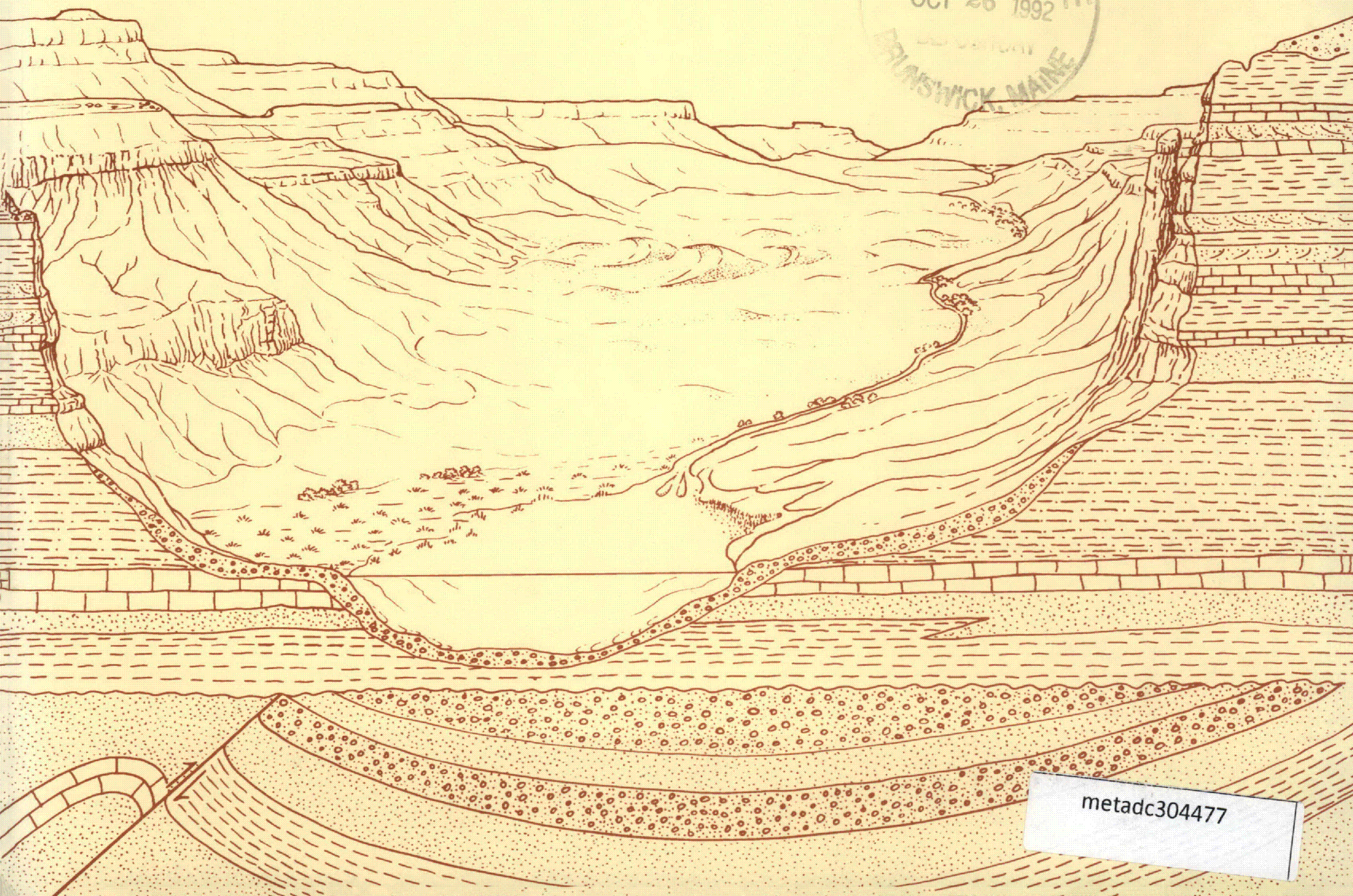
Stratigraphy and Structure of the Seaman Range and Fox Mountain, Lincoln and Nye Counties, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1988–B



Chapter B

Stratigraphy and Structure of the Seaman Range and Fox Mountain, Lincoln and Nye Counties, Nevada

By DONLON O. HURTUBISE and EDWARD A. DU BRAY

A multidisciplinary approach to research studies of sedimentary rocks and their constituents and the evolution of sedimentary basins, both ancient and modern

U.S. GEOLOGICAL SURVEY BULLETIN 1988

EVOLUTION OF SEDIMENTARY BASINS—EASTERN GREAT BASIN

HARRY E. COOK AND CHRISTOPHER J. POTTER, Project Coordinators

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1992

For sale by
Book and Open-File Report Sales
U.S. Geological Survey
Federal Center, Box 25286
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Hurtubise, D.O.
Stratigraphy and structure of the Seaman Range and Fox Mountain, Lincoln and Nye Counties, Nevada / by Donlon O. Hurtubise and Edward A. du Bray.
p. cm.—(Evolution of sedimentary basins—Eastern Great Basin ; ch. B)
(U.S. Geological Survey bulletin ; 1988-B)
Includes bibliographical references.
Supt. of Docs. no.: I 19.3:1988B
1. Geology, Stratigraphic—Paleozoic. 2. Geology, Stratigraphic—Cenozoic. 3. Geology—Nevada—Seaman Range. 4. Geology—Nevada—Fox Mountain (Nye County). I. du Bray, E.A. II. Title. III. Series. IV. Series: U.S. Geological Survey bulletin ; 1988-B.
QE75.B9 no. 1988-B
[QE654]
557.3 s—dc20
[551.7'2'0979314] 91-19195
CIP

CONTENTS

Abstract B1
Introduction B1
Acknowledgments B1
Geologic setting B2
Paleozoic stratigraphy B2
- Ordovician B2
  - Pogonip Group B2
  - Eureka Quartzite B2
  - Ely Springs Dolomite B5
- Silurian Laketown Dolomite B5
- Devonian B8
  - Sevy Dolomite B8
  - Simonson Dolomite B9
  - Guilmette Formation B9
  - West Range Limestone B10
- Devonian and Mississippian Pilot Shale B11
- Mississippian B11
  - Joana Limestone B11
  - Chainman Shale B12
  - Scotty Wash Quartzite B12
- Pennsylvanian Ely Limestone B12

Cenozoic stratigraphy B12
- Prevolcanic units B13
  - Conglomerate B13
  - Sheep Pass Formation B13
- Stratigraphy and distribution of Cenozoic igneous rocks B16
  - Needles Range Group B16
  - Petroglyph Cliff Ignimbrite B16
  - Monotony Tuff B16
  - Correlation of Oligocene dacite tuffs in the Seaman Range B17
  - Seaman volcanic center B17
  - Rhyolite tuffs of the Seaman Range B17
  - Dacite B18
  - Hornblende andesite B18
  - Leach Canyon Formation B18
  - Condor Canyon Formation B19
  - Pahranagat Lakes Tuff B19
  - Harmony Hills Tuff B19
  - Hiko Tuff B19
  - Rhyolite lava B19
  - Andesite B19
- Quaternary units B20
- Chemistry of lava flows B20

Structure of the Seaman Range B20
- Northern Seaman Range B22
- Central Seaman Range B23

Southern Seaman Range B23
Fox Mountain B23
Lineaments B24
Range-bounding faults B24
North Pahroc fault (new) B24
Pahroc fault B24
Seaman Pass fault B25
Timber Mountain fault (new) B26
Local faults B26
County Line fault (new) B26
Key Hill fault (new) B26
Prospect fault (new) B26
Structural history B26
Prevolcanic phase B27
Synvolcanic phase B28
Postvolcanic phase B28
References cited B28

PLATE

[Plate is in pocket]

1. Stratigraphic correlation chart for measured sections in the Seaman Range and Fox Mountain area, Lincoln and Nye Counties, Nevada.

FIGURES

1. Index map of eastern Great Basin showing principal structural features and localities of well-documented measured Paleozoic stratigraphic sections B3
2. Map showing major faults, fault blocks, and line of section in the Seaman Range–Fox Mountain area B4
3. Composite Paleozoic stratigraphic column for the Seaman Range and Fox Mountain, Nevada B5
4. Total alkali-silica variation diagram for lava flows of the Seaman Range, Nevada B20
5. Ternary AFM diagram for lava flows of the Seaman Range, Nevada B22
6. Ternary Ba-Rb-Sr diagram for lava flows of the Seaman Range, Nevada B22
7. Ternary Zr-Sr-Rb diagram for lava flows of the Seaman Range, Nevada B22
8. Map showing major lineaments, volcanic centers, and aeromagnetic anomalies in part of the Great Basin region B25
9. Cross sections showing structural history of the central Seaman Range B27

TABLES

1. Summary of thicknesses and stratigraphic nomenclature for Paleozoic rocks in the Seaman and nearby ranges B6
2. Stratigraphy, age, and thickness of volcanic units in the Seaman Range, Nevada B13
3. Summary of petrographic characteristics of Tertiary volcanic rocks in the Seaman Range, Nevada B14
4. Major oxide analyses and CIPW norms for lava flows in the Seaman Range, Nevada B21
5. Trace element data for lava flows in the Seaman Range, Nevada B21

Stratigraphy and Structure of the Seaman Range and Fox Mountain, Lincoln and Nye Counties, Nevada

By Donlon O. Hurtubise[1] and Edward A. du Bray

Abstract

The north-trending Seaman Range in southeastern Nevada is about 60 kilometers (37 miles) long and 10 to 18 kilometers (6 to 11 miles) wide. Tertiary igneous rocks (principally extrusive) compose 60 percent of the exposed rocks, and Paleozoic sedimentary rocks (principally carbonate rocks) account for the remaining 40 percent of the exposed rocks. The Tertiary section is divided into 21 mappable units, 11 of which are areally extensive ash-flow tuffs that are widely correlated across the middle Tertiary Great Basin volcanic field. A small stratovolcanic center is located in the southwestern part of the range. Paleozoic rocks consist of the upper part of the Ordovician Pogonip Group through the lowermost part of the Pennsylvanian Ely Limestone.

The Seaman Range consists of three main structural blocks (northern, central, and southern) that are bounded by major normal faults and adjacent valley fill. We recognize both prevolcanic and postvolcanic normal faults but have observed no thrust faults or related folds. We initially noted prevolcanic faulting in the Seaman Range and vicinity as we compiled paleo-outcrops on the middle Oligocene unconformity.

INTRODUCTION

The Seaman Range is located in southeastern Nevada 180 km (112 mi) north of Las Vegas, midway between the Antler and Sevier orogenic belts (fig. 1). The range is bounded by the dry bed of White River Valley to the north and east and Coal Valley to the west (fig. 2). To the southwest, the Seaman Range merges with the east-trending Timpahute Range–Irish Mountain massif. The northern limit of the map area (lat 32°15′ N.) was chosen to include Fox Mountain because stratigraphic relations exposed there are critical to understanding relations elsewhere in the Seaman Range. The southern limit of our map area was arbitrarily chosen to coincide with the dirt road that passes west of Fossil Peak. South and east of White River Narrows, the Seaman Range merges with the northern Pahroc Range.

Previous geologic mapping of the Seaman Range is limited to the Lincoln (Tschanz and Pampeyan, 1970) and northern Nye (Kleinhampl and Ziony, 1985) County geologic maps. This report is a companion to the geologic map of the Seaman Range by du Bray and Hurtubise (in press). Du Bray mapped the Cenozoic volcanic and related intrusive rocks, and postvolcanic surficial units. Hurtubise (1990) mapped the Paleozoic and prevolcanic Cenozoic units, and measured 6,963 m (22,845 ft) of the Paleozoic section. Hurtubise wrote all sections of this report except those concerning the stratigraphy and distribution of the igneous rocks and Quaternary deposits and the section on the chemistry of the lava flows, which were written by du Bray. Mapping was conducted from 1984 through 1989.

ACKNOWLEDGMENTS

The work reported on here is an outgrowth of the mineral resource assessment of the U.S. Bureau of Land Management Weepah Spring wilderness study area. The authors are particularly indebted to F.G. Poole and D.A. Sawyer, whose incisive reviews helped sharpen and clarify this report and the companion geologic map (du Bray and Hurtubise, in press). In addition we have benefitted from discussions with Poole, Sawyer, C.A. Sandberg, P.D. Rowley, M.G. Best, and W.J. Taylor concerning the geology of southern Nevada. T. Hutter of T. H. Geological Services identified palynomorphs from the Sheep Pass? lime mudstone.

Manuscript approved for publication March 21, 1991.

[1]Colorado School of Mines, Department of Geology and Geological Engineering, Golden, CO 80401; present address: Mobil Exploration, 4045 Northwest 64th St., Suite 200, Oklahoma City, OK 73116.

GEOLOGIC SETTING

Eastern Nevada lies in the Great Basin part of the Basin and Range province. The area was characterized by persistent deposition from the late Precambrian through the Early Triassic (Stewart, 1980). Uppermost Precambrian and Lower Cambrian strata are dominantly shallow marine siliciclastic rocks, and Middle Cambrian through lower Upper Devonian strata are dominantly shallow marine carbonate-shelf rocks.

During Late Devonian time, central Nevada was disrupted by the onset of the Antler orogeny. Continued orogenesis during the Mississippian Period resulted in the development of a foreland basin in eastern Nevada that was filled with clastic sediments (Poole and Sandberg, 1977; Poole and Claypool, 1984). From the Pennsylvanian through the Permian, eastern Nevada was again characterized by shallow-marine carbonate-shelf deposition.

Mesozoic rocks are generally absent in eastern Nevada except for outcrops in the extreme southeastern part of the State (Tschanz and Pampeyan, 1970; Longwell and others, 1965), and in two synclinoriums north of the map area in White Pine and Elko Counties (Collinson and Hasenmueller, 1978) (fig. 1). During the Mesozoic Era, the Sevier orogeny produced several compressional structures that trend northward from the main orogenic belt into northwestern Lincoln County (Armstrong, 1968). These structures are present west and southwest of the Seaman Range (figs. 1 and 2).

During the Cenozoic Era, southeastern Nevada was the site of widespread voluminous igneous activity, and extension. In the Oligocene and Miocene, much of the area was covered by lavas and ash-flow tuffs that reached cumulative thicknesses greater than 915 m (3,000 ft) (Cook, 1965). In the past 10 m.y., basin and range normal faulting has overprinted earlier compressional and extensional structures resulting in the present-day basin and range physiography (Zoback and others, 1981).

PALEOZOIC STRATIGRAPHY

Paleozoic stratigraphy in southeastern Nevada was studied by Westgate and Knopf (1932) in the Pioche mining district, Tschanz (1960) in northern Lincoln County, Reso (1963) in the Pahranagat Range, and Kellogg (1963) in the southern Egan Range. From our mapping of stratigraphy in the Seaman Range, Paleozoic exposures consist of the Middle Ordovician part of the Pogonip Group through the Pennsylvanian Ely Limestone (fig. 3).

The Seaman Range lies midway between the Egan and Pahranagat Ranges (fig. 1); comparisons with similar stratigraphic sections in those ranges are presented herein. Tabular material is used to summarize unit thicknesses and for comparison with other published data. Plate 1 shows a correlation of stratigraphic relations in sections throughout the Seaman Range.

Ordovician

Exposures of Ordovician rocks in the range are limited to those at Fossil Peak (fig. 2), where 753.5 m (2,472 ft) of the Ordovician section, consisting of 418.8 m (1,374 ft) of the Pogonip Group, 184.1 m (604 ft) of the Eureka Quartzite, and 150.6 m (494 ft) of the Ely Springs Dolomite (fig. 3), is present.

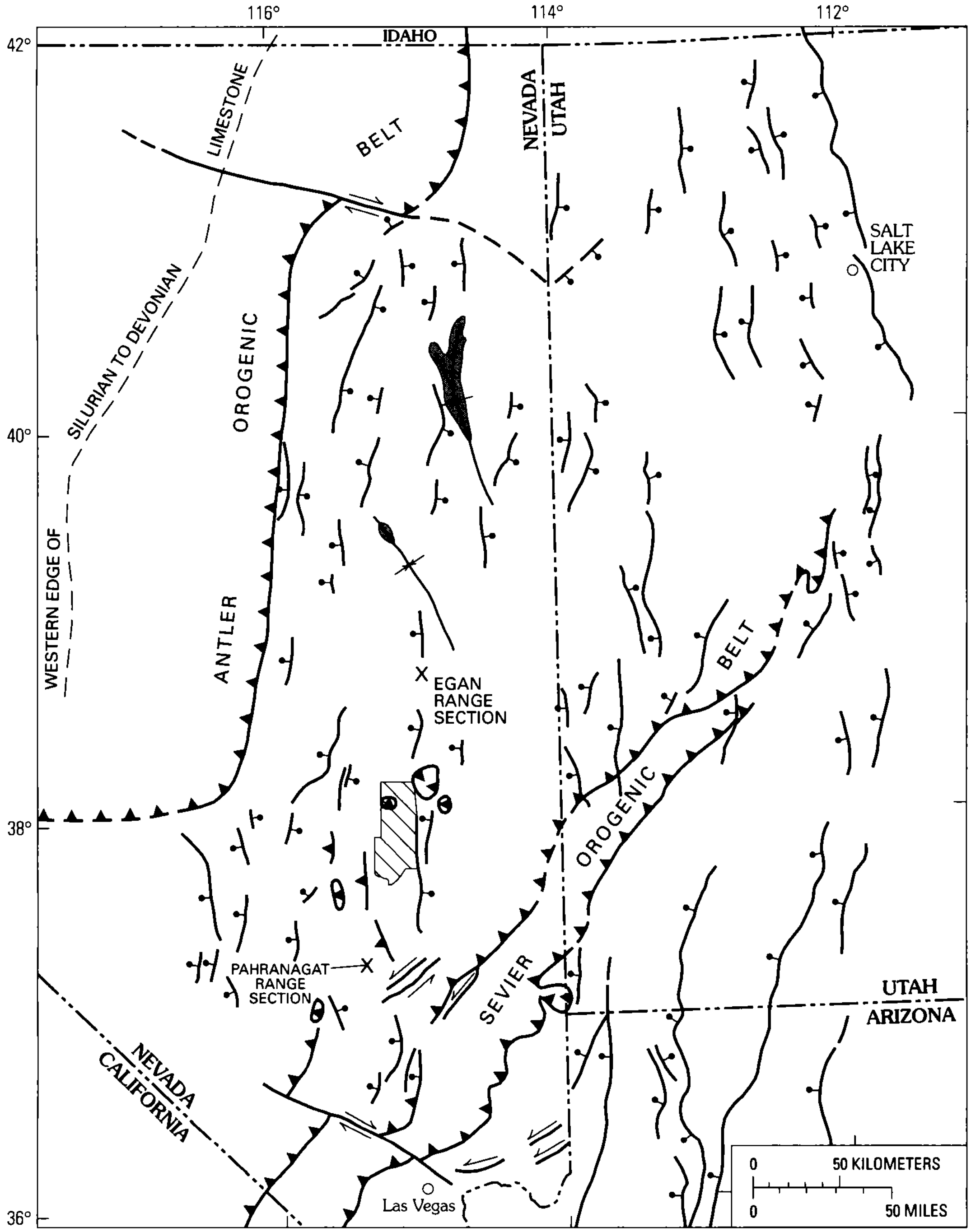
Pogonip Group

In the southern Egan Range, Kellogg (1963) divided the Pogonip Group into five formal formations. In the Pahranagat Range, Reso (1963) divided it into three informal formations. Our Fossil Peak section corresponds more closely to the lithologies described by Kellogg and is lithologically similar to his upper three formations, the Shingle Limestone, Kanosh Shale, and Lehman Formation, and to the upper two formations of Reso, the middle limestone formation and upper limestone formation (table 1). The lower 64 m (210 ft) of the Pogonip Group at Fossil Peak is a partial section of the Shingle Limestone, the middle 128 m (420 ft) is the Kanosh Shale, and the uppermost 226.8 m (744 ft) is the Lehman Formation (fig. 3). The basal 9.1 m (30 ft) of the Kanosh Shale is recognized by an abundance of *Receptaculites* sp. Because exposures of these units are limited to a very small area on the southeast side of Fossil Peak, we did not differentiate the three formations but mapped them as undivided Pogonip Group.

