigham Young University Geology Studies is published semiannually by the department. *Geology Studies* consists of graduate-student and staff research in the department and occasional papers from other contributors. *Studies for Students* supplements the regular issues and is intended as a series of short papers of general interest which may serve as guides to the geology of Utah for beginning students and laymen.

ISSN 0068-1016
Distributed April 1978
Price $5.00
(Subject to change without notice)
4-78 800 31295

Sevier Orogenic Attenuation Faulting in the Fish Springs and House Ranges, Western Utah

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ABSTRACT.– Attenuation faults are unusually clearly exposed in parts of the House and Fish Springs ranges. These ranges display both attenuated and unattenuated sections permitting a more accurate quantitative evaluation of the effects of attenuation than is possible in other ranges in the eastern Great Basin. In the Fish Springs Range these faults pervade Middle Cambrian through Middle Devonian strata and reduce this interval to about 60 percent of its ordinary thickness. The massive carbonate units and the Eureka Quartzite are commonly brecciated, but thin-bedded or shaly units are thinned without apparent brecciation. In the House Range the massive Howell, Dome, and Swasey limestones are, in places, entirely cut out by attenuation faulting.

Areas affected by attenuation faulting are separated from unattenuated areas by southeasterly trending tear faults. In the southern Fish Springs Range the attenuation faults are cut by low-angle normal faults that represent extensional conditions of a later date. These low-angle normal faults are, in turn, cut by high-angle normal faults typical of the Basin and Range province.

Attenuation faulting is localized in a broad northerly trending belt in western Utah and eastern Nevada; the House and Fish Springs Range exposures are on the east edge of this belt. The attenuation faults represent thin-skinned detachment surfaces formed during the Sevier orogeny when a thick sheet of miogeosynclinal Precambrian through Lower Triassic strata moved southeastward. The upper (Late Paleozoic) layers must have moved farther eastward than the lowest (Precambrian to Lower Cambrian) layers; the intermediate Paleozoic beds appear to have been stretched and smeared out between the differentially moving upper and lower parts of the sheet.

Sevier orogenic extensional effects of western Utah and eastern Nevada are believed to be contemporaneous with and related to the stacking up of the Paleozoic section in older-on-younger overthrust sheets in central Utah. Major subsidence of central Utah in Jurassic and Cretaceous time provided a depressed area towards which the miogeosynclinal sheet moved.

INTRODUCTION

What happened in the hinterland of the Mesozoic Sevier orogenic belt in Utah and Nevada has for a number of years been puzzling those interested in the area. The mixture of high- and low-angle faults and local igneous and metamorphic structures of differing ages has been difficult to sort out. This paper is limited to addressing certain relations in the House and Fish Springs ranges in western Utah as they illuminate one facet of the regional problem. The House and Fish Springs ranges are particularly suited to detailed structural work because they are nearly barren of soil and vegetative cover and the exposures are unexcelled. In addition they contain structurally uncomplicated areas where the stratigraphic sequence is exposed in its entirety, juxtaposed against structurally complex areas involving the same stratigraphic units.

The particular emphasis of this paper is a semi-quantitative examination of younger-on-older, near-bedding-plane faults, as they occur in the House and Fish Springs ranges. Armstrong (1972) called such faults "denudation" faults and argued that they are predominantly of Tertiary age and related to basin-range faulting. Hose and Daneš (1973) suggested that the younger-on-older faults of the eastern Great Basin are genetically related to the older-on-younger overthrust faults of central Utah and were produced by differential uplift and gravity sliding in late Mesozoic and early Cenozoic time. The above-mentioned authors have reviewed the regional setting and the history of ideas on these structures so they will not be repeated here. Regional location of the subject area is shown in figure 1. Figure 2 shows which parts of the House and Fish Springs ranges contain the attenuation structures.

STRATA AND THEIR STRUCTURAL BEHAVIOR

Figure 3 shows the stratigraphic units in the subject area and summarizes their structural behavior. The rocks are not metamorphosed except for the normal regional development of mica in the strata at the base of the section in the Pioche and Prospect Mountain formations. These basal units are not apparently involved in attenuation faulting.

Certain massive units (Howell, Dome, Lamb, Notch Peak, Eureka, Ely Springs, and Laketown) are commonly attenuated and brecciated. Shaly units (Chisholm, Whirlwind, Wheeler, Fish Springs, Candland, Fillmore, and Kanosh) are also attenuated but not apparently brecciated. In fact, it is usually not possible to ascertain that attenuation has occurred in the shaly units without measuring the thickness of the stratigraphic interval. Attenuation faulting may cause the apparent thickness of a stratigraphic unit to vary markedly and abruptly along strike. A particularly noteworthy example of this is the disappearance of the entire Howell Limestone (500 feet thick) in the northern House Range on the spur traversed by section 1 shown in figure 4 and table 1.

Widespread brecciation of attenuated units suggests deformation under dry, near-surface conditions similar to those suggested by Brock and Engelder (1977) rather than under Hubbert-Rubey hydrostatic glide conditions.

Because of the great variation in thickness of attenuated beds, it has been rather difficult to quantify the amount of section missing. Drewes (1967, p. 6–7) estimated that younger-on-older low-angle faults had reduced the section in the Schell Creek Range in eastern Nevada by half. See figures 5 and 6 for the Drewes interpretation of attenuation faults in eastern Nevada. Thickness figures presented in table 2 for the Kern Mountains on the Utah–Nevada border suggest approximately the same reduction in section. Table 3, comparing unattenuated and attenuated thickness of Cambrian strata in the House and Fish Springs ranges, suggests that the amount of missing section varies from 10 to 50 percent. The House–Fish Springs area lies near the easternmost edge of known occurrence of attenuation faulting, as shown in figure 1. The lesser percentage of missing section in the House–Fish Springs area as compared to the section along the Utah–Nevada border is taken to mean that the differen-

tial movement which caused the attenuation was greater in the west and died out toward the east. Table 1 summarizes the effects of attenuation in a 3-mile exposure along the west face of the House Range portrayed in figure 4. Beds beneath the lowest formation shown on table 1, the Howell Limestone, were not much affected by attenuation in this area. Measurements show that the stratigraphic section here has been thinned to about two-thirds of its ordinary thickness, found in unattenuated exposures a few miles to the south. The formation that shows the greatest variation here is the Dome Limestone, a relatively massive unit.

For cartographic convenience, only one attenuation fault is drawn at the base of a formation so thinned, coinciding with the formational contact, as in figure 7. In actual fact the formational contact may be intact, and the faulting may lie within the formation.

It must be emphasized that the missing strata have not been found stacked up elsewhere in the area of attenuation. Nor do beds occur out of sequence in any attenuated section. Those beds present are always in their normal order. The best explanation I have for this phenomenon is that the middle (Cambrian–Devonian) part of the miogeosynclinal stratigraphic sequence has been stretched, ground up, and attenuated as the upper part of the rock column (Late Paleozoic–Early Mesozoic) moved differentially southeastward over the lower part (late Precambrian–Early Cambrian).

Another deformational style that I believe is related to attenuation is that identified as "jostle" faulting in figure 2.

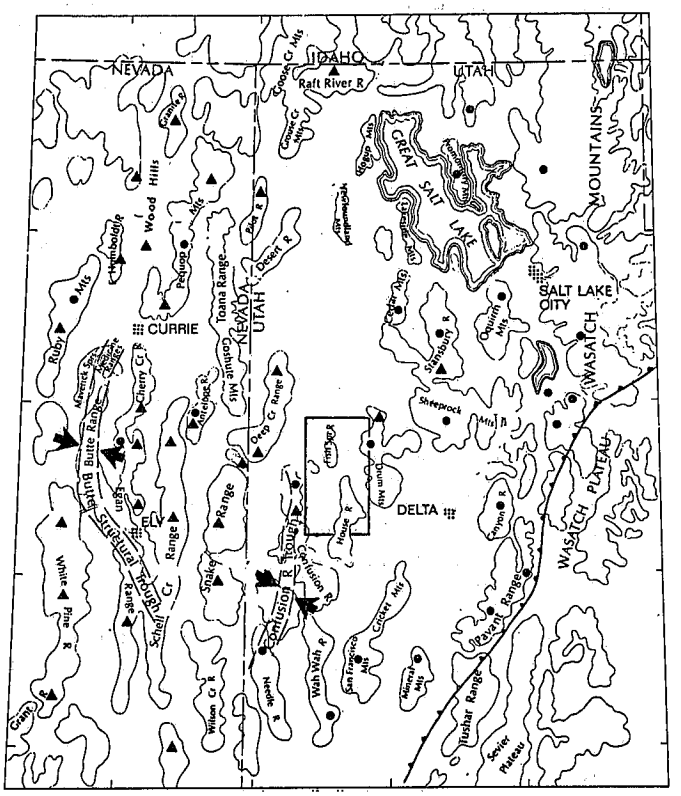

FIGURE 1.– Index map, modified from Hose and Danes (1973) showing the distribution of younger-on-older faulting (triangles) and older-on-younger overthrusts (dots). Toothed line shows the eastern limit of overthrusting in Utah. Arrows indicate compressional directions of structural troughs. Box in center of map is area of figure 2.

