

Base from U.S. Geological Survey, Lucin 4 SW Quadrangle 1983

SCALE 1:24 000

CONTOUR INTERVAL 5 AND 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

UTM GRID AND 1990 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

4.4' 14° 57' 249 MILS

1 1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 5 1 KILOMETER

20 ft. contours

UTAH

QUADRANGLE LOCATION

Field mapping by author 1982-1988; assisted by Mary Johnson, 1982; and Sharon Gusa, 1985. Patricia H. Speranza, Cartographer

GEOLOGIC MAP OF THE LUCIN 4 SW QUADRANGLE, BOX ELDER COUNTY, UTAH

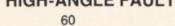
by
David M. Miller
U.S. Geological Survey
1990

MAP SYMBOLS

CONTACT

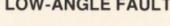
Dashed where gradational; dotted where covered

HIGH-ANGLE FAULT

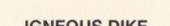


Dashed where location inferred; dotted where covered; bar and ball on downthrown side; dip indicated

LOW-ANGLE FAULT



IGNEOUS DIKE



STRIKE AND DIP OF BEDDING



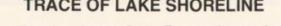
STRIKE AND DIP OF FOLIATION



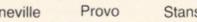
TREND AND PLUNGE OF LINEATION



TRACE OF LAKE SHORELINE



Bonneville Provo Stansbury



Pilot Valley Gilbert

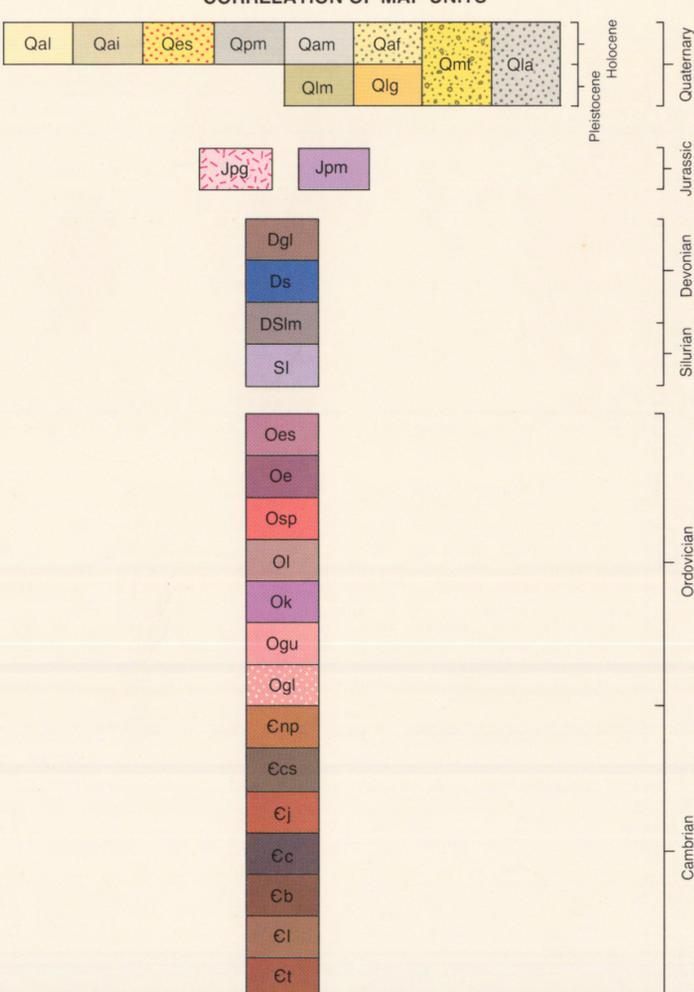
LOCATION OF GEOCHRONOLOGY SAMPLE



LOCATION OF PALEONTOLOGY SAMPLE



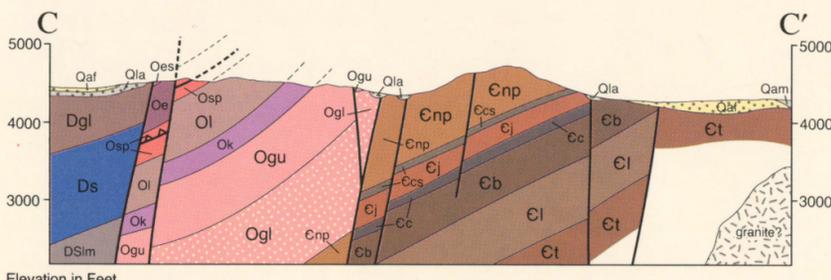
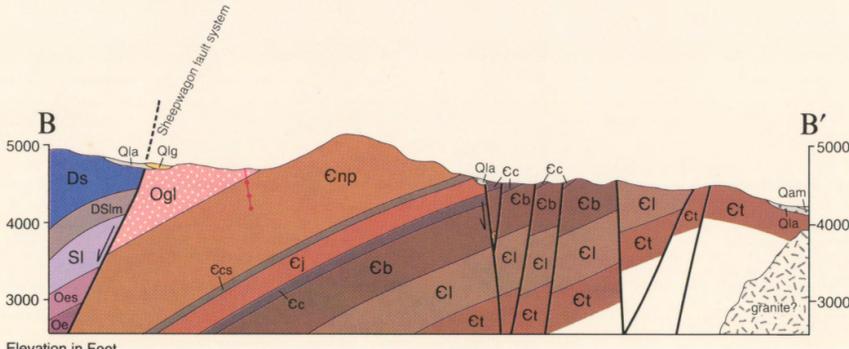
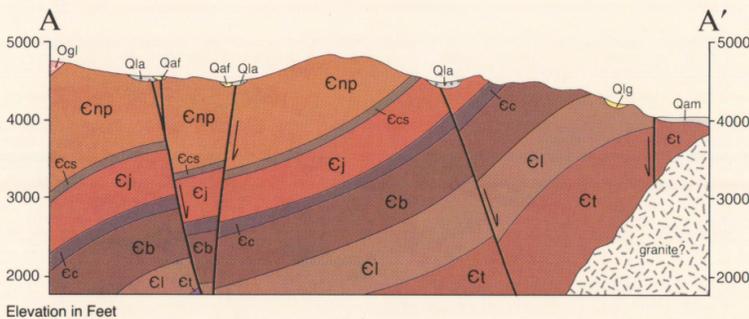
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