Eureka Quartzite

The Eureka Quartzite forms a prominent white band across the eastern base of Fossil Peak. The formation rests conformably on (the Lehman Formation of) the undivided Pogonip Group. The lower contact is placed between a 5.5-m (18-ft)-thick, argillaceous, crossbedded sandstone that weathers reddish brown, and an underlying 13.4-m (44-ft)-thick olive-gray, limy dolomite. The formation is 184.1 m (604 ft) thick and consists of five informal units, units A to E (ascending) (table 1). The lower four units

Figure 1 (facing page). Index map of eastern Great Basin showing principal structural features and localities of well-documented measured Paleozoic stratigraphic sections to which the stratigraphy of the Seaman Range is compared. Thrust faults from Armstrong (1968) and Stewart (1980); normal faults from Stewart (1978); Triassic and Jurassic rock outcrop areas from Armstrong (1968).



EXPLANATION

Triassic and Jurassic sedimentary rocks

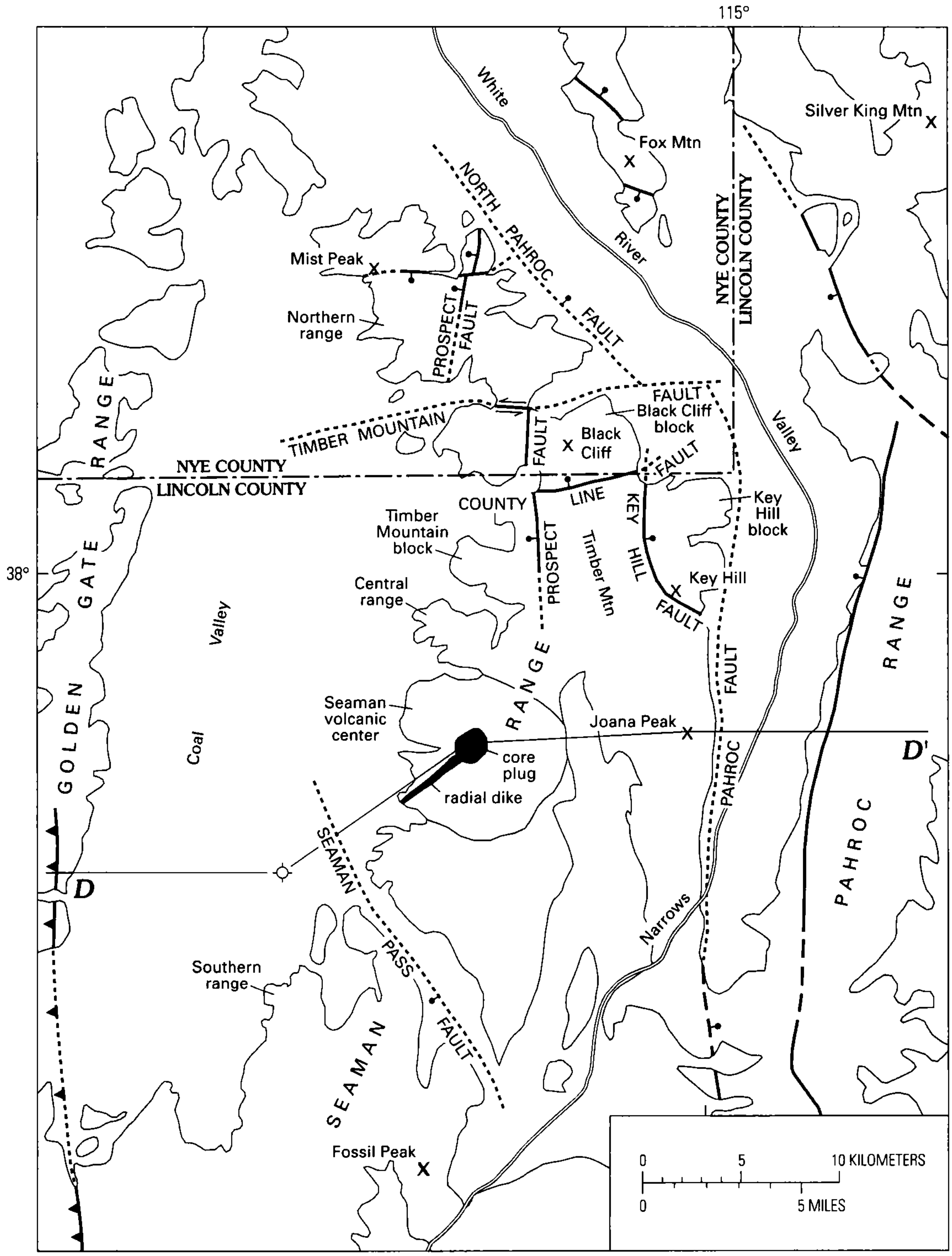
Normal fault—Dashed where inferred or concealed; bar and ball on downthrown side

Thrust fault—Dashed where inferred or approximately located; sawteeth on overthrust block

Strike-slip fault—Dashed where inferred; barbs show relative movement

Syncline

Area described in this report—Geologic map of the Seaman Range (du Bray and Hurtubise, in press)



EXPLANATION

- **Normal fault**—Dashed where inferred, dotted where concealed; bar and ball on downthrown side
- **Thrust fault**—Dotted where concealed; sawteeth on overthrust block
- **Strike-slip fault**—Dotted where concealed; barbs show relative movement
- *D* — *D'* **Line of section (fig. 9)**
- **Gulf exploration well; Gose "EU" #1 Federal**
- **Paved road**

Figure 2. Major faults and fault blocks in the Seaman Range and at Fox Mountain. Profile for line of section *D–D'* is figure 9.

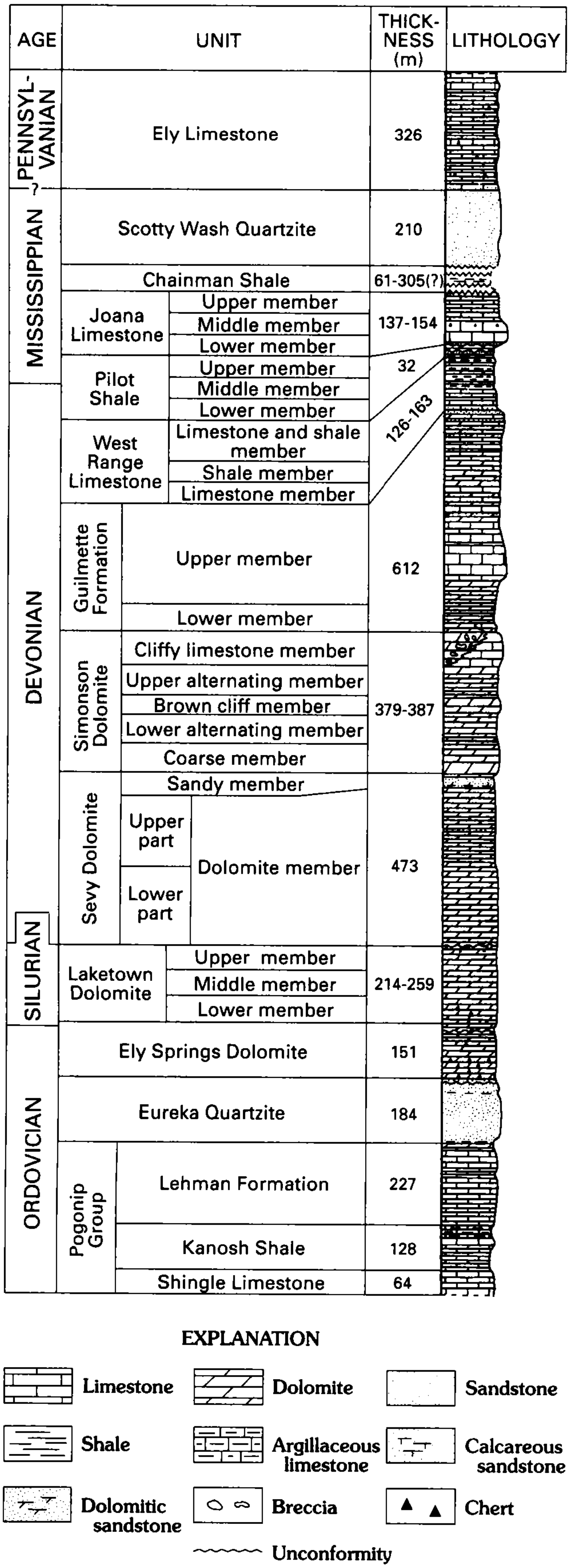


Figure 3 (facing column). Composite Paleozoic stratigraphic column for the Seaman Range and Fox Mountain, Nev. Irregular lines above and below Chainman Shale indicate that neither its top nor its bottom is exposed in the Seaman Range.

correspond to the four informal members of the Eureka recognized by Kellogg (1963). The uppermost (fifth) unit in the Eureka of the Seaman Range is a 12.2-m (40-ft)-thick, recessive dolomitic quartz arenite that weathers medium brown.

Ely Springs Dolomite

On the east side of Fossil Peak, the Ely Springs Dolomite is 150.6 m (494 ft) thick, and it forms a prominent dark-brown to gray band directly above the distinct white band of the Eureka Quartzite. The lower contact is placed between a 2.4-m (8-ft)-thick quartz-rich "sandy" recessive dolomite that weathers medium gray and the underlying, uppermost 12.2-m (40-ft)-thick dolomitic quartz arenite unit of the Eureka Quartzite.

At Fossil Peak three informal lithic units are recognized in the Ely Springs: a 2.4-m (8-ft)-thick basal sandy dolomite, a 95.1-m (312-ft)-thick main dolomite, and a 53-m (174-ft)-thick upper dolomite (table 1). In the Egan Range, Kellogg (1963) called a stratigraphically equivalent, 8.8-m (30-ft)-thick argillaceous dolomite the Fish Haven Dolomite. Poole and others (1977) suggested that the top of the Fish Haven Dolomite in the Egan Range as designated by Kellogg (1963) and P.M. Sheehan, D.R. Budge, and F.G. Poole (unpub. data) is not correlative with the unit's top, as regionally defined, though its stratigraphic position is approximately correct. Poole and others (1977) suggested that the uppermost Ely Springs Dolomite is Silurian in age. In the Pahranagat Range, Reso (1963) recognized informal lower, middle, and upper members in the Ely Springs. The lithology of units recognized in the Fossil Peak section (pl. 1) does not correspond well with the lithology of units in the Pahranagat or Egan Ranges, though Reso's (1963) 45.7-m (150-ft)-thick upper member in the Pahranagat Range and the 53-m (174-ft)-thick upper dolomite described here are similar. The uppermost 17.1 m (56 ft) of the upper dolomite unit at Fossil Peak is recessive, and may correspond to the 8.8-m (29-ft)-thick argillaceous dolomite unit reported by Kellogg (1963) in the Egan Range. The members of the Ely Springs are known to be regionally persistent (F.G. Poole, U.S. Geological Survey, written commun., 1990). The difficulty in identifying these units may indicate that the top of the formation in the Seaman Range is an unconformity and that some of the section is missing.

Silurian Laketown Dolomite

The Laketown Dolomite in the Seaman Range is lithologically similar to the unit as described by Nolan (1935) in the Deep Creek Range and by Tschanz and

Table 1. Summary of thicknesses and stratigraphic nomenclature for Paleozoic rocks in the Seaman and nearby ranges

[Thicknesses in meters (multiply by 3.28 for feet); section identifiers for the Seaman Range keyed to pl. 1; FP, Fossil Peak; BC, Black Cliff; JP, Joana Peak; FM, Fox Mountain; MP, Mist Peak; KH, Key Hill; +, incomplete section; dashed lines, position of stratigraphic datum between mountain ranges; blank, unit not measured]

Stratigraphic	Southern Egan Range		Pahranagat	Seaman	Seaman Range–this report														
section--	Kellogg (1963)	Langenheim (1960b)	Range Reso (1963)	Range Osmond (1954)	FP	BC	JP	SRA	SRB	SRC	SRD	SRE	SRF	SRG	FMA	FMB	MPA	MPB	KH
ELY LIMESTONE																		326+	
SCOTTY WASH QUARTZITE																	210		
JOANA LIMESTONE																			
Total thickness	204-215	298	296–310				79+				54+	66+		84+	4+				31+
		upper member 114												7+					
		-------	member C ~222																
		middle member 99					9+												
		-------	-------																
		basal member 85	member B ~79				70				54+	66+		77+	4+				31+
			member A 8–9																
PILOT SHALE/FORMATION																			
Total thickness	0		250–460				0				0	0			[1]32				
WEST RANGE LIMESTONE/FORMATION																			
Total thickness	0–154		0			15+	161				164	135			126				143+
limestone and shale member	0–35						54				40	36							20+
shale member	0–42						36				66	50							59
limestone member	0–77					15+	71				58	49							64
GUILMETTE FORMATION																			
Total thickness	[2]554–782		[2]661–835			611	169+		55+	39+	88+		221+			280+			466+
upper member	383–581		479–581			482	169+				88+		91+			122+			466+
lower member	171–201		182–254			129			55+	39+			130			158			
SIMONSON DOLOMITE																			
Total thickness			[3]286–344	259		238		369+	178+	218+			32+			207+			
cliffy limestone member			0	0		87		71+	91	101			32+			77			
upper alternating member			94–131	100		84		89	87	78						77			
brown cliff member			29–32	24		44		47		37						41			
lower alternating member			93–94	84		23+		85		2+						12+			
coarse member			70–87	51				77											
SEVY DOLOMITE																			
Total thickness	395–401		411–533	337	472	152+		133+											
sandy member	18–24		[4]13–26	14	42			31											
cherty argillaceous member	0		30–68	0	0			0											
dolomite member	377		368–439	323	430			102+											

LAKETOWN DOLOMITE			
Total thickness	315	195–312	215 258+
		upper member	upper member[5]
		27–68	37 33
	upper member	-------	-------
	169	middle member	middle member
	------	99-140	106 113
	lower member	------	------
	146	lower member	lower member
		69-104	72 112+
ELY SPRINGS DOLOMITE/FISH HAVEN DOLOMITE			
Total thickness	151–161	118–124	150
		upper member	upper member
	argillaceous	46	53
	zone	-------	-------
	9	middle member	middle member
	------	67	95
	main	-------	-------
	part	lower member	lower member
	142–152	5–11	2
EUREKA QUARTZITE			
Total thickness	139–191	111–174	184
			unit E
			12
	upper vitreous		------
	quartzite	upper member	unit D
	19–28	0–6	16
	------	------	------
	upper sandstone		unit C
	15-17	middle member	19
	------	62–115	------
	main quartzite		unit B
	97–131	------	126
	------	lower member	------
	shaly quartzite	49–53	unit A
	8–15		11
POGONIP GROUP			
Total thickness	660–720	563–663	419+
	Lehman Formation	upper limestone	Lehman Formation
	199–232	formation–member B	227
		205–241	
	Kanosh Shale	upper limestone	Kanosh Shale
	111–138	formation–member A	128
		88–107	
	Shingle Limestone	middle limestone	Shingle Limestone
	350	formation–member B	64+
		270–315	

[1]Includes: lower member, 1 m; middle member, 9 m; and upper member, 22 m.

[2]Includes part of unnamed unit below the yellow slope-former.

[3]Does not include Reso's (1963) member A of Simonson Dolomite.

[4]Sandy member is Reso's (1963) member A of Simonson Dolomite.

[5]Lower, middle, and upper members correspond to Budge and Sheehan's (1980a, b) Tony Grove Lake, High Lake, and Portage Canyon Members (of Laketown Dolostone), respectively, and to Poole and others' (1977) units A, B, and C (of dolomite of Spotted Range) in the Spotted Range–Ranger Mountains area of southern Nevada.

Pampeyan (1970) in Lincoln County. Nolan (1935) recognized three lithic units in the formation in the Deep Creek Range. The basal unit, which represents the lower half of the formation, is dark-gray, coarse-grained, mottled and laminated dolomite with several intraformational breccias; pentameroid brachiopods are common in the lower part about 30.5 m (100 ft) above the base. The middle unit is medium-gray, coarse-grained massive dolomite. The upper unit is dark-gray to black dolomite with thin local chert stringers and abundant fossil corals.

In the Seaman Range, a complete 214.3-m (703-ft)-thick Laketown section is present at Fossil Peak (pl. 1), and pentameroid brachiopods were found in float blocks near the base of the section. A partial 258.8-m (849-ft)-thick section was measured at Black Cliff on the southeast side of Timber Mountain Pass (table 1). The base of the Laketown in the Black Cliff section, where it is close to the Timber Mountain fault, is brecciated and silicified. Therefore, the thickness at Black Cliff may not be totally representative, particularly of its lower unit.

The contact between the Laketown and the Ely Springs Dolomite in the Fossil Peak section is placed between a 17.1-m (56-ft)-thick recessive olive-gray, very fine grained dolomite and an overlying 6.1-m (20-ft)-thick cherty dark-brown dolomite. This corresponds to the paraconformable contact described by Reso (1963, p. 907) for these same units in the Pahranagat Range. In both the Black Cliff and Fossil Peak sections, the Laketown is divided into three members (pl. 1) that roughly correspond to the descriptions of the formation as noted by Nolan (1935), Tschanz and Pampeyan (1970), and Poole and others (1977) from other areas: a basal dark-colored dolomite (=lower member), a middle light-colored dolomite (=middle member), and an upper dark-colored dolomite (=upper member) (table 1).

In the Egan Range, Kellogg (1963) divided the Laketown Dolomite into two members: a 145.7-m (478-ft)-thick lower member, and a 169.5-m (556-ft)-thick upper member. In the Pahranagat Range, Reso (1963) divided it into three members: a 69.5–103.9-m (228–341-ft)-thick lower member, a 98.8–140.2-m (324–460-ft)-thick middle member, and a 27.1–67.7-m (89–222-ft)-thick upper member (table 1). The section at Fossil Peak is notably thinner than that in the Egan Range (table 1), which confirms the southward thinning of the Laketown noted by Tschanz and Pampeyan (1970).

Devonian

Devonian formations recognized in the Seaman Range consist of the Sevy Dolomite, Simonson Dolomite, Guilmette Formation, and West Range Limestone. These formations are the most areally extensive Paleozoic exposures in the range.

Sevy Dolomite

The Sevy Dolomite in the Seaman Range is composed of light-gray dolomite as defined in the Deep Creek Mountains of northwest Utah (Nolan, 1935) and has been extended throughout eastern Nevada (Osmond, 1954; 1962). Southeast of Timber Mountain Pass in the Seaman Range, Osmond (1962) reported a complete 336.8-m (1,105-ft)-thick section of the Sevy, with an upper, 14.0-m (46-ft)-thick sandy member. The location listed, sec. 36, T. 1 N., R. 61 E. (Osmond, 1962, table 1, p. 2041) appears to be incorrect; no Sevy is present there. A thick exposure of the Sevy is present in sec. 36, T. 3 N., R. 61 E., but its base is not exposed. Poole and others (1977) indicated that Osmond's sandy member is intimately related to the coarsely crystalline member of the overlying Simonson Dolomite and should be mapped as part of that member. In the Seaman Range, however, we have included strata inferred to be equivalent to the sandy member within the Sevy Dolomite in accordance with the majority of geologic mapping that has been conducted in this region (Kleinhampl and Ziony, 1985, p. 68).

