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Stratigraphy and Structure of the Miocene "Esmeralda" Formation in Stewart Valley, Mineral County, Nevada

Benjamin L. Clausen

Abstract

STRATIGRAPHY AND STRUCTURE OF THE MIOCENE "ESMERALDA" FORMATION IN STEWART VALLEY, MINERAL COUNTY, NEVADA

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The Miocene rocks of Stewart Valley, eastern Mineral County, Nevada, consist of volcanic flows and breccias and fluvio-lacustrine sedimentary rocks. They are called the Esmeralda Formation because they contain lithologies similar to those of the Esmeralda type section 100km south; however, the rocks in Stewart Valley were probably deposited in a separate local basin. The lower part of this formation contains small lacustrine claystone deposits (unit 1) that interfinger with volcanic breccias and flows (unit 2). The main fluvio-lacustrine sequence is above the flows and is divided by the author into five units based on lithology: sandstone and claystone in unit 3, shale in unit 4, claystone and mudstone in unit 5, sandstone and carbonate in unit 6, and sandstone and vitric tuff in unit 7. The total thickness of the formation is about 600m. Younger basalt flows lie unconformably above the Esmeralda Formation in part of the Gabbs Valley Range. Plio-Pleistocene conglomerates and pediment gravels overlie with angular unconformity the Esmeralda

Formation in the valley.

During the early Miocene, Stewart Valley was downdropped as a graben. On the east side of the valley the Cedar Mountains were uplifted, but not to their present height. On the west side of the valley the Gabbs Valley Range was uplifted along the Battle's Well Fault. However, this fault is mainly a strike-slip fault associated with Walker Lane and most of the displacement on the fault was horizontal.

During most of the Miocene the valley was tectonically stable and the main drainage was south. The lake that formed in the valley fluctuated in size and depth, at times connecting with basins to the south and east. In this lake the sediments of the Esmeralda Formation were deposited.

At the end of the Miocene, more faulting occurred on the east and southeast sides of the valley and sub-parallel to the valley axis, altering drainage to the north. These faults cut the Miocene fluvio-lacustrine rocks, but not the later Plio-Pleistocene sediments. The upthrown side of these dip-slip faults is usually on the east side, toward the Cedar Mountains. This fault pattern, along with the general eastward dip of the sediments and the steep gravity gradient near the Cedar Mountains, suggests tilted block faulting. The Gabbs Valley Range-Stewart Valley block was tilted east and was dropped relative to the Cedar Mountain block.

LOMA LINDA UNIVERSITY

Graduate School

STRATIGRAPHY AND STRUCTURE OF THE MIOCENE "ESMERALDA" FORMATION IN STEWART VALLEY, MINERAL COUNTY, NEVADA

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Benjamin L. Clausen

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of the Requirements for the Degree Master of Science
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Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

______________________________, Chairman
H. Paul Buchheim, Assistant Professor of Geology

____
Lanny H. Fisk, Associate Professor of Geology

____
Ivan E. Rouse, Associate Professor of Physics

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INTRODUCTION

Purpose and Scope

Tertiary fluvio-lacustrine rocks cover about 300 square kilometers of Stewart Valley in western Nevada. The varied paleontology of these fluvio-lacustrine deposits has been studied extensively; however, the geology of the valley has not been previously mapped in any detail.

The purpose of this report is to describe the structural history of the valley and the physiographic setting for the deposition of the lake sediments. To do this it was necessary first to describe the physical stratigraphy of Stewart Valley and to map and prepare cross-sections of the central 200 square kilometers of the valley containing the most significant outcrops of Tertiary fluvio-lacustrine rocks.

Geographic Setting

Stewart Valley is located in eastern Mineral County, Nevada, approximately 250km southeast of Reno, Nevada. The north-south trending valley is flanked on the east by the Cedar Mountains and on the west by the Gabbs Valley Range. The valley floor is at an elevation of 5000' to 6000' with the ranges rising to over 8000'. Fingerrock Wash runs along the axis of Stewart Valley and drains north into Gabbs Valley. The location of Stewart Valley in relation to nearby geographic features is shown on figure 1.

The main part of the valley is included in the 7 1/2' Stewart Spring quadrangle (1979) and the lower third of the 7 1/2' Granny Goose Well quadrangle (1980). In addition, small portions of the valley extend into bordering 7 1/2' quadrangles: Gabbs Mountain to the west, Goldyke, Simon, and Dicalite Summit to the east, and Battles Well to the south.

Stewart Valley is accessible by a graded dirt road extending the length of the valley. Mina, on US 95, is 25km southwest by way of a graded dirt road and Gabbs is 20km northeast by way of State Highway 361. Areas off the graded road can be reached by 4-wheel drive vehicles on ranch and mining trails.

The valley is used mainly for cattle ranching with the two ranchers living along the main graded road. Black Cabin Well, Simon Well, and Stewart Spring provide water for the cattle. Olympic Mine (OMCO), Simon Mine, and Mina Gold Mine were active in the valley at one time, but only the OMCO mine is currently active.

Fieldwork and Methods

Most of the fieldwork was done during the summer of 1981 with several short trips in the year and a half following. In all about 55 days were spent in the field.

The mapping was done on 1:16,000 vertical aerial photographs taken in 1967 for project N-03B of the Bureau of Land Management.

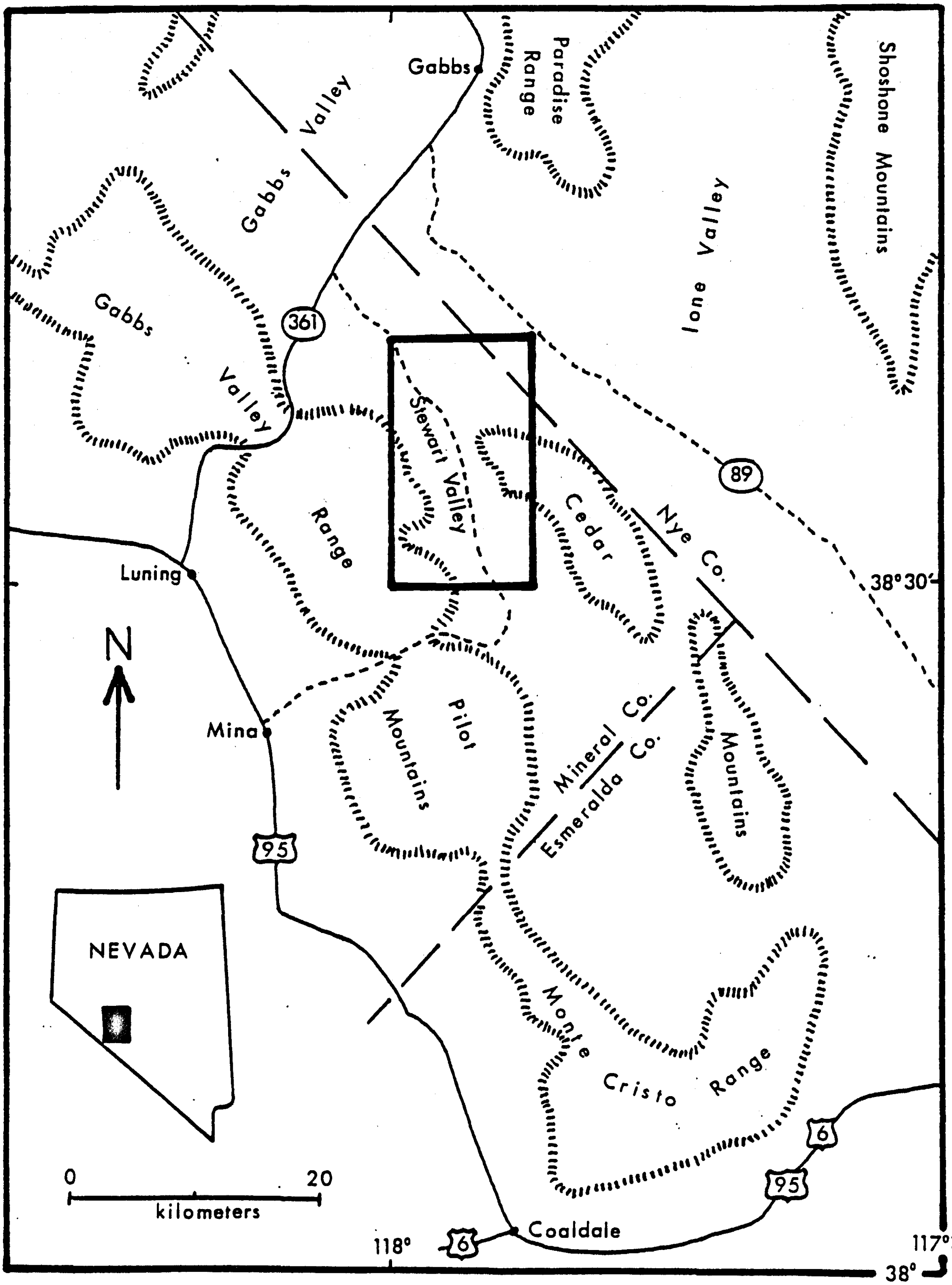


Figure 1. Index map showing location of Stewart Valley. Rectangle shows mapped area.

The final geologic maps were drafted at a scale of 1:24,000 on the 7 1/2' Stewart Spring quadrangle and the lower third of the 7 1/2' Granny Goose Well quadrangle to the north.

In the following unit descriptions two things should be noted: 1) Color codes are from the Geological Society of America rock-color chart (1979); 2) Township lines have not been surveyed for the area mapped; therefore, locations are given to the closest tenth of a kilometer using the 1000-meter Mercator grid on the topographic quadrangle map.

PREVIOUS WORK

The Tertiary lacustrine deposits of Esmeralda County in western Nevada were first studied by Turner (1900a, 1900b, 1902, 1909) and named the Esmeralda Formation. Van Houten (1956), in studying the Cenozoic rocks of Nevada, lumped all the Tertiary sedimentary rocks in west-central Nevada into the Esmeralda Formation. Robinson (1964) and Robinson, McKee, and Moiola (1968) later restudied the Esmeralda Formation in Esmeralda County and Moiola (1969) redefined the location of the type section to be in the Alum area which is only one of Turner's (1900b) original three locations.

Many geologic maps with accompanying reports have been published on the Tertiary deposits in Stewart Valley and vicinity, but they have been large scale, have covered only adjacent areas, and/or have emphasized pre-Tertiary deposits. Muller and Ferguson (1939), Ferguson and Muller (1949), and Ferguson, Muller, and Cathcart (1953) over a number of years mapped the Mesozoic rocks in this area of western Nevada. County geologic maps of both Mineral County (Ross, 1961) and Esmeralda County (Albers and Stewart, 1972) have been published. The Cenozoic geologic map of Nevada (Stewart and Carlson, 1976) and the complete state geologic map of Nevada (Stewart and Carlson, 1977, 1978) with a report (Stewart, 1980a) contain some details of Stewart Valley. A detailed geologic map (Ekren and Byers, 1978) and report (Ekren and others, 1980) have been prepared of the Gabbs Valley Range west of Stewart Valley that covers the Luning SE 15' quadrangle and emphasizes the volcanics. A detailed geologic map and report of Tertiary rocks east of the Cedar Mountains was prepared by Henderson (1962). Nielsen (1964) prepared a report and map of the Pilot Mountains southwest of Stewart Valley. Table 1 gives more details of previous work in the area.

The volcanics in Stewart Valley around OMCO and Simon Mines were first studied by Knopf (1921). More recently Proffett and Proffett (1976) studied the Singatse Tuff and the Guild Mine Member of the Mickey Pass Tuff in the Yerington district. These two units and the lavas of Giroux Valley were later traced south to the Stewart Valley area by Ekren and others (1980).

The stratigraphy, sedimentology, and paleontology of Stewart Valley were first studied by Buwalda (1914). Later Merriam (1916) and Stirton (1932) studied the vertebrate fauna of the Cedar Mountain area. More recently, detailed work has been done on Stewart Valley paleontology by several authors: Axelrod (1956) and Wolfe (1964) on the shale flora, Mawby (1965) on the mammals, Firby (1963, 1966, 1969) on the gastropods, Smedman (1969) on the diatoms, and Harvey I. Scudder (unpublished manuscript, 1981) on the insects. In 1981 the Bureau of Land Management in Nevada published a general overview of the geologic significance of the valley. Concurrent with the work reported here, Nick (1983) studied the depositional environment of the lacustrine rocks in the valley.