Formations in the areas so designated are broken by a myriad of high-angle faults of small displacement, offsetting beds a few feet or at most a few tens of feet. On aerial photographs this displacement has the effect of making the bands of strata appear fuzzy or poorly defined. Deformation in the "jostled" areas might be visualized as being formed by placing some layers of brittle material on a sheet and dragging them over an uneven surface.

IGNEOUS ROCKS

Igneous rocks are not involved in attenuation faulting, but their presence places some constraints on the time the deformation occurred. The north end of the House Range exposes a series of small latite dikes that cut the attenuated strata and therefore postdate them (Chidsey 1977). These dikes have not been radiometrically dated in the study area, but they are similar to quartz latites in the nearby Keg Mountains that are dated as 30.8 m.y. (Oligocene) by Lindsey et al. (1975). In addition, none of the Oligocene–Miocene extrusive rocks anywhere in western Utah show attenuation types of deformation. Attenuation deformation in western Utah is therefore certainly pre-Oligocene and cannot be related to the later basin-range faulting as suggested by Armstrong (1972, p. 1729).

TEAR FAULTS

Easterly to southeasterly trending transverse or tear faults separate attenuated areas from unattenuated areas in the Fish Springs–House Range area as illustrated in figures 4 and 7. This suggests that tear faulting and attenuation faulting developed contemporaneously. Tear faults are major structural features of other areas that have undergone attenuation faulting. Nolan's (1935) map of the northern Deep Creek Mountains showed the attenuation structures (Ochre Mountain and Dutch Mountain thrusts in figure 8) as well as major tear faults. The tear fault between Christiansen Gulch and North Pass Canyon shown in figure 9 is similar to those in the House–Fish Springs area in that it separates an area of attenuation and structural complexity on one side of the fault from an unattenuated section of regular homoclinal dips on the other side.

AMOUNT AND DIRECTION OF TRANSPORT

No geologic reference points are available in the House–Fish Springs area that enable exact measurement of amount of horizontal offset along the attenuation faults. The same formations and even individual key beds within formations are present in both attenuated and unattenuated sections, so the offset has not been so great as to juxtapose different facies. This does not mean that the entire House–Fish Springs blocks cannot have been involved in considerable horizontal transport from their original basin of deposition. But it does show that the differential movement between the upper part of an attenuated block and its lower part was not great enough to produce a juxtaposition of different facies. Over how broad an area these facies were originally distributed is another unknown fact.

The direction of transport is more readily determined than the amount. This direction is ascertained from the trend of tear faults and supported by minor drag folds in a few areas. The tear faults trend easterly to southeasterly as shown by examples in figures 4 and 7. It is believed that the direction of transport was essentially parallel to the trend of the tear faults.

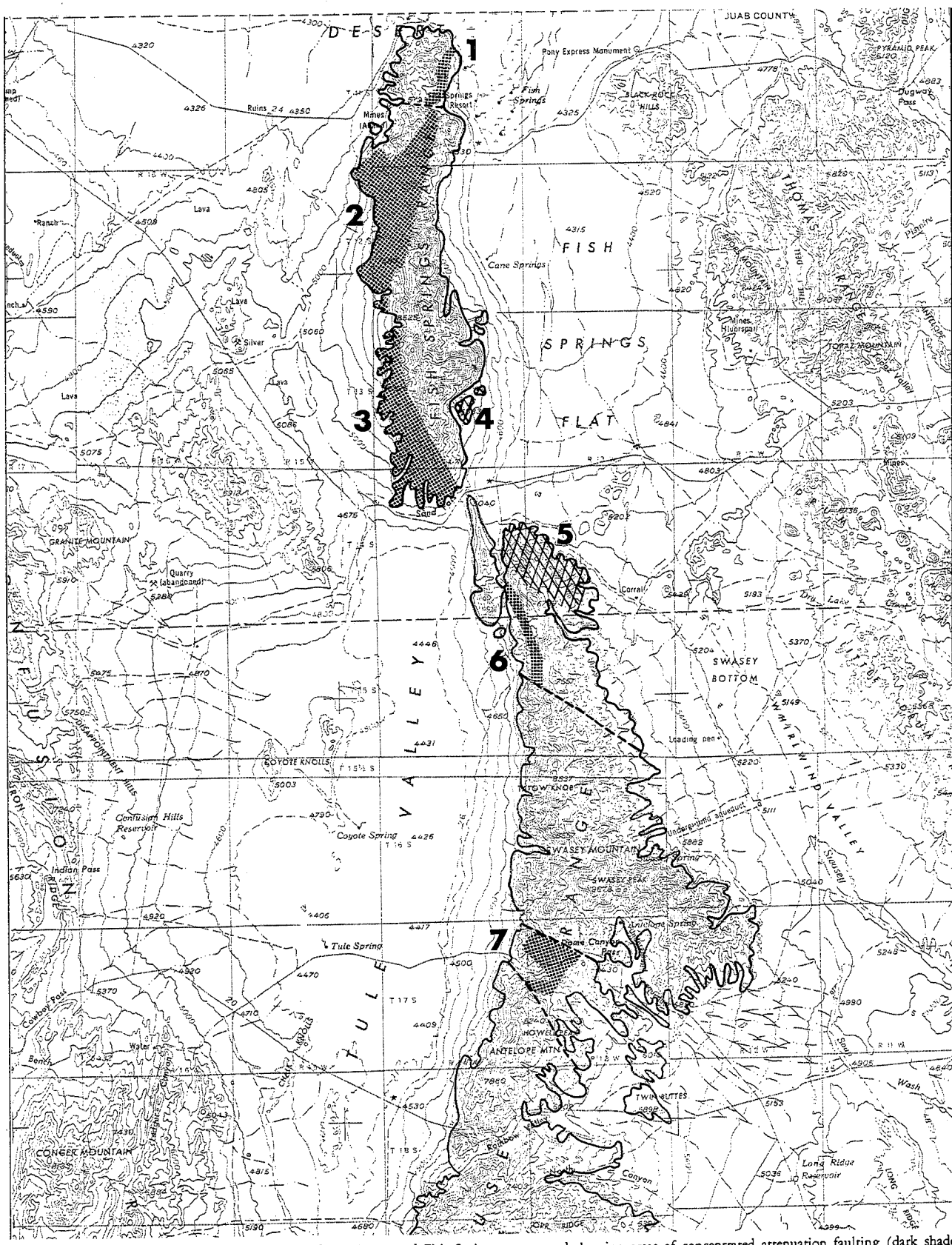

FIGURE 2.– Map outlining the bedrock exposures of the House and Fish Springs ranges and showing areas of concentrated attenuation faulting (dark shaded areas 1–3, 6–7) and "jostle" faulting (light shaded areas 4–5). See text for identity of strata affected in each numbered area. Dashed lines represent major tear faults that bound the areas of attenuation.