A complete 472.7-m (1,551-ft)-thick section of the Sevy Dolomite is present at Fossil Peak. The lower 224.0 m (735 ft) of this section is a massive nonfossiliferous medium-gray dolomite (=dolomite member, lower part) that is lithologically atypical of the Sevy. Alternatively, the strata of this interval may be considered as equivalent to the Silurian Decathon Dolomite of Rush (1956) and (or) the unnamed dolomite called the "transition unit" by F.G. Poole (unpub. data) and Poole and others (1990) and units D and E of the dolomite of Spotted Range (Poole and others, 1977). The upper 203.3 m (667 ft) is a more recessive, generally lighter colored and finer grained (aphanitic) dolomite (=dolomite member, upper part) that contains some local quartz-rich beds and which is overlain by the sandy member (=sandy member of Osmond, 1962) (table 1). The base of the formation is placed at the top of the dark-brown dolomite of the upper member of the Laketown Dolomite. The upper dark-brown dolomite of the Laketown varies in thickness laterally at Fossil Peak, and its uppermost part is locally incised and "filled in" by the Sevy Dolomite, indicating a disconformable contact between these units. Nolan (1935), Kellogg (1963), and Reso (1963) also reported an unconformity at the Sevy-Laketown contact.

The upper contact of the Sevy is placed at the top of the highest fine grained, light-gray dolomite bed in a 6.4-m (21-ft)-thick recessive interval of interbedded fine- and medium-grained quartz-rich dolomite that may be equivalent to the cherty argillaceous member of Osmond (1962). Underlying the uppermost 6.4-m-thick interval is a 36.0-m (118-ft)-thick unit of crossbedded, fine-grained quartz sandstone that weathers gray to light brown. Combined, we correlate these lithic units with the sandy member of Osmond (1954) (table 1).

Kellogg (1963) reported 394.1–403.3 m (1,293–1,323 ft) of the Sevy in the southern Egan Range and recognized a main dolomite part and an upper 18.3–24.4-m (60–80-ft)-thick sandy dolomite zone in the formation. Reso (1963) reported 408.7–481.0 m (1,341–1,578 ft) of the Sevy in the Pahranagat Range. He recognized two members, a 457.2-m (1,500-ft)-thick lower member, and a 30.5–67.7-m (100–222-ft)-thick, recessive argillaceous upper member (=cherty argillaceous member of Osmond, 1962); the Sevy as mapped in the Pahranagat Range includes the dolomite "transition unit." Reso (1963) placed the sandy member within the basal part of the Simonson Dolomite, as his member A (table 1).

In the Seaman Range, the top of the highest light gray, fine-grained dolomite above the sandstone unit was found to be a better and more accurate contact for mapping than the base of the sandstone. The argillaceous upper member of Reso (1963), which is equivalent to the cherty argillaceous member of Osmond (1954, 1962), is not present in the Seaman Range. Therefore, lithologically the 430.4-m (1,412-ft)-thick section below the sandy member at Fossil Peak is equivalent to the 457.2-m (1,500-ft)-thick lower member of Reso (1963) and the dolomite member of Osmond (table 1).

Simonson Dolomite

Osmond (1954) reported a total thickness of 258.8 m (849 ft) for the Simonson Dolomite in the northern Seaman Range. Measured sections of the equivalent interval in this study indicate an average thickness of 292 m (958 ft) (table 1). Osmond did not report an exact location for his section, but according to his index map (Osmond, 1954, fig. 1, p. 1912), it is located southeast of Timber Mountain Pass. However, several reverse faults cut out all or part of the Simonson in that area, which indicates that his measured section is probably incomplete.

Osmond (1954) established four informal members of the Simonson Dolomite that consist of (ascending) the coarse, lower alternating, brown cliff, and upper alternating members. All four members of the Simonson are easily recognized in the Seaman Range (table 1). The lower contact of the Simonson Dolomite is placed at the base of the coarse member, a nearly homogeneous and approximately 61-m (200-ft)-thick coarsely crystalline dolomite that directly overlies the light-gray and locally sandy (quartz) dolomite of the uppermost part of the Sevy of this report.

On the northeast slopes of Fox Mountain, we discovered a previously unrecognized Devonian limestone unit that crops out stratigraphically between the upper alternating member of the Simonson and the yellow slope-forming unit of the overlying Guilmette Formation. In most (though not all) parts of the Seaman Range, rocks in this interval are dolomite and are not mappable as a separate member. At Fox Mountain, this rock interval is cliff forming, massive, thick bedded, brecciated in many places, and is dominantly composed of limestone, though it includes some dolomite. This cliffy limestone is lithologically distinct from the underlying Simonson and overlying Guilmette. The unit contains brachiopods (*Stringocephalus* sp.), gastropods, stromatoporoids, and corals characteristic of the upper part of the Simonson elsewhere in eastern Nevada.

Rocks that are stratigraphically equivalent to the cliffy limestone at Fox Mountain do occur throughout the Seaman Range. A comparison of data from four measured sections (SRB, SRC, Black Cliff, and Fox Mountain, see table 1) revealed a very uniform thickness that ranges from 170.4 to 179.5 m (559 to 589 ft), averaging 174.7 m (573 ft), of rock that occurs in the interval between the base of the upper alternating member and the base of the yellow slope-forming interval. Subtracting the average thickness of the upper alternating member (87.8 m) in the Seaman Range from the average thickness of 174.7 m gives a maximum thickness of 86.9 m (285 ft) for the cliffy limestone beds below the yellow slope-forming unit.

The thickness of 86.9 m closely corresponds to the thickness of 73.2–117.0 m (240–384 ft) reported by Kellogg (1963) for the basal cliffy limestone of the Guilmette Formation in the southern Egan Range, which supports the correlation of the cliffy limestones in the two ranges. In the SRC, SRF, and Fox Mountain sections, fossiliferous limestone beds were noted directly below the yellow slope-forming interval; equivalent beds are dolomite elsewhere in the Seaman Range.

Where the interval between the top of the upper alternating member and the base of the yellow slope-forming unit is dominantly limestone, this interval can be readily divided into three units (A, B, and C) based on texture and fossil content. Units B and C are fossiliferous in contrast to unit A. Except for the basal part of the additional beds (unit A), most of these units do not correlate with the upper alternating member as described by Osmond (1954). At Fox Mountain, these cliffy limestone beds are recognized in this report as a separate member of the Simonson Dolomite, whereas in most of the Seaman Range, the equivalent dolomite beds are not recognized as a separate member of the Simonson.

Guilmette Formation

In the Seaman Range, the Guilmette Formation is characterized by a series of limestone and dolomite cliffs. The quantity of dolomite increases toward the Timber Mountain fault. The top of the Guilmette Formation is placed at the top of a quartz arenite that is overlain by the recessive and thinner bedded West Range Limestone. This contact is prevalent throughout southeastern Nevada, and correlates with the contact established by Westgate and

Knopf (1932) between the type West Range Limestone and the underlying Silverhorn Dolomite in the Pioche district. Reso (1963), Johnson and others (1969), and Poole and others (1977) also used the top of the highest sandstone in the Pahranagat Range to mark the contact between the Guilmette Formation and the West Range Limestone.

At the type section, Nolan (1935) placed the lower contact of the Guilmette Formation at the base of a 7.3-m (24-ft)-thick dolomite conglomerate. Osmond (1954) believed that Nolan's contact was not a conspicuous contact and suggested placing it either at a 1.22-m (4-ft)-thick brachiopod-bearing bed containing the genus *Stringocephalus* 30 m (100 ft) above the dolomite conglomerate or at the base of the first limestone. Osmond preferred the latter placement because the occurrence of the first limestone represents a more meaningful and fundamental contact for units of formational rank. Osmond (1954, p. 1946) warned, however, that the "interfacies nature [limestone and dolomite lithologies of the contact] must be kept in mind." Common practice among stratigraphers working in Nevada has been to include *Stringocephalus*-bearing carbonate beds in the Simonson (F.G. Poole, written commun., 1990).

In the southern Egan Range, Kellogg (1963) reported a 73.2–117.0-m (240–384-ft)-thick cliffy, massive limestone below a recessive yellowish-gray-weathering argillaceous interval within the basal part of the Guilmette Formation. In the Pahranagat Range, Reso (1963, p. 909) reported "about 100 ft of gray limestone with interbedded phaneritic dolomite and incompletely dolomitized limestone" at the base of the Guilmette Formation that is lithologically similar to the yellow argillaceous unit in the southern Egan Range (Kellogg, 1963). Tschanz and Pampeyan (1970, p. 36) referred to the interval throughout Lincoln County as the "so-called yellow bed," and used it to map the Simonson-Guilmette contact on their 1:250,000-scale county map. This same contact has been used by F.G. Poole (unpub. data) throughout the southern Great Basin.

The Guilmette reported by Kellogg (1963) in the southern Egan Range has a basal cliffy limestone that, as has been noted, may be correlated with the fossiliferous and cliffy limestone that directly overlies laminated dolomites of the Simonson in parts of the Seaman Range. In most of the Seaman Range this cliffy limestone has been altered to a massive and brecciated medium-grained, brownish-gray dolomite. In some areas, the brecciation is so intense that all indications of the original bedding and texture have been obliterated; in other places, the limestone-dolomite contact cuts up and down section across marker beds, with little or no brecciation. In any case, the use of a dolomite conglomerate in the type section, or the base of the first limestone (as recommended by Osmond, 1954), is an inadequate criterion for separating the Simonson and Guilmette in the Seaman Range. The most useful map contact in separating the two formations in the Seaman Range is the base of the yellow-weathering argillaceous unit referred to in our mapping as the "yellow slope-forming unit."

At many localities, the Guilmette grades laterally from limestone to dolomite displaying a host of diagenetic features, including secondary dolomite, zebra rock, and brecciation. Zebra rock is a pattern of alternating white, coarse-grained crystalline dolomite, and gray, fine- to medium-grained dolomite at or near limestone-dolomite transitions. These zebra patterns are well displayed on the northwest side of Black Cliff.

Kellogg (1963) described two informal members of the Guilmette Formation in the southern Egan Range: a lower member and an upper member (table 1). In the Seaman Range, the contact between comparable members is placed at the base of a cliffy section of thick- to massive-bedded limestones containing locally abundant stromatoporoids. Although Kellogg did not describe a specific contact between the two members, it seems likely that he used the erosional profile of the Guilmette to select it. The distinction in the Seaman Range is also based mainly on the erosional profile: the basal part of our upper member is a series of prominent cliff-forming stromatoporoidal limestones. A similar bipartite division of the Guilmette has been made throughout the southern Great Basin (F.G. Poole, written commun., 1990).

The thickness of the lower member ranges from 129.2 to 157.6 m (424 to 517 ft) (table 1). At Fox Mountain (pl. 1), where the section is dominantly limestone, the lower 13.7 m (45 ft) of the yellow slope-forming unit is characterized by a 6.1-m (20-ft)-thick ledge-forming limestone containing distinctive columnar (digitate) stromatolites. The ledge-forming interval overlies a 6.1-m (20-ft)-thick light-gray recessive dolomite.

At Black Cliff just south of Timber Mountain Pass, the upper member of the Guilmette Formation is 482.5 m (1,583 ft) thick. Throughout the range, the upper part of the member is characterized by several quartz-bearing dolomites and sandstones. The net sandstone thickness in the upper member, however, increases southward within the range from 4.9 m (16 ft) at Black Cliff to 50.0 m (164 ft) at Joana Peak.

West Range Limestone

The West Range Limestone ranges in thickness from 133.8 to 162.8 m (439 to 534 ft) in the Seaman Range, and thins to 126.5 m (415 ft) at Fox Mountain, where it is conformably overlain by the lower member of the Pilot Shale. The lower contact with the quartz arenite in the uppermost part of the Guilmette Formation is conformable. The limestone contains abundant brachiopods and gastropods, and less abundant cephalopods and crinoids. Throughout the Seaman Range the West Range is divisible into three informal members following Kellogg's (1963) usage in the southern Egan Range (ascending): limestone member, shale member, and limestone and shale member.

Where the West Range Limestone is directly overlain by the Joana Limestone, the contact is unconformable. Several measured sections across the West Range–Joana contact revealed a 3.8-cm to 2.7-m (1.5-in. to 9-ft)-thick quartz sandstone beneath a unit of thin-bedded crinoidal and brachiopod grainstone, directly below the basal part of the cliff-forming Joana. In the Key Hill section, flat pebble rip-up clasts, which indicate erosion and a possible unconformity on the underlying West Range Limestone, were found in the basal 6.4 cm (2.5 in.) of a 2.7-m (9-ft)-thick sandstone. The 2.7-m-thick sandstone may, however, correlate with and be an erosional remnant of the Pilot Shale.

Devonian and Mississippian Pilot Shale

The Pilot Shale is absent in the Seaman Range (strata heretofore mapped as the Pilot by Tschanz and Pampeyan (1970) in the Seaman Range are here reassigned to the West Range Limestone); a 32-m (105-ft)-thick section of the Pilot does occur, however, in a small fault-bounded block on the north side of Fox Mountain (FMA section, pl. 1). The formation occurs stratigraphically between the West Range and Joana Limestones (pl. 1). C.A. Sandberg examined this Pilot Shale section and identified its three informal members, several conodont zones, and the brachiopods mentioned herein.

The lower 1.22-m (4-ft)-thick member is a silty, yellow-weathering shale containing the conodont *Palmatolepis glabra*. The middle 12.6-m (41.2-ft)-thick member is an interbedded sandy argillaceous shale and oncolitic limestone unit that contains the conodont *Branmehla disparalis* and the brachiopods *Rhipidomella missouriensis* and *Spirifer* sp. The upper 23.2-m (76-ft)-thick member is composed of a basal resistant ledge of purple- and gray-weathering quartz sandstone and crinoidal grainstone that contains an Early Mississippian indigenous conodont fauna of the *Siphonodella sandbergi* Zone, and many reworked Late Devonian conodonts (C.A. Sandberg, oral commun., 1989). The upper 16.8 m (55 ft) of the upper member is a recessive pinkish-gray-weathering fine-grained limestone.

Regional biostratigraphic data suggest the occurrence of unconformities between the lower and middle, and middle and upper members of the Pilot (C.A. Sandberg, oral commun., 1989). The contact of the Pilot Shale and the Joana Limestone is covered at Fox Mountain, but is regionally unconformable (Kleinhampl and Ziony, 1985).

Mississippian

Three Mississippian formations are recognized in the Seaman Range: the Joana Limestone, Chainman Shale, and Scotty Wash Quartzite. Mississippian outcrops are much less extensive than Devonian outcrops, but represent the second most areally extensive Paleozoic rocks in the range.

Joana Limestone

The Joana Limestone is exposed throughout most of the Seaman Range. The lower contact of the Joana with the West Range Limestone is unconformable, and the upper contact with the Chainman Shale is mostly concealed. Our members of the Joana Limestone correspond to Langenheim's (1960b) basal cliff-forming, middle bench-forming, and upper cliff-forming members. These members are roughly equivalent to the unnamed Mississippian limestone unit (Ml) of Tschanz and Pampeyan (1970). The lower 52.4–66.1-m (172–217-ft)-thick cliff-forming member is a thick-bedded massive crinoidal limestone that is correlative with the type Joana Limestone near Ely, and the basal cliff-forming member of Langenheim (1960b). F.G. Poole (written commun., 1990) has divided the Joana into three regionally persistent, informal members—lower, middle, and upper members—described as basal slope-forming limestone; cliff-forming fossiliferous, locally encritic limestone; and stair-step, ledgy, sparsely fossiliferous, fine-grained limestone, respectively. Our lower and his middle member, and our middle and upper and his upper members may correlate. The thickness of the Joana in the Seaman Range is considerably less than that reported in the southern Egan and Pahranagat Ranges (table 1).

At several places in the Seaman Range, a yellowish-gray-weathering, thin-bedded crinoidal limestone unit underlies the massive limestone cliff of our lower member of the Joana. Langenheim (1960b, p. 78) mentioned a similar thin-bedded nodular limestone below his basal member and above a "local, thin, basal quartzite." Langenheim (1960a) reported that the basal quartzite ranges in thickness from 15.2 to 30.5 cm (6 to 12 in.), where present. The correlative bed, a sandstone, was found in the SRD and Key Hill sections in the Seaman Range. In the SRD section, this sandstone is 2.5–10 cm (1–4 in.) thick, but in the Key Hill section it is 2.7 m (9 ft) thick and bioturbated. The bioturbated sandstone may be part of the sandstone of the Pilot Shale.

In the Pahranagat Range, Reso (1963) placed the quartzite and a nodular limestone, probably correlative with the thin-bedded nodular limestone of Langenheim, in the basal part of the Joana and treated the unit as a separate member (member A) (table 1). Langenheim (1960a, p. 130) reported the thin-bedded nodular limestone beds in all of his measured sections in east-central Nevada. F.G. Poole (written commun., 1990) has recognized this slope-forming thin-bedded, nodular, fossiliferous limestone unit, which he refers to as the lower member of the Joana Limestone, at the base of the Joana and of lithologically equivalent rocks throughout the southern Great Basin.

The middle member is a recessive thin- to medium-bedded slope-forming limestone interbedded with thin, very fossiliferous ledges containing abundant crinoids, solitary and colonial tetracorals (*Lithostrotionella* sp.), and less abundant brachiopods and gastropods. The trace fossil *Zoophycus* is common. A maximum thickness of 83.8 m (275 ft) for the middle member was measured at the SRG section (pl. 1). In the SRG section (table 1, pl. 1), a 0.5-m (1.5-ft)-thick limestone that contains abundant solitary tetracorals in a matrix of fragmented *Syringopora* packstone marks the highest part of the massive cliff limestone of the lower member.

At Dutch John Mountain, northeast of the Seaman Range, Chilingar and Bissell (1957) reported a 91.4-m (300-ft)-thick section of the Joana Limestone underlain by the Pilot Shale. They designated the uppermost 3.05 m (10 ft) as the *Lithostrotionella* zone, 88.4 to 91.4 m (290 to 300 ft) above base. In the Seaman Range, *Lithostrotionella* sp. is found throughout the middle member and in the lower part of the upper member. F.G. Poole (written commun., 1990) reported that all three of his Joana members are well developed in the Dutch John Mountain area.

The uppermost 7.3 m (24 ft) of the Joana in the Seaman Range section SRG is a mappable ledge-forming unit of thicker bedded crinoidal and coralline (rugose) limestone that correlates with the upper member described by Langenheim (1960b) (table 1). Limited exposure, however, makes the exact correlation questionable. Regionally, Langenheim's (1960b) upper member is restricted to the Pioche area, where he reported thickness from 18.9 to 114.3 m (62 to 375 ft). The thickest section measured by Langenheim is in the Sunnyside area near the south end of the Egan Range (table 1).

Chainman Shale

Exposures of the Chainman Shale are limited to an area on the west side of the Seaman Range in the hanging wall of the Prospect fault between the Timber Mountain fault and the Seaman volcanic center. No complete section was found; only partial sections were seen in small outcrops and cuttings from mineral exploration holes. Neither the lower contact with the Joana Limestone nor the upper contact with the Scotty Wash Quartzite was observed along a single unfaulted traverse. As a result, no accurate estimate of the thickness is possible, but regional trends reported by Tschanz and Pampeyan (1970) indicate that the section could range from 60 to 300 m (200 to 1,000 ft) thick.

Scotty Wash Quartzite

Outcrops of the Scotty Wash Quartzite are present on the west side of the Seaman Range both north and south of the Timber Mountain fault, but do not occur south of the County Line fault. The lower contact with the Chainman Shale is exposed at one location on the west side of the range just north of the County Line fault. The upper contact with the Pennsylvanian Ely Limestone is continuous and mappable in several places, but the exact nature of the contact is uncertain because it forms a recessive profile always covered by talus.

Outcrops commonly form light- to dark-brown low hills, characterized in many places by case-hardened quartzite that is easily mistaken at a distance for Tertiary volcanic rocks. A 210.3-m (690-ft)-thick section is present 2.4 km (1.5 mi) due east of Mist Peak (MPA section, pl. 1).

Pennsylvanian Ely Limestone

In the Seaman Range north of the Timber Mountain fault, the Ely Limestone crops out as low rounded hills. Also, areally limited and much thinner sections are present on the west side of the Seaman Range between the Timber Mountain and County Line faults. The Ely Limestone is also exposed at Fox Mountain. The formation is typically medium gray, cherty (0–30 percent) limestone with several very fossiliferous ledges that contain abundant crinoids and brachiopods, less abundant solitary tetracorals and colonial corals (*Syringopora* sp.), and rare gastropods.