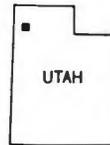
- Qal** Alluvium (Holocene)—Unconsolidated cobble- and pebble-gravel, sand, and silt deposited within ephemeral stream channels; predominantly fine sand, silt, and clay deposits on playa flats.
- Qai** Alluvial silt (Holocene)—Thin sheets of unconsolidated, poorly sorted, tan silt with subordinate fine sand and clay. Deposited by streams and sheet floods along margins of playas; gradational into alluvial mud (Qam) and playa mud (Qpm).
- Qes** Eolian sand (Holocene)—Unconsolidated, brown sand overlying lacustrine, alluvial, and playa deposits. Quartz, feldspar, ooids, and lithic fragments are primary constituents.
- Qpm** Playa mud (Holocene)—White to tan mud, silt, and halite; plastic consistency; underlies nearly flat expanses east of Crater Island.
- Qam** Alluvial mud (Holocene)—Tan to brown mud, silt, and sand deposited along floodplains and in distal parts of alluvial drainage systems. Generally gradational into playa mud (Qpm).
- Qaf** Alluvial fan deposits (Holocene and Pleistocene?)—Unconsolidated, poorly sorted cobble- and pebble-gravel, sand, and silt. Deposited as alluvial cones at flanks of mountains and as piedmonts of coalesced alluvial fans at elevations closer to playa flats.
- Qmf** Mass-movement talus (Holocene and Pleistocene)—Blocky, boulder to cobble deposits on steep slopes.
- Qla** Lacustrine and alluvial deposits, undivided (Holocene and Pleistocene)—Varied, complexly interlayered, deposits with lacustrine and alluvial origins.
- Qlm** Lacustrine marl (Pleistocene)—White and buff, unconsolidated marl, clay, and silt; bears gastropods and ostracods in many locations. Locally includes thin overlying gravel.
- Qlg** Lacustrine gravel (Pleistocene)—Moderately to well-sorted, pebble, cobble, and sand deposits, with sand and silt matrix. Ranges from unconsolidated to strongly cemented; in places cemented by tufa.
- Jpg** Porphyritic granodiorite (Jurassic)—Light-gray, porphyritic, biotite granodiorite and monzogranite forming light-brown, rounded outcrops.
- Jpm** Porphyritic monzogranite (Jurassic)—Medium-gray, medium- to coarse-grained, subequigranular to porphyritic biotite monzogranite and finer grained granite in extensive dike swarm north of pluton.
- Dgl** Guilmette Formation (Devonian)—Thick-bedded, black limestone. (Only lower member of the formation present). (Cross section only.)
- Ds** Simonson Dolomite (Devonian)—Laminated dolomite consisting of black and light-gray units interlayered on 1.8- to 6-meter (6-20 ft) scale. Forms ledgy slopes with alternating light and dark colors.
- DSIm** Lone Mountain Dolomite (Devonian and Silurian)—Light-gray to buff coarse-grained, thick-bedded to massive dolomite. Characteristically laminated or mottled.
- SI** Laketown Dolomite (Silurian)—Thick-bedded, mottled dolomite with abundant chert in lower part. (Cross section only.)
- Oes** Ely Springs Dolomite (Ordovician)—Black, medium- to thick-bedded dolomite. Upper part mottled. Cliff former.
- Oe** Eureka Quartzite (Ordovician)—White, well-sorted, medium-bedded orthoquartzite. Generally weathers to orange-brown patinae. Forms prominent pale-colored cliffs.
- Osp** Swan Peak Quartzite (Ordovician)—Unit in this area consists of strata correlative with the middle part of the formation exposed at the type locality in northeastern Utah. Here, consists of interlayered brown dolomite, gray silty limestone, brown sandy dolomite, and dolomitic quartzite. Unit is lithologically heterogeneous on 6- to 18-meter (20-60 ft) scale. Forms gentle slopes.
- Ol** Lehman Formation (Ordovician)—Dark-gray, slightly silty, coarse-grained limestone. Thin-bedded, with distinctive interbeds of ostracod and gastropod coquina. Forms gentle slopes.
- Ok** Kanosh Shale (Ordovician)—Dark-brown, thin-bedded siltstone and calcareous siltstone. Forms topographic benches.
- Ogu** Garden City Formation (Ordovician)—Divided into:
 Upper member—Light- to medium-gray, thick-bedded to massive, slightly silty limestone forming steep slopes. Where metamorphosed, unit is composed of alternating bands of yellow, blue-gray, and dark-gray marble.
 Lower member—Medium-gray and tan, thin-bedded, silty limestone. Forms gentle slopes.
- Ogl** Garden City Formation (Ordovician)—Lower member—Medium-gray and tan, thin-bedded, silty limestone. Forms gentle slopes.
- Cnp** Notch Peak Formation (Cambrian)—Dark-gray to black, medium- to thick-bedded dolomite and limestone. Upper part carries abundant chert nodules, commonly black. Forms cliffs and steep slopes.
- Ecs** Corset Spring Shale (Cambrian)—Brown, laminated to thin-bedded, calcareous siltstone and silty limestone. Forms saddles and gentle slopes.
- Cj** Johns Wash Limestone (Cambrian)—Medium- to thick-bedded limestone and dolomite forming tripartite section: upper part is white to gray, recrystallized limestone marble; middle part is brownish-gray dolomite; lower part is dark-gray, slightly silty limestone. Forms steep slopes.
- Cc** Candland Formation (Cambrian)—Medium- to dark-gray, calcareous shale to silty limestone. Includes beds of red, calcareous, quartz sandstone and sandy limestone. Forms benches.
- Cb** Big Horse Limestone (Cambrian)—Dark-gray, thin-bedded, silty, oolitic limestone. Lower part is well-layered and silty; upper part is medium bedded to massive. Forms cliffs and steep slopes.
- Cl** Lamb Dolomite (Cambrian)—Buff to light-gray, thick-bedded dolomite. Forms ledgy moderate slopes.
- Ct** Trippe Limestone (Cambrian)—Black to dark-gray, thin-bedded, silty and oolitic limestone.

FORMATION	THICKNESS feet (meters)	SYMBOL	LITHOLOGY
Simonson Dolomite	1170 (355)	Ds	[Lithology diagram]
Lone Mountain Dolomite	370 (113)	DSIm	[Lithology diagram]
Ely Springs Dolomite	280 (85)	Oes	[Lithology diagram]
Eureka Quartzite	430+ (130+)	Oe	[Lithology diagram]
Swan Peak Quartzite	325+ (100+)	Osp	[Lithology diagram]
Lehman Formation	440 (135)	Ol	[Lithology diagram]
Kanosh Shale	280 (85)	Ok	[Lithology diagram]
Garden City Formation	Upper member 450+ (135+)	Ogu	[Lithology diagram]
	Lower member 700+ (210+)	Ogl	[Lithology diagram]
Notch Peak Formation	1100 (335)	Cnp	[Lithology diagram]
Corset Spring Shale	60 (18)	Ecs	[Lithology diagram]
Johns Wash Limestone	400 (120)	Cj	[Lithology diagram]
Candland Formation	190 (58)	Cc	[Lithology diagram]
Big Horse Limestone	600 (180)	Cb	[Lithology diagram]
Lamb Dolomite	250 (75)	Cl	[Lithology diagram]
Trippe Limestone	450+ (135+)	Ct	[Lithology diagram]



**GEOLOGIC MAP OF THE LUCIN 4 SW QUADRANGLE,
BOX ELDER COUNTY, UTAH**

David M. Miller
U.S. Geological Survey



MAP 130

1990

UTAH GEOLOGICAL AND MINERAL SURVEY
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GEOLOGIC MAP OF THE LUCIN 4 SW QUADRANGLE BOX ELDER COUNTY, UTAH

David M. Miller
U.S. Geological Survey

ABSTRACT

The Lucin 4 NW 7.5-minute quadrangle lies in northwestern Utah and includes part of the northern Silver Island Mountains and the adjacent Great Salt Lake Desert. A thick sequence of miogeoclinal Paleozoic rocks, ranging from Cambrian to Permian in age, underlies the Silver Island Mountains. Cambrian to Devonian rocks in this sequence are exposed in the quadrangle. This sequence was faulted and then intruded by several Jurassic granitoid plutons and numerous dikes. During the Cenozoic, the mountain range was blocked out by north-striking basin-and-range faults that separate it from adjacent basins containing thick Cenozoic deposits. During Pleistocene time, Lake Bonneville inundated much of the quadrangle area; shorelines cut into bedrock and alluvial fans indicate that the lake reached about 1589 meters (5210 ft) at its maximum depth.