SYMBOL	FORMATION NAME	THICKNESS	DESCRIPTION	STRUCTURAL BEHAVIOR
Dsi	Simonson Dolomite	1000	Interbedded dark-brownish-gray dolomite and light-gray laminated dolomite. Some beds contain tubular stromatoporoids and gastropod impressions	Exposed mostly in alluvium-surrounded outcrops at northern tip of Fish Springs Range. Chief deformation is lateral displacement by northwest trending tear faults
Ds	Sevy Dolomite	1000	Light-gray fine-grained unfossiliferous thin- to medium-bedded laminated dolomite; forms low ledges and rounded slopes without any cliffs; contains no distinctive marker beds	Lack of marker beds within this formation makes it difficult to ascertain fault offsets within this unit. Its complete succession is shown only in one section in the northern Fish Springs Range. Elsewhere this formation is attenuated 20-90% and is locally pervasively brecciated
Slt	Laketown Dolomite: Thursday Member	155	Interbedded dark-gray and pinkish-gray coarsely crystalline dolomite	Ely Springs and Laketown Dolomite behave the same structurally. Unbroken sequence is known only at the north end of the Fish Springs Range. Elsewhere these units exhibit internal brecciation which changes the usual sharply banded appearance of these units on aerial photographs to fuzzy bands. In the west central Fish Springs Range, the units are so smeared that they cannot be differentiated. Brecciation intense locally
Sll	Laketown Dolomite: Lost Sheep Member	180	Lower 80 feet pinkish weathering; remainder dark-gray with 10% chert	
Slh	Laketown Dolomite: Harrisite Member	130	Prominent dark band on aerial photos	
Slb	Laketown Dolomite: Bell Hill Member	530	Banded light- to dark-gray finely to coarsely crystalline dolomite; forms ledge-slope topography. Contains some poorly preserved corals and brachiopods	
Oesf	Ely Springs Dolo: Florida Member	135	Light-gray finely crystalline dolomite	
Oes	Ely Springs Dolo: Lower member	255	Upper 115 feet is dark cliff-forming dolomite above slopes and ledges	
Oe	Eureka Quartzite	90 (N)-300 (S)	Orthoquartzite and quartz sandstone, white to light-gray, pock-marked	Eureka Quartzite is usually broken and attenuated 20 to 90%
Owr	Pogonip Group: Watson Ranch Qtzt	0-150	Fucoidal brown calcareous sandstone	Pogonip Group units do not usually give overt signs of much deformation. Attenuation shows as variation in thickness of units within short distances along the strike. However, units also appear to thin stratigraphically and change facies (particularly from the Kanosh Shale upwards) towards the north end of the Fish Springs Range as the units approach the paleogeographic Tooele Arch, active in this part of Ordovician time
Od	Pogonip Group: Deadman Spring Dolo	160- 0	Light-reddish-brown sandy dolomite	
Ok	Pogonip Group: Kanosh Shale	0-130	Fissile shale and thin-bedded ls	
Oj	Pogonip Group: Juab Limestone	70-150	Medium-gray cliff-forming limestone	
Ow	Pogonip Group: Wah Wah Limestone	110-270	Silty limestone that forms slopes and ledges. Much intraformational ls cg	
Of	Pogonip Group: Fillmore Limestone	750(N)-1100(S)	Medium-gray thin-bedded intraformational limestone conglomerate interbedded with light-olive-gray silty shale. Forms rounded slopes and low ledges and low-lying topography	
Oh	Pogonip Group: House Limestone	150-110	Light-bluish-gray finely crystalline quartzose limestone; forms low ledges	
O€n	Notch Peak Formation	1250	Mostly dark-gray finely to coarsely crystalline massive cliff-forming dolomite; some thin beds of medium-gray limestone near base and top; unfossiliferous except for a few algal stromatolites near the top	Notch Peak Formation exhibits a great range of deformational behavior. From Fish Springs Station southward for 10 miles it is an undeformed, competent, cliff-forming unit. Southward from there it becomes pervasively brecciated and greatly attenuated and forms low ragged hills
€os	Orr Fm: Sneakover Ls Mbr	120	Distinctive blocky limestone at base	These thin upper Orr units usually survive in attenuated sequences with less brecciation than more massive units do
€ocs	Orr Fm: Corset Spring Sh Mbr	50	Fissile bright green shale; covered	
€oj	Orr Fm: Johns Wash Ls Mbr	170	Dark ls capped with light dolomitic ls	

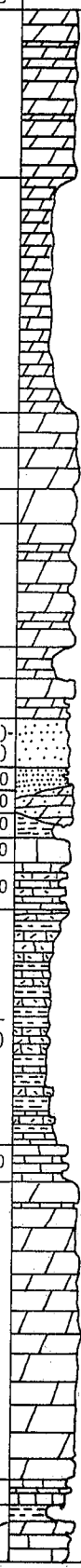

FIGURE 3A.—Paleozoic strata exposed in the Fish Springs Range and their structural behavior. Thickness in feet.

SYM-BOL	FORMATION NAME		THICK-NESS	DESCRIPTION	STRUCTURAL BEHAVIOR
€oc	Orr Formation	Candland Shale Mbr	220	Fissile olive-gray shale interbedded with thin-bedded fossiliferous ls	Commonly thinned but not brecciated in attenuated sections.
€ob	Orr Formation	Big Horse Ls Mbr	440	380-440: slope-ledge siliceous ls 190-380: mottled ls, partly bioclastic 80-190: brown platy siliceous limestone 0-80: medium-gray oolitic limestone	Big Horse is generally more brecciated than upper Orr units but not as thoroughly brecciated as Notch Peak Fm in attenuated areas
€lu	Lamb Dolomite	Upper member	460	Banded light-pinkish-gray to dark-gray dolomite; unfossiliferous; forms irregular cliffs and ledges.	Behaves similarly to Notch Peak Formation which it resembles lithologically.
€ll	Lamb Dolomite	Lower member	390	Coarsely crystalline massive dolomite; forms brownish-gray cliff; contains oncolites in lower half; lowest 30 feet is oncolitic limestone	
€trf	Trippe Limestone	Fish Springs Member	130	Fissile shale and intraformational cg	Attenuates without brecciation
€trl	Trippe Limestone	Lower member	640	Distinctive thin-bedded light-gray laminated dolomitic boundstone interbedded with mottled dark-gray massive limestone; forms slopes, ledges and cliffs. Shows on aerial photographs as three paired light-dark bands	Generally less brecciated than those massive units that lack thin-bedded interbeds. Attenuates from 0 to 100% in southern Fish Springs Range
€pcu	Pierson Cove Formation	Upper member	1150	Dark-gray mottled massive unfossiliferous limestone and dolomotic limestone with interbeds of thin-bedded medium- to light-gray silty limestone; forms cliffs and ledges; shows on aerial photographs as darkest gray unit in the sequence.	Pierson Cove Formation is less commonly attenuated than most of the other massive formations in the sequence, possibly because it overlies the thickest shale, the Wheeler, in the entire stratigraphic succession
€pcl	Pierson Cove Formation	Lower member	200	Dark-gray thin-bedded limestone with pinkish gray silty partings	
€wh	Wheeler Shale		590	490-590: thin-bedded limestone with fissile shale interbeds 185-490: yellowish-gray limy platy shale with 25% interbeds of thin-bedded silty limestone 0-185: papery shale with few trilobites	Wheeler Shale serves as a major glide plane in the southern Fish Springs and northern House Ranges. Its entire thickness is believed to be present in two locations, but the Wheeler is generally attenuated 50% or more
€s	Swasey Limestone		200	Cliff-forming limestone	Commonly attenuated to 50%
€w	Whirlwind Formation		160	Basal slope-forming shaly limestone; middle limestone ledge; upper shaly ls	Attenuates without brecciating: never entirely removed
€d	Dome Limestone		220	Cliff-forming unfossiliferous ls	Attenuates 0-100%
€c	Chisholm Formation		240	Basal olive-gray shale with pisolitic ls; middle oncolitic ls; upper shaly ls	Attenuates without brecciating; seldom entirely removed
€h	Howell Limestone		560	Cliff-forming limestone in House Range where lower half weathers dark gray and upper half is light gray. In Fish Springs Range lower half is thin-bedded platy silty orange-gray limestone	Howell attenuates to complete absence in part of northern House Range, there causing the western range front to be less bold by the absence of the Howell cliffs
€pt	Pioche Fm	Tatow Member	170	Phyllitic quartzite with interbedded siltstone and brown-weathering ls	Not much affected by brecciation or attenuation
€pl	Pioche Fm	Lower member	420	Dark-brown phyllitic quartzite with interbedded green phyllitic shale and siltstone. *Olenellus* 150-160 feet above base.	Not affected by brecciation or attenuation
€pm	Prospect Mountain Quartzite		2000+	Pinkish-gray to light-brownish-gray quartzite that weathers reddish-brown; shows cross-bedding; forms ledges and cliffs; base not exposed	Not affected by brecciation or attenuation

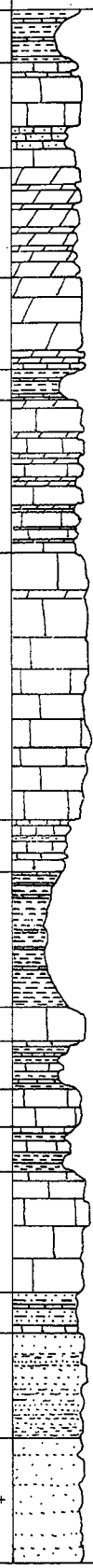

FIGURE 3B.– Cambrian strata exposed in the Fish Springs Range and northern House Range and their structural behavior. Thickness in feet. Units below the Pierson Cove Formation are not exposed in the northern half of the Fish Springs Range.