An incomplete 326-m (1,070-ft)-thick section of the Ely Limestone was measured in the MPB section south of Mist Peak, where the Ely is thickest and most continuous. The basal part of the Ely Limestone in the MPB section contains a sandstone unit, which indicates that its basal contact with the Scotty Wash Quartzite is transitional. Tschanz and Pampeyan (1970) estimated that the combined thickness of Pennsylvanian and Permian strata in Lincoln County totalled 1,067 to 1,524 m (3,500 to 5,000 ft) before post-Paleozoic erosion.

CENOZOIC STRATIGRAPHY

The Cenozoic record in the Seaman Range is dominated by Oligocene and Miocene volcanic rocks (table 2). However, the oldest Tertiary-age rocks in the Seaman Range are a conglomerate and a lacustrine lime mudstone that is correlated with the Sheep Pass Formation of east-central Nevada (Winfrey, 1960). The relative ages of the lime mudstone and conglomerate are not known, because they are nowhere in contact, but both are overlain by middle Tertiary volcanic rocks.

Eighteen Tertiary volcanic units crop out in the range; 11 are part of the extensively studied (Cook, 1965; Williams, 1967 a, b; Ekren and others, 1977; Best and Grant, 1987; Best, Christiansen, and others, 1989), areally extensive Great Basin volcanic field. The volcanic field consists of intermediate to silicic ash-flow tuffs that are areally extensive and volumetrically large. Each tuff unit is characterized by diagnostic petrographic (table 3) and compositional (E.A. du Bray, unpub. data, 1990) features.

Of the seven remaining volcanic units, four are lavas and three are components of the Seaman volcanic center, including its lava flows, core plug, and radial dike. The lava units consist of two temporally and petrographically distinct andesites, a rhyolite, and a flow-banded dacite, all of which have limited areal extent. The petrographic and compositional characteristics of the volcanic units are summarized in tables 3–5.

Prevolcanic Units

Conglomerate

A well-lithified conglomerate, characterized by pebble- to cobble-size Paleozoic rock clasts, crops out in two areas on the east side of the Seaman Range, in and adjacent to relatively narrow valleys just north of Fossil Peak (T. 2 S., R. 61 E.). The conglomerate was deposited on eroded exposures of the upper part of the Sevy Dolomite and lower part of the Simonson Dolomite, and is overlain by the oldest of the ash-flow tuffs; the attitude of the unit indicates that it was deposited with little or no angular unconformity on the Paleozoic section. The conglomerate is poorly sorted, well cemented, and locally well bedded.

Table 2. Stratigraphy, age, and thickness of volcanic units in the Seaman Range, Nevada

Unit	Age[1] (Ma)	Approximate thickness (m) in Seaman Range
Rhyolite lava		3
Hiko Tuff	18.5	15
Andesite	18.2	20–150
Harmony Hills Tuff	21.6	0–10
Pahranagat Lakes Tuff	22.65	15
Condor Canyon Formation		
Bauers Tuff Member	22.78	25
Swett Tuff Member	23.9	10
Leach Canyon Formation	24.6	140
Hornblende andesite		[2]100
Dacite		([3])
Rhyolite tuffs of the Seaman Range	26.0–26.7	300
Seaman volcanic center		
Radial dike		([3])
Core plug		([3])
Outflow unit		[2]350
Monotony Tuff	27.1	60
Petroglyph Cliff Ignimbrite		10
Needles Range Group		
Lund Formation	27.9	40
Wah Wah Springs Formation	29.5	20

[1]See text for source of age data. No radiometric age determinations have been made for units that contain no data in age column.

[2]Maximum thickness.

[3]Intrusive mass, thickness estimate irrelevant.

A striking characteristic of the unit is its varying provenance. All the clasts were derived from Devonian formations, but the fact of areally distinct changes in the proportions of clasts from various Devonian formations indicates very local sources.

Winfrey (1960, p. 128–130) described the lowest of six members of the Sheep Pass Formation (member A), in the Egan Range, as a "calcareous cemented conglomerate breccia composed of very angular (near the bottom) to subrounded (near the top) cobbles and boulders" of Paleozoic rocks. Kellogg (1963) noted that sources of the clasts in member A are limited to Paleozoic units just below the Sheep Pass, indicating that they were locally derived. In the Pahranagat Range, Reso (1963) reported from 0 to 220 ft of prevolcanic conglomerate overlain by limestone in his Hells Bells Canyon Formation that unconformably overlies Paleozoic rocks.

Winfrey's (1958, 1960), Kellogg's (1964), and Fouch's (1979) observations of the extent and character of the Sheep Pass Formation in the southern Egan Range suggest that the conglomerate in the Seaman Range was deposited in an environment similar to that characteristic of member A. However, in the Seaman Range none of the upper members of the Sheep Pass? were found directly above the conglomerate, and therefore the only age that can be established for it is that it is prevolcanic.

The conglomerate was probably deposited in fault-bounded basins because it rests on Devonian rocks of different ages and it contains varying proportions of different, but exclusively Devonian, rock clasts. The amount of throw on the bounding faults was probably minor, that is, less than the composite thickness of the Devonian section. Further, the prevolcanic age of the conglomerate and the absence of volcanic rock clasts in the conglomerate indicate prevolcanic faulting in the southernmost part of the range.

Sheep Pass Formation

At the type locality of the Sheep Pass Formation in Sheep Pass Canyon on the west side of the Egan Range, the formation unconformably overlies the Pennsylvanian Ely Limestone and is overlain by the informally named Oligocene Garrett Ranch volcanic "group" of Winfrey (1960). Winfrey correlated the Sheep Pass Formation on the surface and into the subsurface over an area of 1,100 mi^2 in east-central Nevada. This area extends from the Pancake Range in the west to the Egan Range in the east. His southernmost reported exposures are in T. 6 N., R. 59 E. (Winfrey, 1960), just north of the northern Seaman Range.

Table 3. Summary of petrographic characteristics of Tertiary volcanic rocks in the Seaman Range, Nevada

[Characteristics based on petrographic analysis of more than 125 thin sections in transmitted and reflected light. Crystal abundances are visual estimates; no petrographic modal analyses were performed. Leaders (--), not observed; tr, trace; N/A, not applicable. Crystallinity: a, anhedral; s, subhedral; e, euhedral; where two crystallinities are indicated, the first is dominant]

Unit	Form	Crystals Approx. modal abund. (pct.)	Plag	San	Qtz	Bi	Hb	Opx	Cpx	Mag	Acc. min.[1]	Degree of welding, devitrification[2]	Abund. pumice, lithic	Matrix, dust or shard dominated	Color, textures (non-tuffs only)	Other[3]
			Approximate modal abundances, percent Crystallinity Grain size, millimeters													
Rhyolite	lava	10	1 a 0.5	3 s,e 1.5	5 e,s 0.5–7.0	1 s 0.5	--	--	--	--	--	N/A, com	N/A, N/A	N/A	Pale pinkish orange, gray, porphyritic.	
Hiko Tuff	tuff	20	5 a,s 0.2–1.5	4 a 1.5	7 a 0.1–2.0	3 s 0.2–1.5	tr a,s 0.2–1.0	--	--	1 a 0.1–0.5	sp,al	mod, incip	low, low	shards	Pinkish gray.	
Andesite	lava	variable	5–60 s,e 0.5–1.0	--	--	--	0–3 s,e 1.5	--	0–5 a,s 0.5	0–1 a 0.1	ol	N/A, com	N/A, N/A	N/A	Medium dark gray, porphyritic, pilotaxitic.	Locally vesicular.
Harmony Hills Tuff	tuff	20	15 s 0.2–3.0	--	tr a 0.5–1.5	3 s 0.2–2.0	1 s,a 0.1–0.6	--	tr a,s 0.4–1.0	1 a 0.1–0.5	al	weak-mod, variable	low, low	shards	Grayish orange pink.	
Pahranagat Lakes Tuff	tuff	15	4 s 0.2–2.0	3 s 0.5–1.5	6 s 0.2–3.0	1 s 0.1–0.5	tr s 0.4	--	1 s 0.4–0.8	tr a 0.1–0.4	al	weak, mod	high, low	shards	Pinkish gray.	
Bauers Tuff Member	tuff	8	5 s,e 0.2–6.0	2 s,e 0.2–2.0	--	1 s 0.2–1.0	--	--	tr s 0.4	tr a,s 0.5	al,zr	weak-den, com	low, low	shards	Pale red; grayish black (basal vitrophyre).	
Swett Tuff Member	tuff	3	2 s,e 0.1–3.0	--	--	1 s 0.2–2.0	--	--	tr s 0.3	tr a,s 0.1–0.4	zr	weak-den, incip	low, low	shards	Pale brown and medium gray (basal vitrophyre); pale red (tuff midsection); pinkish gray (poorly welded top).	
Leach Canyon Formation	tuff	12	5 s 0.2–2.0	2 s 0.2–2.0	4 s 0.2–1.5	1 s 0.1–2.0	tr* a,s 0.1–1.2	--	tr a 0.3	tr a 0.3	sp,al,zr	weak, mod	mod, mod	dust	White and pinkish gray.	
Hornblende andesite	lava	5–30	0–20 s 0.1–1.0	--	--	--	0–7 e,s 3.0–5.0	0–5 s 0.4	0–1 a 0.1–0.5	--	ol	N/A, mod	N/A, N/A	N/A	Dark gray, porphyritic, pilotaxitic.	
Dacite	lava	10	2 s,e 2.0–3.0	--	3 s 2.0	1 s 0.5	3** s,e 0.2–1.5	--	tr s 1.0	1 s 0.1	--	N/A, mod	N/A, N/A	N/A	Pale grayish red purple, porphyritic, flow banded.	
Trs[4] Unit 7	tuff	3	1.5 s,e 0.2–3.0	--	tr s 0.5	--	tr s 0.1–0.5	--	0.5 s 0.2–0.8	1 a,s 0.1–0.4	zr	den, mod-com	mod, mod	shards	Grayish orange pink; dark gray (basal vitrophyre).	Glomerocrysts of plagioclase, augite, and opaque oxides.
Trs Unit 6	tuff	3	2 s,e 0.5–2.0	1 s,e 0.5–4.0	tr s,a 0.5	tr s 0.5–1.5	tr a 0.5	--	tr a 0.2	tr a 0.1–0.4	al,zr	den, variable	high, low	shards	Pale red purple to grayish orange pink; medium dark gray to light olive gray (basal vitrophyre).	

Trs Unit 5	tuff	12	5 a,s 0.2–2.0	3 s 0.2–1.6	3 s 0.2–3.0	1 s 0.4–1.5	tr s 0.2–2.5	tr s 0.5	–	tr s 0.2	zr	mod, com	low, low	dust	Pale red purple to pinkish gray.	
Trs Unit 4	tuff	18	5 s,e 0.2–2.0	3 s,e 0.4–2.0	8 s,e 0.2–2.0	1 s 0.3–0.6	tr s,a 0.1–0.8	–	–	1 a 0.1–0.4	zr,al	mod- den, weak-mod	low, low	shards	Pale pink to pale red purple.	
Trs Unit 3	tuff	10	4 a,s 0.4–2.0	4 a,s 1.0–3.0	2 s 0.2–1.2	–	tr s 0.5	–	–	tr a 0.1	zr,al	den, mod- com	mod, low	shards	Pale red purple.	
Trs Unit 2	tuff	6	2 a,s 0.5–3.0	3 s 0.5–2.5	1 a,s 0.3–2.0	–	tr s 0.5	–	–	tr a 0.1–0.4	zr,al	den, com	high, low	shards	Pale red to very pale red purple; dark gray (basal vitrophyre).	
Trs Unit 1	tuff	5	4 s 0.4–5.0	–	–	–	tr s 0.1–0.5	–	tr a,s 0.2–0.5	1 a,s 0.2	al	den, weak- mod	high, low	shards	Pale red; medium dark gray (basal vitrophyre).	Glomerocrysts of plagioclase, magnetite, and augite.
Seaman volcanic center	dike	10	5 s 0.5–4.0	2 a 1.0–8.0	1 a 1.0–3.0	tr s 0.1–1.0	1 s 0.5	1 s,a 0.2–0.4	–	–	–	N/A, com	N/A, N/A	N/A	Grayish black to light yellowish gray, porphyritic.	Trace glass.
Seaman volcanic center	stock	8	5 s 1.5–3.0	–	tr a 2.0–4.0	3 s 0.5–2.0	tr s,e 1.0–1.5	tr s 1.0	tr s 0.5	tr a 0.1	–	N/A, N/A	N/A, N/A	N/A	Light greenish gray to light brownish gray, porphyritic.	Glomerocrysts of plagioclase, pyroxene, and magnetite.
Seaman volcanic center	lava	10	5–7 s 0.2–4.0	–	tr a 2.0	–	tr** s 1.0–3.0	0–3 s 0.2–2.5	0–5 s 0.2–3.0	tr a,s 0.1	–	N/A, com	N/A, N/A	N/A	Light brownish gray to dark gray, pilotaxitic, porphyritic.	Glomerocrysts of plagioclase, pyroxene, and hornblende.
Monotony Tuff	tuff	15	3 a,s 0.2–1.5	1 s 0.8	10 a 0.2–1.5	1 s 0.2–0.5	tr a 0.2	tr a 0.2	–	tr a 0.1	–	incip, incip	high, high	dust	Pale pinkish gray.	
Dacite	tuff	2–20	1–15 s,a 0.1–1.0	–	tr a,s 0.2–1.0	tr s 0.2–0.5	0–5 a,s 0.1–1.0	–	0–1 a,s 0.4	tr–2 a,s 0.1–0.5	–	den, incip	high, high	dust	Medium light gray, moderate reddish orange, and grayish pink.	Upper part contains distinctive, flattened black glass blocks.
Lund Formation	tuff	35	21 s 0.2–2.5	–	10 s,e 0.2–3.0	2 s 0.1–2.5	1 a,s 0.1–1.5	–	–	1 a 0.1–0.4	sp,al,zr	mod, incip- mod	high, low	dust	Very light gray to light gray.	
Wah Wah Springs Formation	tuff	35	15 s 0.2–0.8	–	5 s 0.2–1.0	3 s 0.5–3.0	10 a,s 0.1–2.0	–	tr s 0.4–1.5	2 a 0.1–0.3	zr,ap	mod, weak	mod, low	dust	Light to medium gray.	

*Lower ash-flow tuff in the Leach Canyon Formation contains no hornblende.

**Oxyhornblende.

[1]Acessory minerals: al, allanite; zr, zircon; sp, sphene; ap, apatite; ol, olivine.

[2]Degree of welding: non, unwelded; incip, incipient; mod, moderate; den, dense. Degree of devitrification: non, nondevitrified; incip, incipient; mod, moderate; com, complete.

[3]Additional petrographic observations concerning the volcanic rocks are: (1) a major proportion of the crystals in the ash-flow tuffs are broken; (2) plagioclase is albite twinned and zoned; (3) sanidine is carlsbad twinned; (4) the predominant opaque oxide phase is magnetite (weakly altered to hematite in many samples; some grains contain trace amounts of chromite); (5) biotite is pleochroic from tan to very dark reddish greenish brown; (6) hornblende is pleochroic from yellowish green to olive green.

[4]Trs, Rhyolite tuffs of the Seaman Range.

Fouch (1979), Emry and Korth (1989), and Fouch and others (in press) provided additional information on the origin and age of the Sheep Pass Formation.

In the Seaman Range, we have found rocks that may belong to the Sheep Pass Formation exposed along the west side of the range about 0.5 km south of the Lincoln-Nye County line. The exposure is in a roadcut on the west side of a series of generally north-south-trending jasperoid zones. The rock is a whitish-gray-weathering lime mudstone, brown on fresh surfaces, with trace fossils and a distinct petroliferous odor.

Palynomorphs recovered from the lime mudstone include *Limnocarpus forbesi*, *Potamogeton pygmaeus*, *Stratiotes headonensis*, *Corsinipollis* spp., *Graminidites* spp., and *Nymphaeacidites* spp. Fresh-water algal cysts are also abundant in the limestone.

Stratigraphy and Distribution of Cenozoic Igneous Rocks

The oldest and youngest volcanic rocks exposed in the Seaman Range are the 29.5 Ma (Best and Grant, 1987) Wah Wah Springs Formation and 18.2 Ma (E.H. McKee, unpub. data, 1989) andesite lava flows. Volumetrically dominant middle Tertiary ash-flow tuffs are the outflow deposits emplaced following eruptions that caused the development of numerous calderas in southern Nevada. Best, Christiansen, and others (1989) summarized existing data for calderas, and their eruptive products, of the Great Basin volcanic field. The majority of the tuffs exposed in the Seaman Range are composed of rhyolite, though massive accumulations of dacite tuff are present as well. Sources of lava flows exposed in the Seaman Range are within the range. Petrographic features of the volcanic rocks are summarized in table 3.

The classification scheme (Le Bas and others, 1986) proposed by the International Union of Geological Science (IUGS) was used to classify the chemistry of the volcanic rocks in the Seaman Range. Chemistry of the Cenozoic lavas is described here, whereas the chemistry of the Seaman Range volcanic center and ash-flow tuffs is part of du Bray's ongoing research.

Needles Range Group

The oldest volcanic rocks in the Seaman Range are ash-flow tuffs of the Needles Range Group (Best and Grant, 1987) that in most places were deposited on an undulating surface of exposed Paleozoic carbonate rocks. The Needles Range Group, named for exposures in the Needles Range of western Utah, was reported in the Seaman Range by Cook (1960, 1965). Cook (1965) described two detailed sections of volcanic rocks in the range: (1) a well-exposed section along the White River in the White River Narrows, and (2) a section on the north side of Seaman Wash. At White River Narrows, Cook measured a thickness of approximately 161.5 m (530 ft).

Best, Christiansen, and Blank (1989) indicated that dacite tuffs of the Cottonwood Wash Tuff, Wah Wah Springs Formation, and Lund Formation (all of the Needles Range Group) (total volume at least 6,600 km^3) were successively erupted from the nested Indian Peaks caldera complex. A distribution map for the Cottonwood Wash Tuff (Best and Grant, 1987) suggests that the tuff could be present in the northern Seaman Range, but we did not find the tuff in that region. Small and major amounts, respectively, of the 29.5 Ma (Best and Grant, 1987) Wah Wah Springs and the 27.9 Ma (Best and Grant, 1987) Lund Formations are present, however. The Wah Wah Springs forms limited outcrops along the east flank of Timber Mountain; the tuff appears to wedge out in the subsurface west of these outcrops. The Lund Formation forms massive outcrops throughout the Seaman Range, and is particularly well exposed north of the White River Narrows. In the Seaman Range an intermediate amount of the Monotony Tuff is exposed in a north-south-trending belt several kilometers (miles) wide that extends from about 4.8 km (3 mi) south of White River Narrows to about 9.6 km (6 mi) south of Black Cliff.

Petroglyph Cliff Ignimbrite

The Petroglyph Cliff Ignimbrite of Cook (1965), which overlies the Lund Formation, is a light-brown to moderate-reddish-brown, blocky, lithic, dacite ash-flow tuff that forms bold outcrops. The uppermost part of this tuff contains subangular, unflattened blebs (20 cm) of black devitrified glass. The northernmost exposures of this unit are medium to dark gray and contain flattened black glass blocks that impart a horizontal parting (compaction foliation). The unit, whose source is unknown, is only about 15.2 m (50 ft) thick but may extend over an area of 4,662 km^2 (1,800 mi^2) (Cook, 1965).

Although the Petroglyph Cliff Ignimbrite as described by Cook (1965) is not exposed at his type section, a grossly lithologically similar unit, the lowest of the ash-flow tuffs that compose the rhyolite tuffs of the Seaman Range, is exposed there. The Petroglyph Cliff Ignimbrite is well exposed a few kilometers (miles) north of Cook's designated type section along the east side of the ridge north of White Rock Spring, as well as farther north along the east face of Timber Mountain.