INTRODUCTION

The Lucin 4 SW quadrangle encompasses the eastern part of Crater Island and the western part of the Great Salt Lake Desert playa. Crater Island is the northernmost mountain of the Silver Island Mountains (figure 1). Crater Island ranges in elevation from 1615 meters (5297 ft) to about 1295 meters (4250 ft) within the quadrangle, and the adjacent desert lowland ranges in elevation from about 1295 to 1284 meters (4250-4212 ft). The mountain named Crater Island is one of several described by Stansbury (1853) as appearing to be islands rising from the surrounding vast salt flats, as if from water. Stansbury also suggested that the structure of the northern part of the island resembled a crater, which is probably the source of the name.

Early studies of parts of Crater Island and vicinity by Stansbury (1853) and Gilbert (1890) dealt chiefly with the surrounding desert. Anderson (1957; many articles in Schaeffer, 1960) conducted the

only previous systematic geologic mapping studies of Crater Island, identifying Cambrian to Permian strata, several granitoid plutons, and several types of surficial deposits including extensive sediments deposited by Lake Bonneville. Doelling (1980) described the economic geology of Crater Island and compiled a geologic map of the county.

Current detailed geologic mapping has updated several aspects of the stratigraphy and structure of Paleozoic rocks at Crater Island and has firmly established the age of granitoids as Jurassic. The basic map pattern of stratigraphic units and portrayal of structures have not changed dramatically with respect to Anderson's pioneer mapping, but the new refinements have aided considerably in our understanding of several regional geologic problems (Miller and others, 1990b). This report on the Lucin 4 SW quadrangle was prepared with a companion report on the adjacent Crater Island quadrangle (Miller and others, 1990a) (figure 2).

GEOLOGIC SETTING

The Silver Island Mountains are one of a series of fault-bounded north-trending mountains comprising the Basin and Range physiographic province. Although range-bounding faults generally are not exposed adjacent to the Silver Island Mountains, they are present to the west in the Pilot Range (figure 1) and in many other ranges that exhibit geomorphology and structure similar to that of the Silver Island Mountains.

Thick miogeoclinal Paleozoic sedimentary rocks, predominantly carbonate, were deposited in northwestern Utah. Later Mesozoic tectonism included plutonism, metamorphism, folding, and faulting and was followed by Cenozoic normal faulting associated with region-wide extensional tectonics and magmatism that led to the development of the Basin and Range province. During Quaternary time, Lake Bonneville (Gilbert, 1890) and its precursor lakes sporadically covered much of northwestern Utah, leaving distinctive lacustrine sediments and geomorphological features.

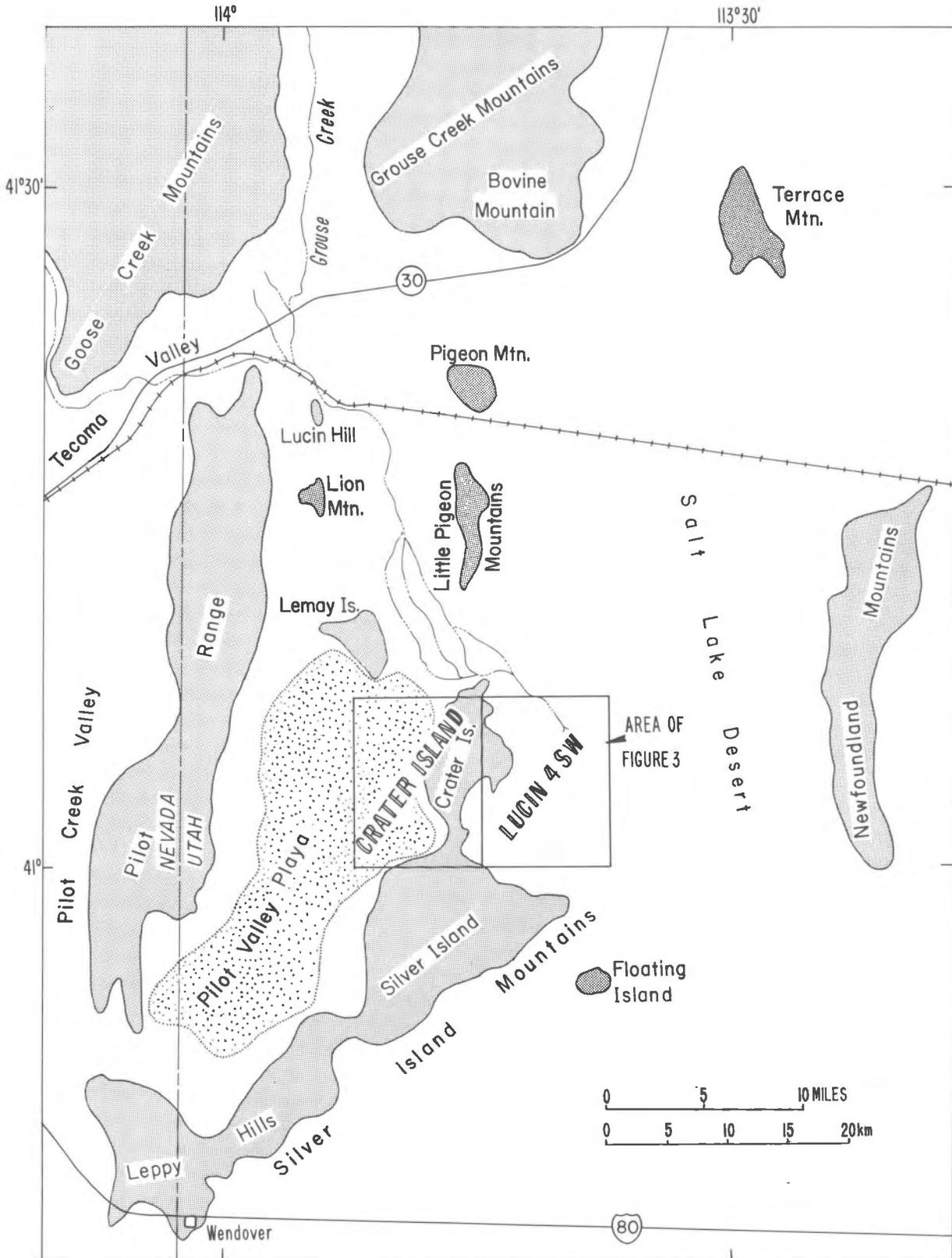


Figure 1. Location of Crater Island in northwestern Utah. Lucin 4 SW and Crater Island quadrangles indicated.

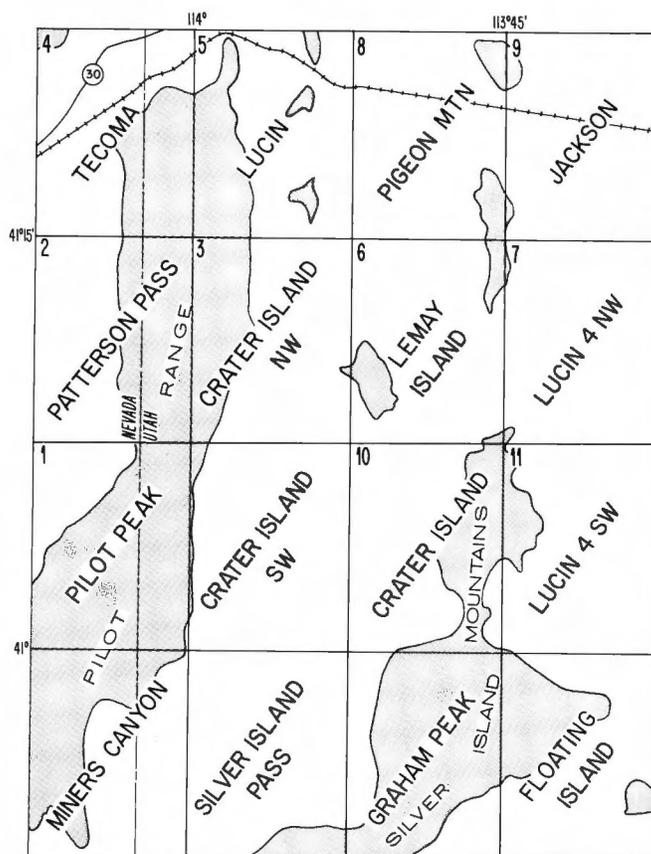


Figure 2. Quadrangle index for Crater Island and vicinity, showing geologic maps published at 1:24,000. 1. Miller and Lush, 1981; 2&3. Miller, Lush, and Schneyer, 1982; 4. Miller and Schneyer, 1985; 5. Miller, 1985; 6. Miller and Glick, 1986; 7. Glick and Miller, 1986; 8. Glick and Miller, 1987; 9. Miller and Glick, 1987; 10. Miller and others, 1990a; 11. this report.