A number of papers on Basin and Range geology relate directly to the geology of Stewart Valley. McKee (1971) discussed the periods of Cenozoic volcanic activity. Western Nevada contains a region of

Buwalda 1914	Knopf 1921	Ferguson, et.al. 1953	Ross 1961	Henderson 1962	Webb, Wilson 1962	Nielsen (Plate2) 1964	Wolfe 1964	Clausen 1983
---	---	125,000 #	250,000	20,000	500,000	30,000	---	24,000
		Qw	Qal	Qal	Qal	Qw		alluvium
fangl.mantle		Qg	Qal	Qpl	Qal	Qw		pediment gravels
fanglomerate		Qg	Qal	QTal	Qal	Qw		older alluvium
		QTb	QTm	Tb	Qv	Tb**		basalt
		Tg	Tvi	Ta/Tyha ?		Tir		-----
gravels		Tes	Te	Teu/Tem	Ts	Tes	Cedar Mtn. Fauna	Unit 7
carbonate		Tes	Te	Tel	Ts	Tes	?	Unit 6
pyroclastics		Tes	Te		Ts	Tes	?	Unit 5
shale		Tes	Te		Ts	Tes	StewartSpringFlora	Unit 4
ss/chert		Tes	Te		Ts	Tes	StewartSpringFauna	Unit 3
agglomerate		Teb (Tg?)	Tvi/Te	Toha/Tag ?	Tv	Ta/Tab	flows	Unit 2
		Teb	Te		Ts		Fingerrock Flora	Unit 1
			Tpe					andesite
(basalt,	x	Tol	Tvf*		Tv			quartz latite
andesite,	x	Tol	Tpe	Tdt	Tv	Tad		dacite tuff
rhyolite)	x	Tol	Tpe		Tv			pyroxene andesite
"	x	Tol	Tpe		Tv			keratophyre
"	x	Tol	Tpe		Tv			Mammoth andesite
"	x		Tpe		Tv			Simon keratophyre
	x		Tpe		Tv			rhyolite/trachyte
				Tol	Tv			GirouxValley lava
limestone		TRl	TRl	TRl	TR	TRl		Luning Formation

Table 1. Previous divisions of rock units in, or similar to those in, Stewart Valley.

- # map scale; NOTE: abbreviations in the table are for mapped units
- x rock types discussed by Knopf
- * Ross shows Tvf as post-Te
- ** Nielsen shows Tb between Tes and Ta on his Plate 10
- ~~~ unconformity

Mawby 1965	Firby 1969	Albers, Stewart 1972	Stewart, Carlson 1974,1976, 1978,1980	Stewart, Carlson 1977	Bur. of Land Management (Schorn) 1981	Ekren, Byers 1978,1980	Clausen 1983
---	---	250,000#	500,000	1,000,000	---	48,000	24,000
	x	Qal	Qa	Qa	alluvium	Qa	alluvium
	x	Qoa	Qa	Qa	terrace gravel	QTf/Tfg	pediment gravels
		Qoa	Qa	Qa	older gravels		older alluvium
		QTb	Tba	Tvu	basalt	Tl	basalt
		Tg	Ta3	Tvu			-----
4	x	Ts	Ts3	Ts	biotite tuff/blue volc.ss	Te	Unit 7
4	x	Ts	Ts3	Ts	variable; ss,congl.	Te	Unit 6
3	x	Ts	Ts3	Ts	diatomite/mudstone	Te	Unit 5
3	x	Ts	Ts3	Ts	laminated shale	Te	Unit 4
2	x	Ts	Ts3	Ts	variable; ss,congl.	Te	Unit 3
1			Ta3(Tmi)	Tvu	hbld. dacite breccia	Tlf	Unit 2
1			Ts3	Ts	tuff/ss,congl.	Te	Unit 1
	x		Tt2	Tvl	hornblende andesite		andesite
		Taw	Tt2	Tvl		Tbs	quartz latite
		Taw	Tt2	Tvl	older andesite		dacite tuff
		Taw	Tt2	Tvl	older andesite		pyroxene andesite
		Taw	Tt2	Tvl	older andesite		keratophyre
		Taw	Tt2	Tvl	older andesite		Mammoth andesite
			Tt2	Tvl			Simon keratophyre
			Tt2	Tvl	older volcanics	Tbmg	rhyolite/trachyte
			Ta2			Tlg	GirouxValley lava
			TRc	Mzr		TRl	Luning Formation

Table 1 continued. Previous divisions of rock units.

- # map scale; NOTE: abbreviations in the table are for mapped units
- 1,2,3,4 unit divisions listed by Mawby
- x shown by Firby on a columnar section in his figure 1
- ~~~ unconformity

topographic discordance first called the Walker Lane by Locke and others (1940). The right lateral strike-slip faulting in Walker Lane is discussed by Nielsen (1965), Albers (1967), and Stewart and others (1968). The typical Basin and Range normal faulting was analyzed by Stewart (1971, 1980b). Gianella and Callaghan (1934a, 1934b) commented on the Cedar Mountain earthquake in 1932 and the resulting faults. An overview of the regional geology of Nevada was given by Stewart (1980a). Models of Basin and Range structure have been discussed by a number of authors (Nolan, 1943; Atwater, 1970; Proffett, 1977). These models were summarized by Stewart (1978). Eaton (1982) has published a more recent paper on one of these models.

REGIONAL GEOLOGIC SETTING

In the previous section, papers were listed dealing with Basin and Range geology. The geology relative to Stewart Valley will be summarized here briefly. A more detailed summary is given by Stewart (1980a). In this report tne relations used between epoch, series, mammalian stages, and radiometric dates are those of Berggren and van Couvering (1974).

During the early Tertiary, western Nevada was a flat, elevated area undergoing erosion of pre-Cenozoic rock. Igneous activity began in the late Eocene and continued until the early Miocene. During this time the main lavas had an andesitic to rhyolitic composition. There was a hiatus of activity and then lavas of basaltic composition were extruded up to the present. Both types of lavas are represented in Stewart Valley.

Right lateral strike-slip faulting formed Walker Lane starting possibly before Cenozoic time and continuing to the present. West of Stewart Valley the Battle's Well Fault and the Soda Spring Valley Fault are part of a fault zone that according to Nielsen (1965) has had an aggregate right-lateral displacement of 20 km. Figure 2 shows Walker Lane and the associated strike-slip faults.

Normal faulting in the Basin and Range province has been caused by east-west extension beginning in the early Miocene. Several models of faulting were reviewed by Stewart (1971, 1978). One model suggested tilted blocks with the upslope part forming the mountains and the downslope part the valleys. Another model suggested

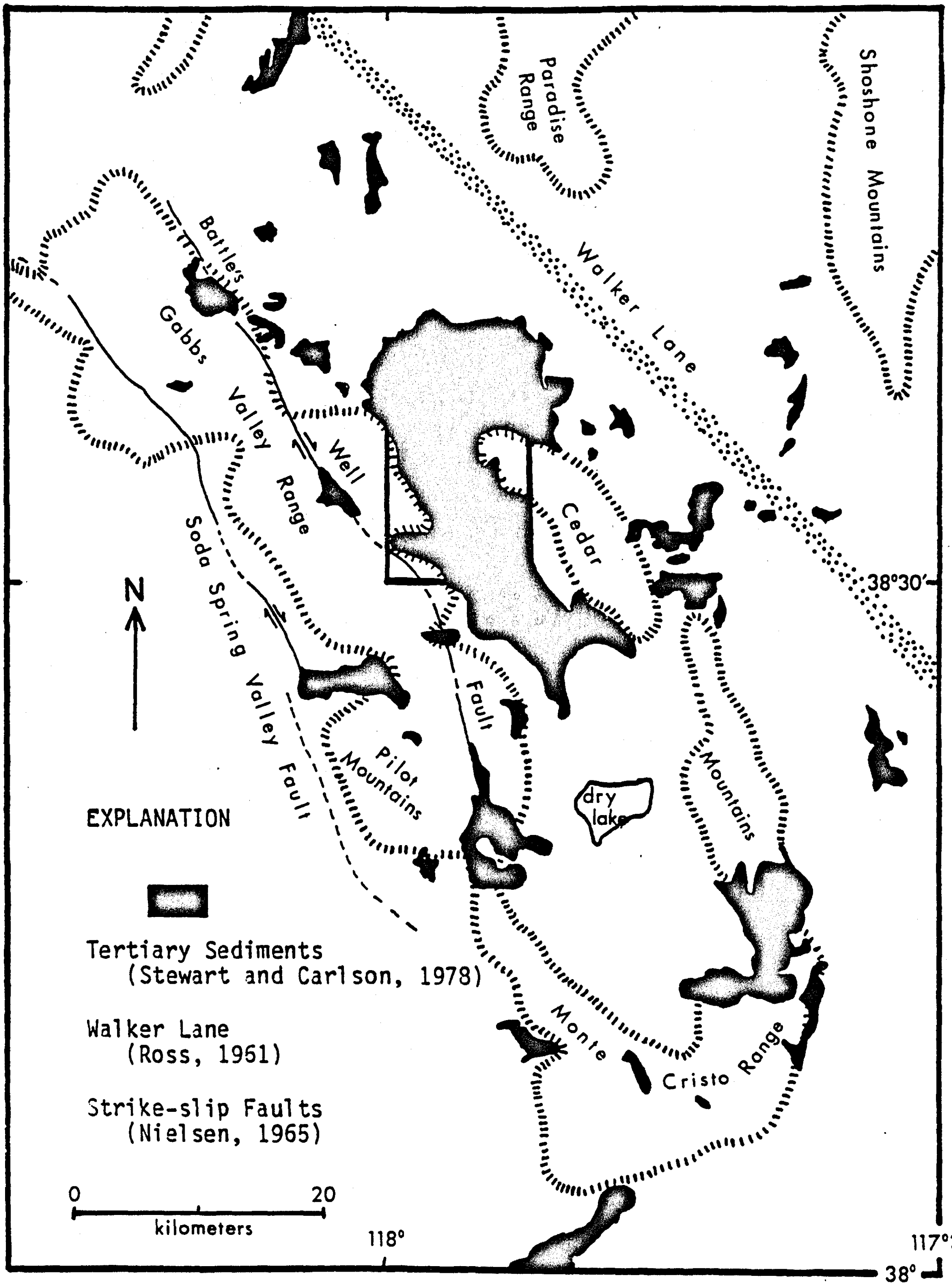
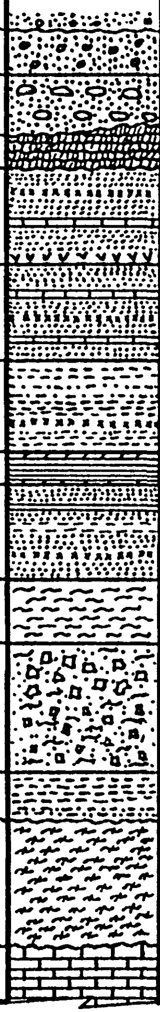


Figure 2. Regional map showing relation of Stewart Valley to nearby geologic features. Rectangle shows mapped area.

alternating horsts forming mountains and symmetrical to highly asymmetrical grabens forming valleys. In both models the blocks could be tilted. Stewart (1980b) showed Stewart Valley as an area where the blocks tilt east in his paper on basin-range tilt patterns.

The Tertiary sedimentary record shows lakes developing in the basins formed by faulting, and later drying up. Feth (1964) maps the extent of these lake deposits during the Tertiary epochs.

The general arrangement of rock outcrops in Stewart Valley is typical for a Basin and Range valley. Pre-Cenozoic rocks and mid-Tertiary lavas occur in the upthrown mountains. Late Tertiary lavas and breccias, fluvio-lacustrine rocks, and Plio-Pleistocene sediments are in the downdropped valleys. Figure 3 gives a generalized columnar section of the lithostratigraphic sequence in Stewart Valley. Each stratigraphic unit is described in the sections which follow.



AGE				UNIT	SECTION	THICKNESS	DESCRIPTION
QUAT	Recent			Alluvium (Qa)			unconsolidated stream deposits
							unconformity
QUAT	Pleist.			Ped. Gravel (Qp)		0-20m	unconsolidated pediment gravels
QUAT				Older Alluvium (QToa)		0-30m	indurated sandstone and pebble conglomerate
TERTIARY	Plioc.						unconformity
TERTIARY	Miocene	Late	Clarendon	Basalt (Tb)		50m	dark gray to black basalt
							unconformity
TERTIARY	Miocene	Late	Clarendon	Esmeralda Formation: Unit 7 (Te7)		160m	sandstone, limestone, and tuff; with a prominent vitric tuff layer; (11m.y.)
TERTIARY	Miocene	Middle	Clarendon ?	Esmeralda Formation: Unit 6 (Te6)		80-200m	white to gray sandstone, limestone, tuff, and occassional dolomite; stromatolites
TERTIARY	Miocene	Middle	Barstov	Esmeralda Formation: Unit 5 (Te5)		50-200m	white to brown claystone, mudstone, and tuff; gray vitric tuff bands; gypsum; some diatomite
TERTIARY	Miocene	Early	Barstov	Esmeralda Formation: Unit 4 (Te4)		0-50m	well laminated shale with some dolomite; grades into tuff near top
TERTIARY	Miocene	Early	Barstov	Esmeralda Formation: Unit 3 (Te3)		50-150m	mostly sandstone; some claystone, tuff, shale, chert, and lignite
TERTIARY	Miocene	Early	Hemingf	Esmeralda Formation: Unit 2 (Te2f) flows		0-200m	andesitic and basaltic volcanic flows; (15-23m.y.)
TERTIARY	Miocene	Early	Hemingf	Esmeralda Formation: Unit 2 (Te2b) breccia		0-300m	andesite clasts in gray andesite matrix; locally a conglomerate with sandstone matrix
TERTIARY	Miocene	Early	Hemingf	Esmeralda Formation: Unit 1 (Te1)		0-40m	light colored claystone, silicified in places; gray to red, poorly indurated mudstone
							unconformity
TERTIARY	Oligo.			Pre-Esmeralda Volcanics (Tpe)		200-400m	volcanics consisting of latite, andesite, tuff, keratophyre, trachyte, and rhyolite; (27m.y.)
							unconformity
TRIASSIC				Luning Form. (TRl)		1000m+	gray dolomitic limestone

Figure 3. Generalized columnar section of rocks in Stewart Valley

PRE-ESMERALDA ROCKS

Two pre-Esmeralda units were mapped in Stewart Valley--the Luning Formation and the pre-Esmeralda volcanics. Both units are an important part of the Gabbs Valley Range and the Cedar Mountains and are the source of Esmeralda sediments. The pre-Esmeralda and the Esmeralda volcanics can be easily confused in the Gabbs Valley Range.