Monotony Tuff

The Monotony Tuff is a pumiceous, dacite ash-flow tuff that forms recessive outcrops. Ekren and others (1971) reported ages of 26.8, 28.1, and 28.5 Ma, recalculated using decay constants of Steiger and Jäger (1977); however, some of these ages are for tuffs whose correlation with the Monotony is suspect. Best, Christiansen, and others (1989) reported an age of 27.3 Ma for a tuff (their "Monotony Tuff, Lower unit") exposed below the Petroglyph Cliff Ignimbrite of Cook (1965) near White Rock Spring in the Seaman Range. Our work suggests that this unusual tuff has no stratigraphic correlatives, at least elsewhere within the Seaman Range. It may, in fact, have been a product of the same eruptive events that gave rise to the more widely recognized Monotony, though its position beneath the Petroglyph Cliff is problematic. Taylor and others (1989) reported an age of 27.1±0.6 Ma for a tuff that is exposed above the Petroglyph Cliff in the North Pahroc Range, and which Taylor has correlated with the Monotony.

In many places, the Monotony contains subangular, dark-gray, cobble- and boulder-size lithic fragments. The tuff appears to be composed of a single, thick ash flow-tuff deposit. Ekren and others (1971) suggested that the source region for this tuff was in the southern Pancake Range.

Correlation of Oligocene Dacite Tuffs in the Seaman Range

Many problems developed during early attempts to establish stratigraphy and correlation of the several similar, massive dacitic ash-flow tuffs in southern Nevada. More recent detailed studies have shown that the Cottonwood Wash Tuff, Wah Wah Springs Formation, Lund Formation, and Monotony Tuff were frequently mistaken for one another; their characteristic petrographic, compositional, geochronologic, and paleomagnetic characteristics are still being established (Best and Grant, 1987). The massive dacite tuffs of the Seaman Range were correlated with their regional equivalents using field relationships, petrographic characteristics, and chemical data (Ekren and others, 1971; Best and Grant, 1987). In the Seaman Range, in particular, it has been difficult to distinguish the Lund from the Monotony in outcrops that lack stratigraphic indicators such as the Petroglyph Cliff Ignimbrite of Cook (1965).

Best and Grant (1987) indicated that the presence of accessory sphene is diagnostic of the Lund, but we have found this criterion not always reliable. Trace element abundances (E.A. du Bray, unpub. data, 1990) indicate that the Lund and Monotony are compositionally distinct. In particular, the Lund exhibits barium abundances that are distinctly lower than those characteristic of the Monotony. Most but not all of the "lower" barium samples also contain sphene and, thus, are readily identifiable as the Lund. However, some "lower" barium samples from massive dacitic ash-flow tuffs of the Seaman Range do not contain sphene. Sphene breaks down readily during weathering and, although present in the magmatic phase, it may be lost during weathering. Unfortunately, the presence of sphene alone is probably not sufficient to identify the Lund.

M.G. Best (written commun., 1989) has suggested that clinopyroxene is diagnostic of the Monotony. No pyroxene was identified during our petrographic analysis of 10 compositional Lund-type samples from the Seaman Range, whereas all 6 samples of compositional Monotony-type rock contained clinopyroxene. Thus, the presence or absence of clinopyroxene in these tuffs may be diagnostic, but because of the extremely fine grain size and sparse abundance of clinopyroxene, this criterion could be of limited utility in the field. In the absence of stratigraphic relations, a tentative identification of the Lund or Monotony may be achieved using the observed presence or absence of sphene or clinopyroxene. Any definitive compositional distinction can be made only after chemical analyses in the laboratory, as a check on tentative field identifications.

Seaman Volcanic Center

The west-central part of the Seaman Range is dominated by the Seaman volcanic center (fig. 2), a feature first noted by D.C. Noble and K.A. Sargent (in Ekren and others, 1977). The center, an exhumed middle Tertiary stratovolcano, is about 10 km (6 mi) in diameter and includes a hypabyssal core plug, a radial dike 50 m (160 ft) wide and about 3 km (1.8 mi) long, a thick pile of dacite lava flows, and minor lahar deposits. The dacite lava flows dip radially away from the central part of the volcanic center and form prominent cliffs. The lahars are composed of varicolored, poorly sorted, bouldery mud-flow deposits; multiple separate flows were recognized. The hypabyssal core plug shows weak hydrothermal alteration locally, and weathers to bouldery outcrops. The dacite dike is characterized by a black-glass, chilled margin several meters wide; it resists weathering and forms prominent castellated outcrops along its length. The dike is petrologically and compositionally zoned along its length as well as across its width.

The volcanic center is located in one of the least deformed parts of the range. There is no direct evidence of structural control for localizing the volcanic center, although it is likely that rocks of the volcanic center conceal prevolcanic center faults. Ekren and others (1977) suggested that the volcanic center was active in the late Oligocene and early Miocene (its age is bracketed between the ages of the Lund Formation and the rhyolite tuffs of the Seaman Range) and that correlative extrusive rocks crop out in the Pahranagat, southern Egan, and Golden Gate Ranges. No volcanic rocks in the Seaman Range seem to have been derived from the volcanic center. The west side of the volcanic center is coincident with a relatively minor magnetic anomaly of 2,925 gammas (U.S. Geological Survey, 1976).

Rhyolite Tuffs of the Seaman Range

Rocks above the Needles Range Group and below the Leach Canyon Formation in the Seaman Range were termed the Pahrock sequence by Cook (1965). The original Pahrock sequence of Cook consisted of the Petroglyph Cliff Ignimbrite and Shingle Pass Ignimbrite (which was subsequently renamed the Shingle Pass Tuff by Ekren and others (1967)). Subsequent work has demonstrated that the Petroglyph Cliff Ignimbrite is not present in the interval between the Monotony Tuff and the Leach Canyon Formation but rather is stratigraphically beneath the Monotony and, as stated previously, is not exposed at its type section (Petroglyph Cliff, about 0.5 km (0.3 mi) north of the north end of White River Narrows). The type section of the Shingle Pass Tuff is at Shingle Springs (in Shingle Pass) in the southern Egan Range where the unit is only 38.1 m (125 ft) thick (Cook, 1965). In the southern Seaman Range, Cook (1965) reported that its thickness ranges from 6.1 m (20 ft) at White River Narrows to as much as 22.9 m (75 ft) on the north side of Seaman Wash. Cook estimated that the tuff covers about 10,880 km^2 (4,200 mi^2) with an average thickness of only 39.6 m (130 ft). Ekren and others (1971) reported Shingle Pass ages of 26.0 and 26.1 Ma (recalculated to the decay constants of Steiger and Jäger, 1977). Best, Christiansen, and others (1989) reported similar ages of 26.0–26.7 Ma for the unit.

In the Seaman Range, seven lithologically similar ash-flow tuffs crop out above the Monotony Tuff and below the Leach Canyon Formation. These units (units 1–7, from oldest to youngest) are here informally designated as the rhyolite tuffs of the Seaman Range. They can be differentiated on the basis of chemistry (E.A. du Bray, unpub. data, 1990). Deposition and preservation of complete, unfaulted sections of the ash-flow tuffs that compose the rhyolite tuffs of the Seaman Range are rare, however; one complete section is present about 1.5 km (0.9 mi) north of Fossil Peak. The section exposed in the White River Narrows region is anomalously thin and includes only a few of the ash-flow tuffs known to occur in this interval elsewhere.

In most places, the basal part (unit 1) of the rhyolite tuffs of the Seaman Range is a trachytic, 1- to 2-m-thick black vitrophyre. This erosion-resistant ash-flow tuff, well exposed in the northern cliffs of White River Narrows, is probably one of several tuffs compositionally similar to the Isom Formation as described by Best, Christiansen, and others (1989) and may be correlative with the 27.4±2.5-Ma tuff of Hamilton Spring (Taylor and others, 1989). Its source is unknown. Above it are six rhyolitic ash-flow tuffs (units 2–7) that form both massive bouldery outcrops and subordinate recessive intervals. Petrographic and compositional data suggest that units 2 and 3 are probably correlative with the lower ash flow unit of the Shingle Pass Tuff that was probably erupted from the Quinn Canyon caldera (Sargent and Houser, 1970). M.G. Best (oral commun., 1989) suggested that unit 4 is correlative with the tuff member of Rosencrans Peak (of the Blawn Formation) (Willis and others, 1987) and with the tuff of the Golden Gate Range. Unit 5 may be correlative with the tuff of Hancock Summit (Best, Christiansen, and others, 1989), whose inferred source is an unnamed caldera located 85 km west northwest of Caliente, Nev. Unit 6 is petrographically and compositionally similar to the upper ash flow unit of the Shingle Pass Tuff and may be a correlative. Unit 7 may be another of the Isom compositional-type tuffs described by Best, Christiansen, and others (1989). More work is needed in order to document the stratigraphic relations and distribution of ash-flow tuffs in this interval. Mapping these units, at least locally, may be possible in the Seaman Range. Locally, in the southern part of the range, a bed of freshwater limestone 5–20 m thick crops out between unit 1 and the overlying tuffs.

Dacite

Ekren and others (1977) originally described this cliff-forming unit that crops out in the west-central part of the range as rhyolite lava flows. It forms a discrete flow-dome or volcanic neck complex that intrudes surrounding rhyolite tuffs, and correlates with a 3,281-gamma magnetic anomaly (U.S. Geological Survey, 1976).

Hornblende Andesite

Throughout the southeastern part of the range, dark-gray, dense, fine-grained, hornblende porphyritic andesite crops out between the rhyolite tuffs of the Seaman Range and the overlying Leach Canyon Formation. The andesite forms prominent cliffs composed of numerous thick flows.

Leach Canyon Formation

The type locality of the Leach Canyon Formation is at Leach Canyon in Utah (Cook, 1965; Anderson and Rowley, 1975). Cook (1965) reported a thickness of at least 137.2 m (450 ft) at White River Narrows and a regional extent of 12,950 to 18,130 km^2 (5,000 to 7,000 mi^2). Best (1988) estimated its thickness to be as much as 200 m, and suggested that its thickness was controlled by topography during deposition. Williams (1967a) suggested that the Caliente cauldron complex was the source of the Leach Canyon, whereas Best, Christiansen, and others (1989) suggested an unnamed caldera located south of the Caliente cauldron complex as its source. Armstrong (1970) reported an age of 24.6 Ma (recalculated using decay constants of Steiger and Jäger, 1977) for the Leach Canyon.

The Leach Canyon Formation is widespread in the southeastern part of the Seaman Range, where it forms prominent cliffs, some of which have columnar jointing. At White River Narrows and elsewhere in the Seaman Range, the Leach Canyon is composed of upper and lower ash flow units. The upper ash flow unit contains hornblende phenocrysts, whereas the lower unit does not. Compositions of the two ash-flow units are also different. In contrast to the upper ash flow unit, the lower unit contains higher abundances of SiO_2, Rb, and Y, and lower abundances of FeO, CaO, Sr, Zr, Ba, and the light rare earth elements (E.A. du Bray, unpub. data, 1990).

Condor Canyon Formation

The Condor Canyon Formation, named by Cook (1965, p. 23), consists of two members—the lower 9.1-m (30-ft)-thick Swett Tuff Member, and the upper 32-m (105-ft)-thick Bauers Tuff Member. Cook (1965) estimated that the Swett has a distribution of 9,065 km^2 (3,500 mi^2), and that the Bauers covers more than 15,540 km^2 (6,000 mi^2). Both ash-flow tuffs were probably erupted from the Caliente cauldron complex (Williams, 1967a), and extend as far east as Cedar City, Utah. Armstrong (1970) reported preferred ages (recalculated using decay constants of Steiger and Jäger, 1977), of 23.9 Ma and 22.1 Ma for the Swett and Bauers, respectively. Best, Christiansen, and others (1989) reported an age of 22.78 Ma for the Bauers Tuff Member.

The basal part of the Swett Tuff Member is a pale-brown and medium-gray vitrophyre as much as 1.5 m (5 ft) thick, overlain by a thin interval of densely welded pale-red tuff (0.5 m; 1.6 ft) that grades upward into a nearly aphyric, poorly welded, pale-red tuff (2 m; 6.6 ft), which is overlain by about 2 m (6.6 ft) of poorly welded pinkish-gray tuff. The Bauers Tuff Member includes a variably devitrified black vitrophyre that is several meters thick. Above its base is about 20 m (66 ft) of densely welded pale-red tuff. The uppermost part of the Bauers is characterized by densely welded tuff that weathers to form resistant slabs.

Pahranagat Lakes Tuff

The type section of the Pahranagat Lakes Tuff of Williams (1967a,b) is in the Pahranagat Valley in southeastern Nevada. Williams (1967a) reported that its thickness ranges from 0 to 35 m (0 to 115 ft) and averages 15 m (50 ft); he suggested an original extent of 6,734 km^2 (2,600 mi^2). In the White River Narrows area, the only place in the Seaman Range where the unit is present, the tuff is exposed discontinuously between the underlying Bauers Tuff Member (Condor Canyon Formation) and Harmony Hills Tuff; where exposed, it is less than 15 m (50 ft) thick. As a consequence of poor welding and induration the rhyolite tuff weathers to form recessive outcrops.

Ekren and others (1977) suggested the Kawich or Cactus Ranges as a likely source for the tuff; Best, Christiansen, and others (1989) suggested the Kawich caldera as the source. Deino and Best (1988) reported an age of 22.65 Ma for the tuff and suggested that it is correlative with all or part of the ash-flow tuffs known elsewhere as the tuff of White Blotch Spring (Ekren and others, 1971) and the granite-weathering tuff (Snyder and others, 1972).

Harmony Hills Tuff

The type locality of the Harmony Hills Tuff is at Harmony Hills in Utah (Cook, 1965). Cook (1965) recorded a thickness of 46.3 m (152 ft) in the White River Narrows and reported a regional average thickness of 76.2 m (250 ft) and an approximate areal distribution of more than 15,540 km^2 (6,000 mi^2). Blank (1959) suggested that the tuff was erupted from the Bull Valley center in southwest Utah, whereas Best, Christiansen, and others (1989) suggested the Caliente cauldron complex as the source. Armstrong (1970) reported a preferred age (recalculated using decay constants of Steiger and Jäger, 1977) of 21.6 Ma for the Harmony Hills.

Outcrops of the Harmony Hills Tuff in the Seaman Range are limited to a small area around White River Narrows, where it is thin and discontinuous. The tuff is a dacitic ash flow that weathers to form recessive outcrops.

Hiko Tuff

The type locality of the Hiko Tuff is on the east side of the Hiko Range in southern Nevada (Cook, 1965). Cook (1965) reported its thickness as 66–351 m (213–1,135 ft), and its approximate areal distribution as 12,950 km^2 (5,000 mi^2). In the White River Narrows area, the only area where the Hiko Tuff is present, only the basal 15 m is exposed. A detailed description of the petrography, distribution, and field relationships was presented by Dolgoff (1963). The rhyolite tuff weathers to prominent low cliffs covered by a distinctive moderate-reddish-brown patina. Ekren and others (1977) suggested that the Hiko Tuff was erupted from the Caliente cauldron complex. Armstrong (1970) reported a preferred age of 18.3 Ma (recalculated using decay constants of Steiger and Jäger, 1977), and Taylor and others (1989) reported an age of 18.5±0.4 Ma for the unit.

Rhyolite Lava

Rhyolite lava was found in only one place in the range. This isolated outcrop, located in the extreme northwestern part of the range, is composed of pale-pinkish-orange-gray rhyolite lava. Its mode of occurrence, mineralogy, and chemical composition are atypical of Tertiary volcanic rocks of the region. Maps compiled by Ekren and others (1977), and Kleinhampl and Ziony (1985) indicate that this type of rhyolite lava may be more extensive west of the Seaman Range in the southwestern part of the nearby Quinn Canyon Range.

Andesite

A voluminous accumulation of Tertiary andesite crops out in the southeastern part of the range. E.H. McKee reported an age of 18.2±0.5 Ma for the unit (oral commun., 1989). Andesite also crops out in several restricted areas within the Seaman Range. The location of andesitic outpourings appears to be fault controlled. Andesite locally exhibits columnar jointing.

Quaternary Units

A variety of Quaternary deposits occur in and around the Seaman Range. Dark-weathering beach and shoreline deposits form arcuate ridges that encircle playa lake deposits. The light-colored playa deposits are composed of reworked silt, clay, and evaporites that were deposited as lake beds in broad, flat intermontane basins.

Colluvium forms loose, heterogeneous, and incoherent masses of soil material and rock fragments deposited on slopes by rainwash, sheetwash, or slow continuous downslope creep at the base of slopes or on hillsides. Poorly sorted, braided-distributary alluvial-fan deposits, including angular material that ranges from silt to boulder size, form aprons around the range. Alluvium occurs principally as sediment in active stream channels but includes undifferentiated surficial deposits, such as local talus, windblown sand, silt, or evaporite deposits.

Chemistry of Lava Flows

Major element abundances were determined for nine samples of various lavas of Seaman Range (table 4). The analyses were performed in the analytical laboratories of the U.S. Geological Survey, Denver, Colo., by J. Taggart, A. Bartel, D. Siems, and K. Stewart using wavelength dispersive X-ray fluorescence spectrometry (Taggart and others, 1987). The lavas are classified (fig. 4) according to the scheme of Le Bas and others (1986). Trace element abundances were determined for 16 lava samples (table 5). These analyses were performed by du Bray using an energy dispersive X-ray fluorescence spectrometer equipped with a Si-Li detector and radioisotope excitation sources; reported data are considered accurate within plus or minus 5 percent.

Four subalkaline lava types were mapped in the Seaman Range. The youngest of these as well as a hornblende-porphyritic lava are composed of andesite; major oxide compositions of these two units are similar. A small flow-dome complex is composed of dacite, whereas a small outcrop in the northwestern part of the range is composed of high-silica rhyolite. As K_2O contents exceed those of Na_2O in the dacite and rhyolite, both of these units are potassic (Le Bas and others, 1986). Lava flows in the Seaman Range are similar to other potassic middle Tertiary volcanic rocks of the Basin and Range province in that Al_2O_3, total iron, CaO, MgO, TiO_2, P_2O_5, and MnO contents decrease with increasing SiO_2, whereas Na_2O, K_2O, and total alkali contents increase. Compositions of the rhyolite and dacite lavas plot near the calc-alkaline trend

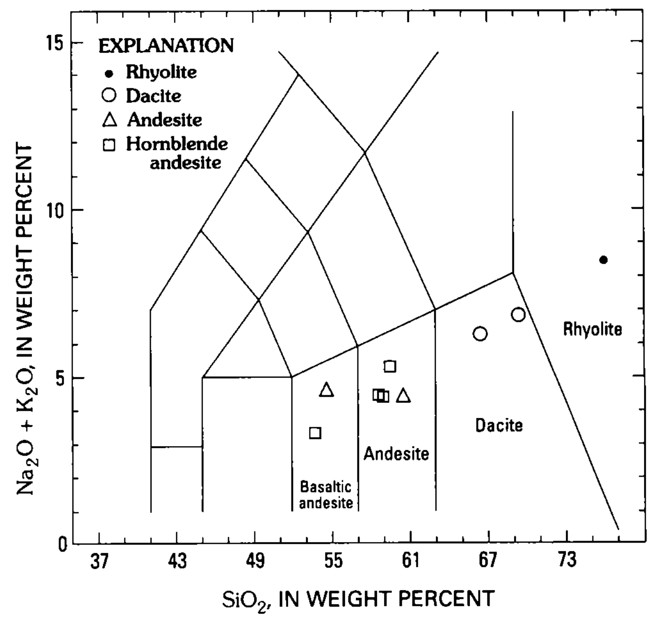


Figure 4. Total alkali-silica variation diagram with IUGS classification grid (Le Bas and others, 1986) for lava flows of the Seaman Range, Nev.

relative to volcanic rocks of the Cascades, whereas compositions for the two andesite flow units are slightly iron enriched and plot along the calc-alkaline trend defined by volcanic rocks of the Aleutian island arc (fig. 5). It is noteworthy that the rhyolite lava has a relatively high normative corundum content (table 4).