MAP UNITS

Many rock units at Crater Island were identified by Anderson (1957). However, most units are for the first time geographically extended to Crater Island in this report. The Cambrian rock units are mainly extended from central Utah. Ordovician units are extended from two places—the central Utah to central Nevada sequences, and the northeastern Utah sequences. Only two younger Paleozoic units are exposed in the Lucin 4 SW quadrangle; they are extended from units defined in western Utah to central Nevada. Igneous rocks in the quadrangle were tentatively assigned Tertiary ages by Anderson (1957) but are shown in this report to be entirely Jurassic.

Cambrian Rocks

Cambrian strata at Crater Island were recognized by Anderson (1957) and published in Schaeffer (1960). Anderson assigned strata to (in ascending order): a lower undivided unit, Dome Limestone, Swasey Limestone, Wheeler Shale, Marjum Limestone, Weeks Limestone, Dunderberg Shale, and an upper undivided

unit. Schaeffer (1960) made similar assignments at Silver Island, but assigned Anderson's upper undivided unit to the Notch Peak Formation. These formational assignments indicated an anomalously thick Middle Cambrian section and anomalously thin Upper Cambrian section in the Silver Island Mountains, prompting Robison and Palmer (1968) to restudy sections at Silver Island (figure 1). They tentatively identified several Upper Cambrian units (in ascending order): Dunderberg Shale, Johns Wash Limestone, Corset Spring Shale, and Notch Peak Formation. In dealing with the Upper Cambrian formations in this study, the stratigraphic terminology of Robison and Palmer (1968) is followed with one exception. Their Dunderberg strata are assigned to the locally revised Candland Formation (McCullum and Miller, in press) to establish more stratigraphic consistency with the units of the Orr Formation (of which Candland, Johns Wash and Corset Spring are members) in central Utah (Hintze and Palmer, 1976). For consistency, strata underlying Robison and Palmer's (1968) Dunderberg are assigned to two units that are also derived from central Utah stratigraphy.

Much of the stratigraphic section below the Notch Peak Formation is recrystallized and bears a cleavage, making fossil identification and stratigraphic assignments difficult.

Trippe Limestone: The Trippe Limestone (Et), composed of dark-gray silty limestone, is the oldest unit at Crater Island and concordantly underlies the Lamb Dolomite in the easternmost ridges. The unit is distinguished by its dark-gray to black color, common silty laminae, and wavy bedding to mottled texture. Oolite and onkolite beds locally are cross stratified and, in places, silty beds show soft-sediment deformation. In northern exposures of the Trippe and near fault zones the limestone is altered to dolomite, but it maintains its lamination and dark color, which distinguish it from the Lamb Dolomite. Limestone beds similar to those in the Trippe are interbedded with the lower dolomite beds of the Lamb. The Trippe is greater than 135 meters (450 ft) thick at Crater Island and is considered to be Middle Cambrian. No fossils have been identified from the Trippe Limestone at Crater Island. The strata here identified as the Trippe were mapped as "Cambrian?" by Anderson (in Schaeffer, 1960, p. 115). The Trippe is correlated with the formation in central Utah on the basis of stratigraphic position and lithology although its base is not exposed.

Lamb Dolomite: The Lamb Dolomite (Ei) is light-brownish-gray to buff dolomite at Crater Island. It forms ledge outcrops controlled by regular, thick bedding. The unit darkens and coarsens downward, as a response to either primary sedimentary features or metamorphism. The lowest 7.6 meters (25 ft) of the unit contain dark, silty limestone or dolomite interbeds, representing a transition from the Trippe Limestone. Although the Lamb Dolomite characteristically contains limestone (Hintze and Palmer, 1976), that rock type is rare at Crater Island. The unit is about 75 meters (250 ft) thick at Crater Island and is considered to be Late Cambrian.

The Lamb Dolomite at Crater Island is correlated with the formation in central Utah on the basis of stratigraphic position and lithology. These strata at Crater Island previously were assigned to the Dome Limestone by Schaeffer (1960, p. 23).

Big Horse Limestone: The Big Horse Limestone (Eb), which is herein locally revised, is a thick, resistant, dark, coarse-grained limestone unit. Its lower, well-layered part is marked by silty limestone beds containing abundant oolites, onkolites, and rip-up clasts. The upper, massive part consists of less silty, medium-bedded coarse limestone. The uppermost part of the unit is marked by red silt and fine-sand laminations. In places throughout the unit, beds are replaced by brown dolomite; dolomitization (probably diagenetic) seems to be more pervasive northward. The unit is about 180 meters (600 ft) thick at Crater Island and is considered to be Late Cambrian.

The Big Horse Limestone at Crater Island is correlated with the Big Horse Limestone Member of the Orr Formation (Hintze and Palmer, 1976) in central Utah on the basis of stratigraphic position and lithology (see McCollum and Miller, in press). These strata were previously assigned to the Swasey Limestone by Schaeffer (1960).

Candland Formation: The Candland Formation (Ec) consists predominantly of calcareous shale and silty limestone; it forms a bench between the more resistant adjacent units. The unit is marked by two distinctive, brown to red, quartz-sand zones near the top and bottom of the formation. At or near the top of the unit is a zone 2.5 to 9 meters (8-30 ft) thick composed of calcareous quartzite. Near the base of the unit is a thicker, less quartz-rich

zone consisting of sandy limestone, about 3.6 to 6 meters (12-20 ft) thick. Both zones thicken northward. The sand grains in both zones are well size-sorted (medium-sand) and are predominantly single-crystal quartz. Five to 15% of the grains are feldspar, and minor polycrystalline quartz grains and heavy minerals also occur. Although recrystallization obscures detrital features in the calcite matrix, some calcite clasts remain. The Candland is about 58 meters (190 ft) thick here and is considered to be Late Cambrian at Crater Island.

The Candland Formation at Crater Island is correlated with the unit identified by Robison and Palmer (1968) at Silver Island as the Dunderberg Shale. Because adjacent units at Silver Island were subsequently grouped by Hintze and Palmer (1976) along with the Candland as members of the Orr Formation in central Utah, the Candland Formation terminology is preferred in this report. However, the Candland is raised from member to formation to be consistent with the rest of Robison and Palmer's unit assignments (McCollum and Miller, in press). These strata previously were assigned to the Wheeler Shale by Schaeffer (1960).