Luning Formation

The Luning Formation was first described by Muller and Ferguson (1936) and later mapped by them (1939). They dated it as Upper Triassic based on "an offshore ammonite facies, a near-shore pelecypod facies, and a coral-reef facies" (1936, p.246). Only the upper member of the Luning Formation, consisting of gray (N3) limestone and dolomite (Ekren and Byers, 1978), is found in the part of the Gabbs Valley Range and Cedar Mountains mapped for this report. These carbonate rocks erode to high rounded hills and cliffs in the mountains flanking the valley.

Pre-Esmeralda Volcanics

The resistant pre-Esmeralda volcanics form the northern end of the Cedar Mountains, the low hills in the southwest corner of the mapped area, and one small hill in the middle of the valley. The only place the lower contact of this unit is exposed is west of Simon

Mine and there it is in fault contact with the Luning Formation.

Combined in this unit are a number of different volcanic rocks described by previous workers (see table 1). According to Ekren and others (1980, p.8,9), Stewart Valley is at the edge of lava flows originating to the northwest.

The lavas of Giroux Valley are found in the area around 13 x 66 and extend west off the map. In the Gillis Range these lavas have given a K/Ar date of 26.7 ± 0.9 m.y. (Ekren and others, 1980, p.14).

Knopf (1921, p.379-381) described rhyolite and trachyte southwest of OMCO mine. Ekren and others (1980, p.15) included these in the Guild Mine Member of the Mickey Pass Tuff. In the Gillis Range this member gave K/Ar dates from 24 to 28m.y.

North of Simon Mine, Knopf (1921) described a sequence from bottom up of Mammoth andesite, keratophyre, pyroxene andesite, dacite tuff, and quartz latite. Some of these rocks are found in other locations in Stewart Valley. The chalky white keratophyre is found in several places at the north end of the Cedar Mountains. The dacite tuff is found in several outcrops east of Stewart Spring and in the southwest corner of the mapped area. This tuff has a white to light green (5 G 7/2) matrix containing prominent biotite and occasional feldspar phenocrysts. Nielsen (1964, p.128,131) described this same dacite tuff in the Pilot Mountains. The quartz latite covers most of the area north of Simon Mine as well as occurring in the southwest. It has a purple matrix with feldspar, biotite, and some quartz phenocrysts and is silicified locally. Ekren and others

(1980, p.26,27) considered this quartz latite to be part of the Singatse Tuff which gave a K/Ar date of 27m.y. in the Pilot Mountains. Ross (1961) mapped this quartz latite as "post-Esmeralda felsic" on his map of Mineral County, although later maps show it as pre-Esmeralda (see table 1).

An andesite that has not yet been described is found in the vicinity of 20 x 73 and west. It has a pink, purple, gray, or green matrix with prominent euhedral feldspar phenocrysts.

ESMERALDA FORMATION

Introduction

Previous Work on the Esmeralda Formation

The name Esmeralda Formation was proposed by Turner (1900a, 1900b) for sedimentary beds in Esmeralda County, Nevada that were "composed of sandstone, shales, and lacustral marls, with local developments of breccia and conglomerate" but including no volcanics. He felt that "the basin containing Lake Esmeralda was bounded on the south by the Palmetto Mountains at the south end of Clayton Valley, on the east by the Montezuma Mountains, and on the west by the Inyo Mountains, the northern limit being entirely unknown." Turner (1900b) described a sequence 15,000 feet thick in the Silver Peak area. Buwalda (1914, p.343) was able to trace the beds from Stewart Valley to Ione Valley and then south through the Monte Cristo Range to Turner's type locality in the Silver Peak Range.

More recently the concensus has been that the lake sediments were deposited in isolated basins and often interfinger with volcanics. What the Esmeralda Formation includes is now a two-fold question: 1) should it include only Turner's original locality, or all nearby Tertiary lacustrine deposits? and 2) should it include only sedimentary rocks, or all interfingering volcanics as well? The following paragraphs give a summary of various conclusions.

Ferguson and others (1953) mapped the Coaldale quadrangle between Stewart Valley and Turner's Silver Peak Range. They split the

Esmeralda Formation into an upper unit (mostly sedimentary) and a lower unit of rhyolite breccia. On their map, however, they do not show the Esmeralda Formation as continuous, but with distances as great as 14km between outcrops.

Van Houten (1956) used the term "vitric tuff unit" to refer to all Tertiary lake deposits throughout Nevada consisting of tuff, mudstone, sandstone, limestone, and diatomite. He showed the Esmeralda Formation as the "vitric tuff unit" in west-central Nevada. The Truckee, Humboldt, and Panaca Formations are the "vitric tuff unit" in other parts of the state.

In studying the floras of west-central Nevada Axelrod (1956) was of the opinion "that the Late Tertiary continental basins in this area were relatively local in extent. The common practice of indiscrimately applying such formation names as Esmeralda, Truckee, and Humboldt over wide areas in Nevada finds little support in field evidence."

In mapping Mineral County, Ross (1961, p.45) used the Esmeralda Formation "for all the late Tertiary sedimentary rocks because of the need for a term to include both the rocks studied in detail and those mapped only in reconnaissance fashion."

Robinson (1964, p. 11,12) held the opinion "that the Esmeralda Formation was not deposited in a single lake but rather in a number of small, isolated basins, each having an individual history. . . . Volcanic rocks underlie, interfinger with, and overlie individual sedimentary units." He redefined the Esmeralda Formation "to include all Tertiary sedimentary and volcanic rocks in the Silver Peak quadrangle." Moiola (1969, p.29) later decided that "the Alum Area . . . contains the most complete section of the Esmeralda Formation in the Silver Peak Region and is its type section."

In mapping Esmeralda County, Albers and Stewart (1972) restricted the use of Esmeralda Formation to apply only to the sedimentary rocks in the Alum area. Other similar outcrops are designated only as "Tertiary sedimentary rocks."

More recently in mapping the Luning SE 15' quadrangle Ekren and Byers (1978) mapped two Tertiary sedimentary units: the Esmeralda Formation (Te) and (Miocene) Sedimentary Rocks (Ts). They considered the Esmeralda Formation to be "continuous with the strata at the type locality in Esmeralda County." The "Sedimentary Rocks" were found to be interbedded with the lower part of the tuffs and lavas of Mount Ferguson including flow brecciated rock (Ekren and others, 1980, p. 46).

The Esmeralda Formation in Stewart Valley

This report uses the term Esmeralda Formation to refer mainly to the fluvio-lacustrine rocks in Stewart Valley, but also to breccias and related lavas that interfinger with the fluvio-lacustrine rock.

In Stewart Valley small deposits of claystone (unit 1) interfinger with the volcanic breccias and lavas (unit 2). Above these breccias lie the main fluvio-lacustrine sediments that have been divided into five units based on predominant lithology:

sandstone and claystone in unit 3, shale in unit 4, claystone and mudstone in unit 5, sandstone and carbonate in unit 6, and sandstone and vitric tuff in unit 7 (see figure 3). Altogether seven units are mapped as part of the Esmeralda Formation. Plate 1 is a surface geologic map showing outcrops. Plate 2 is a bedrock geologic map showing the inferred geology underlying the Plio-Pleistocene deposits.

Esmeralda Formation outcrops in Stewart Valley extend about 6km east to west and 30km north to south. They extend beyond the area mapped in this report as shown on figure 2. Nielsen (1964, p.132) mapped the Esmeralda Formation in the pass between the Pilot Mountains and the Gabbs Valley Range as continuous laterally with the Stewart Valley beds and with the same sequence of sediments. Stewart and Carlson's map (1978) shows other nearby Tertiary sedimentary outcrops (see figure 2), but they are not continuous with those in Stewart Valley and thus may have been deposited in separate, isolated basins.

According to the gravity maps of Healey and others (1980, 1981), the sediments are thin across the middle of Stewart Valley (see figure 4) and become progressively thicker north to Gabbs Valley and south to the dry lake. This author's estimates based on gravity anomalies suggest a sediment thickness of 1000m below the dry lake and 500m in Gabbs Valley.

A complete section of the Esmeralda Formation can be seen in several places in Stewart Valley. One east-west section is located south of cross-section B-B" on plate 3. Two other complete sections extend north (see figure 5) and south from the middle of the valley as

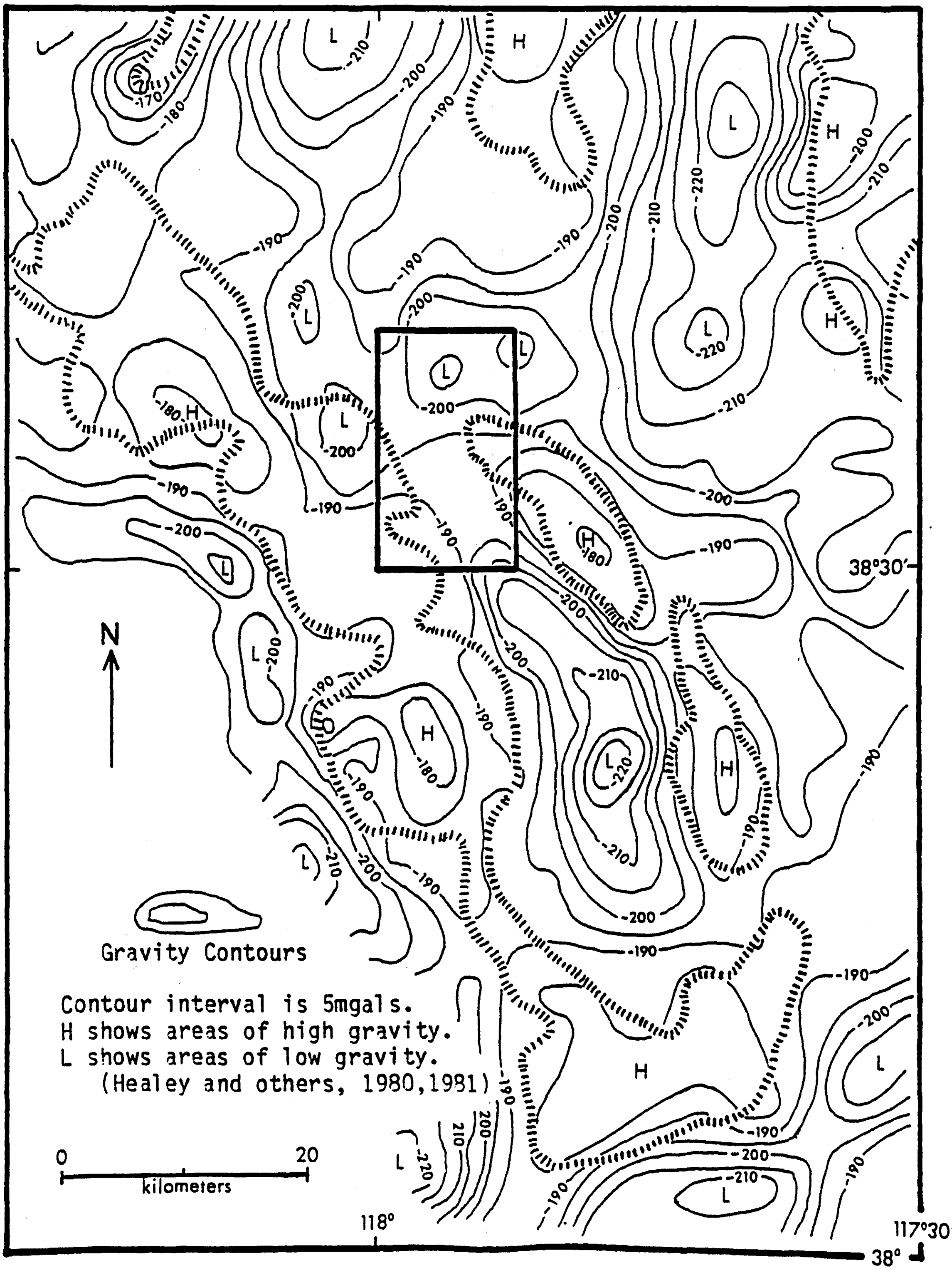
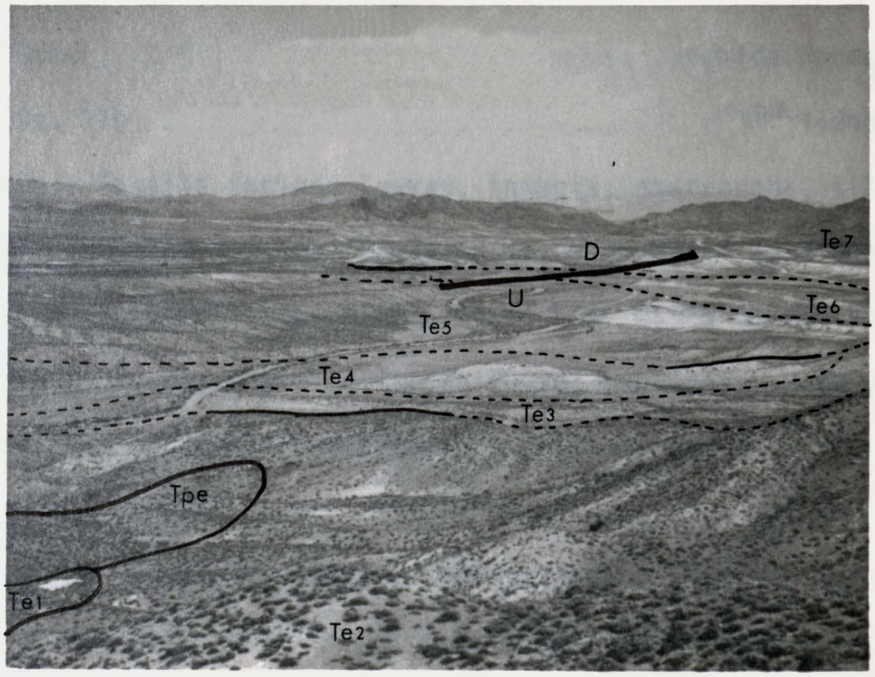


Figure 4. Bouguer gravity map of region around Stewart Valley. Rectangle shows mapped area.