Trace element abundances in the four lava flow types are similar to abundances reported for calc-alkaline andesites, dacites, and rhyolites from elsewhere in the world. The two andesite flow units are remarkably similar in trace element abundances (table 5, figs. 6 and 7). Diagnostic trace element characteristics (table 5) of the andesites include very low Rb/Sr ratios, large abundances of compatible trace elements (Sr and Ba), and small abundances of incompatible trace elements (Rb, Y, and Nb). In contrast, the rhyolite lava flow is enriched in incompatible trace elements and depleted in compatible elements. The rhyolite lava flow is also characterized by a depletion of light rare earth elements relative to other low-calcium igneous rocks. The enrichment and depletion of elements in the rhyolite are extreme; its trace element abundances, light rare-earth-element depletion, and high normative corundum content are similar to igneous rocks with associated rare metal (Sn, W, and Mo) ore deposits. Trace element abundances in the dacite (table 5, figs. 6 and 7) are between those of the andesites and the dacites, as predicted from their major element composition.

STRUCTURE OF THE SEAMAN RANGE

Structures in the Seaman Range and surrounding region are categorized in three magnitudes: lineaments,

Table 4. Major oxide analyses and CIPW norms for lava flows in the Seaman Range, Nev.

[Analyses normalized to 100 percent (anhydrous); FeO/FeO_T (total iron as FeO) = 0.9; leaders (--), not present]

	Dacite			Andesite			Hornblende andesite					Rhyolite
Sample No.	201374	201375	mean	201404	201492	mean	201359	201377	201384	201395	mean	201435
Chemical analyses, weight percent												
SiO_2	69.44	65.50	67.97±2.08	60.52	54.65	57.59±4.15	58.70	58.73	59.59	53.80	57.71±2.63	75.77
Al_2O_3	14.67	14.97	14.82±0.21	15.70	16.05	15.87±0.25	16.15	15.48	15.53	15.37	15.63±0.35	13.47
Fe_2O_3	.37	.46	0.42±0.07	.75	1.13	0.94±0.27	.88	.79	.75	1.04	0.86±0.13	.13
FeO	3.00	3.76	3.38±0.53	6.05	9.13	7.59±2.17	7.11	6.38	6.10	8.43	7.00±1.04	1.07
MgO	1.15	2.11	1.63±0.68	3.38	4.85	4.11±1.04	3.36	3.62	4.43	6.35	4.44±1.35	.27
CaO	3.83	4.96	4.39±0.80	7.46	7.67	7.56±0.15	7.47	8.95	6.57	9.29	8.07±1.27	.79
Na_2O	3.06	3.10	3.08±0.03	2.63	2.87	2.75±0.17	2.59	2.74	3.00	2.50	2.71±0.22	3.51
K_2O	3.75	3.20	3.48±0.39	1.84	1.73	1.78±0.08	1.89	1.69	2.31	0.84	1.68±0.62	4.96
TiO_2	.48	.61	0.55±0.09	1.11	1.37	1.24±0.19	1.25	1.06	1.24	1.83	1.35±0.34	.04
P_2O_5	.18	.24	0.21±0.04	.45	.41	0.43±0.03	.47	.41	.38	0.37	0.41±0.05	<0.05
MnO	.07	.09	0.08±0.01	.11	.14	0.13±0.02	.14	.14	.09	.17	0.14±0.03	<0.02
LOI	2.02	1.30	1.66±0.51	2.22	.11	1.16±1.49	.96	2.19	.76	.58	1.12±0.73	1.70
CIPW norms, weight percent												
Q	26.39	21.78	24.09	16.22	4.59	10.40	13.46	12.19	11.42	5.63	10.67	33.51
C	--	--	--	--	--	--	--	--	--	--	--	.91
or	22.18	18.90	20.54	10.86	10.21	10.53	11.16	10.00	13.68	4.97	9.95	29.28
ab	25.86	26.19	26.03	22.28	24.33	23.30	21.91	23.14	25.43	21.16	22.91	29.66
an	15.21	17.51	16.36	25.58	25.79	25.69	26.85	24.97	22.06	28.24	25.53	3.93
di	2.15	4.56	3.36	7.00	7.98	7.49	5.98	13.87	6.63	12.63	9.77	--
hy	6.32	8.66	7.49	13.82	21.93	17.87	15.91	11.71	16.48	21.53	16.41	2.45
mt	.54	.67	.61	1.08	1.63	1.36	1.27	1.14	1.09	1.51	1.25	.19
il	.92	1.16	1.04	2.10	2.60	2.35	2.37	2.02	2.35	3.48	2.56	.08
ap	.44	.58	.51	1.08	.96	1.02	1.11	.98	.89	.87	.96	--

Table 5. Trace element data for lava flows in the Seaman Range, Nev.

[All values in parts per million]

	Dacite				Andesite						Hornblende andesite								Rhyolite
Sample No.[1]	373	374	375	mean	404	406	492	501	638	mean	359	377	380	384	395	396	482	mean	435
Rb	140	147	116	134±16	51	85	45	40	41	52± 19	57	47	41	62	41	98	50	57± 20	639
Sr	412	412	513	446±58	918	1,028	824	831	607	842±155	714	909	856	726	566	926	768	781±127	21
Y	22	27	27	25± 3	29	22	26	23	24	25± 3	37	30	35	22	28	25	28	29± 5	114
Zr	167	166	193	175±15	271	187	248	247	194	229± 37	261	253	234	293	228	278	282	261± 25	114
Nb	13	15	13	14± 1	14	8	15	14	10	12± 3	17	13	12	16	15	13	12	14± 2	62
Ba	750	719	719	729±18	633	1,043	729	689	413	701±227	555	622	644	845	356	1,112	685	688±238	31
La	43	35	36	38± 4	46	43	40	45	24	40± 9	40	42	44	54	35	58	46	46± 8	22
Ce	69	62	65	65± 4	88	84	75	85	56	78± 13	84	76	74	109	66	110	94	88± 17	71
Nd	36	36	36	36± –	44	39	38	45	258	85± 97	41	40	41	52	36	48	52	44± 6	39

[1]All sample numbers should be prefixed by 201.

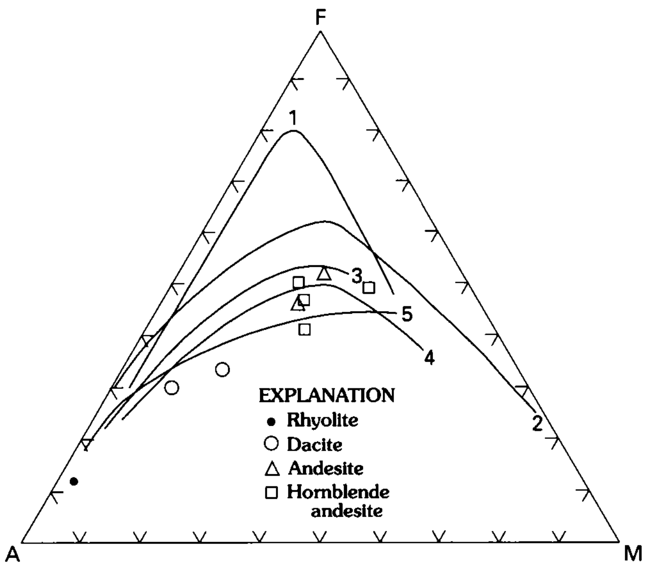


Figure 5. Ternary AFM diagram for lava flows of the Seaman Range, Nev. Trend lines from Irvine and Baragar (1971). 1, Skaergaard tholeiitic; 2, Thingmuli and Hawaii tholeiitic; 3, Hawaii alkaline; 4, Aleutian calc-alkaline; 5, Cascade calc-alkaline.

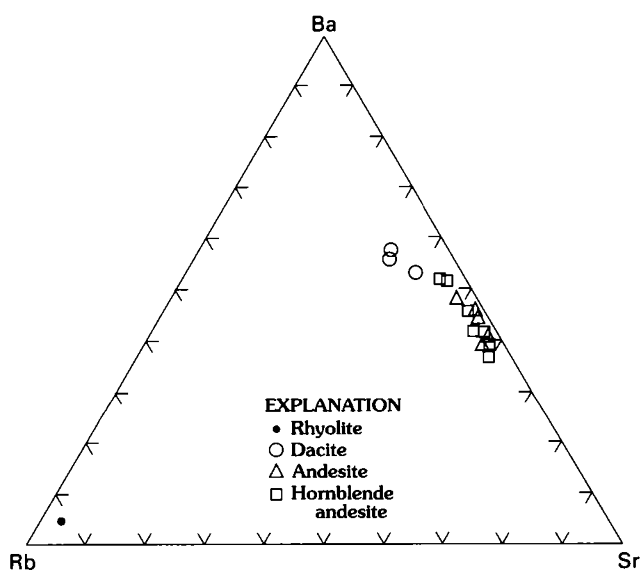


Figure 6. Ternary Ba-Rb-Sr diagram for lava flows of the Seaman Range, Nev.

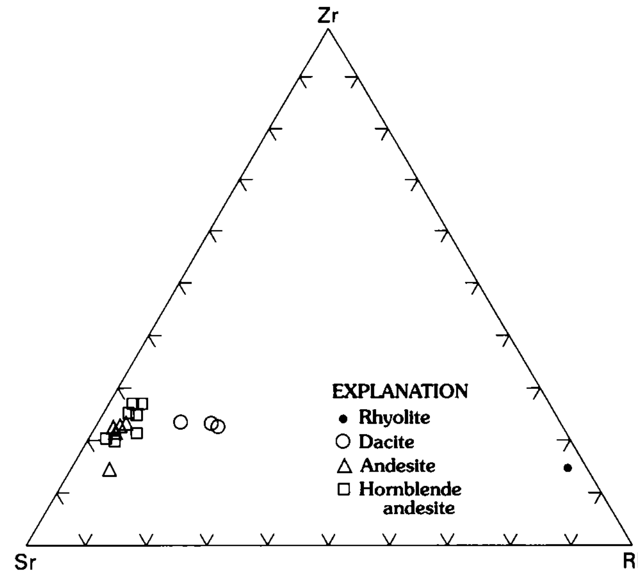


Figure 7. Ternary Zr-Sr-Rb diagram for lava flows of the Seaman Range, Nev.

range-bounding faults, and local faults. Lineaments are large-scale physiographic features, not limited to the Seaman Range. Range-bounding faults are those that bound and (or) traverse the range and project into other ranges. Local faults are defined as those that traverse but do not extend beyond the Seaman Range; these faults are primarily normal faults.

The Timber Mountain and Seaman Pass faults separate three physiographically distinct parts of the Seaman Range. Hereafter, the northern, central, and southern parts of the Seaman Range are referred to as the northern range, central range, and southern range, respectively.

Northern Seaman Range

The northern range, located north of the Timber Mountain fault (fig. 2), consists of several fault blocks. Normal faults that bound these blocks dominantly trend either north or east. Outcrops in the fault blocks are about equally divided between Tertiary volcanic rocks and Paleozoic marine rocks. Directly north of the Timber Mountain fault, the northern range is covered by volcanic rocks that are limited to the upper part of the Lund Formation and the rhyolite tuffs of the Seaman Range. These highly faulted and fractured rocks strike east and have dips from a few degrees to 25°.

Outcrops of Paleozoic carbonate rocks predominate in the north half of the northern range. They consist of the Lower Devonian Sevy Dolomite through the Pennsylvanian Ely Limestone. The northwestern part consists of a 5.6-km (3.5-mi)-long, east-trending block of the Upper Devonian Guilmette Formation through the Mississippian Joana Limestone. The block is characterized by consistent northeast strikes, and 25°–50° NW. dips.

A northern extension of the Prospect fault (fig. 2) was mapped in the northeastern part of the northern range. About 6 km (3.6 mi) north-northwest of Timber Mountain Pass (du Bray and Hurtubise, in press) the Prospect fault is offset by an east-trending, down-to-the-south fault. North of this offset the Prospect fault is a single trace that juxtaposes the Guilmette Formation on the west and the Sevy Dolomite on the east. South of the offset the Prospect fault bifurcates and becomes two strands that enclose a sliver of the Guilmette Formation that separates the footwall Sevy Dolomite on the east from the hanging-wall Joana Limestone on the west. These structural relations indicate that throw along the fault decreases northward. Farther south, about 5 km (3 mi) north-northwest of Timber Mountain Pass, the Prospect fault passes under Tertiary volcanic rocks with no apparent displacement of the Cenozoic cover rocks.

Outcrops of the Pennsylvanian Ely Limestone occur in various parts of the south half of the northern range. This distribution pattern is in contrast to (1) the central range where the limestone crops out in only two isolated areas on the west side of the range and (2) the southern range where none of the Ely is present. Ely outcrops in the northern range are located along the margin of Tertiary volcanic rock cover. This outcrop pattern suggests that the volcanic rocks, which cover much of the south half of the northern range, are contained in a pre-Oligocene east-trending graben block bounded on the south by the Timber Mountain fault. Furthermore, the Ely Limestone is thickest in this area indicating preservation related to the downdropping.

Central Seaman Range

The central range is bounded on the north by the Timber Mountain fault and on the south by the Seaman Pass fault (fig. 2). Paleozoic carbonate rocks, which strike northwest and dip southwest 5°–25° (averaging 15°), dominate the northern part of the central range, and Tertiary volcanic rocks dominate the southern part. One exception to this pattern is the northwest-trending belt of Paleozoic carbonate units that crop out along the north side of the Seaman Pass fault. Exposed carbonate units consist of the Silurian Laketown Dolomite through the Pennsylvanian Ely Limestone. A complete suite of volcanic units is exposed in the central range.

Three fault-bounded blocks recognized in this part of the central range are the Black Cliff, Key Hill, and Timber Mountain blocks (fig. 2). The Black Cliff block is bounded on the north by the Timber Mountain fault and on the south by the County Line fault. Both bounding faults trend east and have down-to-the-north displacement. The west side of the Black Cliff block is cut by the north-trending, down-to-the-west Prospect fault. The Prospect fault juxtaposes the Lower Mississippian Joana Limestone on the west and Upper Devonian Guilmette Formation on the east. The trace of the fault projects southward and is covered by Tertiary volcanic rocks northeast of the Seaman volcanic center (fig. 2).

Several high-angle reverse faults cross the east edge of the Black Cliff block. In the extreme northeastern part of the central range, across a distinct linear fault trace, the Sevy and Laketown Dolomites on the north are faulted against the Simonson Dolomite on the south. Farther to the south just north of the County Line fault, several reverse faults of small displacement juxtapose members of the Simonson, and cut out section. No reverse faults were recognized south of County Line fault.

The Key Hill block is bounded on the west and south by the Key Hill fault and on the east by the range-bounding Pahroc fault. The name Key Hill comes from the profile resembling an old-style key at the top of the highest hill in the block, which is capped by the Joana Limestone. Strikes are consistently northwest, and dips are 5°–15° SW.

The main part of the central range is referred to as the Timber Mountain block. The block is bounded on the north by the County Line fault, on the south by the Seaman Pass fault, and on the northeast by the Key Hill fault. The block, which is topographically high on the north, dips southwestward; Paleozoic rocks project under the Tertiary volcanic rock cover to the south with no apparent offset.

The Timber Mountain block appears to be a relatively undeformed part in the range. The Paleozoic rocks exposed around the edge of the volcanic cover show only minor prevolcanic faulting and relatively minor postvolcanic faulting. The Timber Mountain block forms a broad syncline-like sagging horst block. The Seaman volcanic center is in the core of a large-scale fold defined by the attitude of units to the north and south.

Southern Seaman Range

The southern range is bounded on the north by the Seaman Pass fault and is fringed by outcrops of Paleozoic carbonate rocks on the east, south, and west. The core of the southern range is underlain mainly by Tertiary volcanic rocks, and includes several erosional windows that expose Paleozoic rocks. Paleozoic outcrops consist of the Guilmette Formation through the Joana Limestone. Fossil Peak provides an exception: Paleozoic rocks consist of the Ordovician Pogonip Group through the coarse member of the Simonson Dolomite. The east and west sides of the southern range are topographically high relative to the low-relief core of this region. The southern range is structurally similar to the southernmost part of the central range where strikes and dips are typically northeast and dips average 15° NW.

Fox Mountain

The Fox Mountain area is a 2.4-km (1.5-mi)-wide by 9.6-km (6-mi)-long, northwest-trending exposure of Paleozoic rocks that consists of the uppermost Sevy Dolomite through the Ely Limestone. Fox Mountain is composed of several fault blocks containing a conjugate set of northwest- and northeast-striking normal faults. The older northwest-trending faults downdropped and preserved the Ely Limestone on the east and southwest sides of Fox Mountain proper. The younger northeast-trending faults have considerably less displacement.

Fox Mountain includes a well-exposed block of Devonian units that strike about N. 35° W. and dip 30°–35° SW. Most of Fox Mountain is characterized by relatively consistent strikes and dips within the different fault blocks. The topographic high of Fox Mountain may be related to the history of development of the southern White River Valley. The relatively steep dipping strata on Fox Mountain may indicate that the area was tilted as a result of movement on the North Pahroc fault.

Lineaments

Several east-trending lineaments (fig. 8) have been recognized in Nevada and Utah (Ekren and others, 1977; Rowley and others, 1978; and Rowan and Wetlaufer, 1973, 1981). In southern Nevada, Ekren and others (1976) recognized four distinct lineaments or zones that range from a few kilometers to 25 km (15 mi) wide; the lineaments are indicated by topographic and structural discontinuities and aeromagnetic-trend disruptions. One of these, the Timpahute lineament recognized by Ekren and others (1976), borders the Seaman Range on the south. Rowley and others (1978) used the combination of coincident aeromagnetic trends and mineralized areas to define the 25-km (15.5-mi)-wide east-west Blue Ribbon lineament in western Utah and eastern Nevada. The Silver King lineament, identified during our mapping in the Seaman Range, is the westward extension of the Blue Ribbon lineament; it crosses and structurally disrupts the northern Seaman Range.

Most of the Seaman Range is north of the Timpahute lineament (fig. 8) within the aeromagnetic quiet zone (Stewart and others, 1977) in southeastern Nevada. The east-trending Blue Ribbon and Warm Springs lineaments appear to project along strike into a structurally disrupted part of the northern Seaman Range and Fox Mountain (fig. 8).

The newly identified Silver King lineament, named after Silver King Mountain in the center of the feature, probably links the Warm Springs and Blue Ribbon lineaments through the aeromagnetic quiet zone. The east end of the lineament strikes into the Indian Peaks and White Rock caldera complexes in the Wilson Creek Range, and its west end strikes into the Pancake Range caldera complex. The Silver King lineament is approximately 24 km (15 mi) wide and at least 125 km (78 mi) long and is interpreted as a deep-seated weak crustal zone.

Evidence for this deep-seated crustal structure includes: (1) east-trending strike-slip faulting along what we recognize as its boundaries, (2) north-south extensional deformation of fault blocks, (3) localized secondary dolomitization of Devonian limestone along what are seen as boundary faults, (4) spatially associated large Tertiary caldera complexes (the White Rock–Indian Peaks, Quinn Canyon, and Pancake Range), and (5) Tertiary and Quaternary basalt and andesite flows that seem to have vented from faults logically related to a lineament (for example, andesite exposed along the fault north of Fox Mountain).

In most places throughout its length, the Silver King lineament is associated with relatively low topography (2,225 m or less) and numerous small, east-trending fault blocks, which together contrast with scenarios of higher topography and few, relatively unfaulted large blocks to the north and south. The Silver King lineament is bounded on the north and south by high-angle faults. The southern boundary fault coincides with the Timber Mountain fault, which separates the northern and central parts of the Seaman Range. The northern boundary fault coincides with the high-angle fault on the north side of Gap Mountain, recognized by Kellogg (1964). Both faults appear to extend much farther east and west.

Range-Bounding Faults

These structures include the North Pahroc, Pahroc, Seaman Pass, and Timber Mountain faults (fig. 2). The Pahroc and Seaman Pass faults were previously recognized by Tschanz and Pampeyan (1970). The North Pahroc and Timber Mountain faults were identified during our mapping in the Seaman Range.