Johns Wash Limestone: The Johns Wash Limestone (Ej) forms ridges in eastern Crater Island and is comprised of three lithic intervals: a lower dark-gray limestone interval, a middle brown dolomite interval, and an upper predominantly white marble interval. The lower interval consists of silty limestone showing abundant rip-up clasts, trough cross stratification, and common oolite beds. The middle interval consists of featureless brown dolomite. The upper interval consists predominantly of white calcite marble showing ghosts of brown siltstone laminae and containing sparse round masses less than 1 meter (3 ft) in diameter that are composed of brown dolomite. The uppermost 3 to 6 meters (10-20 ft) of the upper interval consists of dark-bluish-gray, medium- to thick-bedded limestone showing wavy, silt partings. This rock type grades over an interval of 1 meter (3 ft) into the overlying Corset Spring Shale by an increase in silt content. The Johns Wash at Crater Island is about 120 meters (400 ft) thick and is considered to be Late Cambrian.

The Johns Wash Limestone at Crater Island is correlated with the Johns Wash Limestone Member of the Orr Formation (Hintze and Palmer, 1976) in central Utah on the basis of stratigraphic position and lithology. The Johns Wash strata were previously assigned to the Marjum Limestone and Weeks Limestone (part) by Schaeffer (1960). Robison and Palmer (1968) used the name Johns Wash Limestone in their study at Silver Island.

Corset Spring Shale: The Corset Spring Shale (Ecs) forms a prominent bench below the massive cliffs of the Notch Peak Formation. It consists of brown calcareous siltstone, calcareous shale, and silty limestone. The unit is laminated throughout, and many parts show wavy bedding and bioturbation features. Its uppermost part is gradational into the lower, brown part of the Notch Peak Formation. The Corset Spring is about 18 meters (60 ft) thick at Crater Island and is considered to be Late Cambrian.

The Corset Spring Shale at Crater Island is correlated with the Corset Spring Shale Member of the Orr Formation (Hintze and Palmer, 1976) in central Utah on the basis of stratigraphic position and lithology. These strata were previously assigned by Schaeffer (1960) to the Dunderberg Shale. Robison and Palmer (1968) used the name Corset Spring Shale at Silver Island.

Notch Peak Formation: The Notch Peak Formation (Cnp) is a thick-bedded, ridge-forming limestone and dolomite unit. Its basal part consists of brown silty and cherty limestone that in many places forms thinly striped cliffs. This basal unit is the lateral equivalent of the Sneakover Limestone Member of the Orr Formation, a unit about 18 meters thick (60 ft). Overlying this basal part is a thick interval of thick-bedded limestone and dolomite bearing little or no silt, which is crudely recognizable as consisting of four lithic intervals (from base to top): (1) black to dark-gray limestone, and dark limestone containing light-brown dolomite beds; (2) light-brown dolomite with rare limestone beds; (3) dark-gray to black dolomite; and (4) chert-rich, dark-gray dolomite interbedded with dark-gray limestone. Zebra-stripping coloration, algal buildups, and pisoliths are common features of the Notch Peak. The Notch Peak is approximately 335 meters (1100 ft) thick. The age of the Notch Peak at Crater Island is considered to be Late Cambrian, although it may include a few beds of Ordovician age (John Repetski, 1985, oral communication).

The Notch Peak Formation at Crater Island is correlated with the Notch Peak elsewhere in eastern Nevada and western Utah on the basis of stratigraphic position and lithology.

Ordovician Rocks

Lower and Middle Ordovician strata present at Crater Island represent mappable parts of two different widely distributed stratigraphic sections. The stratigraphic nomenclature for units from the eastern, thin margin of the miogeocline in northeastern Utah (Garden City Formation and Swan Peak Quartzite) can be applied locally. However, mappable subdivisions within much of the Ordovician section at Crater Island correspond more closely with parts of the Pogonip Group and Eureka Quartzite of west-central Utah and east-central Nevada. Thus, where possible, Pogonip Group terminology is applied to the map units at Crater Island. Schaeffer (1960) previously applied a similar nomenclature to these rocks. The Garden City Formation and a part of the Swan Peak Quartzite, units defined in northeastern Utah, are used here; other unit names derive from the Pogonip Group and related strata.

Garden City Formation: The Garden City Formation is a thick, predominantly silty, limestone unit lying below shale and siltstone of the Kanosh Shale. It is divisible into a lower, extremely silty, thin-bedded member and an upper, less silty, thick-bedded to massive member.

The lower member of the Garden City Formation (Ogl) consists of thin- to medium-bedded gray limestone, brown silty limestone, and brown calcareous siltstone. Typical features are orange-colored sand and silt laminae and intraformational conglomerate. The base of the lower member is truncated by faults; it has a minimum thickness of 210 meters (700 ft).

The upper member of the Garden City Formation (Ogu) consists of predominantly medium- to thick-bedded, medium-bluish-gray limestone with minor silty laminae. Oolith beds, intraformational conglomerate, megafossils, and chert occur locally. The top of the upper member is structurally truncated; the unit has a minimum thickness of 135 meters (450 ft). Where metamorphosed, it consists of yellow, white, and blue-gray marble.

Conodonts from the lower member of the Garden City Formation confirm its Early Ordovician age at Crater Island (John Repetski, 1985, oral communication). The Garden City at Crater Island is correlated with the formation elsewhere in western Utah on the basis of age, stratigraphic position, and lithology.

Kanosh Shale: The Kanosh Shale (Ok) predominantly consists of deep-brown siltstone and shale and grayish-brown calcareous siltstone. Thin gray bioclastic limestone interbeds containing abundant ostracods are diagnostic. Where metamorphosed, the unit consists of dark-brown hornfels. The Kanosh is about 85 meters (280 ft) thick at Crater Island and considered to be Middle Ordovician.

The Kanosh Shale at Crater Island is correlated with the formation in central Utah and eastern Nevada, where it is part of the Pogonip Group, on the basis of lithology and stratigraphic position. It is probably lithologically equivalent to the lower part of the Swan Peak Quartzite occurring in northeastern Utah.

Lehman Formation: The Lehman Formation (Ol) consists of dark bluish-gray, silty limestone that is homogeneously bedded on a thin scale. Thin bioclastic beds contain gastropods and ostracods. The unit is about 135 meters (440 ft) thick at Crater Island and is considered to be Middle Ordovician.

The Lehman Formation at Crater Island is correlated with the formation in east-central Nevada, where it is part of the Pogonip Group. However, at the type locality the Lehman Formation rests beneath the Eureka Quartzite, whereas at Crater Island, strata assigned to the Swan Peak Quartzite intervene between the Eureka and the Lehman. The Lehman Formation at Crater Island may be equivalent to only the lower part of the Lehman type section, or the Eureka Quartzite at Crater Island may be younger than at the type section.

Swan Peak Quartzite (middle part): The interval between the Lehman Formation and the Eureka Quartzite is lithologically heterogeneous, consisting of brown, gray, and black dolomite, gray and black silty limestone, and brown and white sandstone. These strata are assigned to the Swan Peak Quartzite (Osp). The proportions and stratigraphic positions of these rock types change along strike; the changes are partly depositional and partly structural. Quartzite and calcareous sandstone form lens-shaped bodies in several places, and faults duplicate and truncate section in other places. Quartzite locally is as pure as that in the overlying Eureka Quartzite but generally contains minor amounts of dolomite, calcite, or feldspar. In the only location at which the unit appears not to be faulted against the Eureka, the upper beds of the Swan Peak are dark-gray calcareous dolomite that may correlate with the Crystal Peak Dolomite of central Utah. The unit is greater than 100 meters (325 ft) thick. Conodonts recovered from a bed about 7.6 meters (25 ft) below the top of the unit at Crater Island are considered to be Middle Ordovician in age (table 1, number 1). The age of the Swan Peak at Crater Island is considered to be Middle Ordovician.