Figure 5. All seven units as seen looking north from a hill (19 x 73 near the middle of Stewart Valley. Tpe (pre-Esmeralda volcanics), Te1 (claystone), Te2 (volcanic flows and breccia), Te3 (sandstone/claystone), Te4 (shale), Te5 (claystone/mudstone), Te6 (sandstone/carbonate), Te7 (sandstone/vitric tuff). Normal fault in distance.

Figure 6. An excellent exposure of unit 1. (18.7 x 72.7)


D
Te7
U
Te6
Te5
Te4
Te3
Tpe
Te1
Te2

shown on plate 3, C-C'.

In Stewart Valley total thickness of the Esmeralda Formation is about 600m. The sediments are exposed in small cliffs, rounded hills, and washes. Fossils include leaves, insects, gastropods, silicified wood, and vertebrates. The formation has been dated as Miocene based on the paleontology (Wolfe, 1964) and on K/Ar dates (Ekren and others, 1980) as discussed in the following sections. Both upper and lower contacts are unconformable.

Unit 1 (Claystone)

The most distinctive lithology of unit 1 is the light colored (often pink) claystone that weathers a bright white. X-ray analysis shows these to be opaline claystone (Nick, 1983). This claystone is silicified in places, noticeable mainly in the large outcrops on the east side of the valley. Around 20.5 x 73.6 the claystone contains concretions that weather out as egg-shaped rocks.

The major outcrops are on the southwest side of the valley, and on the east side surrounding outcrops of the pre-Esmeralda volcanics (see figure 6). In addition several small erosional remnants are found on the uplifted pre-Esmeralda volcanics of the Cedar Mountains. Most outcrops are small and laterally discontinuous suggesting isolated depositional sites. Wolfe (1964, p.N1) noted that "[t]here is no evidence in the lower part [this report's units 1 and 2] of widespread lacustrine conditions, and the sediments appear to have been deposited in rivers and ponds."

The white claystone weathers to small blocks and chips on hillsides. Few cliffs with good exposures are found but there is one at 14 x 64.6 protected by an overlying, resistant volcanic flow.

Associated with the white claystone locally are poorly indurated mudstone and tuff. In general light gray (N6) mudstone is above the white claystone and bright red (5 R 4/7) mudstone is below it. The red mudstone is very noticeable around 14 x 66, 20.3 x 75.5, and 21.2 x 69.5. At the last location the stratigraphic relations are not clear because of complex faulting and folding. These mudstones weather to rounded hills.

The best exposure of this unit is at 18.7 x 72.7 where it is 60m thick. Other outcrops average closer to 40m and small outcrops are between 10m and 20m thick.

Work on the western Nevada Miocene flora, including flora in this unit, was summarized by Axelrod in 1956. Wolfe (1964) later studied the flora specifically in this unit and dated it as late Hemingfordian. The best collecting locality for fossil leaves is in the white claystone around 19 x 73.

In most places unit 1 rests unconformably on the pre-Esmeralda volcanics; however, some of the claystone in the southwest area of the map (plate 1) interfingers with the volcanic breccias above. Wolfe (1964) showed this relationship in his generalized columnar section of Stewart Valley.

Unit 2 (Volcanic flows)

In the mapped area unit 2 consists of brecciated and unbrecciated flows. Ekren and Byers (1978) lumped all the flows together as "lavas of Mount Ferguson, undivided." Mount Ferguson is a volcanic feeder neck about 15km west of Stewart Valley. The flows range in composition from hypersthene andesite to quartz latite with a maximum thickness of 2000m. Rocks of Mount Ferguson have been K/Ar dated between 15 and 23.5 m.y. (Ekren and others, 1980, p.12).

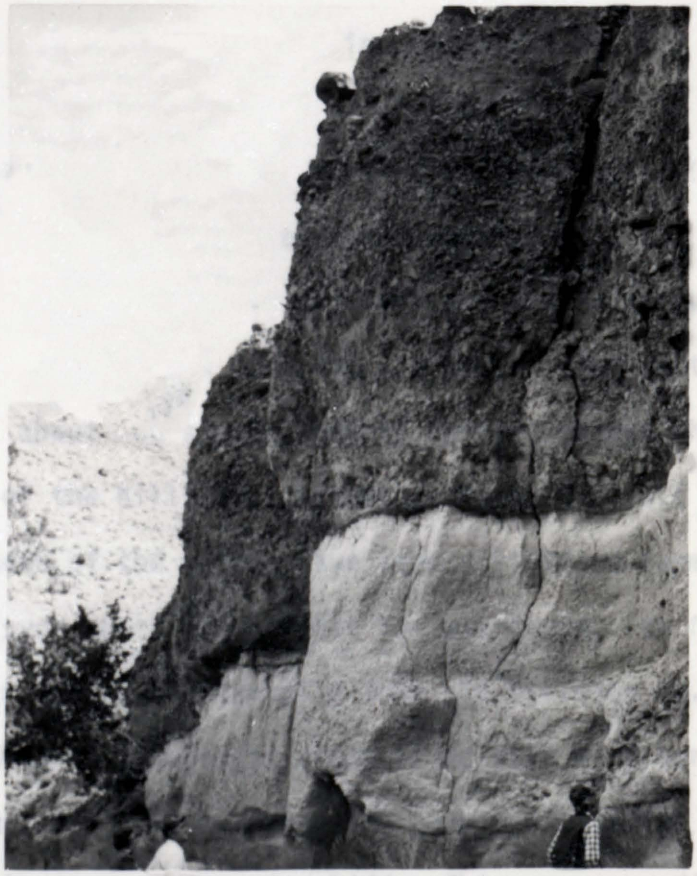
Nielsen (1964) lumped these volcanic breccias and flows and the pre-Esmeralda volcanics into the "Tertiary Andesite Breccia." In this unit he included hypersthene-andesite breccia, hornblende andesite breccia (lahar) and flows, dacite, and olivine basalt. He also mapped a hornblende andesite volcanic neck on a Tertiary fault in the central Pilot Mountains. He concluded (p.131) that the "andesite sequence is built up of accumulations of breccia, possibly mud flow deposits or autobrecciated lavas mixed with tuffaceous material. Ignimbrites are minor in the sequence."

Brecciated Flows

These flows consist mainly of andesite to rhyolite clasts in a gray andesite matrix. In most places the clasts weather reddish brown (10 R 6/6). At 16.4 x 66.8 the flow has been stained green (10 G 4/2). The andesite contains abundant hornblende lathes and some plagioclase phenocrysts. In the southwest area of the map (plate 1) autobrecciation can be seen in several places. At 14.3 x 63.6 the columnar jointed andesite grades into a breccia with the same mineralogy in the matrix as in the clasts. Clasts are up to several meters in diameter. In many areas two distinct layers can be seen near the bottom of the unit (figure 7). The lower layer consists of clasts up to 4cm in diameter in a pink (5 R 8/2) matrix. The upper layer contains clasts up to 1m in diameter in a dark gray matrix. Each layer is at least 5m thick wherever seen. Associated with the upper part of the unit on the hill at 18.5 x 72.5 is an extensively silicified layer 1m thick. South of Stewart Springs the base of the unit is mainly an agglomerate with distinctive pre-Esmeralda clasts. In the area around 18.4 x 73 the base of the unit is a conglomerate with a sandstone matrix and clasts up to 1m in diameter. In the area west of Simon Mine is a lapilli tuff that is stratigraphically in the same position as the volcanic flows, but it is only a couple meters thick and was not mapped.

The major outcrops of the brecciated flows are in the foothills on the west edge of the valley. In most places the flows can only be seen low on the canyon walls. However, in the area around 15 x 67 the breccia is quite thick and is not everywhere covered by the unbrecciated flows. The best exposure is in the main canyon and has a thickness of 350m. Other outcrops on the west side of the valley have an average thickness of 75m. The rest of the outcrops are on the east side of the valley near Stewart Spring and have a maximum thickness of 75m. There is also one small outcrop in the middle of

Figure 7. Two layers of breccia in unit 2. (14 x 66.5)



the valley exposed by fault uplift.

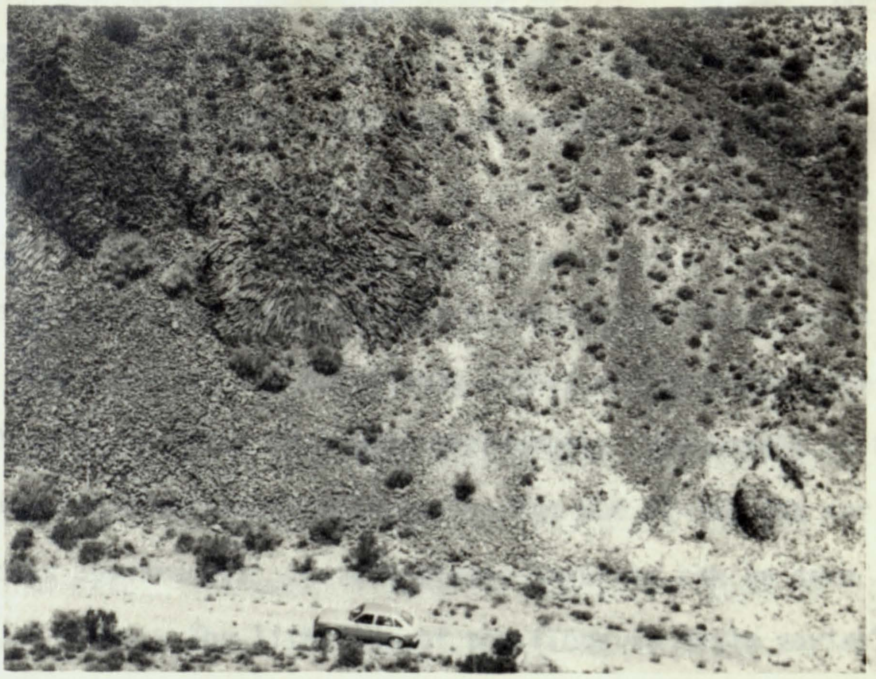
The breccias form high ridges at the northwest extension of the Cedar Mountains into Stewart Valley. They are more resistant to weathering than the pre-Esmeralda volcanics. The matrix weathers to light colored hillsides and the clasts remain as float. In the southwest corner of the map (plate 1) columnar jointing of andesite can be seen at Poleline Spring and in the canyon at 14.2 x 63.7 (figure 8).

Fossil remains in this unit consist of numerous silicified trees in the area within about 1.5km east and west of 15 x 66. These were first noted by Buwalda (1914). The best and most numerous specimens are in the canyon at 16.5 x 65.9 and southwest. The north side of the canyon has about 100 stumps, mostly upright except where they are weathered out of the hillside. Diameters range from 0.5m to 2m. The flows around some of the stumps have been silicified forming a case. In the next canyon south the largest log was found. It is 2m in diameter and protrudes horizontally from the hillside 4m. A cliff at 15.6 x 65.5 contains an upright stump along with many horizontal branches (figure 9). The branches are poorly silicified and weather out leaving holes in the breccia cliff. This cliff is directly above outcrops of the tuff unit. Mawby (1965, p.16) stated that the "tree stumps are preserved in growing position where an agglomerate flow over-ran a thin soil zone developed on a previous flow."

In many places the breccias lie unconformably upon pre-Esmeralda volcanics. In other places there is a gradational contact with unit 1

Figure 8. Columnar joints and breccia in unit 2. (14.2 x 63.7)

Figure 9. Silicified tree stump in breccia cliff of unit 2. (15.6 x 65.5)



below or an interfingering relation with unit 1. In the Stewart Spring area the contact is obscured in most places, but in the southwest area the contact is better exposed.

Unbrecciated flows

The unbrecciated flows of unit 2 consist of either andesite or basalt. The andesite has hornblende lathes and in some places plagioclase phenocrysts in a gray groundmass. The basalt is black and aphanitic with microphenocrysts weathering out giving the surface a scoriaceous appearance. In some places layering can be seen within individual flows. The lithology of the flows is quite variable and is described by Ekren and others (1980, p.46,47).

These volcanic flows cover most of the hills on the west side of the valley, particularly over the Luning Formation in the southwest corner and north of 14 x 68. They also cap unit 1 southwest of 15 x 65. On the east side of the valley is a small exposure at 18.8 x 72.2. The maximum thickness of these flows in the mapped area is about 200m, although they are much thicker further west. They form resistant plateaus and shear cliffs.

The flows were deposited on a pronounced unconformable surface formed by erosion of the volcanic breccias and the Luning limestone.