North Pahroc Fault (New)

The hypothetical North Pahroc fault is inferred to be a range-bounding fault, or a series of fault segments, on the northeast side of the northern range, where the faulting is entirely concealed. Movement on this fault is inferred because of observed horizontal axis rotation of Paleozoic strata of the Fox Mountain area to steep dips; older normal faults have also been rotated in the dip direction. The fault, however, may be an offset part of the Pahroc fault that was segmented by the Timber Mountain fault (fig. 2). Both the Pahroc and North Pahroc faults appear to have been active at the same time, resulting in development of the southern part of White River Valley.

Pahroc Fault

The Pahroc fault, recognized by Tschanz and Pampeyan (1970), forms the eastern boundary of the central Seaman Range. Although the Pahroc fault is not exposed in this area, we have considerable geologic evidence for its existence. First, at the south end of the eastern range front, about 4 km (2.5 mi) north-northeast of White Rock Spring (du Bray and Hurtubise, in press), exposures of Paleozoic strata are gently folded. The general stratal dip in the central

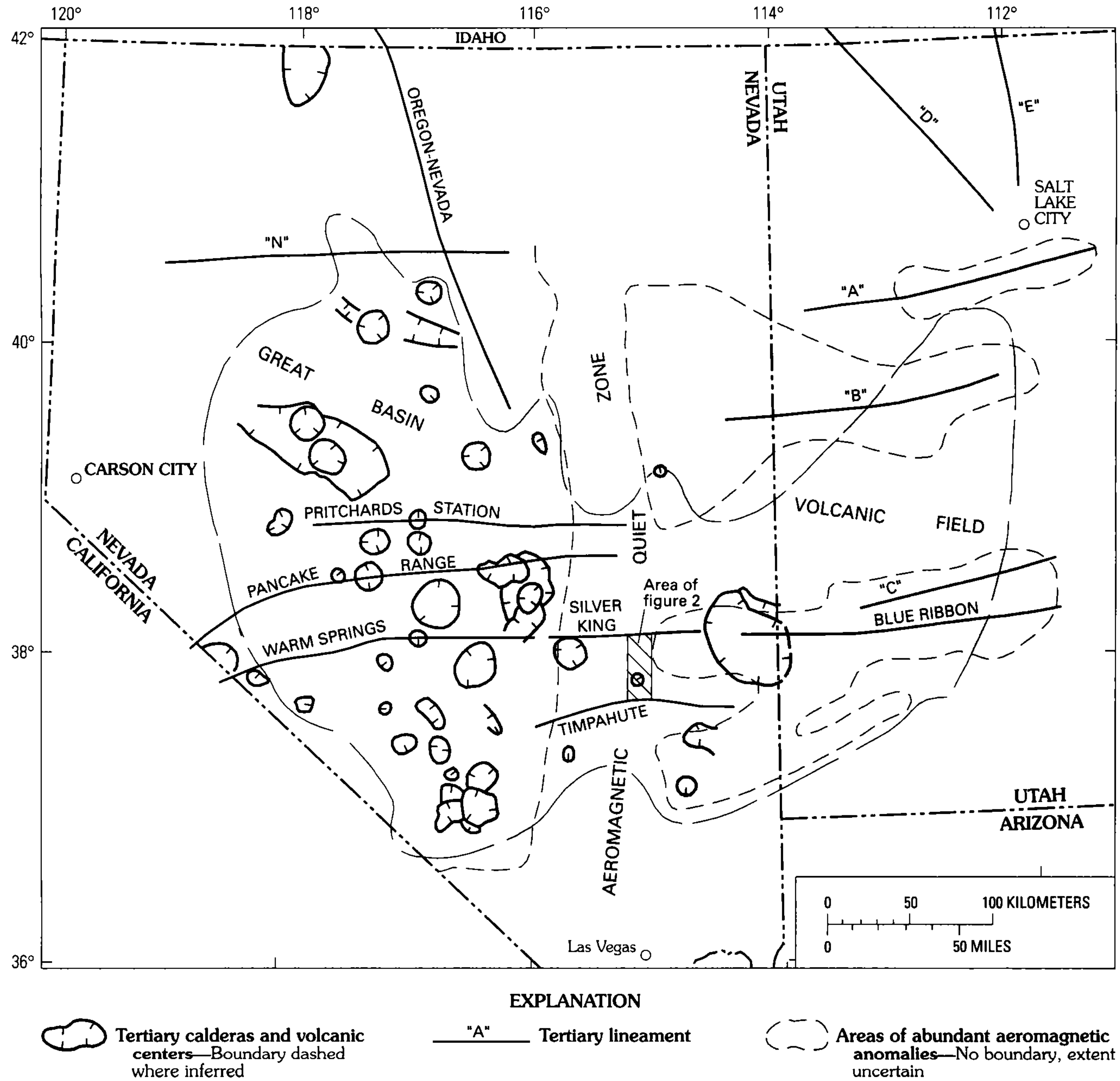


Figure 8. Major lineaments, volcanic centers, and aeromagnetic anomalies in part of the Great Basin region. Lineaments from Fuller (1964), Robinson (1970), Stewart and others (1975), Ekren and others (1976), Mabey and others (1978), and Rowley and others (1978). Igneous features from Albers and Kleinhampl (1970), Burke and McKee (1979), Cook (1965), and Stewart (1980). Aeromagnetic anomalies from Stewart and others (1977), and Mabey and others (1978).

range is 10°–15° SW. On the east side of the range, the strata roll over and dip to the southeast as much as 32°. Second, in the vicinity of the steeper dipping beds, strata within a limestone slide block dip discordantly 43° SE. Third, in the northern Pahroc Range east of the Seaman Range, a continuous north-trending block 22.5 km (14 mi) long is composed of Pennsylvanian and Permian strata that dip 20°–35° W. When projected into a structural profile, these strata suggest 3,600 to 4,300 m of displacement on the Pahroc fault. Ekren and others (1977) indicated that these Paleozoic strata are bounded on the west by a fault that juxtaposes them against Tertiary volcanic rocks exposed to the west.

Seaman Pass Fault

The Seaman Pass fault, recognized by Tschanz and Pampeyan (1970), separates the central and southern parts of the range, and may bound the west side of the central range in Coal Valley (fig. 2). Time of movement (down to the south and west), is mostly or entirely postvolcanic; the presence of the Chainman Shale beneath Tertiary volcanic rocks in the Gulf exploration well in southern Coal Valley (fig. 2) suggests that some downdropping may have occurred prior to volcanism. None of the Chainman crops out under Tertiary volcanic rocks on the northeast side of the fault.

Timber Mountain Fault (New)

The Timber Mountain fault bounds the Black Cliff block on the north, and separates the northern and central parts of the range (fig. 2). The fault is concealed in most places, but lithologic juxtapositions across the trace of the fault at Timber Mountain Pass suggest oblique-slip with left-lateral and down-to-the-north components. The most compelling evidence for left-lateral movement is the apparent displacement of the older (possibly Eocene) north-trending Prospect fault. Furthermore, the contrasting northwest bedding trend of the northern range and the north-northeast bedding trend of the central range imply drag related to left-lateral offset.

Lateral movement along the Timber Mountain fault may also explain the origin of reverse faults on the northeast and east sides of the Black Cliff block. The east-west fault within the northernmost part of the Black Cliff block is probably a splay of the Timber Mountain fault that juxtaposes Silurian and lowermost Devonian rocks on the north against the Middle Devonian Simonson Dolomite on the south. Other relatively minor reverse faults in this area do not clearly relate to the Timber Mountain fault, but may represent structures related to movement on the County Line fault. The absence of reverse faults south of the County Line fault reinforces this interpretation.

Local Faults

Major local faults include the County Line, Key Hill, and Prospect faults. All local faults were identified during our mapping in the Seaman Range; they bound blocks within the three physiographically distinct parts of the range. The Prospect fault, although much older (possibly Eocene) than the other faults, is considered a third-order structure because it does not bound or cut through the range.

County Line Fault (New)

The County Line fault is a N. 70° E.-trending, down-to-the-north normal fault that bounds the south side of the Black Cliff block (fig. 2). The County Line fault cuts the older (prevolcanic) north-trending Prospect fault on the west side of the central range, but no volcanic units are in contact with the fault. An indication of the fault's relatively late development is suggested by its linear trace and lack of displacement by younger faults.

The County Line fault is believed to have developed in response to continued movement along the Timber Mountain fault. The entire north half of the central range is characterized by a 15° tilt to the southwest. This same area is topographically high in contrast to the south half, due to offset along the deep-rooted Timber Mountain fault. The topographically high standing north end of the central range apparently could not be supported over the entire north-south length of the central range. As a result, the central range fragmented, and the Black Cliff part became a separate block that was bounded on the south by the County Line fault.

Key Hill Fault (New)

The Key Hill fault, which bounds the west and south sides of the Key Hill block (fig. 2), is a down-to-the-northeast normal fault that probably developed in response to the intersecting east-trending County Line fault and the north-trending Pahroc fault. The large displacement on both faults reduced lateral support to the northeast and resulted in downdropping the Key Hill block.

Prospect Fault (New)

The Prospect fault trends north both on the west side of the central range and on the east side of the northern range. It is offset by several east-trending faults, most notably by the Timber Mountain fault (fig. 2). In the central range, the Prospect fault extends south beneath volcanic cover (Lund Formation) indicating a prevolcanic (possibly Eocene) age. The presence of the Eocene Sheep Pass Formation in the hanging wall but not in the footwall suggests that deposition of the lime mudstone was controlled in part by the fault. Kellogg (1963) inferred a similar relationship between the Sheep Pass Formation and the Eocene Shingle Pass fault in the southern Egan Range.

The Prospect fault is believed to extend into the northern range for the following reasons: First, there are no other local, down-to-the-west normal faults in the Seaman Range. Second, the fault is covered in the southern part of the northern range by volcanic units of the Needles Range Group, indicating that the fault is prevolcanic as it is in the central range. Third, most of the same units are offset by the fault in the central and northern parts of the range, but more importantly, they have similar offsets.

Structural History

Phanerozoic sedimentation persisted through Triassic time in the Great Basin (Armstrong, 1968; Stewart, 1980) with little or no significant structural deformation in the

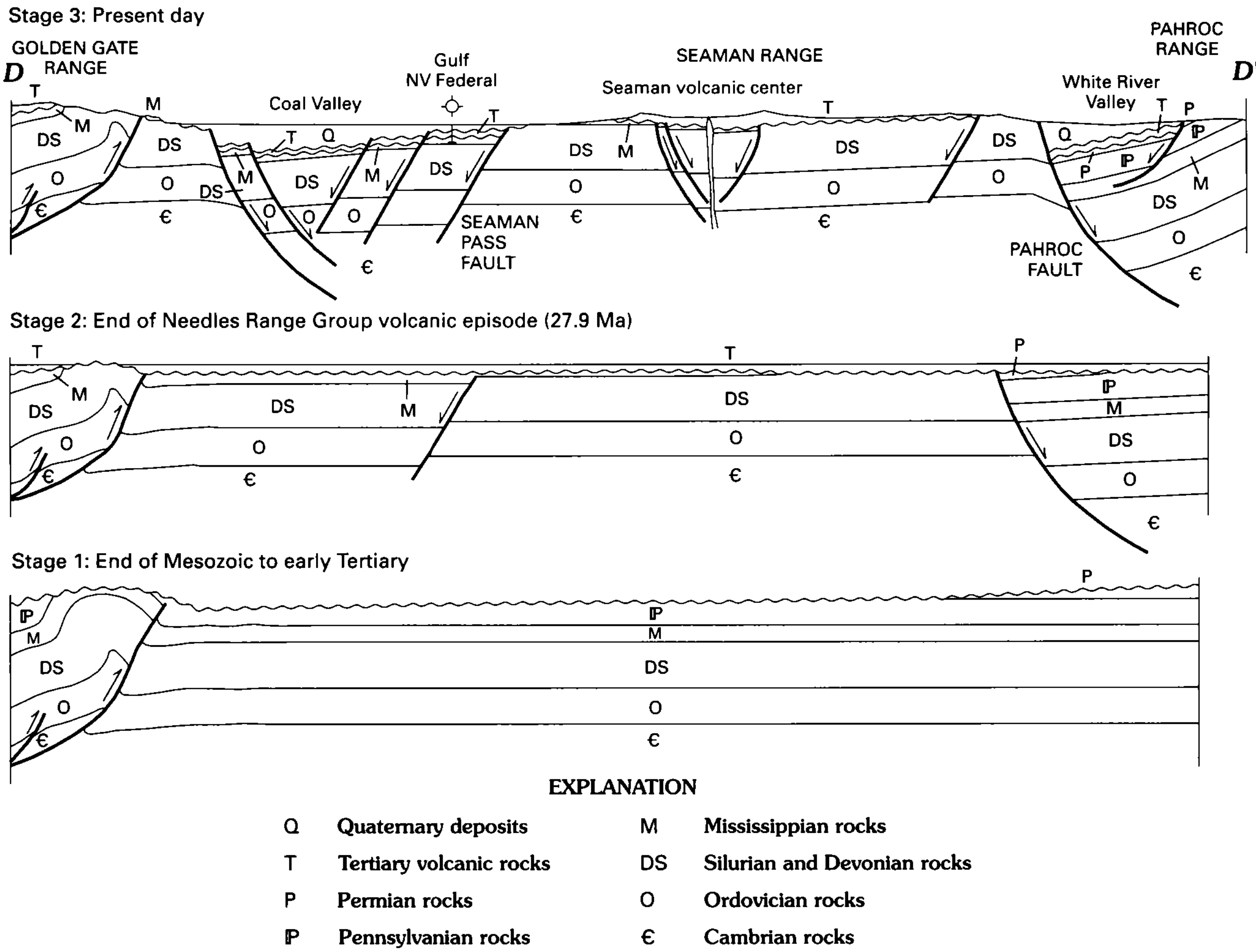


Figure 9. Schematic structural history profile *D–D′* of the central Seaman Range. Heavy line, fault; barbs show direction of relative movement. See figure 2 for location of profile.

vicinity of the Seaman Range. No record of post-Triassic sedimentation is preserved in the immediate area, but regional patterns suggest that some Jurassic and Cretaceous strata may have been deposited. North-trending thrust faults related to the Late Cretaceous Sevier fold-and-thrust belt have been reported in western Lincoln County south and west of the Seaman Range (Armstrong, 1968; Tschanz and Pampeyan, 1970) (fig. 1).

Deformation in the vicinity of the Seaman Range probably began in the Cretaceous with thrusting in western Lincoln County. In the southern Golden Gate Range, a fault-propagated fold marks the northern terminus of the Pahranagat fold-and-thrust belt (Tschanz and Pampeyan, 1970) (fig. 2). No thrusting has been reported or observed in the Seaman Range. Armstrong (1968, pl. 1) reported an extensional "thrust" feature involving Pennsylvanian strata in the upper plate of an inferred low-angle fault in the northern Seaman Range (fig. 1); however, we found no evidence to support Armstrong's postulated feature.

The structural history of the Seaman Range can be divided into three episodes: prevolcanic, synvolcanic, and postvolcanic. These episodes are illustrated by a set of schematic cross sections through the southern Seaman Range extending from the south end of the Golden Gate Range to the Pahroc Range (figs. 2 and 9; profile *D–D′*).

Prevolcanic Phase

Prevolcanic fault movement in the Seaman Range and vicinity was initially recognized during a compilation of paleo-outcrops on the middle Oligocene unconformity (Hurtubise, 1990). Prevolcanic fault movement, though greatest along the Timber Mountain Pass and Pahroc faults, was not limited to those structures (fig. 9, stages 1 and 2). Taylor and others (1989) have recognized significant prevolcanic deformation east of the Seaman Range but suggested (incorrectly) that prevolcanic deformation within the Seaman Range was minimal. Early movement may also have occurred along a segment of the Seaman Pass fault. In Coal Valley, the Gulf "EU" Federal Nevada well (fig. 2) penetrated the Mississippian Chainman Shale on the west side of the Seaman Pass fault, whereas none of the Chainman is present in the range to the northeast. The youngest stratigraphic unit exposed nearby in the Seaman Range is the lower part of the Joana Limestone. Movement may, however, have been on another concealed fault that passes between the exploratory well and the range. If prevolcanic movement did occur on the Seaman Pass fault, it was relatively minor as illustrated in stage 2 of figure 9.

The Prospect fault also had prevolcanic movement. The presence of the Sheep Pass Formation unconformably on Mississippian rocks in the hanging wall suggests that movement on the fault may have predated Sheep Pass deposition. The fault may represent part of a border fault system on the east side of the Eocene Sheep Pass basin. In the Egan Range, Kellogg (1963) found the thickest section of the Sheep Pass on the downthrown side (west side) of the Shingle Pass fault. There the Sheep Pass contains large boulders of Paleozoic rocks eroded from the upthrown block. Although no conglomerate was found below the limestone unit of the Sheep Pass in the Seaman Range, there is no evidence of Sheep Pass deposition east of the Prospect fault.

Prevolcanic faulting along Seaman Wash in the Seaman Range is also apparent: along the north side of the wash, observed faults below the volcanic rock cover do not displace the cover rocks. The offsets, however, are relatively minor. Additional prevolcanic faulting is suggested by the presence of conglomeratic gravels in fault-controlled drainages north of Fossil Peak. Again, we believe these offsets to be minor because the conglomeratic outcrops are few, small, and thin, and Paleozoic rock clasts are of a few types derived from nearby sources.

Synvolcanic Phase

Taylor and others (1989) presented evidence for synvolcanic faulting in the North Pahroc Range, but evidence of significant synvolcanic deformation in the Seaman Range is limited. In the Seaman Range, no angular discordances between successive ash-flow units were noted. Sedimentary deposits between these units and (or) structures that truncate some ash-flow units and are overlapped by younger units have been recognized in a very few places.

Volumetrically minor, areally restricted limestone occurring between volcanic units north and west of Fossil Peak suggests that some synvolcanic deformation occurred. Cook (1965, p. 53) reported lacustrine white limestone and limestone conglomerate overlying the Needles Range Group at White River Narrows. Those limestone outcrops suggest the possibility that synvolcanic faulting exposed Paleozoic carbonate units that supplied the calcium carbonate deposited in lake basins. Alternatively, relief on some prevolcanic paleohills may have been sufficient to maintain island-like exposures of Paleozoic rocks above the ash flows of the Needles Range Group (fig. 9, stage 3). Cook (1965) suggested that deposition of the Needles Range Group was unimpeded and that Needles Range ash-flow tuffs form a relatively uniform cover over the central range (fig. 9, stage 3).

The lowest exposed lava flows of the Seaman volcanic center are topographically below older rocks of the Lund Formation as well as the Paleozoic-Tertiary unconformity. Consequently, evolution of the Seaman volcanic center must have been accompanied by some synvolcanic structural subsidence. This synvolcanic faulting is probably directly related to withdrawal and eruption of magma from the chamber responsible for development of the Seaman volcanic center and is not related to regional deformation.

Postvolcanic Phase

Postvolcanic structures are common throughout the range. Later movement occurred along the Timber Mountain and Pahroc faults (fig. 9, stage 3). The Seaman Pass fault either developed at this time or was rejuvenated with much-increased offset (fig. 9, stage 3). Numerous basin and range faults displaced Tertiary volcanic units along the range fronts, resulting in the present-day topography.

REFERENCES CITED

Albers, J.P., and Kleinhampl, F.J., 1970, Spatial relation of mineral deposits to Tertiary volcanic centers in Nevada: U.S. Geological Survey Professional Paper 700–C, p. C1–C10.

Anderson, J.J., and Rowley, P.D., 1975, Cenozoic stratigraphy of southwestern High Plateaus of Utah, *in* Anderson, J.J., Rowley, P.D., Fleck, R.J., and Nairn, A.E.M., Cenozoic geology of southwestern High Plateaus of Utah: Geological Society of America Special Paper 160, p. 1–52.

Armstrong, R.L., 1968, Sevier orogenic belt in Nevada and Utah: Geological Society of America Bulletin, v. 79, p. 429–458.