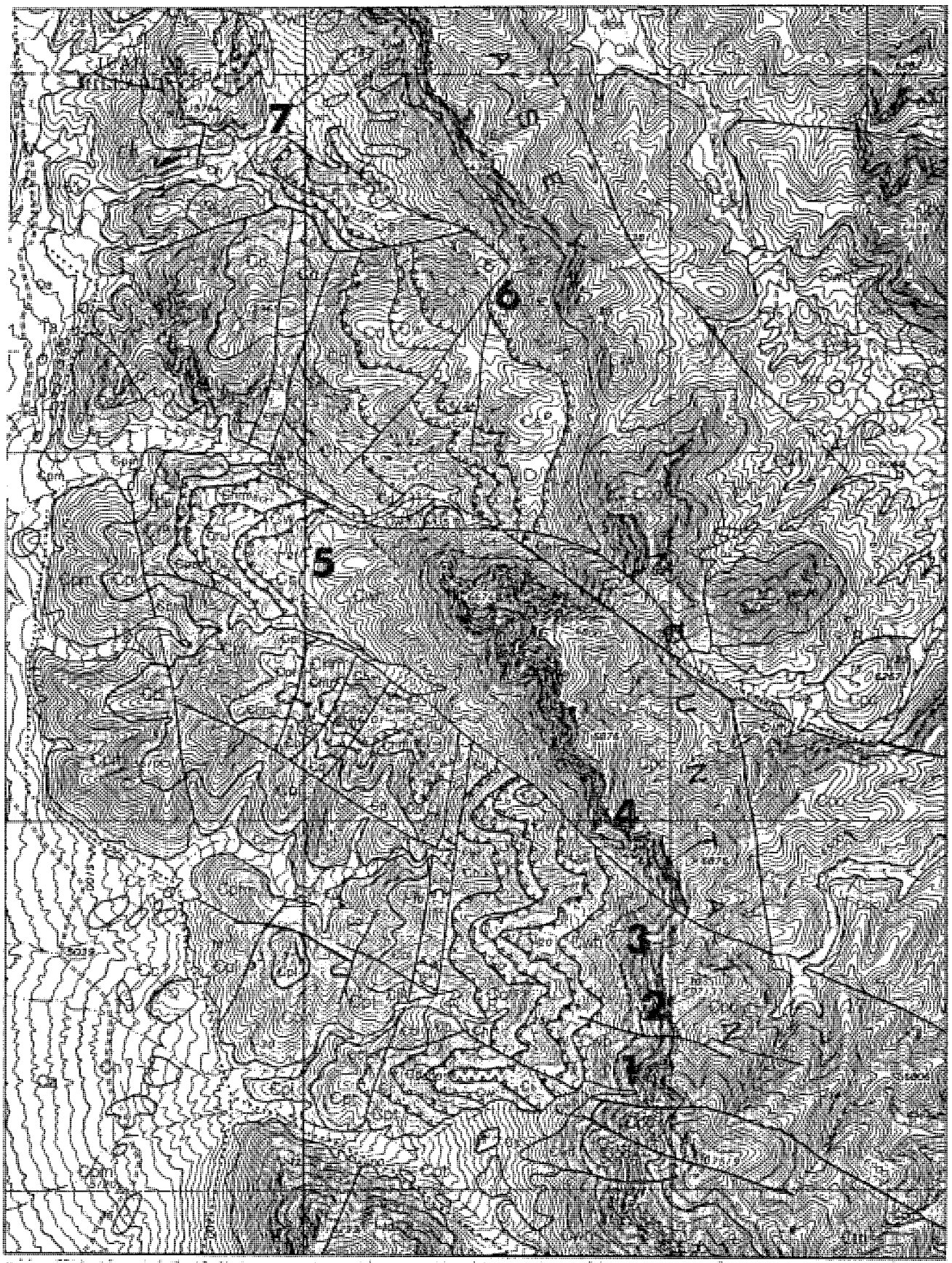

FIGURE 4.—Geologic map of part of the northern House Range near area 6 of figure 2. Southeasterly trending tear fault shown as line of dots near bottom of map separates the attenuated area from unattenuated strata south of the map edge.

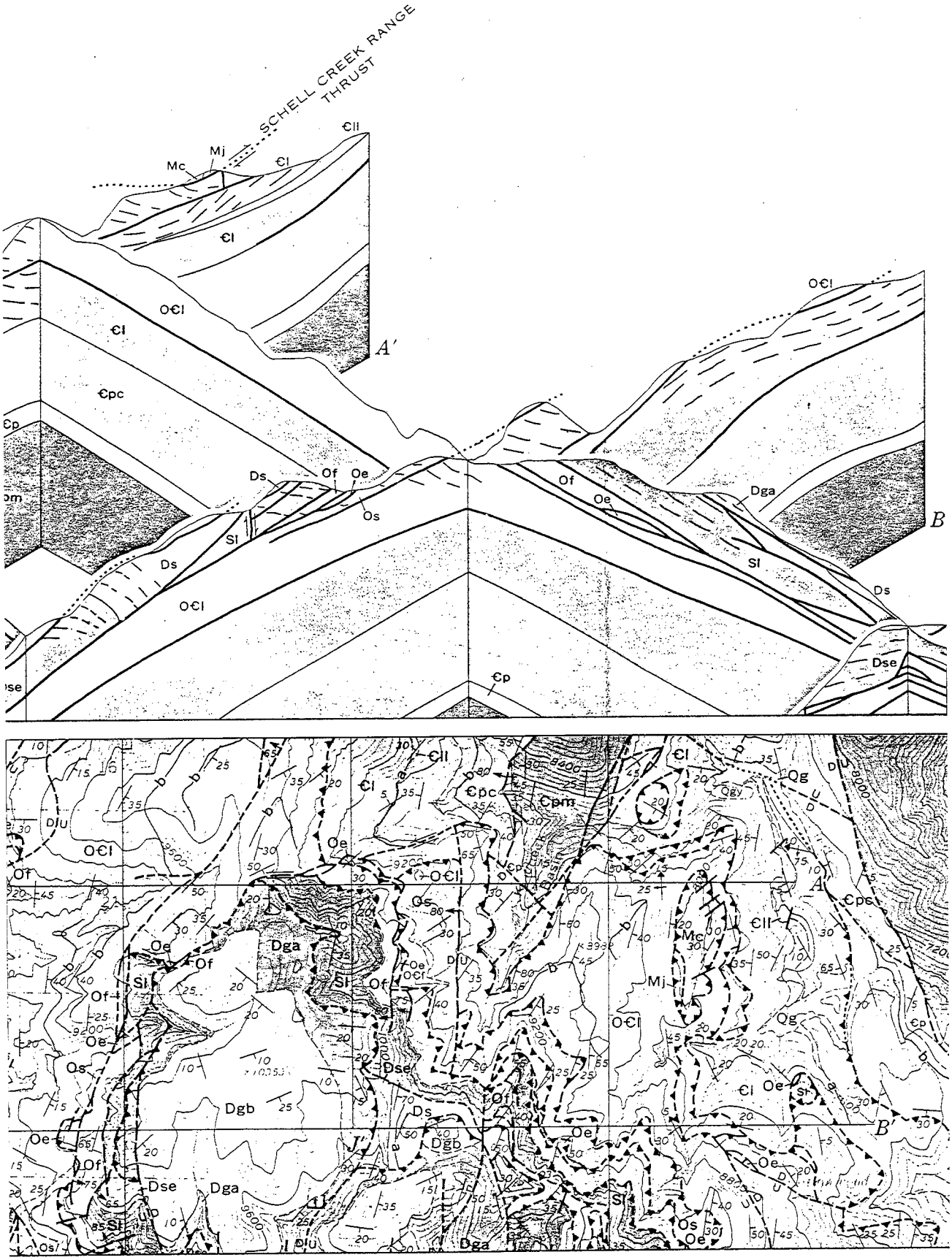

FIGURE 5.– Geologic map and fence diagrams of part of the Schell Creek Range from Drewes (1967). Drewes estimates that half the normal stratigraphic sequence in this area is missing because of attenuation faulting. Note that the basal Cambrian units are not affected.