Unit 3 (Sandstone/claystone)

Sandstone is the predominant lithotype in this unit. Most of the sandstone is orange to brown, but some prominent strata are light gray (N6), some are iron stained, and one around 17 x 66 is green (5 R 6/6). Around 18 x 73 some of the beds are cross-bedded. In places there is a bed up to a meter thick that is very well indurated. Around 18 x 73 the sandstone forms 20m high cliffs, and around 17 x 66 a very well indurated sandstone forms a cuesta.

Alternating with sandstone beds are red, brown, and olive-colored claystones, white tuffs, and shale, some of which have been silicified. Silicified claystones form resistant benches in the southern outcrops, and west of 17 x 72 they form ridges up to 25m high. A very resistant gray limestone bed within this unit crops out north of 14 x 74. Lignitic siltstones up to 2m thick outcrop in the tributary valley around 17.8 x 71.8.

In general, unit 3 forms a strip around the valley with a dip away from the underlying volcanics. Along the west side of the valley unit 3 is from 50m to 150m thick. On the east side of the valley it has a maximum thickness of 70m, but in several places it either pinches out or is faulted out. The third general location for unit 3 is east-west across the narrowest part of the valley. Here again the unit dips away from volcanics. The best exposure of this unit is in the canyon at 17 x 66.

Vertebrate fossils in this unit were named the Stewart Spring Fauna by Stirton (in Teilhard and Stirton, 1934, p.285). Mawby (1965, p.19,28,29) reviewed previous study on the vertebrate fauna and assigned it an early Barstovian age. Ekren and Byers (1978) dated rhyolite Apache tears in stratigraphically similar beds in the Luning NE quadrangle. They arrived at an age of 15.2 + 0.4m.y. Gastropods are also plentiful in this unit throughout the valley and are most abundant as a coquina in the area around 18.3 x 73.6. Firby (1963, 1966) studied and described this gastropod fauna. Silicified wood is also found in unit 3. The best specimens are 1m diameter stumps on the north side of the canyon around 17.7 x 72.4. Silicified wood was also found at 18.3 x 73.4 and 19.3 x 71.4. Occasional stromatolites occur in the unit, most significantly in the area around 22.5 x 67.7, but also northeast of 17 x 63.

The lower contact of unit 3 is conformable above the volcanic breccias of unit 2 in most places. At Stewart Spring is a fault contact with the volcanic breccia. Around 22 x 68 unit 3 directly overlies unit 1, but the contact is covered by pediment gravels in most places. In the northeast, northwest, and south, unit 3 unconformably overlies the pre-Esmeralda volcanics with particularly good exposures at 13.8 x 74.3.

Unit 4 (Shale)

Unit 4 is predominantly shale that is well laminated to the point of being paper thin, but in places it is blocky. Orange (10 R 6/6) dolomite layers up to 30cm thick occur at the bottom and top of this unit. Dendrites are found frequently on weathered surfaces. North of 19 x 71 the dolomite is sandy. Near the top of the unit the shales grade into claystones with a vitric tuff layer in places. Gypsum and brown (5 YR 5/2) calcite is occasionally found.

The main shale outcrops are in the center of the valley and cover about 5km by 7km (figure 10). North of the central part of the valley the shale can be seen to pinch out laterally between units 3 and 5. Unit 4 covers a much smaller area than the three units above it, suggesting a unique depositional environment in this small area. The shale reaches a maximum thickness of about 60m at 18 x 70 and north, but the average thickness of the unit is closer to 40m. Measured sections east and south of the main area (Nick, 1983) gave thicknesses of 40m and 20m respectively.

The shale is light brown (5 YR 5/1) when fresh, but weathers to a bright white. In many places the shale covers the ground with small white chips and bedding is apparent only with trenching. Cliffs of shale are exposed mainly along stream channels (figure 11). The dolomite is much more resistant and forms prominent ridges. It is usually jointed perpendicular to the bedding plane.

Most of the shale beds are nearly flat lying, but with numerous small scale folds. In particular, the shale beds in the tributary valley south of 19 x 69 have no general dip pattern at all.

Unit 4 contains abundant fossils. The Stewart Spring Flora was studied and described by Wolfe (1964). Harvey I. Scudder (unpublished manuscript, 1981) studied the insects. There is also an abundance of undescribed fish fossils. Most of the fossils have been collected in the central part of the basin. Wolfe (1964, p.N1)

Figure 10. Main outcrops of unit 4 are in the distance with units 1 and 2 in the foreground as seen looking southwest from a hill (19 x 73) near the middle of Stewart Valley.

Figure 11. A cliff of well-laminated shale in unit 4. (18.3 x 70.3)

considered the age of the shales to be "early, or more probably middle, Barstovian."

The contact with underlying unit 3 is placed at the lowest dolomite layer. In most places this lowest dolomite marks a rather abrupt change from sandstone and claystone below to shale above. In the area of 17 x 72 however the contact is less well defined.

Unit 5 (Claystone/mudstone)

Unit 5 is predominately fine grained claystone and mudstone with some shale. The claystone and mudstone is brown (5 YR 4/4) or white, with some red (5R 4/6) layers. Bands of white vitric tuff up to 0.5m thick are interspersed throughout the unit. Gypsum occurs in 5cm thick beds in places, but is found most abundantly weathered out of claystone hills. The gypsum occurs as satin spar and as selenite crystals up to 10cm in longest dimension.

In the central and eastern part of the valley sandstone and dolomite are prominent in places. A 3cm thick orange (10 YR 6/6), medium-grained sandstone layer is found near the bottom of the unit and a meter-thick, well indurated, coarse sandstone is found in the middle of the unit. In the area of 20 x 69 and northeast dolomite is found in the middle of the unit. The area south of 21 x 70 is unique for unit 5. There is a facies change into coarse sandstone and vitric tuff layers up to 3m thick dipping east into the fault contact with the volcanics.

Unit 5 is distributed mainly along the axis of the valley extending off the northwest corner of the mapped area about 2km. Outcrops that are not continuous with the ones in the main valley occur north of the Cedar Mountains. In general unit 5 has little lateral variation.

The best exposure of unit 5 is located west of 21 x 69. The section is well exposed in this area with a total thickness of 200m. This is a maximum with averages along the valley axis closer to 150m. North of the Cedar Mountains thickness is closer to 100m.

The claystone and mudstone weather to rounded hills (figure 12) or to flat clay and mud outcrops. West of 19 x 68 the sandstone in this unit has weathered to a pure coarse-grained sand. Much of the unit is covered by pediment gravels or alluvium.

Unit 5 is structurally quite complex in the east central portion of the map (plate 1) as a result of faulting and related folding. There is complex folding in the dolomite at 20.3 x 69, a relatively large anticline in the claystone at 21 x 69.4 (figure 13), and the nose of another anticline at 19.5 x 66.9.

According to Wolfe (1964, p.N3), the mammals of the Clarendonian Cedar Mountain local fauna may have been found as low as this unit 5; however, Mawby (1965) showed the fauna as collected from higher in the Esmeralda Formation, mainly from what this report calls unit 7. Smedman (1969) studied the diatomite in the cliffs around 18 x 75 and stated that the age is probably Barstovian. Silicified wood and a paleosol with roots in the stream bed have been found east of 21 x 69

Figure 12. Rounded claystone hills in unit 5. (18 x 74.5)

Figure 13. Large anticline in unit 5 as seen looking south toward hill at 21.2 x 69.4.

(Nick, 1983).

The contact with underlying unit 4 in the middle of the mapped area is gradational over 20m or so with alternating, varicolored beds of claystone and shale. In places a conspicuous dolomite layer is used to mark the contact. In the northern part of the mapped area unit 4 is missing and unit 5 lies directly on unit 3. North of the Cedar Mountains unit 5 overlies the volcanics in places and appears to be weathered directly from them.

Unit 6 (Sandstone/carbonate)

Unit 6 consists predominately of alternating beds, up to several meters thick, of sandstone, limestone, claystone, and occasional dolomite. The claystone and limestone beds are white to light gray. In most places there is a resistant gray (N4) limestone bed more than 1m thick near the bottom of the unit forming a ridge with up to 5m of relief. Cross-bedded sandstone deposits in this unit form cliffs up to 10m high in the areas around 19.3 x 73.6 and 20 x 68. Pebble conglomerates occur east of the first location. Both appear to be fluvial deposits. Occasional gypsum bands can also be found in the unit.

Unit 6 outcrops in the north and southeast and extends both northeast and south of the mapped area. The main lateral variation is in relative abundance of claystone, sandstone, and limestone. The best exposure of this unit is 80m thick and is located in the east-west valley at 21 x 68.7. 100m is about the average thickness for the unit with a maximum in the southeast of close to 200m.

Stromatolites are common in this unit particularly around 22 x 67 and 19.4 x 73.8. Because of their resistance to weathering they are usually found as float. The layered limestone is concentric around a hollow center. In the northern area a stromalite is found growing around a silicified tree trunk. In the same area are several dozen stromatolites a meter high with vertical holes in the center. In the southern area some of the stromatolites are as large as 2m in diameter. Buwalda (1914, p.345) referred to the stromatolites as "lithoid tufa domes."

Extensively burrowed limestones are found in the same locations as the stromatolites. Individual burrows are about 5mm in diameter and are horizontal at the surface of a limestone bed (figure 14).

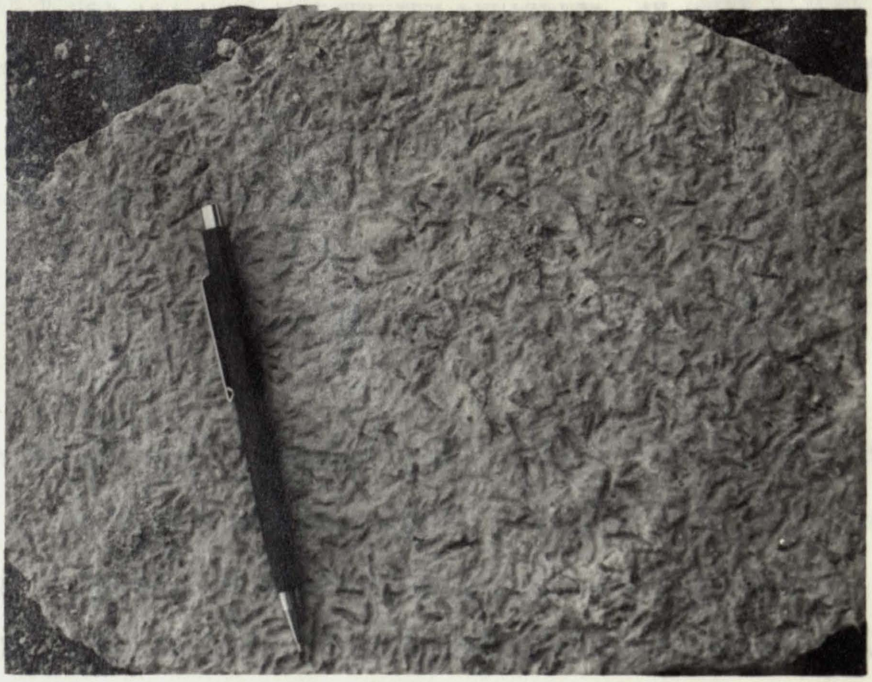
The third type of fossils found in this unit are molluscs studied by Firby (1966, 1969) and found associated with limestones.

In general the claystone, limestone, and sandstone weather to white discontinuous outcrops. Scrub trees are abundant on this unit in comparison with unit 5 below (figure 15). In places the contact with unit 5 could be drawn based solely on vegetation.

Two faults are important in this unit. In the southeast corner of the map (plate 1) a normal fault causes repetition of the unit. At 14.4 x 77.5 a fault has formed an anticline entirely within unit 6. Dips on both limbs of the anticline were measured, but the axis of the fold has been eroded away.

Figure 14. Burrowed limestone in unit 6.

Figure 15. Fault between unit 5 on left and unit 6 on right as seen looking south from ridge at 20.3 x 68.2. Scrub trees are growing mainly on unit 6.



Unit 6 has fairly well defined contacts. In most places the lower contact with unit 5 is abrupt. However, in the northwest the contact is more gradational and is placed about 10m below the base of the resistant gray limestone described above.

Unit 7 (Sandstone/vitric tuff)

The distinctive lithology in unit 7 is a vitric tuff. At the base of the unit is a medium grained, blue-gray (5 B 7/1) vitric tuff averaging 2m thick. It weathers to grottos and locally forms cliffs. About 10m higher in the section is the main cliff former--a coarse grained, white vitric tuff containing biotite. These cliffs are the most prominent in the valley and are up to 4m high. The cliffs are partly massive and partly laminated and locally contain ripple marks. A distinctive feature is contortions due to soft sediment deformation (figure 16). In places this tuff weathers a rust orange (10 R 7/4).

Unit 7 contains predominately sandstone, limestone, and claystone similar to that in unit 6, but the sandstone is coarse grained and grades into pebble conglomerates and cross-bedding and graded bedding are common. The sandstone is light brown, gray, and orange. A few of the layers are well indurated. Poorly indurated white limestones predominate higher in the unit with some weathering to pink (5 R 8/2) rounded hills in the northwest. Thin layers of limestone pseudomorphs that look like "desert roses" outcrop locally.

This unit outcrops in two main places as shown on plate 1--the

Figure 16. Soft sediment deformation in vitric tuff of unit 7.