______ 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range Province, western Utah, eastern Nevada, and vicinity, U.S.A.: Geochimica et Cosmochimica Acta, v. 34, p. 203–232.

Best, M.G., 1988, Easterly trending Oligocene to early Miocene (30–20 Ma) paleotopography and other geologic features, southeastern Great Basin: Geological Society of America Abstracts with Programs, v. 20, no. 3, p. 143.

Best, M.G., Christiansen, E.H., and Blank, H.R., Jr., 1989, Oligocene caldera complex and calc-alkaline tuffs and lavas of the Indian Peak volcanic field, Nevada and Utah: Geological Society of America Bulletin, v. 101, p. 1076–1090.

Best, M.G, Christiansen, E.H., Deino, A.L., Grommé, C.S., McKee, E.H., and Noble, D.C., 1989, Excursion 3A—Eocene through Miocene volcanism in the Great Basin of the western United States, *in* Chapin, C.E., and Zidek, J., eds., Field excursions to volcanic terranes in the Western United States, Volume II—Cascades and Intermountain West: New Mexico Bureau of Mines and Mineral Resources Memoir 47, p. 91–133.

Best, M.G., and Grant, S.K., 1987, Stratigraphy of the volcanic Oligocene Needles Range Group in southwestern Utah and eastern Nevada: U.S. Geological Survey Professional Paper 1433–A, 28 p.

Blank, H.R., Jr., 1959, Geology of the Bull Valley district, Washington County, Utah: Seattle, Wash., University of Washington Ph. D. thesis, 177 p.

Budge, D.R., and Sheehan, P.M., 1980a, The Upper Ordovician and Silurian of the eastern Great Basin—Part 1, Introduction: Milwaukee Public Museum Contributions to Biology and Geology 28, 26 p.

_____ 1980b, The Upper Ordovician and Silurian of the eastern Great Basin—Part 2, Lithologic descriptions: Milwaukee Public Museum Contributions to Biology and Geology 29, 80 p.

Burke, D.B., and McKee, E.H., 1979, Mid-Cenozoic volcano-tectonic troughs in central Nevada: Geological Society of America Bulletin, v. 90, p. 181–184.

Chilingar, G.V., and Bissell, H.J., 1957, Mississippian Joana Limestone of Cordilleran miogeosyncline and use of Ca/Mg ratio in correlation: American Association of Petroleum Geologists Bulletin, v. 41, p. 2257–2274.

Collinson, J.W., and Hasenmueller, W.A., 1978, Early Triassic paleogeography and biostratigraphy of the Cordilleran miogeosyncline, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the Western United States: Pacific Coast Paleogeography Symposium 2, p. 175–187.

Cook, E.F., 1960, Great Basin ignimbrites—Guidebook to geology of east-central Nevada: Intermountain Association of Petroleum Geologists, 11th Annual Field Conference, p. 134–141.

_____ 1965, Stratigraphy of Tertiary volcanic rocks in eastern Nevada: Nevada Bureau of Mines Report 11, 61 p.

Deino, A.L., and Best, M.G., 1988, Use of high-precision single crystals $^{40}Ar/^{39}Ar$ ages and TRM data in correlation of an ash-flow deposit in the Great Basin: Geological Society of America Abstracts with Programs, v. 20, no. 7, p. A397.

Dolgoff, A., 1963, Volcanic stratigraphy of the Pahranagat area, Lincoln County, southeastern Nevada: Geological Society of America Bulletin, v. 74, p. 875–900.

du Bray, E.A., and Hurtubise, D.O., in press, Geologic map of the Seaman Range, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I–2282, scale 1:50,000.

Ekren, E.B., Anderson, R.E., Rogers, C.L., and Noble, D.C., 1971, Geology of northern Nellis Air Force Base bombing and gunnery range, Nye County, Nevada: U.S. Geological Survey Professional paper 651, 91 p.

Ekren, E.B., Bucknam, R.C., Carr, W.J., Dixon, G.L., and Quinlivan, W.D., 1976, East-trending structural lineaments in central Nevada: U.S. Geological Survey Professional Paper 986, 16 p.

Ekren, E.B., Orkild, P.P., Sargent, K.A., and Dixon, G.L., 1977, Geologic map of Tertiary rocks, Lincoln County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I–1041, scale 1:250,000.

Ekren, E.B., Rogers, C.L., Anderson, R.E., and Botinelly, Theodore, 1967, Geologic map of the Belted Peak quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ–606, scale 1:62,500.

Emry, R. J., and Korth, W.W., 1989, Rodents of the Bridgerian (Middle Eocene) Elderberry Canyon local fauna of eastern Nevada: Smithsonian Contributions to Paleobiology 67, 14 p.

Fouch, T.D., 1979, Character and paleogeographic distribution of Upper Cretaceous(?) and Paleogene nonmarine sedimentary rocks in east-central Nevada, *in* Armentrout, J.M., Cole, M.R., and TerBest, Harry, eds., Cenozoic paleogeography of the Western United States: Pacific Coast Paleogeography Symposium 3, p. 97–111.

Fouch, T.D., Lund, Karen, Schmitt, J.G., Good, S.C., and Hanley, J.H., in press, Late Cretaceous(?) and Paleogene sedimentary rocks and extensional? basins in the region of the Egan and Grant Ranges, and White River and Railroad Valleys, Nevada—Their relation to Sevier and Laramide contractional basins in the southern Rocky Mountains and Colorado Plateau: Nevada Petroleum Society 1991 Guidebook to the geology of east-central Nevada.

Fuller, M.D., 1964, Expression of E–W fractures in magnetic surveys in parts of the U.S.A.: Geophysics, v. 29, p. 602–622.

Hurtubise, D.O., 1990, Stratigraphy and structure of the Seaman Range, Nevada, with an emphasis on the Devonian system: Golden, Colo., Colorado School of Mines Ph. D. thesis, 443 p.

Irvine, T.N., and Baragar, W.R.A., 1971, A guide to the chemical classification of the common volcanic rocks: Canadian Journal of Earth Sciences, v. 8, p. 523–548.

Johnson, J.G., Reso, A., and Stephens, M., 1969, Late Upper Devonian brachiopods from the West Range Limestone of Nevada: Journal of Paleontology, v. 43, p. 1351–1368.

Johnson, J.G., Sandberg, C.A., and Poole, F.G., 1988, Early and Middle Devonian paleogeography of Western United States, *in* McMillan, N.J., and Glass, D.J., eds., Devonian of the world: Calgary, Canadian Society of Petroleum Geology Memoir 14, v. 1, p. 161–182.

Kellogg, H.E., 1963, Paleozoic stratigraphy of the southern Egan Range, Nevada: Geological Society of America Bulletin, v. 74, p. 685–708.

_____ 1964, Cenozoic stratigraphy and structure of the southern Egan Range, Nevada: Geological Society of America Bulletin, v. 75, p. 949–968.

Kleinhampl, F.J., and Ziony, J.I., 1985, Geology of northern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 99A, 172 p.

Langenheim, R.L., Jr., 1960a, The Pilot Shale, the West Range Limestone, and the Devonian-Mississippian boundary in eastern Nevada: Illinois State Academy of Science Transaction, v. 53, p. 122–131.

_____ 1960b, Early and Middle Mississippian stratigraphy of the Ely area, *in* Boettcher, J.W., and Sloan, W.W., eds., Guidebook to geology of east-central Nevada: Intermountain Association of Petroleum Geologists, 11th Annual Field Conference, p. 72–80.

Lawson, A.C., 1906, The copper deposits of the Robinson mining district, Nevada: California University Department of Geology Bulletin, v. 4, p. 287–357.
Le Bas, M.J., Le Maitre, R.W., Streckeisen, A., and Zannetin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, p. 745–750.
Longwell, C.R., Pampeyan, E.H., Bowyer, D., and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 218 p.
Mabey, D.R., Zietz, Isidore, Eaton, G.P., and Kleinkopf, M.D., 1978, Regional magnetic patterns in part of the Cordillera in the western United States, *in* Smith, R.B., and Eaton, G.P., eds., Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 93–106.
Merriam, C.W., 1940, Devonian stratigraphy and paleontology of the Roberts Mountains region, Nevada: Geological Society of America Special Paper 25, 114 p.
Nolan, T.B., 1935, The Gold Hill mining district, Utah: U.S. Geological Survey Professional Paper 177, 77 p.
Osmond, J.C., 1954, Dolomites in Silurian and Devonian of east-central Nevada: American Association of Petroleum Geologists Bulletin, v. 38, p. 1911–1956.
______ 1962, Stratigraphy of Devonian Sevy Dolomite in Utah and Nevada: American Association of Petroleum Geologists Bulletin, v. 46, p. 2033–2056.
Poole, F.G., and Claypool, G.E., 1984, Petroleum source rock potential and crude-oil correlation in the Great Basin, *in* Woodward, Jane, Meissner, F.F., and Clayton, J.L., eds., Hydrocarbon source rocks of the Greater Rocky Mountain region: Rocky Mountain Association of Geologists, p. 179–229.
Poole, F.G., and Sandberg, C.A., 1977, Mississippian paleogeography and tectonics of the Western United States, *in* Stewart, J.H., Stevens, C.H., and Fritsche, A.E., eds., Paleozoic paleogeography of the Western United States: Pacific Coast Paleogeography Symposium 1, p. 67–85.
Poole, F.G., Sandberg, C.A., and Boucot, A.J., 1977, Silurian and Devonian paleogeography of the Western United States, *in* Stewart, J.H., Stevens, C.H., and Fritsche, A.E., eds., Paleozoic paleogeography of the Western United States: Pacific Coast Paleogeography Symposium 1, p. 39–65.
Poole, F.G., Stewart, J.H., Palmer, A.R., Sandberg, C.A., Madrid, R.J., Ross, R.J., Jr., Hintze, L.F., Miller, M.M., and Wrucke, C.T., in press, Latest Precambrian to latest Devonian time—Development of a continental margin, *in* Burchfiel, B.C., Lipman, P.W., and Zoback, M.L., eds., The Cordilleran Orogen—Conterminous U.S.: Boulder, Colo., Geological Society of America, The Geology of North America, v. G–3.
Reso, Anthony, 1963, Composite columnar section of exposed Paleozoic and Cenozoic rocks in the Pahranagat Range, Lincoln County, Nevada: Geological Society of America Bulletin, v. 74, p. 901–918.
Robinson, E.S., 1970, Relations between geological structure and aeromagnetic anomalies in central Nevada: Geological Society of America Bulletin, v. 81, p. 2045–2060.
Rowan, L.C., and Wetlaufer, P.H., 1973, Structural geologic analysis of Nevada using ERTS–1 images—A preliminary report, *in* Freden, S.C., Mercanti, E.P., and Becker, M.A., eds., Symposium on significant results obtained from Earth Resources Technology Satellite, volume 1: Technical Presentations, Section A, NASA, paper G20, p. 413–423.
______ 1981, Relation between regional lineament systems and structural zones in Nevada: American Association of Petroleum Geologists Bulletin, v. 65, p. 1414–1432.
Rowley, P.D., Lipman, P.W., Mehnert, H.H., Lindsey, D.A., and Anderson, J.J., 1978, Blue Ribbon lineament, an east-trending structural zone within the Pioche mineral belt of southwestern Utah and eastern Nevada: U.S. Geological Survey Journal of Research, v. 6, no. 2, p. 175–192.
Rush, R.W., 1956, Silurian rocks of western Millard County, Utah: Utah Geological and Mineralogical Survey Bulletin 53, 66 p.
Sargent, K.A., and Houser, F.N., 1970, The Shingle Pass Tuff of central Nevada: Geological Society of America Abstracts with Programs, v. 2, no. 2, p. 140–141.
Snyder, R.P., Ekren, E.B., and Dixon, G.L., 1972, Geologic map of the Lunar Crater quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I–700, scale 1:48,000.
Steiger, R.H., and Jäger, Emile, 1977, Subcommission on geochronology—Convention on the use of decay constants in geo- and cosmology: Earth and Planetary Science Letters, v. 36, p. 359–362.
Stewart, J.H., 1978, Basin and range structure in western North America—A review, *in* Smith, R.B., and Eaton, G.P., eds., Cenozoic tectonics and regional geophysics of the western Cordillera: Geological Society of America Memoir 152, p. 1–31.
______ 1980, Geology of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.
Stewart, J.H., Moore, W.J., and Zietz, Isidore, 1977, East-west patterns of Cenozoic igneous rocks, aeromagnetic anomalies, and mineral deposits, Nevada and Utah: Geological Society of America Bulletin, v. 88, p. 67–77.
Stewart, J.H., Walker, G.W., and Kleinhampl, F.J., 1975, Oregon-Nevada lineament: Geology, v. 3, p. 265–268.
Taggart, J.E., Lindsay, J.R., Scott, B.A., Vivit, D.V., Bartel, A.J., and Stewart, K.C., 1987, Analysis of geologic materials by X-ray fluorescence spectrometry, Chapter E *in* Baedecker, P.A., ed., Methods for geochemical analysis: U.S. Geological Survey Bulletin 1770, p. E1–E19.
Taylor, W.J., Bartley, J.M., Lux, D.R., and Axen, G.J., 1989, Timing of Tertiary extension in the Railroad Valley-Pioche transect, Nevada—Constraints from $^{40}Ar/^{39}Ar$ ages of volcanic rocks: Journal of Geophysical Research, v. 94, p. 7757–7774.
Tschanz, C.M., 1960, Geology of northern Lincoln County, Nevada, *in* Boettcher, J.W., and Sloan, W.W., eds., Guidebook to geology of east-central Nevada: Intermountain Association of Petroleum Geologists, 11th Annual Field Conference, p. 198–208.
Tschanz, C.M., and Pampeyan, E.H., 1970, Geology and mineral deposits of Lincoln County, Nevada: Nevada Bureau of Mines and Geology Bulletin 73, 188 p.

U.S. Geological Survey, 1976, Aeromagnetic map for parts of Caliente and Lund 1 degree by 2 degree quadrangles, Nevada: U.S. Geological Survey Open-File Report 76–364.

Westgate, L.G., and Knopf, A., 1932, Geology and ore deposits of the Pioche district, Nevada: U.S. Geological Survey Professional Paper 171, 79 p.

Williams, P.L., 1967a, Stratigraphy and petrography of the Quichapa Group, southwestern Utah and southeastern Nevada: Seattle, Wash., University of Washington Ph. D. thesis, 139 p.

_____ 1967b, Stratigraphy and petrography of the Quichapa Group, southwestern Utah and southeastern Nevada: Dissertation Abstracts sec. B, v. 28, no. 5, p. 2003–B.

Willis, J.B., Best, M.G., Kowallis, B.J., and Best, V.C., 1987, Preliminary geologic map of northern Wilson Creek Range, Lincoln County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF–1971.

Winfrey, W.M., Jr., 1958, Stratigraphy, correlation, and oil potential of the Sheep Pass Formation, east-central Nevada: American Association of Petroleum Geologists, Rocky Mountain Section, Geological Record, p. 77–82.

_____ 1960, Stratigraphy, correlation, and oil potential of the Sheep Pass Formation, east-central Nevada, *in* Boettcher, J.W., and Sloan, W.W., eds., Guidebook to geology of east-central Nevada: Intermountain Association of Petroleum Geologists, 11th Annual Field Conference, p. 126–133.

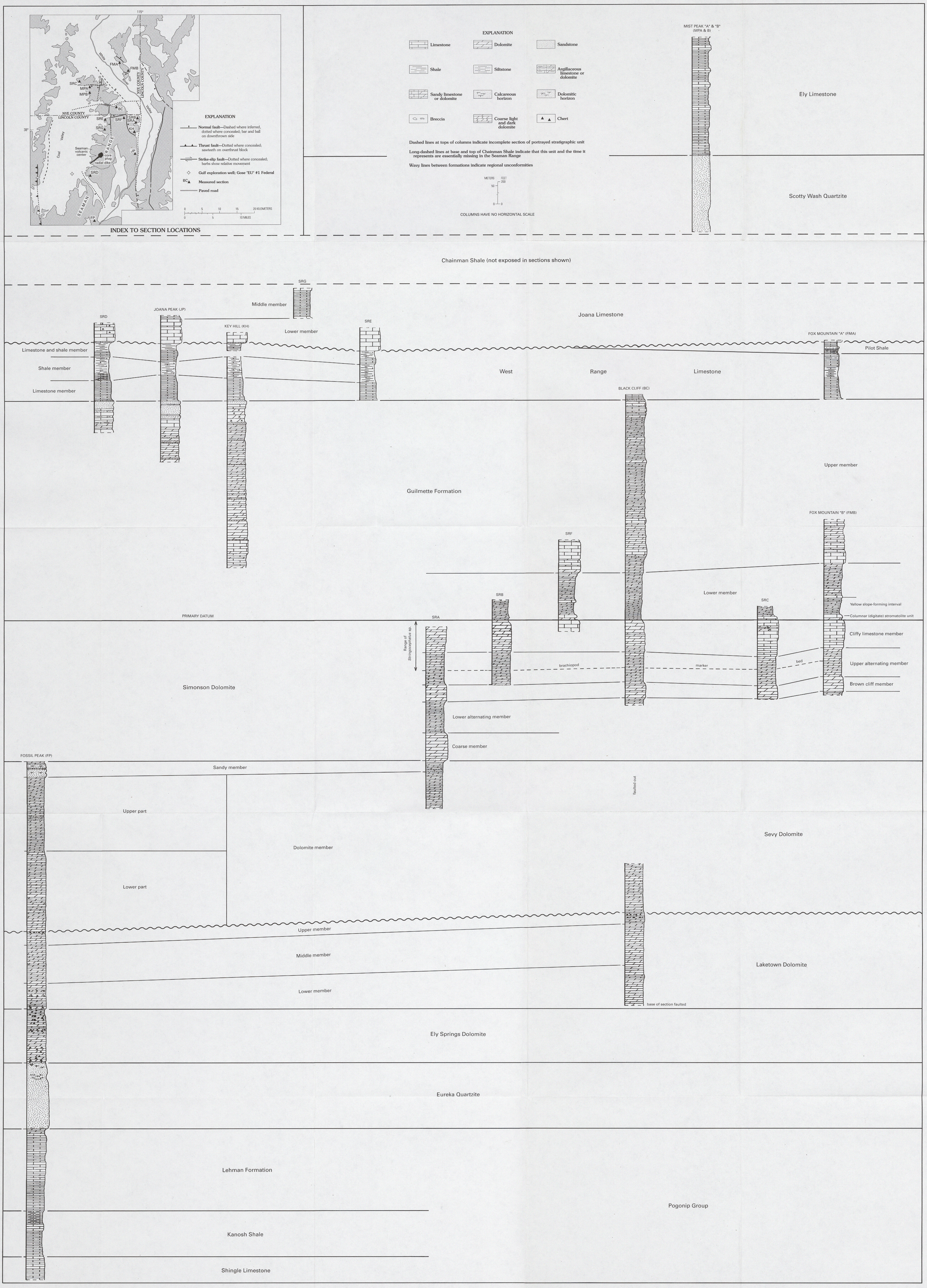
Zoback, M.L., Anderson, R.E., and Thompson, G.A., 1981, Cainozoic evolution of the state of stress and style of tectonism of the Basin and Range province of the Western United States: Royal Society of London Philosophical Transactions, A300, p. 407–434.

This book was prepared in USGS Central Region, Denver, CO

Typesetting by Marie F. Melone and Joan G. Nadeau
Illustration preparation by Roger Highland
Edited by Lorna Carter

☆U.S. GOVERNMENT PRINTING OFFICE: 1992-673-049/46053

BULLETIN 1988–B
PLATE 1



STRATIGRAPHIC CORRELATION CHART FOR MEASURED SECTIONS IN THE SEAMAN RANGE AND FOX MOUNTAIN AREA, LINCOLN AND NYE COUNTIES, NEVADA

By

Donlon O. Hurtubise and Edward A. du Bray

1992

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Hurtubise and du Bray—SEAMAN RANGE AND FOX MOUNTAIN, NEVADA—U.S. Geological Survey Bulletin