AGE OF ATTENUATION FAULTING

As discussed above under "Igneous Rocks," the attenuation faulting in western Utah is certainly pre-Oligocene. The youngest unit involved in Sevier orogenic deformation in western Utah is the Early Triassic Thaynes Formation (see Hose 1977 for latest discussion). So the age bracket for attenuation faulting lies somewhere between Triassic and Oligocene time. Jurassic activity in western Utah includes the emplacement of the granitic stock in the House Range, K-Ar dated at 143 million years by Armstrong and Suppe (1973, p. 1379). It is not known whether the House Range granitic body is sheared off underground and hence whether it predates or postdates the horizontal transport. The major evidence for documenting the age of deformation in the Sevier orogenic belt comes from orogenically induced sedimentation in central Utah. It commenced in Jurassic time but reached its culmination in the extensive deposits of the Late Cretaceous exogeosyncline. I believe that the attenuation faulting of the House–Fish Springs area is part of the widespread younger-on-older faulting documented by Hose and Daneš (1973) and shown in figure 1. Furthermore I believe that the younger-on-older faulting of the Sevier orogenic hinterland is related to the older-on-younger Sevier overthrusting of central Utah because I think that the areal separation of these two contrasting structural styles of approximately the same age is not mere coincidence but is more likely two effects produced by the same cause. Within the eastern Great Basin there are certainly areas affected by low-angle faulting and folding of Tertiary age as documented by Compton et al. (1977) in northwestern Utah and by Ahlborn (1977) in the Kern Mountains. Ahlborn, in particular, shows that Tertiary

TABLE 1

PERCENTAGE OF TOTAL FORMATION THICKNESS PRESENT IN SEVEN MEASURED SECTIONS, NORTHERN HOUSE RANGE

Traverses are located on the west face of the range as shown by the traverse numbers on the accompanying geologic map. Sections were measured by Chidsey (1977).

	1	2	3	4	5	6	7
Wheeler Shale	70	92	87	NM[1]	100	84	100
Swasey Limestone	64	54	51	56	69	39	29
Whirlwind Formation	64	75	57	83	67	74	55
Dome Limestone	98	0	54	51	0	87	100
Chisholm Formation	80	BC[2]	BC	BC	0	90	94
Howell Limestone	0	NE[3]	NE	NE	16	NE	92

[1]Not measured
[2]Base concealed
[3]Not exposed

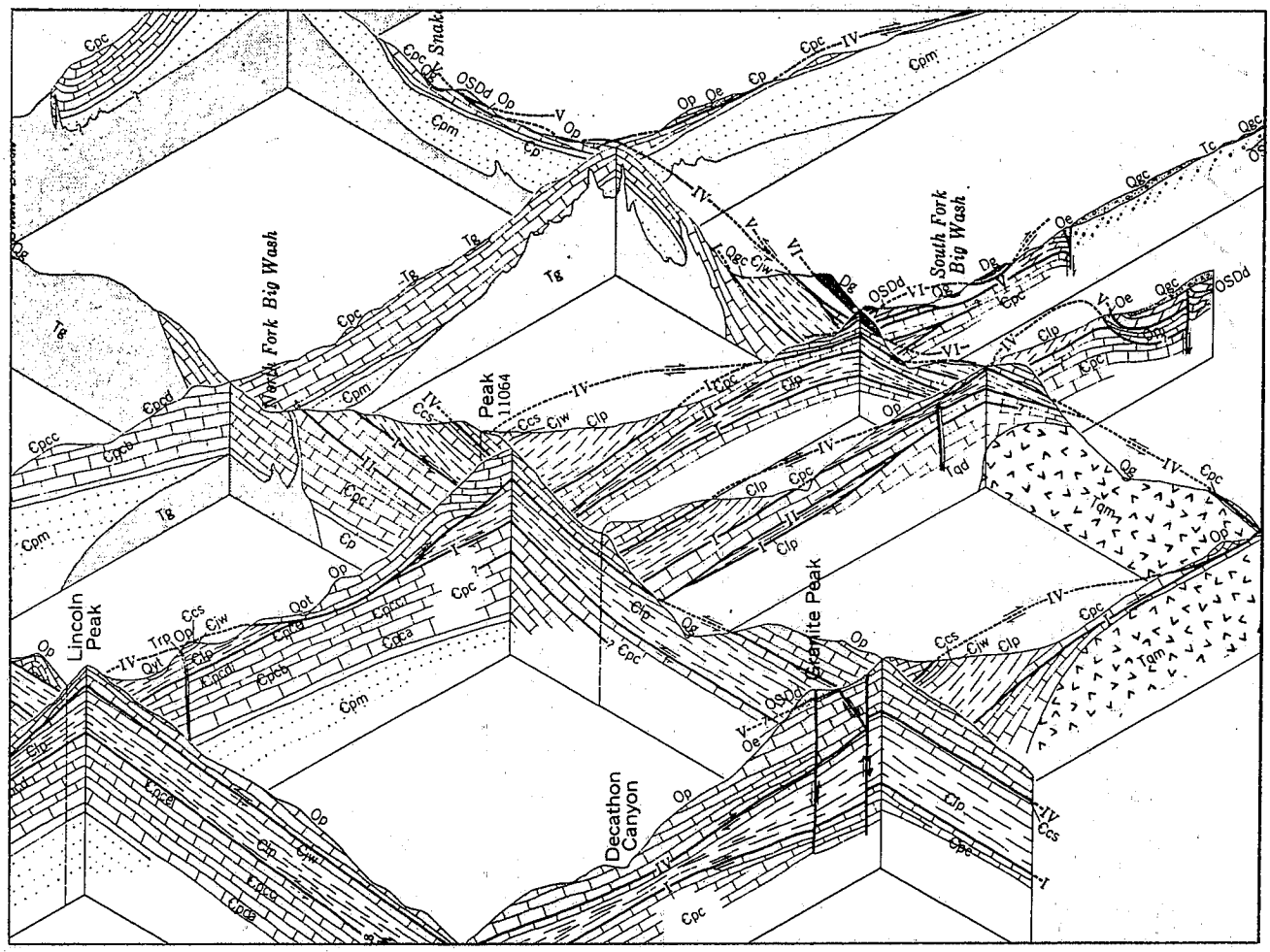

FIGURE 6.—Fence diagram by Drewes (1958) showing attenuation faults in the southern Snake Range. Note that the faults do not cut the basal Cambrian Prospect Mountain Quartzite.

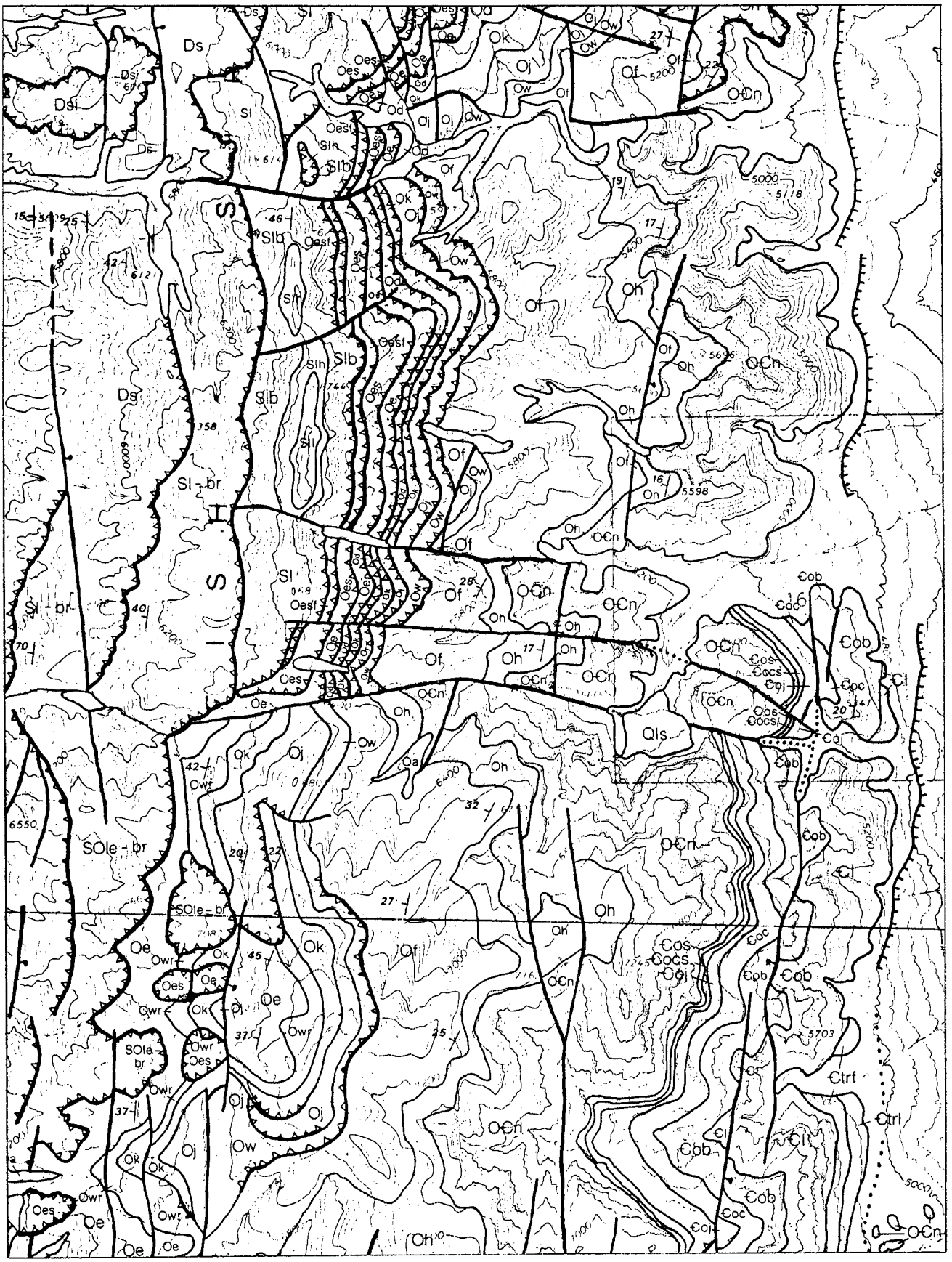

FIGURE 7.– Geologic map of part of the Fish Springs Range near area 2 of figure 2. Note the abrupt termination of attenuation faults where they abut east-trending tear faults in the middle of the map area.