Figure 17. Basalt capping Table Mountain southwest of mapped area as seen looking west from the Stewart Valley graded road.

southeast, and in a large arc in the north. The vitric tuff pinches out in both the northeast and northwest corners of the large arc. In these areas the unit grades into coarse-grained sandstone. The vitric tuff has been silicified in the area around 20 x 74. In several places the distinctive vitric tuff cliffs are not in their usual stratigraphic position. They lie above unit 5 around 20 x 66 and at an erosional unconformity above unit 6 around 15 x 75. The second location appears to be a stream channel deposit. Apparently the vitric tuffs were deposited on an uneven topographic surface.

The most complete section for unit 7 is east-west at 17 x 77, but because of faulting the section does not include a contact with unit 6. The 160m thick section exposed here is a little greater than average for the unit. At the top the unit is covered, so this may not be total thickness. Faulting, variations in dip, and widespread alluvial cover make an accurate estimate difficult.

A 3.4km fault in the northwest corner causes repetition of the vitric tuff cliffs. Along the east side of the valley are several smaller faults terminating this unit against lower units.

Mawby (1965) has studied the vertebrate fauna in this unit in northern Stewart Valley, Ione Valley, and north of the Cedar Mountains and given them a Clarendonian age. He reviewed (p.28-30) studies on this fauna since they were first called the Cedar Mountain Fauna by Merriam (1916). Stirton (1932) first correlated this fauna with vertebrates found in Fish Lake Valley, Nevada. Samples from the northern part of the unit have also been dated by K/Ar methods

(Evernden and others, 1964). Biotite from a vitric tuff gave an age of 10.7m.y. (KA452) and a sample 15m higher in the section gave an age of 11.5m.y. (KA577).

The lower contact is placed at the base of the lowest vitric tuff layer. Firby (1969, p.8,9) suggested that an unconformity exists between Barstovian and Clarendonian strata; however, his report is not clear as to where the boundary is. His columnar section would put the boundary below this report's unit 7, but his report puts the Barstovian/Clarendonian boundary (?) below unit 6 (see figure 3).

POST-ESMERALDA ROCKS

Basalt and Plio-Pleistocene sediments unconformably overlie the Esmeralda Formation.

Basalt (latite)

This unit is described as aphyric latite with clinopyroxene microphenocrysts by Ekren and Byers (1978). They give it a Miocene age. Stewart and Carlson (1978) mapped this unit as andesite and basalt flows. In Stewart Valley this basalt is dark gray (N3) to greenish gray (5 GY 5/2).

The main outcrops of basalt within the map area are in the southwest corner. The thickness there is about 50m. The basalt forms resistant plateaus with talus slopes. The largest plateau in the area is Table Mountain (figure 17) where the basalt rests unconformably on the Luning limestone. Just off the northwest corner of the mapped area is Fingerrock, another latite outcrop. According to Ekren and Byers (1978), it is a latite volcanic neck.

One 5m thick dike of latite is found at 20.7 x 72.3 intruding pre-Esmeralda volcanics. The contact between dike and volcanics is obscured by float on the hillside.

Plio-Pleistocene Deposits

Older Alluvium

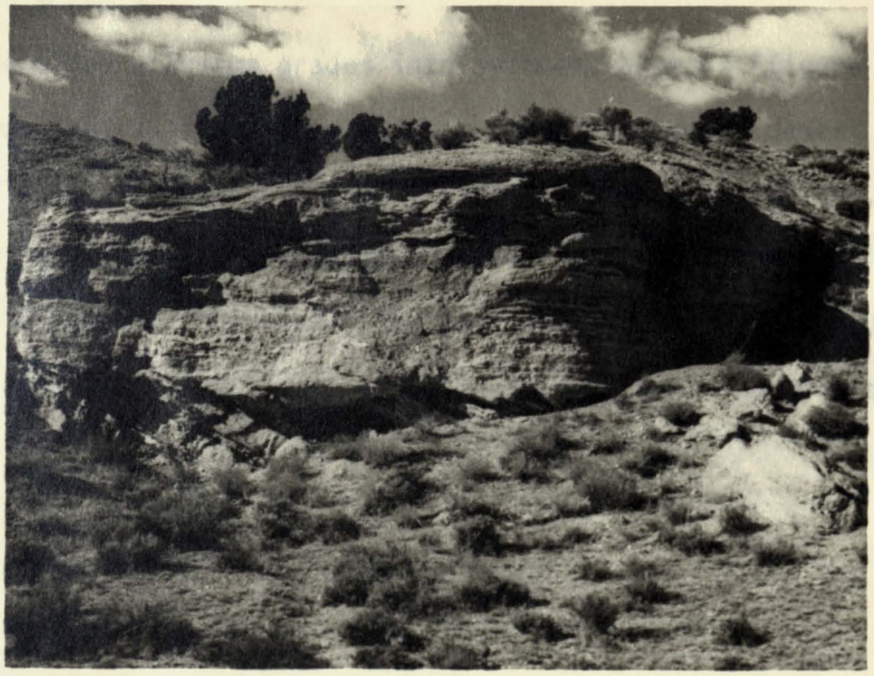
The older alluvium occurs in two main areas in Stewart Valley: 1) north of the Cedar Mountains and 2) in the southeast corner of the mapped area extending north along the axis of the valley.

The large outcrops of older alluvium north of the Cedar Mountains consist mainly of poorly indurated sandstones and pebble conglomerates. The best outcrops are near the road in the northeast corner. Mawby (1965, p.23) found no fossils in these outcrops but suggested an age of "Late Pliocene or Early Pleistocene." Conglomerate cliffs of older alluvium in the canyon at 23.5 x 72.2 suggest that the northern Cedar Mountains were the source of this alluvium.

Outcrops of older alluvium in the southeast and along the axis of the valley consist of indurated, coarse grained sandstone to conglomerate. The conglomerate contains volcanic and limestone clasts up to 20cm in diameter. The outcrops form well indurated cliffs up to 30m high east of 23 x 65 and off the map south of the canyon around 24 x 67. The cliffs have several distinct layers that dip west away from the Cedar Mountains. Along the axis of the valley on the highest hills are small outcrops of this conglomerate with some cliffs up to 10m high. These conglomerates lie unconformably on the lacustrine sediments. At 21.1 x 68.6 is a well exposed angular unconformity between the conglomerate and unit 6 (figure 18).

Figure 18. Older alluvium lying above an angular unconformity with unit 6 beneath. (21.1 x 68.6)

Figure 19. Dissected pediment gravels from the Gabbs Valley Range as seen looking northwest from a hill (19 x 73) near the middle of Stewart Valley.



Pediment Gravels

The older alluvium grades into pediment gravels (figure 19) throughout the valley. The pediment surfaces forming desert pavement consist mostly of volcanic clasts--many covered with caliche. The pediment gravels were deposited in alluvial fans at several levels. Along the sides of the valley the pediment gravels grade into alluvium (Qa). Dohrenwend (1981) dated the pediment gravels as Pleistocene.

STRUCTURAL GEOLOGY

General Dip

The general dip of the Esmeralda Formation in Stewart Valley is east. However, the beds dip north and south away from the part of the Cedar Mountains extending into the valley.

The beds in the Esmeralda Formation generally have gentle dips, rarely greater than 20° except close to faults. North of 19 x 73 is an exception with the sandstone unit dipping northeast away from the hill of volcanic breccia at 60°.

Faults

Several types of faults are found in Stewart Valley: 1) a major strike-slip fault in the southwest corner and perhaps one in the middle of the valley, 2) a reverse fault at OMCO mine, and 3) numerous normal faults.

The right-lateral strike-slip Battle's Well Fault (see figure 2) extends across the southwest corner of the mapped area. The northwestern half of this fault has been mapped by Ekren and Byers (1978). They show the fault as downdropped on the east side in the Gabbs Valley Range. In studying this fault in the northeastern Pilot Mountains, Nielsen (1965, p.1305) found one mile of right lateral displacement of welded tuffs in the andesite breccia. He noted that the Esmeralda Formation is also cut by the fault but that the displacement is small. On his map Nielsen showed this fault downdropped on the west side rather than the east side. On plate 1 this fault was mapped as a strike-slip fault based on the above sources, but a vertical displacement of roughly 350m was also found with the downdropped side on the east. This fault brings in contact the Luning Formation and the volcanic breccia of unit 2. Movement on the Battle's Well Fault in Stewart Valley apparently occurred after the breccias were deposited, but before the later lava flows of unit 2 because the lavas have not been disturbed by the fault.

Mawby (1965, p.23) described "a fault, striking approximately N 30° W, with right lateral strike-slip displacement . . . on the west side of Stewart Valley, 2 1/2 miles west of Stewart Spring. Part of the fault plane, with highly polished horizontal slickensides, is exposed. An outcrop of volcanic rock is offset at least fifty yards by the fault." This is probably fault number 8 on figure 20. However, it must be mainly a dip-slip fault as suggested by the uplift of the unit 2 breccia and pre-Esmeralda volcanics in the middle of the valley and the associated syncline (see plate 1).

At OMCO mine Knopf (1921, p.379) shows two faults cutting the mine shaft (see cross-section A-A' on plate 3). One of these is a reverse fault, cut by a later normal fault.

The rest of the faults in Stewart Valley are steeply dipping normal faults inferred from stratigraphic relations and/or seen as lineaments on aerial photographs. Some of these faults may have a strike-slip component (e.g., faults 34 and 35 in figure 20), but in

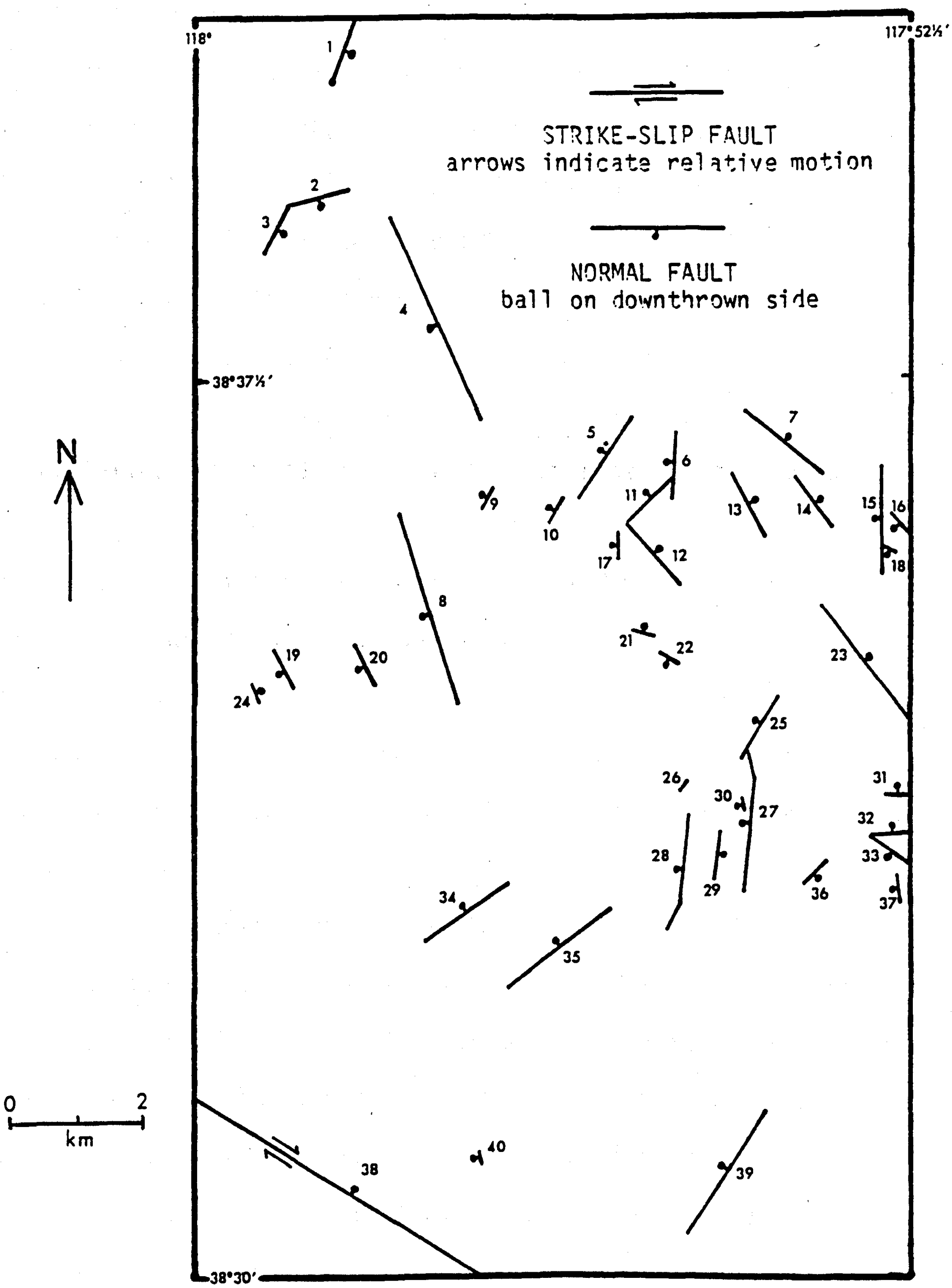


Figure 20. Map showing Tertiary faults in Stewart Valley (copied from plate 1). Fault numbers are referred to on table 2.

most places the fault surface could not be found in order to check for slickensides. Figure 20 and table 2 list the 40 faults mapped. Two dominant sets of faults are present, with trends of N 25° W and N 10° E. This conjugate fault system is what would be expected as a result of faulting in the Basin and Range Province. Another minor set of faults has a trend direction of N 45° E. Figure 21 illustrates these relations with a diagram plotting fault lengths at 15° class intervals. The axis of the valley is approximately N 27° W, paralleling the trend of one of the dominant set of faults. In general the dip direction of the faults is on the west as shown in figure 22. Most of the faults are associated with the Cedar Mountains and are downdropped on the side away from the mountains. Three faults in the northwest corner are associated with Fingerrock and downdropped on the side away from it. In the south three faults are more centrally located in the valley and are downdropped on the northwest side.