The Swan Peak Quartzite at Crater Island (Osp) is correlated with the middle part of the Swan Peak Quartzite, as exposed at its type locality in northeastern Utah, on the basis of lithology, conodont age, and stratigraphic position. The unit also correlates broadly with the Crystal Peak Dolomite of Webb (1956) and possibly the Watson Ranch tongue of the Swan Peak Quartzite of Webb (1956), units lying stratigraphically between the Lehman Forma-

Table 1. Paleontology data for the Lucin 4 SW quadrangle

Field Number	USGS Collection	Rock Unit	Fossil Age	Date of Report	Paleontologist	Faunal Description	Location Latitude	Location Longitude	Map Number
JR6-14-84S	10672-CO	Swan Peak Quartzite	Middle Ordovician (Late Whiterockian)	6/7/88	John Repetski	The following conodonts were identified: 1 <i>Ansellia?</i> sp. <i>Drepanoistodus suberectus</i> (Branson and Mehl) 2 drepanodontiform elements 1 suberectiform el. <i>Erismodus</i> sp. 1 Pa element 1 Pb el. 1 S(?) el. 21 <i>Erraticodon balticus</i> Dzik 11 <i>Panderodus</i> spp. <i>Phragmodus flexuosus</i> Moskalenko? 57 P elements 61 M els. 129 S (?) els. 1 <i>Scandodus?</i> sp.; Sd(?) el. 14 unassigned genticulate coniform elements 1 undetermined M(?) el. 1 undetermined multidenticulate blade-like el. 28 indeterminate elements The species association indicates assignment to the <i>Cahabagnathus friendsvillensis</i> through <i>C. sweeti</i> conodont zones, as used by Sweet and Bergstrom. The North American Mid-Continent Province faunal assemblage, the physical condition of the conodont elements (badly battered and broken), and the lithology of the host-rock all indicate that this was a shallow, high-energy environment. CAI is about 5.	41°04'26"	113°44'37"	1

tion and Eureka Quartzite in central Utah. Anderson and Schaeffer (Schaeffer, 1960) did not subdivide rock units between the Garden City and Eureka on their geologic maps. However, Schaeffer described several units within this stratigraphic interval, including two units between the Lehman Formation and the Eureka Quartzite. These units, the Crystal Peak Dolomite and the tongue of Swan Peak quartzite, together comprise the Swan Peak Quartzite unit as used here.

Eureka Quartzite: The Eureka Quartzite (Oe) is a prominent, cliff-forming white orthoquartzite unit. Medium sand grains are superbly size-sorted and rounded, and cemented by silica. Locally, gray ellipsoidal patches are observed and are due to the presence of dolomitic cement. Color variations in the quartzite include blue, yellow, and gray-blue tones. The Eureka is fault-bounded in all exposures at Crater Island; its minimum thickness here is 130 meters (430 ft). The Eureka Quartzite is here considered to be Middle Ordovician in age.

The Eureka Quartzite at Crater Island is correlated with the formation as exposed at its type locality in central Nevada on the basis of lithology and stratigraphic position. It probably also is lithologically correlative with the upper quartzite member of the Swan Peak Quartzite in northeastern Utah.

Ely Springs Dolomite: The Ely Springs Dolomite (Oes) consists of dark dolomite divisible into three lithic intervals. The lower interval consists of medium-bedded, very dark-gray dolomite. The middle interval consists of dark-gray dolomite containing sedimentary structures such as cross stratification, scour features, and intraformational conglomerate. The upper interval consists of black, medium- to thick-bedded dolomite mottled by white burrow fillings (Sheehan, 1979). Total thickness of the unit is about 85 meters (280 ft) in this area. The Ely Springs is considered to be Late Ordovician in age at Crater Island.

The Ely Springs Dolomite at Crater Island is correlated with the formation at its type locality in Nevada on the basis of age, stratigraphic position, and lithology (Sheehan, 1979; Carpenter and others, 1986). It is lithologically similar to, and stratigraphically equivalent to, the Fish Haven Dolomite of northeastern Utah.

Silurian and Devonian Rocks

Lone Mountain Dolomite: The Lone Mountain Dolomite (DS1m) consists of uniformly thick-bedded, light-gray dolomite. The lower part of the unit is indistinctly laminated and the upper part is well laminated. Burrows occur in places, and rip-up clasts are common in the upper part. The unit occurs as fault slices. It overlies the Silurian Laketown Dolomite (not present at the surface in the Lucin 4 SW quadrangle). Its age at Crater Island is considered to be Silurian and Early Devonian.

Devonian Rocks

Simonson Dolomite: The Simonson Dolomite (Ds) consists of thick-bedded, superbly laminated dolomite and subordinate limestone. The lower part of the unit consists of ledge, alternating light and dark dolomite. Dark dolomite ranges from black, dark brown, and dark gray to light gray and light-medium gray. The lighter colored beds constitute about 20% of the lower part. Some beds show intraclasts, scour features, and cross-stratification. Sedimentary breccia beds also occur. One characteristic bed in the lower part consists of jumbled algal heads overlain by *Amphipora* "hash." The upper part of the formation consists of generally dark-gray and black dolomite with interbeds of dark-gray and black limestone. The Simonson is about 355 meters (1170 ft) thick at Crater Island and is considered to be Middle Devonian.

The Simonson Dolomite at Crater Island is correlated with the unit elsewhere in eastern Nevada and western Utah on the basis of stratigraphic position and lithology.

Jurassic Rocks

Several plutons and numerous dikes that are entirely Jurassic in age (Miller and others, in press) are exposed at Crater Island. These intrusive rocks show many modal, chemical, and textural affinities, and they are considered to represent a magmatically related suite. Unifying features include overlapping modal and chemical compositions, broadly collinear variations of oxides with respect to SiO₂, identical xenolith suites, ubiquitous dikes, and features indicating a moderately deep level of emplacement. All plutons and dikes yield K-Ar ages of 150 to 155 Ma, and muscovite from an altered dike was dated at 148 Ma by K-Ar (Miller and others, 1990b). These cooling ages were interpreted by Miller and others (1990b) to indicate emplacement ages of about 160 to 165 Ma.

The igneous suite at Crater Island is primarily exposed as plutons in the northern and southern parts of the quadrangle but also includes several dike swarms and scattered dikes. Dikes range widely in composition and texture but seem to mirror the compositional variations seen in plutons in the adjacent Crater Island quadrangle.

Porphyritic granodiorite: A granodiorite pluton (Jpg) underlying the northern end of Crater Island was named the North stock and Sheepwagon stock by Schaeffer (1960) and the northern parts were described by Glick and Miller (1986) and Miller and Glick (1986). The part of the pluton within the northern Lucin 4 SW quadrangle consists of light-gray, porphyritic biotite granodiorite. The medium- to coarse-grained matrix contains gray, clear, and white plagioclase, clear to gray quartz, euhedral biotite, and white to pink orthoclase. Quartz and biotite also occur as very coarse-grained crystals, and orthoclase phenocrysts are as much as 2.5 cm (1 in) in diameter. Accessory hornblende, apatite, and sphene are common. Total mafic mineral content ranges from 10 to 18%.