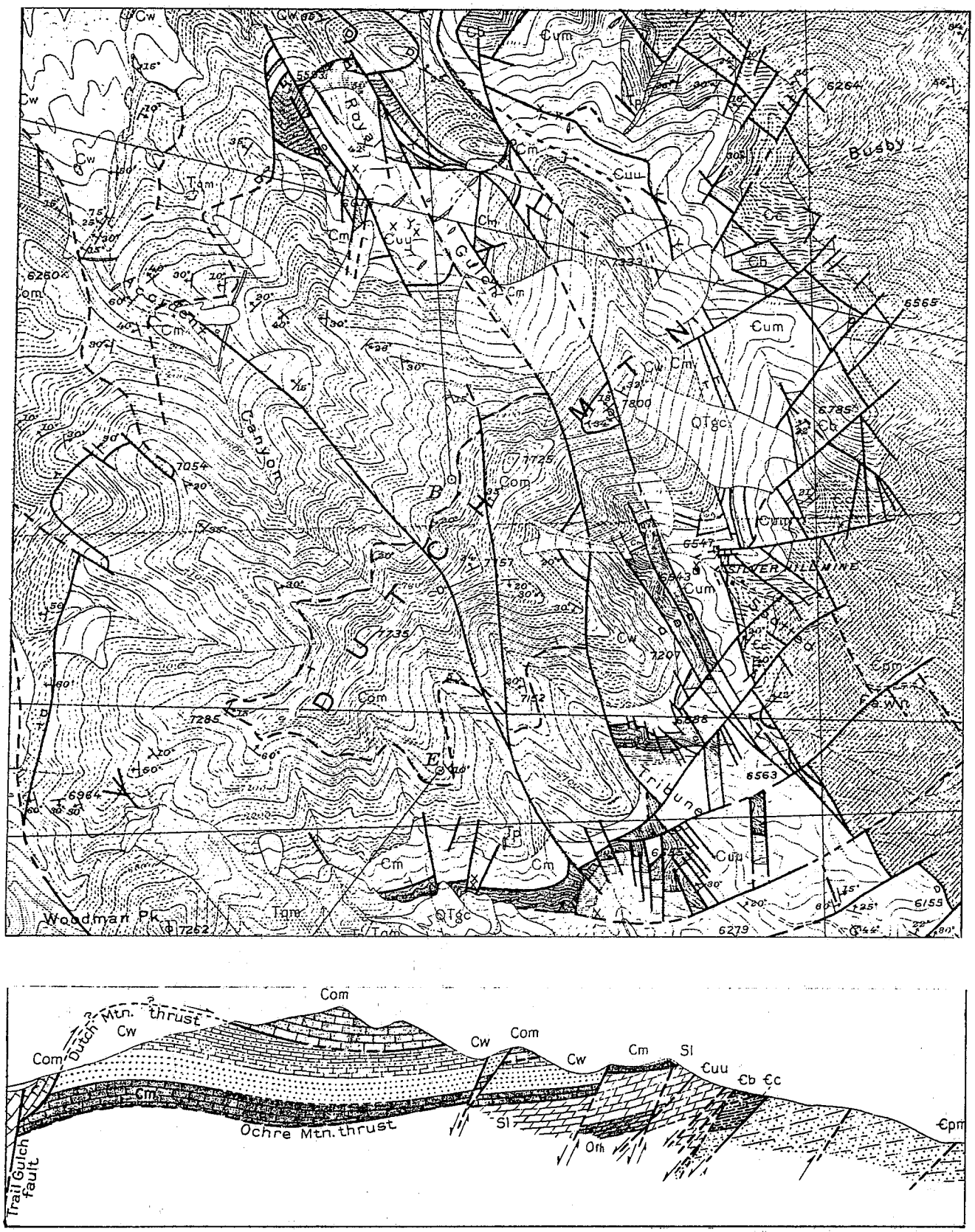

FIGURE 8.– Geologic map and cross section of part of the northern Deep Creek Mountains from Nolan (1935). Nolan delineated five cycles of deformation beginning with Cretaceous thrusting and ending with Tertiary transverse and normal faulting.

intrusions, metamorphism, and folding affected an area which had already undergone attenuation faulting.

Because of their similarities, I believe that the attenuation structures mapped by Nolan (1935) in the northern Deep Creek Mountain and those mapped by Drewes (1958, 1967) in the southern Snake and Schell Creek ranges, and the preintrusive attenuation structure mapped by Ahlborn (1977) in the Kern Mountain–Southern Deep Creek Mountains are of the same age and origin as the attenuation structures in the House and Fish Springs ranges, and are contemporaneous with and related to tear faults in these areas.

POSTATTENUATION GLIDE FAULTS

The southeast side of the Fish Springs Range shows spectacular exposures of low-angle normal faults that are here referred to as glide faults. Their effect is to drop the westward dipping strata down to the east in a series of steps, thus repeating the same stratigraphic sequence several times. The faults strike north and dip east at dips as low as 30 degrees but ranging as high as 60 degrees. Often the Wheeler Shale acts as a glide surface on these faults and can be seen smeared out along the fault planes. The stratigraphic displacement along these faults ranges up to several thousand

TABLE 2

COMPARISON OF REGIONAL THICKNESS OF PALEOZOIC STRATA IN WESTERN UTAH WITH ATTENUATED THICKNESS PRESENT IN THE KERN MOUNTAINS (after Ahlborn 1977)

KERN MOUNTAINS–NEVADA–UTAH		Regional Thickness (ft.)	Kern Mtns. Maximum (ft.)
Permian	Arcturus Formation	3000	2000
Pennsylvanian	Ely Limestone	2600	1400
Mississippian	Chainman Shale	1800	900
	Joana Limestone	600	250
Devonian	Pilot Shale	500	300
	Guilmette Formation	2800	1200
	Simonson Dolomite	900	700
	Sevy Dolomite	1700	1100
Silurian	Laketown Dolomite	1200	800
Ordovician	Ely Springs Dolomite	500	400
	Eureka Quartzite	500	300
	TOTAL	16,200	9350