The normal faults cut the Esmeralda Formation and in places bring it in contact with pre-Esmeralda volcanics. However, the faults do not appreciably offset the Plio-Pleistocene deposits. The vertical displacement on fault surfaces in the central portion of the valley is anywhere from 10m to 150m (see table 2). Faults bounding the ranges have a displacement of up to 300m. In places where fault surfaces could be seen, they have dips greater than 60°. These dips are indicated for faults 4 and 10 on plate 1.

Recent faulting occurred in Stewart Valley in December of 1932,

Fault Number	Strike	Length (km)	Dip Direction	Maximum Vertical Offset (m)	Associated Folds A=anticline S=syncline
1	19°	1.1	109°	20	
2	83°	0.9	173°	150	
3	31°	0.9	121°	40	A
4	157°	3.4	247°	140	
5	34°	1.6	304°	120	A (from drag)
6	2°	1.1	272°	40	A (from drag)
7	130°	1.6	40°	90	A
8	164°	3.1	254°	90	S (from drag)
9	26°	0.4	296°	10	
10	24°	0.4	294°	10	
11	55°	1.0	325°	200	
12	139°	1.3	49°	20	
13	150°	1.1	60°	30	
14*	142°	1.0	52°	60	
15	1°	1.7	271°	80	
16	144°	0.4	234°	50	
17	175°	0.4	265°	20	
18	112°	0.2	202°	10	
19	164°	0.7	254°	35	
20	165°	0.7	255°	50	
21	117°	0.4	27°	30	S (from drag)
22	123°	0.4	213°	20	
23	142°	2.1	52°	60	
24	158°	0.3	68°	30	
25	21°	1.2	291°	300	A
26	47°	0.2	-	10	S (tight)
27	5°	2.1	275°	250	S (from drag)
28	6°	1.8	276°	220	A (from drag)
29	8°	0.8	98°	60	
30	171°	0.3	261°	45	
31	93°	0.3	3°	50	
32	79°	0.6	349°	200	
33	127°	0.7	217°	300	
34	57°	1.6	327°	150	
35	53°	2.0	323°	110	A (from drag)
36	42°	0.5	132°	35	
37	175°	0.3	265°	50	S (from drag)
38**	120°	5.2	30°	350	
39	33°	2.2	303°	130	
40	171°	0.2	261°	15	

Table 2. Strike, length, dip direction, displacement, and folds associated with faults in Stewart Valley. (Fault numbers from figure 20.)

* Normal fault at OMCO Mine

** Battle's Well Fault

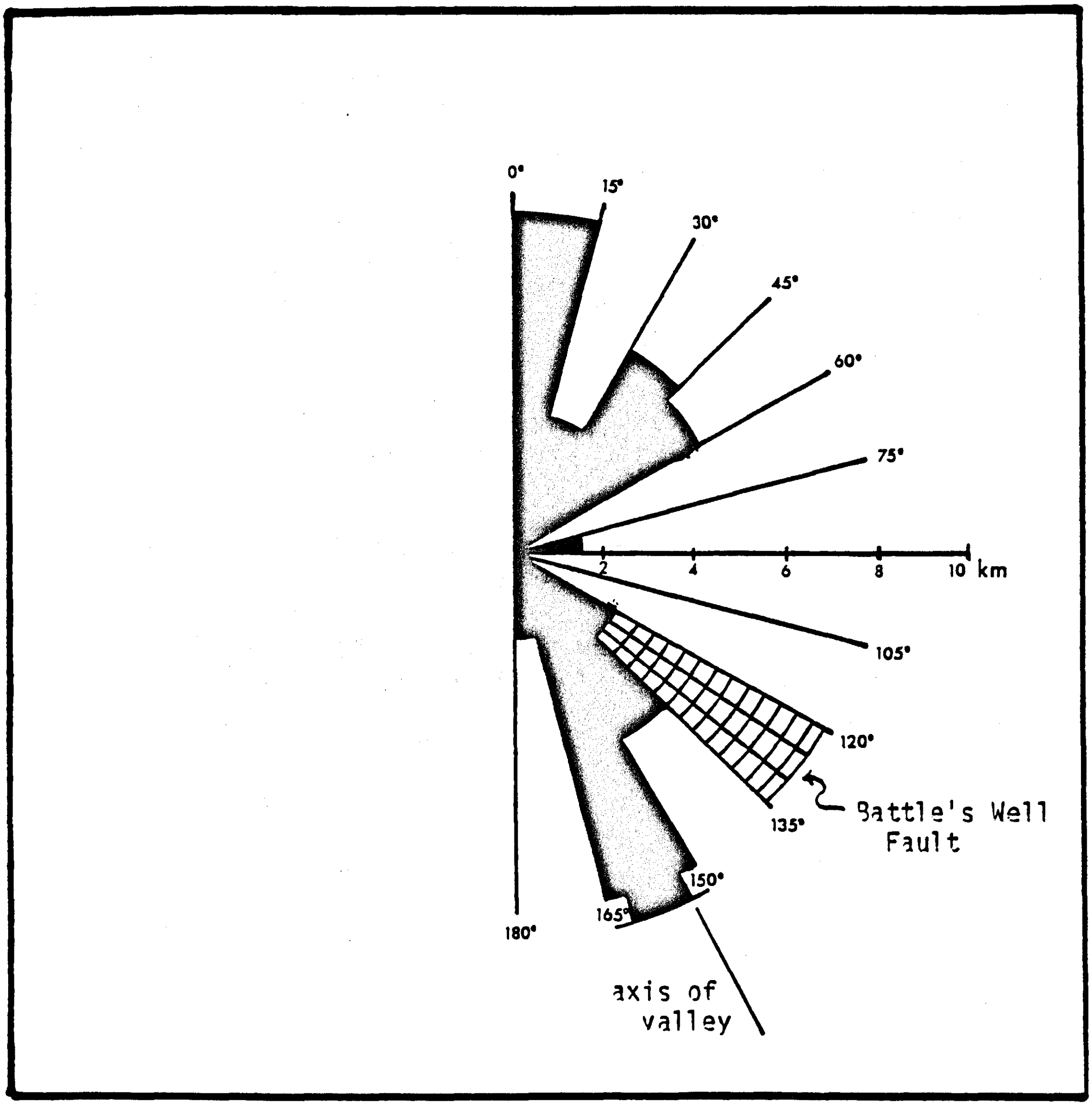


Figure 21. Fault-strike diagram for Stewart Valley with total length of faults plotted in 15° class intervals.

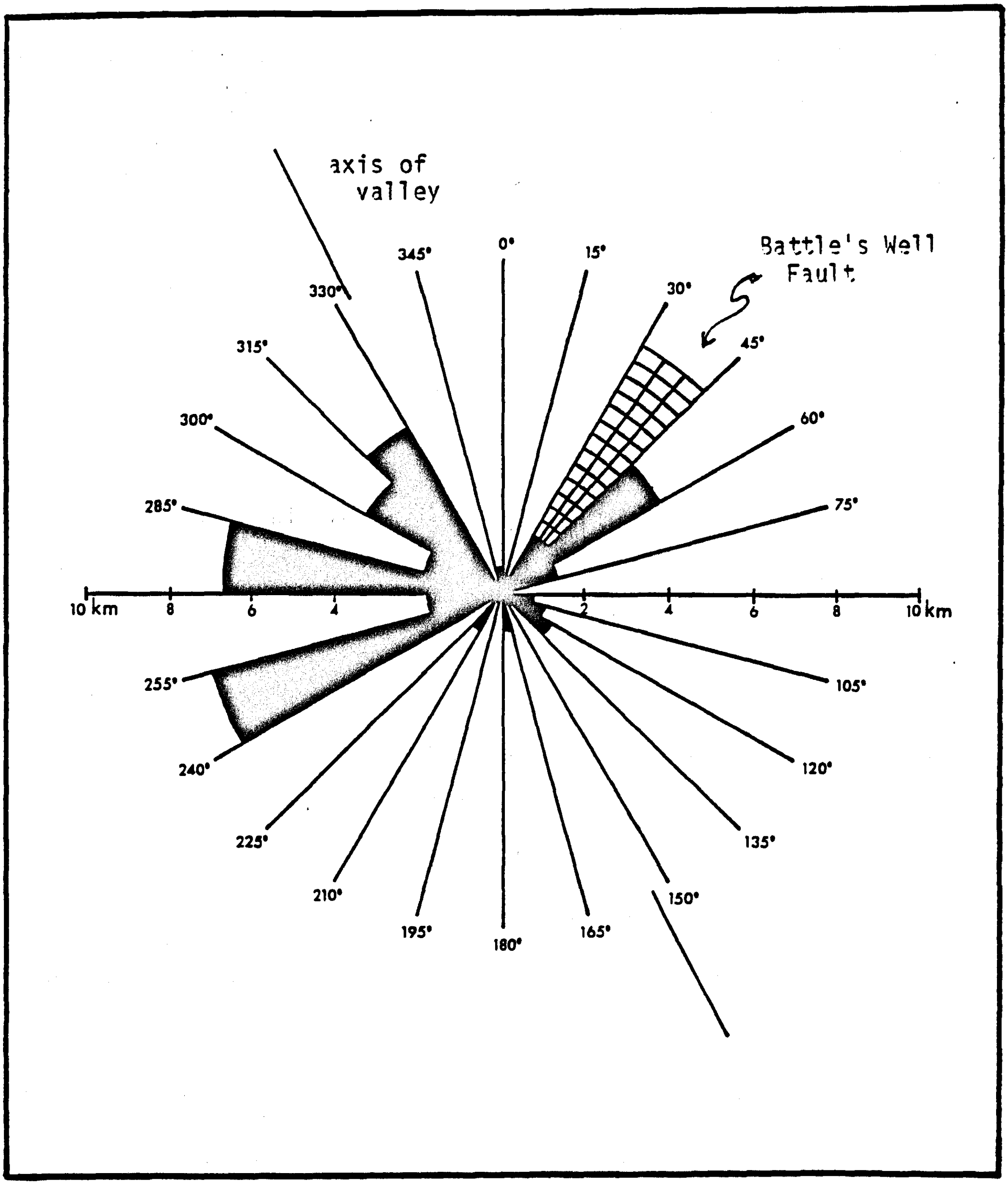


Figure 22. Diagram showing direction of dip for normal faults in Stewart Valley with total length of faults plotted in 15° class intervals.

and was described by Gianella and Callaghan (1934a, 1934b). The most significant rifts they described had a strike of N 11° E. Other rifts had strikes of N 11° W and N 61° E. Many grabens were formed, but the net vertical displacement in the valley was approximately zero; however, right lateral offset of up to 1m was found on many of the faults.

Folds

The folds in the valley fall into three main categories: 1) relatively large scale folds not directly associated with faults, 2) folds related to faults and sub-parallel to them, and 3) small scale folds not directly associated with faults. In the first category there are two folds north and one south of the Cedar Mountains. Also in this category is a dome in unit 1 at 18.7 x 72.8. Folds in the second category have been listed on Table 2 along with the associated faults. More than half of the folds are the result of drag during faulting. The other folds are anticlines on the downdropped side of a fault and thus give attitudes opposite to the direction that drag would be. Also in this category are the tight synclines associated with fault 26. Since the folds are perpendicular to the fault, they are apparently related to the regional faulting rather than just the one fault. In the third category are numerous small-scale folds all of which are at least partially in unit 4 (see plate 1 for locations).

CENOZOIC GEOLOGIC HISTORY

Drainage

The volcanic breccias and lava flows of unit 2 are found across the middle of Stewart Valley (see plate 2) and across the northern end of the valley (Stewart and Carlson, 1978) just north of the mapped area. They probably blocked drainage in a northerly direction in the early Miocene causing a lake to form. However, there was external drainage according to Firby (1965, p.252). "This determination is based on the low tolerance of the molluscan assemblage for (1) salinity and (2) alkalinity of the depositional environment." During most of the Miocene, then, drainage for the valley was probably to the south. Gravity maps (figure 4), showing thicker sediments beneath the dry lake to the south than in Gabbs Valley to the north, also suggest a southerly drainage direction.

At the end of the Miocene drainage shifted to the north as suggested by several facts. First, the cliffs of Plio-Pleistocene older alluvium that are thickest west of the Cedar Mountains (in the southest corner of the mapped area) get progressively thinner further north. Also, the older alluvium north of the Cedar Mountains has a gradual dip north away from the mountains, perhaps from an original dip. Limestone clasts from the Luning Formation also suggest the Cedar Mountains as the source of the older alluvium. Older alluvium in both outcrop areas, then, probably had its source in the Cedar Mountains and was transported northward. Second, several faults across the southern part of the valley were downdropped on the northern side at the end of the Miocene since they cut the Esmeralda Formation, but not the Plio-Pleistocene sediments. This faulting could have caused the drainage direction to shift to the north. Third, the tributary valleys in Stewart Valley all have a northerly component; therefore, the pediment surfaces were eroded by a northerly drainage. This drainage direction continues to the present.