Associated with the pluton are mafic segregations or schlieren, several types of dikes, and two common xenolith types. Segregations are biotite-rich and in rare cases show size grading similar to sedimentary current deposits. Pink aplite dikes and pink pegmatite dikes are common and porphyritic fine-grained dikes are locally abundant. The porphyritic dikes may represent a fine-grained phase of the plutonic complex (Miller and Glick, 1986). Aplite dikes are most common near the margin of the pluton; they typically strike N 20° W and dip moderately northeast, parallel to the pluton margin. Other dikes appear to have non-systematic orientations. Xenoliths occur widely and comprise two types: (1) porphyritic biotite quartz monzodiorite, which is dark gray, speckled with biotite and plagioclase phenocrysts, and generally forms larger xenoliths than (2) equigranular hornblende-plagioclase quartz diorite, which is fine grained and black. All xenoliths are generally less than 30 cm (1 ft) in diameter and are round to oval in shape.

An isotopic date of 150.3 ± 3.8 Ma on biotite (Miller and others, 1990b) establishes the granodiorite as Jurassic in age. Dikes within the pluton probably are associated with late stages of emplacement.

Rare foliation in the granodiorite is inconsistently oriented and probably of igneous origin. Prominent vertical joints oriented N 50° E to N 60° E create a blocky outcrop appearance.

Porphyritic monzogranite: A small pluton composed of porphyritic biotite monzogranite (Jpm) crops out in the southern bedrock exposures within the quadrangle. The pluton is medium grained with sparse orthoclase phenocrysts (1 cm; 0.5 in) and coarse quartz in its interior, but is fine grained within 9 meters (30 ft) of its border with Ordovician strata. The subequigranular matrix consists of plagioclase, orthoclase, quartz, and biotite; mafic minerals are 10% modally. Accessory minerals are hornblende, zircon, and sphene.

Sparse xenoliths consist of porphyritic, fine-grained, biotite-hornblende quartz monzodiorite carrying medium-grained phenocrysts of quartz, plagioclase, biotite, and hornblende. Rare aplite dikes strike approximately eastward and are 0.5 to 2.5 cm (¼ - 1 in) wide.

Biotite from a sample of the porphyritic monzogranite (table 2, number 1) yielded a K-Ar age of 154.2 ± 3.9 Ma, suggesting that the pluton was emplaced at approximately the same time as other plutons at Crater Island (Miller and others, 1990b).

Table 2.
K-Ar sample locations

Map Location	Sample Number	Age (Ma)	Material Dated
1	M85CI-14	154.2 ± 3.9*	Biotite
2	M84CI-48	148.1 ± 3.7*	Sericite

*Data reported by Miller and others (1990b)

Dike rocks: Other than aplite and pegmatite dikes associated with plutons, igneous dikes at Crater Island fall into three general types: (1) common granodioritic dikes occurring as swarms cutting the Crater Island pluton (Crater Island quadrangle) and most sedimentary rocks, (2) sparse mafic dikes present only in sedimentary rocks, and (3) rare felsite dikes cutting sedimentary rocks. The three types of dikes were referred to by Schaeffer (1960) as andesite, lamprophyre, and rhyodacite dikes, respectively. Representatives of all three dike types cut faults in several places at Crater Island, but felsite dikes were not found in the Lucin 4 SW quadrangle. All dikes generally strike northerly and dip steeply east or are vertical.

Granodioritic dikes: Dikes of generally granodioritic composition form a swarm north of the porphyritic monzogranite pluton and occur as less common dikes northward for 3 kilometers (2 mi). Their spatial and compositional association with the pluton suggests that they are derived from it and were emplaced at the time of plutonism. The dikes are medium to dark gray when fresh and have a fine- to medium-grained matrix bearing phenocrysts of quartz, plagioclase, orthoclase, and biotite. In the Crater Island quadrangle, similar dikes have been dated at 152 to 154 Ma (K-Ar biotite). In a few locations, these dikes are highly sericitized. One such dike (table 2, number 2) yielded a K-Ar isotopic age of 148.1 ± 3.7 Ma on sericite, indicating that alteration occurred somewhat after emplacement.

Mafic dikes: Black to dark-greenish-gray dikes and pods are locally common within Ordovician strata and sparse in other rocks. Most dikes consist predominantly of augite, with hornblende, biotite, and plagioclase together constituting less than 50%. One

dike sampled contained no augite but an unusually great amount of hornblende. Mafic dikes are generally highly altered; sericite after plagioclase and chlorite after biotite are common. Dikes are as wide as 5.5 meters (18 ft). One dike only 1.8 meters (5 ft) wide caused a bleached zone in wallrock limestone 5 meters (15 ft) wide on each side.

Table 3.
Elevations of prominent shorelines at Crater Island

Shoreline	Feature (this report)	Elevation		Schaeffer (1960) feet
		This report feet	meters	
Gilbert	beach crest	4262 ± 1	1299	
Pilot Valley	beach crest	4285 ± 2	1306	
Stansbury	tufa-coated platform	4490 ± 5	1368	4484
Provo	abrasion platform	4870 ± 10	1484	4834
Bonneville	abrasion platform	5210 ± 5	1588	5204

Quaternary Deposits

Lacustrine gravel: Gravel (Qlg) deposits are found along three of four previously recognized regional shorelines of Lake Bonneville at Crater Island (Schaeffer, 1960). The elevations of regionally mappable shorelines at Crater Island, including the herein informally designated Pilot Valley shoreline, are summarized in table 3. The Bonneville shoreline is only present in the Lucin 4 SW quadrangle at one point, but it is well displayed nearby to the west in the Crater Island quadrangle. The Provo shoreline is represented by broad erosional platforms and gravel constructions. Shorelines from about the Provo level and below typically display tufa-cemented gravel.

The Pilot Valley shoreline was recognized north of Crater Island along the margin of Pigeon Mountain (Miller and Glick, 1987), Little Pigeon Mountain (Glick and Miller, 1986; Miller and Glick, 1986), and Lemay Island (Miller and Glick, 1986) as a prominent transgressive shoreline gravel accumulation about 1306 meters (4285 ft) in elevation. This shoreline also is prominently developed around Crater Island and farther south in the Silver Island Mountains, warranting its informal designation for exposures bordering Pilot Valley. At this elevation of Lake Bonneville, the Pilot Valley basin was integrated with the main lake, and thus the Pilot Valley shoreline may represent an event that is recorded by lake deposits in other parts of the basin.

The Gilbert shoreline is underlain by pebbly sand in most locations. At the southernmost "peninsula" of Crater Island, the Gilbert beach crest was hand-leveled at 4262 ± 1 feet (1299 m).

Lacustrine marl: The white marl unit (Qlm) of Gilbert (1890) is widely exposed at Crater Island as thick accumulations in many protected valleys and thin accumulations elsewhere. In these valleys it typically includes silt and sand beds derived from nearby bedrock sources, and extremely shelly intervals. At lower elevations along the margin of the flats, the marl unit typically is composed of clay, marl, and diatoms; here it is permanently wet and of plastic consistency. In some places below 1298 meters (4260 ft) elevation, silt and sand overlie the marl and probably represent deposits formed during regression from the Gilbert shoreline. Cemented plastic beds of ooids also overlie the marl in many places at low

elevations, and at some low-elevation locations ooid beds occur near the base of the marl unit. Typically overlying the marl along the flanks of the range is poorly to well-sorted gravel representing terminal regressive lacustrine gravel and (or) alluvial gravel.

Lacustrine and alluvial deposits, undivided: In many places, alluvial and lacustrine deposits (Qla) are difficult to distinguish at 1:24,000, and are mapped as an undivided unit. Pre-Lake Bonneville alluvial units at Crater Island are commonly overlain by gravels slightly reworked by waves and displaying lake shorelines, or by irregular sheets of lacustrine marl. In other places, thin sheets of Holocene alluvium overlie lacustrine deposits.