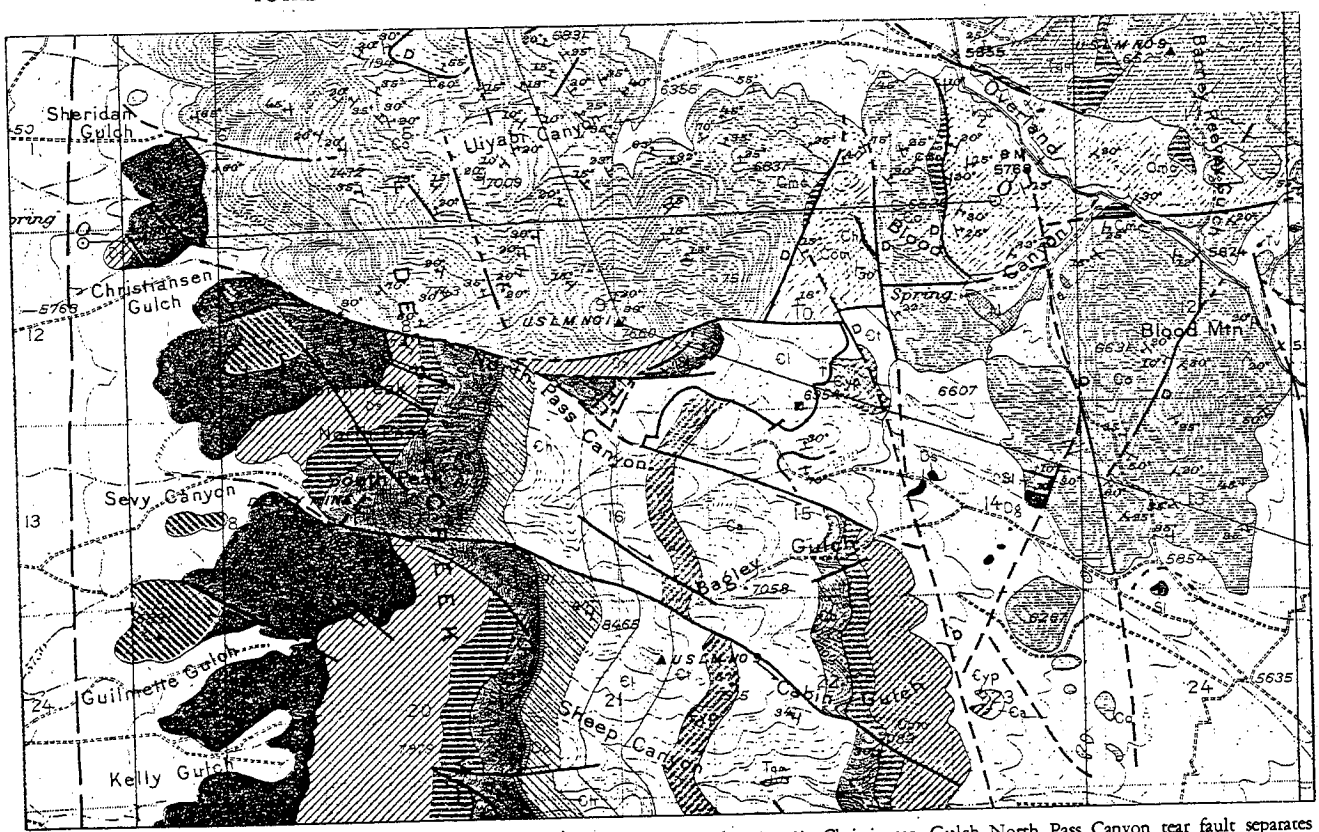

FIGURE 9.– Geologic map of part of the northern Deep Creek Mountains from Nolan (1935). Christiansen Gulch–North Pass Canyon tear fault separates structurally complex area to the north from structurally simple area to south.

feet but is usually a few hundred feet. The glide faults offset strata which had previously been attenuated. Therefore the glide faulting postdates the attenuation. The glide faults appear like mega-slumps. They may be related to basin-range faulting ("denudation" faults) as suggested by Armstrong (1972). Similar faults were noted in the Deep Creek Mountain by Nolan (1935). Drewes (1967) mapped glide faults in the Schell Creek Range, but his glide faults involved Tertiary strata rather than Paleozoic and may be more closely related to what Hintze (1972) referred to as "volcanic-landslide" features.

The glide faults are presumed to be truncated by normal high-angle basin-range faults along the east side of the Fish Springs Range. The sequence of faulting in the southern Fish Springs Range is shown in figure 10.

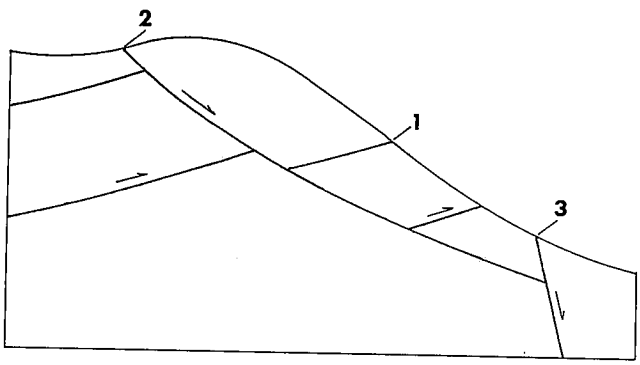

FIGURE 10.– Schematic diagram showing sequence of faulting in the southern Fish Springs Range. Attenuation faults (1) are the oldest. Glide faults (2) are intermediate in age. Range front normal faults (3) are the youngest.

ATTENUATION FAULTING IN A REGIONAL MODEL

Hose and Daneš (1973) presented a model, shown here as figure 11, to explain the geometry of the development of the younger-on-older structures of the eastern Great Basin. While agreeing with most aspects of their model, I would like to represent the attenuation structures slightly differently than they show on the left side of figure 11D. My alterna-

TABLE 3

COMPARISON OF UNATTENUATED AND ATTENUATED THICKNESS OF CAMBRIAN STRATA, NORTHERN HOUSE AND SOUTHERN FISH SPRINGS RANGES

	Unattenuated Thickness (ft.)	Attenuated Thickness (ft.)
Notch Peak Formation	1250	500-1200
Orr Formation	1000	400-900
Lamb Dolomite	850	400-850
Trippe Limestone	770	300-600
Pierson Cove Formation	1350	1200
Wheeler Shale	590	100-500
Swasey Limestone	200	0-90
Whirlwind Formation	160	100-160
Dome Limestone	220	0-240
Chisholm Formation	240	200-290
Howell Limestone	560	0-500
Pioche Formation	590	no change
TOTAL	7780	3800-7150

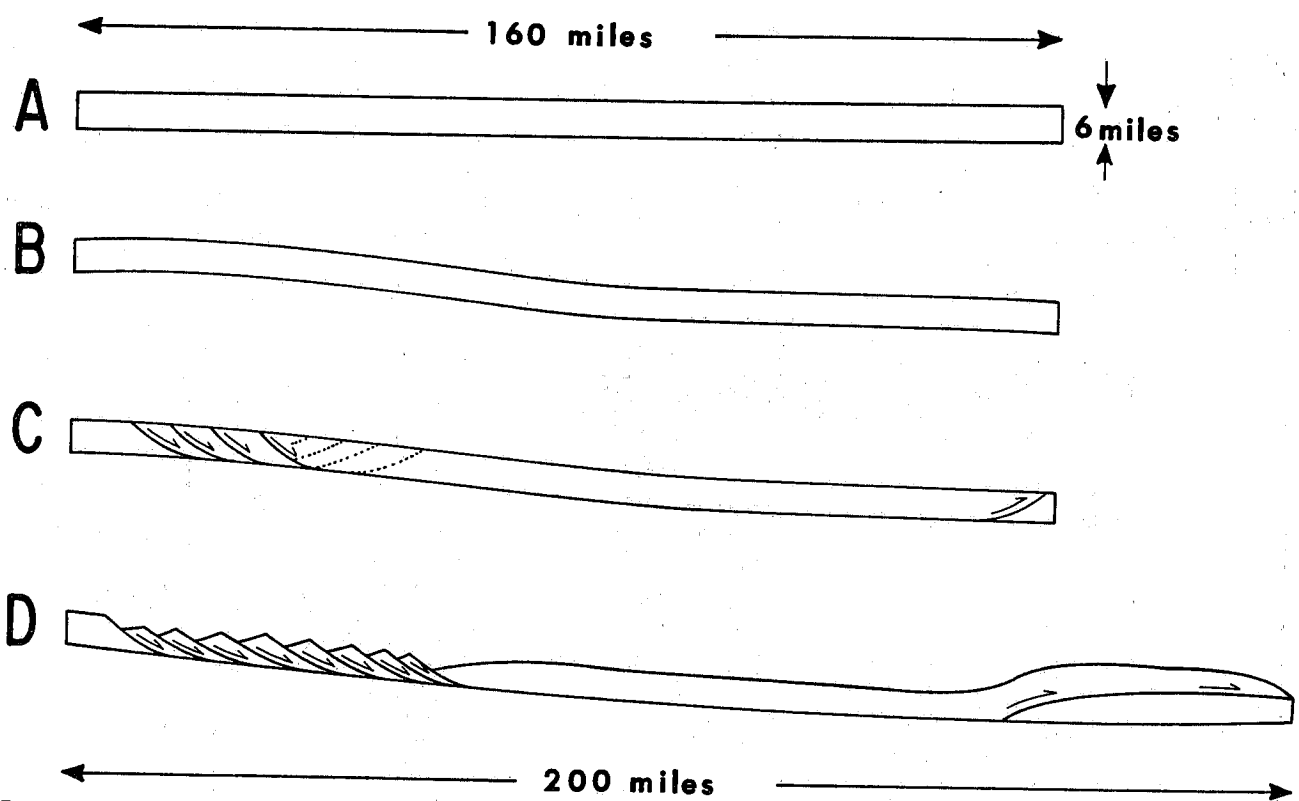

FIGURE 11.– Diagrammatic cross section of the eastern Great Basin showing development of younger-on-older faults taken from Hose and Daneš (1973, fig. 6). (A) Configuration of slab at outset; (B) development of gradient; (C) development of shear trajectories (dotted) of cycloidal form in the rearward or active part of the allochthon; (D) final configuration showing younger-on-older faults on the west and older-on-younger faults on the east.

tive explanation is shown in figure 12, section B, where I indicate that the deformation has been concentrated mostly in the middle part of the stratigraphic sequence. The implication here is that the upper part of the sequence has differentially overridden the lower part of the sequence in some not yet clearly defined way. This may help explain why Upper Paleozoic and Lower Triassic rocks are relatively less widely distributed in western Utah and eastern Nevada than the older miogeosynclinal rocks, as well as why they comprise such a conspicuous part of the overthrust sheets in the zone of overriding in central Utah. Much has been written about the location of "frontal break-through" of the overthrust sheet, but the matter has still not been clearly explained. Further combined analyses of structures both in the Sevier orogenic hinterland and in the frontal overthrust belt will be necessary before a completely satisfactory model is obtained.