Relation of Stewart Valley to the Cedar Mountains and Ione Valley

Two lines of evidence suggest that the Cedar Mountains were present during the deposition of the lake sediments. First, the stratigraphic sequences in Stewart and Ione Valley are different (Mawby, 1965, p.20), showing that the valleys were not part of a single basin. They were probably separated by the Cedar Mountains. Second, there are no Miocene lacustrine sediments found in the Cedar Mountains according to Stewart and Carlson's map (1978).

However, the Cedar Mountains probably had less relief during the Miocene than now as shown by 1) later faulting along the Cedar Mountains that appreciably offsets fluvio-lacustrine sediments and 2) the paleocurrent data in Ione Valley directed toward the Cedar Mountains (Henderson, 1962, p.71).

Even though most of the stratigraphic sequence in Stewart and Ione Valley is not the same, unit 7 in Stewart Valley and the upper member in Ione Valley were correlated by Firby (1969, p.9). This correlation suggests that the two valleys were isolated parts of one basin during the later depositional stages and were connected north of the Cedar Mountains.

Discussion of Structure

Following is one possible synthesis of the faulting and associated folding in Stewart Valley during the Miocene.

Faulting in the Stewart Valley area began in early Miocene. The valley was downdropped at the Battle's Well Fault on the west and on faults along the east side of the valley including, possibly, the reverse fault at OMCO mine. This faulting was associated with strike-slip faulting along Walker Lane and occurred as the breccias and lava flows were being deposited. The faulting disrupted the external drainage and formed a closed intermontane basin. The Cedar Mountains were uplifted at this time, but not to their present height.

No faults were found that cut only part of the units in the Esmeralda Formation; therefore, tectonic stability must have prevailed during the rest of Miocene time.

The main block faulting in the area occurred during late Miocene and early Pliocene, and uplifted the Cedar Mountains to their present height. This faulting appears to be of a different type than the earlier faulting. Four points suggest that Stewart Valley forms the downdropped portion and the Gabbs Valley Range the upthrown portion of a single tilted fault block: 1) Most of the faults are on the eastern side of the valley or associated with the volcanics in the middle and northern end of the valley. Very few late Miocene faults, if any, are associated with the Gabbs Valley Range. 2) Most of the faults are downdropped on the side away from the Cedar Mountains. 3) According to the gravity maps of Healey and others (1980, 1981) the gravity gradients are steeper along the western edge of the Cedar Mountains than along the eastern edge of the Gabbs Valley Range (figure 4). 4) In general the Tertiary sediments dip eastward. The Cedar Mountains then are part of a separate block that has been uplifted relative to Stewart Valley. This interpretation fits well with Stewart's (1978) model of regional tilt patterns and specifically with his map showing an eastward tilt for blocks in this area.

This late Miocene faulting explains the folds in the valley: 1) The relatively large folds north and southwest of the Cedar Mountains resulted from drag as the mountains were uplifted. The volcanics at the northwest extension of the Cedar Mountains (19 x 73) apparently experienced a very marked relative uplift as indicated by the structural dome there and by dip angles of up to 60° N in unit 3; 2) Folds formed as a result of drag along many of the faults; however, anticlines that formed on the downdropped side of faults cannot be the result of drag and must have formed under tension. 3) The folds in the shale of unit 4 sub-parallel the Cedar Mountains. This shale veneer was probably easily deformed as it slid over the more competent layers beneath during tectonic movements.

Faulting has occurred intermittently until the present as suggested by the Cedar Mountain earthquake of 1932 (Gianella and Callaghan, 1934a,1934b).

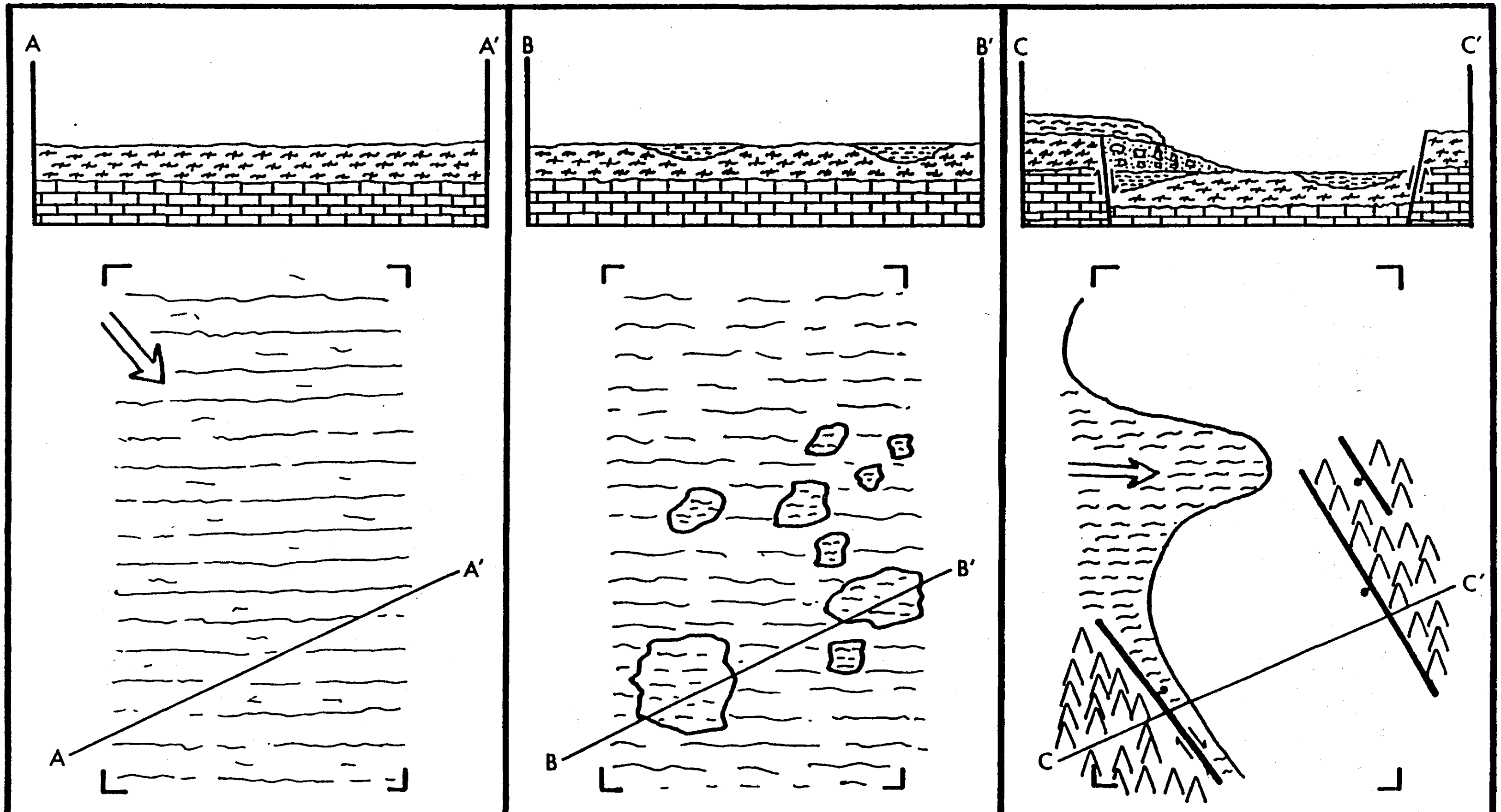
History

During the early Tertiary the Luning Formation in western Nevada had only a moderate relief as part of an eroding highland. The Oligocene pre-Esmeralda volcanics were extruded on this highland from the northwest (figure 23-A).

After a hiatus during the early Miocene, volcanism began again. Local ponds developed in the valley (figure 23-B) and were buried by volcanic breccias and lavas from Mt. Ferguson (figure 23-C). The volcanism was accompanied by wide spread faulting. This horst/graben faulting formed Stewart Valley as an isolated basin, but with the Cedar Mountains having much less relief than at present.

The volcanics blocked northerly drainage of the faulted valley and a basin formed with external drainage south (figure 23-D). During the tectonically quiet Miocene time, sediments were deposited in a lake that fluctuated in size and depth. At times this lake extended south toward the dry lake and northeast toward Ione Valley.

At the end of the Miocene, tilted block faulting on the east side of the valley raised the Cedar Mountains to their present height. The Gabbs Valley Range and Stewart Valley formed the other tilted block

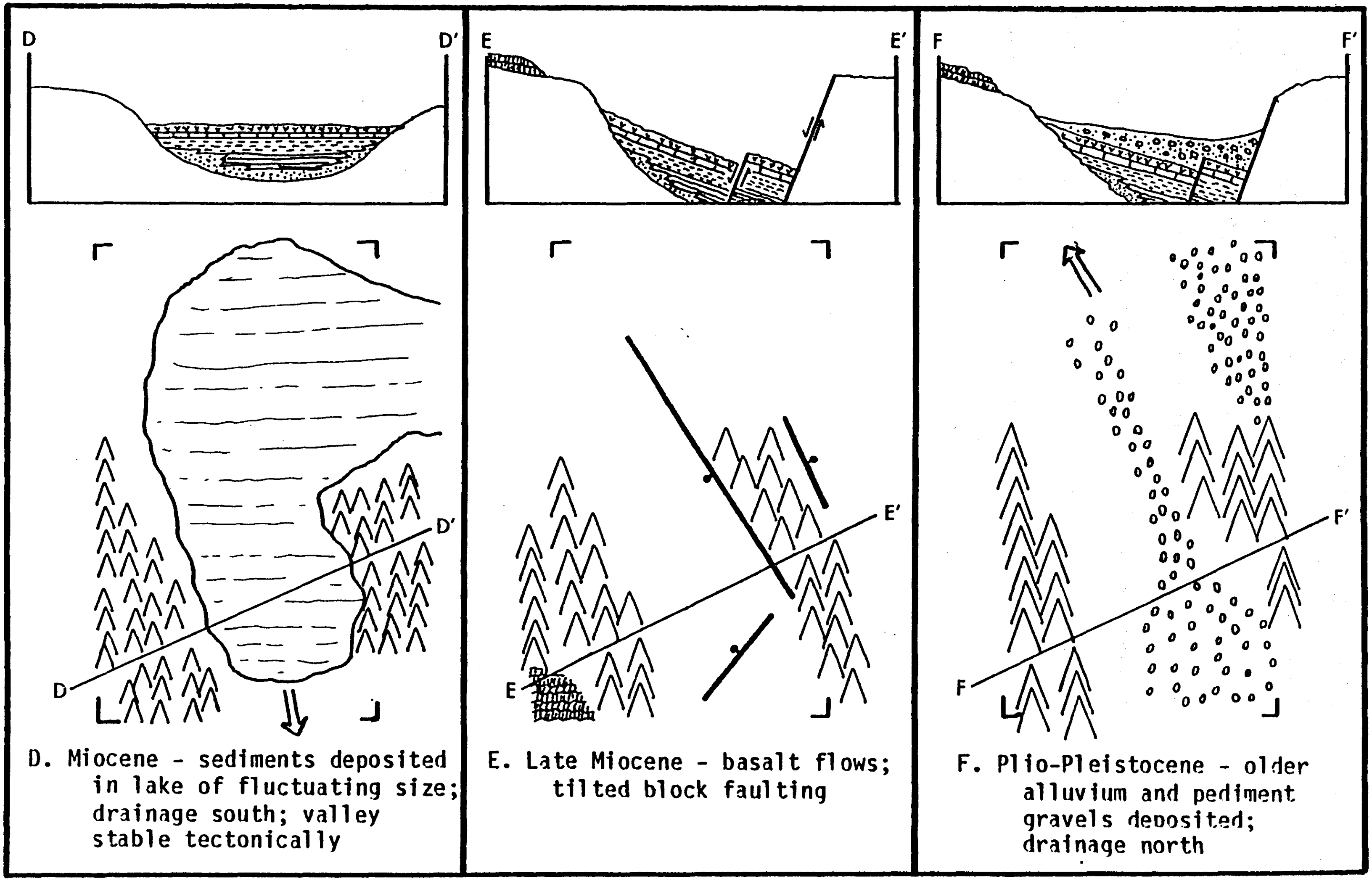


A. Oligocene - pre-Esmeralda volcanic flows from northwest

B. Early Miocene - Unit 1 deposited in isolated ponds

C. Early Miocene - volcanics from Mt. Ferguson; horst/graben faulting and right-lateral faulting

Figure 23. Paleogeographic maps and cross-sections showing Cenozoic geologic history of Stewart Valley. Same lithologic symbols used as on figure 3.



D. Miocene - sediments deposited in lake of fluctuating size; drainage south; valley stable tectonically

E. Late Miocene - basalt flows; tilted block faulting

F. Plio-Pleistocene - older alluvium and pediment gravels deposited; drainage north

Figure 23 continued. Paleogeographic maps.

(figure 23-E). The present topography of the valley was established by Pliocene time. Also at about this time basalts flowed over the Gabbs Valley Range in the southwest.

The drainage shifted north towards Gabbs Valley after the late Miocene faulting. Older alluvium and fanglomerates were deposited above an angular unconformity (figure 23-F) resulting from this faulting. Late Pleistocene and Recent erosion dissected the fans and older alluvium to their present configuration.

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