ACKNOWLEDGMENTS

I am indebted to several scores of students who have done geologic mapping in the House and Fish Springs ranges since 1957 as part of Brigham Young University Geology Department summer field camp exercises. Douglas Steed has been particularly helpful in the south end of the Fish Springs Range, and Thomas Chidsey mapped part of the northern House Range for a master's thesis under my direction. The Utah Geological and Mineral Survey and the U.S. Geological Survey have supported part of the mapping program. Rolf Kraft, director of the Fish Springs National Wildlife Refuge Station, made our field experience more pleasant by permitting our use of their facilities, as did Leland Davis of Brush Beryllium Company. I thank Myron Best for editorial help with this paper.

REFERENCES CITED

Ahlborn, R. C., 1977, Mesozoic-Cenozoic structural development of the Kern Mountains, eastern Nevada and western Utah: Brigham Young Univ. Geol. St., v. 24, pt. 2, p. 117-31.

Armstrong, R. L., 1972, Low-angle (denudation) faults, hinterland of the Sevier orogenic belt, eastern Nevada and western Utah: Geol. Soc. America Bull., v. 83, p. 1729-54.

Armstrong, R. L., and Suppe, John, 1973, Potassium-argon geochronometry of Mesozoic rocks in Nevada, Utah, and southern California: Geol. Soc. America Bull., v. 84, p. 1375-92.

Brock, W. G., and Engelder, Terry, 1977, Deformation associated with the movement of the Muddy Mountain overthrust in the Buffington window, southeastern Nevada: Geol. Soc. America Bull., v. 88, p. 1667-77.

Chidsey, T. C., Jr., 1977, Attenuation faulting and alteration in the northern House Range, Utah: Master's thesis, Brigham Young Univ., Provo, Utah, 50 p.

Compton, R. R., Todd, V. R., Zartman, R. E., and Naeser, C. W., 1977, Oligocene and Miocene metamorphism, folding, and low-angle faulting in northwestern Utah: Geol. Soc. America Bull., v. 88, p. 1237-50.

Drewes, Harald, 1958, Structural geology of the Southern Snake Range, Nevada: Geol. Soc. America Bull., v. 69, p. 221-40.

———, 1967, Geology of the Connors Pass quadrangle, Schell Creek Range, east central Nevada: U.S. Geol. Survey Prof. Paper 557, 93 p.

Hintze, L. F., 1972, Oligocene volcanic-landslide deposits in west central Utah: Geol. Soc. America Abs. with Programs v. 4, no. 7, p. 538-39.

———, 1976, Attenuation faulting in the Fish Springs and House ranges, western Utah: Geol. Soc. America Abs. with Programs, v. 8, no. 6, p. 918-19.

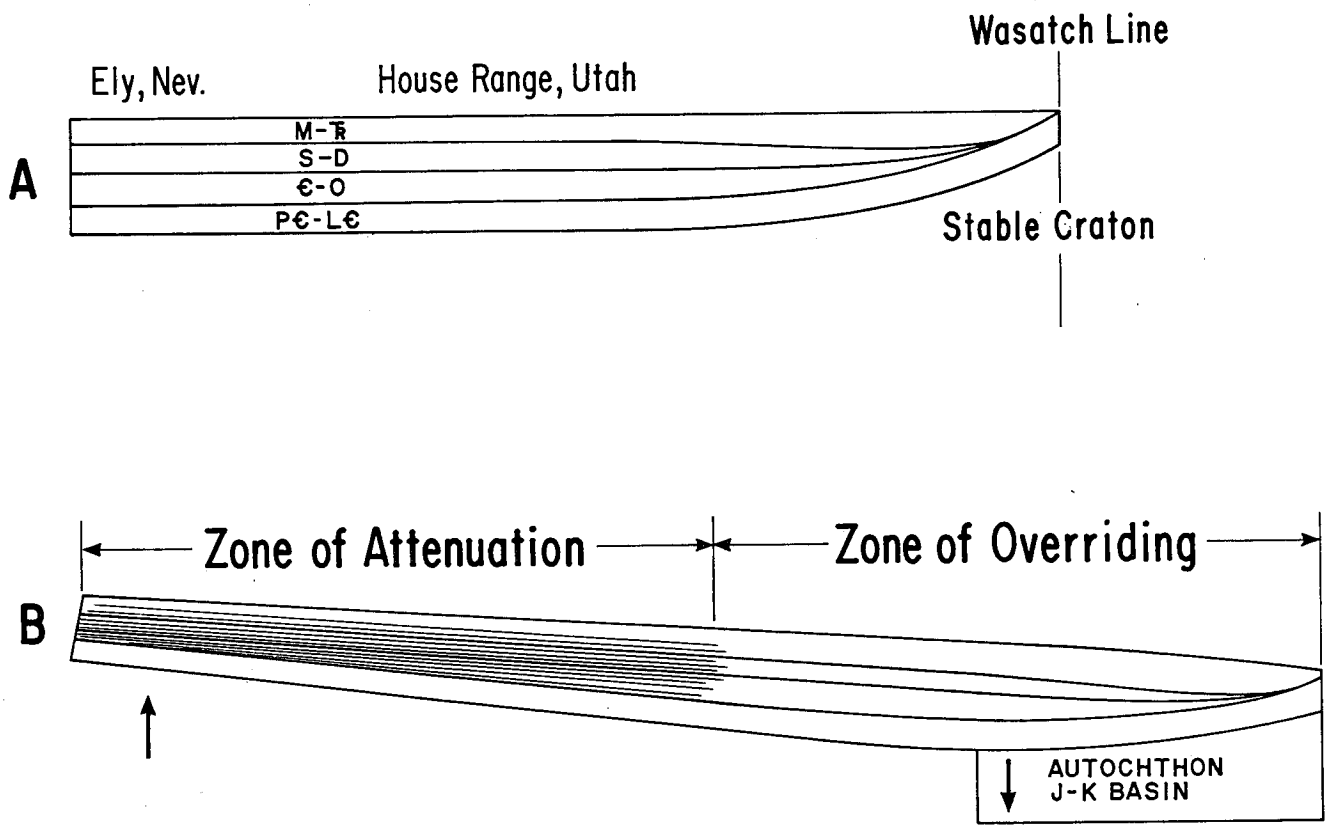

FIGURE 12.– (A) Diagrammatic cross section of miogeosynclinal strata from eastern Nevada to central Utah. Vertical scale exaggerated, but thickness of strata drawn to show relative thickness of different parts in different locations. (B) Postattenuation distribution of miogeosynclinal strata. Eastward movement resulted not only from orogenic uplift on the west but also from subsidence in the Jurassic-Cretaceous autochthonous basin in central Utah. The thin lines in the Middle Paleozoic strata represent the attenuation faulting.

Hintze, L. F., and Robison R. A., 1975, Middle Cambrian stratigraphy of the House, Wah Wah, and adjacent ranges in western Utah: Geol. Soc. America Bull., v. 86, p. 881–91.

Hose R. K., 1977, Structural geology of the Confusion Range, west central Utah: U.S. Geol. Survey Prof. Paper 971, 9 p.

Hose, R. K., and Daneš, Z. F., 1973, Development of the late Mesozoic to early Cenozoic structures of the eastern Great Basin: In DeJong, K. A., and Scholten, Robert (eds.), Gravity and tectonics: New York, John Wiley and Sons, p. 429–41.

Kepper, J. C., 1960, Stratigraphy and structure of the southern half of the Fish Springs Range, Juab County, Utah: Master's thesis, Univ. Washington (Seattle), 92 p.

Lindsey, D. A., Waeser, C. W. and Shawe, D. R., 1975, Age of volcanism, intrusion, and mineralization in the Thomas Range, Keg Mountain, and Desert Mountain, western Utah: U.S. Geol. Survey Jour. Research, v. 3, no. 5, p. 597–604.

Nolan, T. B., 1935, The Gold Hill mining district, Utah: U.S. Geol. Survey Prof. Paper 177, 172 p.