Mass-movement talus: Talus and scree deposits (Qmt) form slopes in places adjacent to prominent hills of Eureka Quartzite. Small talus deposits elsewhere are not depicted on the geologic map.

Alluvial mud: Alluvial-mud deposits (Qam) cover much of the flatland, mainly occurring in the distal parts of the Grouse Creek drainage and small ephemeral streams emanating from Crater Island (mud in the two depositional sites is grouped in a single unit). Sediments in the Grouse Creek drainage system deposited in the Lucin 4 SW quadrangle have travelled for several miles at gradients averaging 1.2 meters (4 ft) per mile (figure 1); they consequently consist primarily of mud and silt. These alluvial-mud deposits commonly display scars of meandering-stream channels in aerial photographs and appear much darker than adjacent playa mud and alluvial mud derived from local streams emanating from Crater Island. The alluvial mud derived from local ephemeral streams contains halite, which may account for its lighter color as compared to alluvial mud derived from more distant drainages. To the north, Glick and Miller (1986) distinguished the local alluvial mud as playa mud on the basis of the color, which is strikingly lighter than that for muds deposited by Grouse Creek. However, the composition and geomorphology of their playa mud unit (as more clearly seen in the Lucin 4 SW quadrangle) require an alluvial origin. The alluvial-mud deposits in the Lucin 4 SW quadrangle are gradational with playa mud, which represents alluvial-derived mud as well as mud deposited during periods of standing water.

Playa mud: Mud and silt deposited by a combination of alluvial and lacustrine processes (Qpm) underlie broad flats east of Crater Island. These mud deposits contain varying amounts of salt crystals. Dessication polygons are common on the playas.

Eolian sand: Thin sheets of tan eolian silt and fine sand (Qes) lie along the margins of playas east of Crater Island and inferred sand dunes lie in the south-central part of the quadrangle. Irregular mounds in the sand sheets are locally as much as 1.2 meters (4 ft) thick. Apparent dunes on the playa muds, tentatively identified by morphology determined from aerial photographs, form linear ridges within the playa. These features were not field checked because they were flooded from 1987 to 1989 by pumping Great Salt Lake water into the West Desert. Although one hypothesis for these possible dunes is that they were localized along a series of shorelines near the 1284.7 meters (4215 ft) elevation, the more precise topography of the area shown by Chapman and Sappington (1986) indicates the contours of 1285 to 1284.4 meters (4216-4214 ft) cross the inferred dunes. Alternatively, their source may be entrapment of eolian fines by ground-water discharge zones.

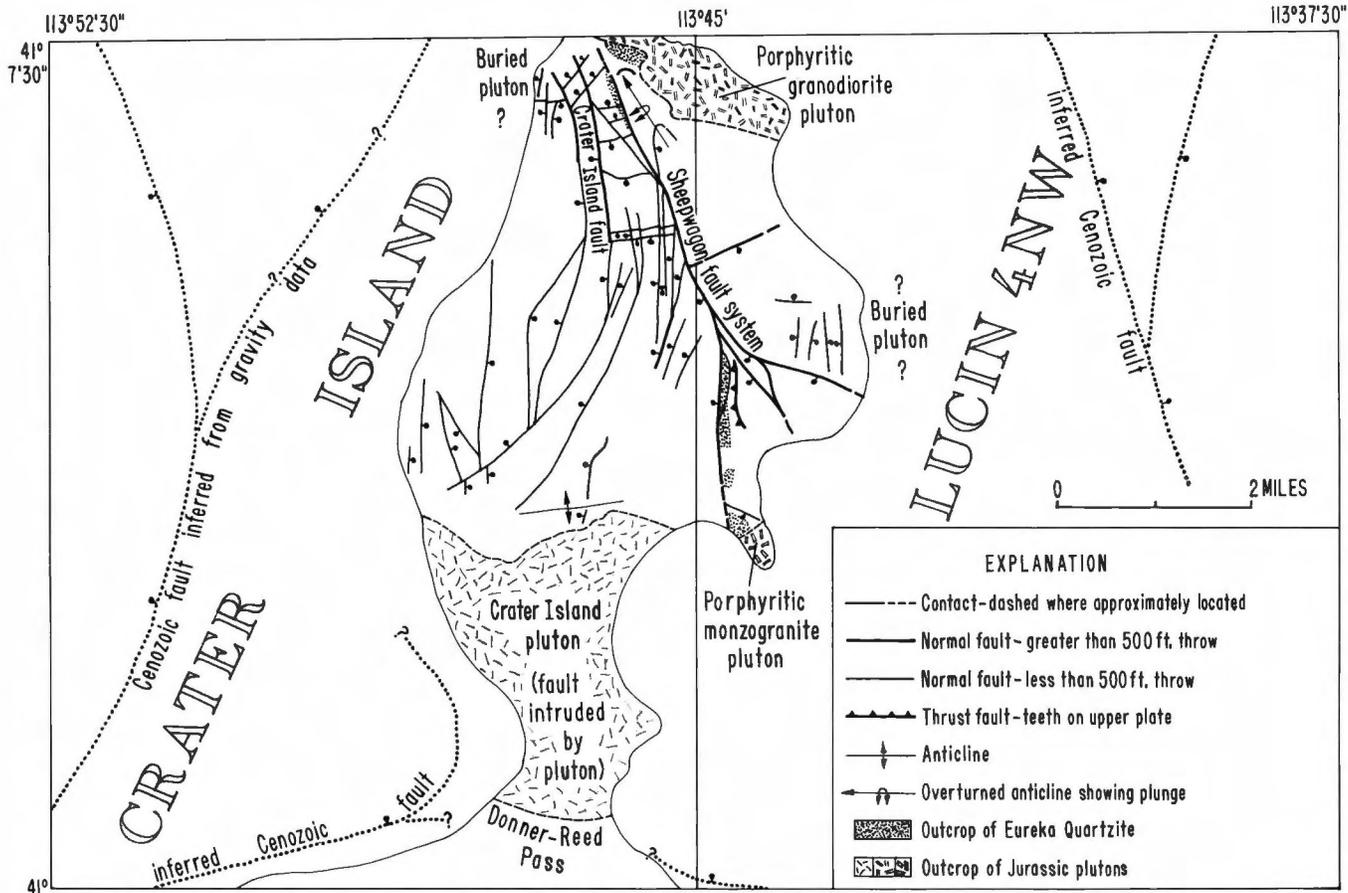


Figure 3. Generalized structure map of Crater Island and Lucin 4 SW quadrangles, showing mountainous areas and plutons. Cenozoic faults are inferred from gravity data (Cook and others, 1964). Possible buried plutons inferred from distribution of metamorphic rocks.

Alluvial silt: Bordering the range are extensive sheets of alluvial silt (Qai) that constitute a facies transitional between the coarse alluvial deposits of the mountains and the alluvial mud and playa deposits of the lowest parts of the flats. These deposits are composed of moderately sorted sand, silt, and clay and are bounded by gradational contacts with playa deposits and alluvial mud deposits. The alluvial silt probably was deposited predominantly as low-gradient alluvial sheets during sheet-flow and flood events.

Alluvium: Unconsolidated alluvium (Qal) in, and adjacent to, ephemeral stream channels contains detritus ranging in size from cobbles to clay. In low-gradient parts of the channels, sand to clay predominate.

Alluvial-fan deposits: Geomorphologically, alluvial-fan deposits (Qaf) primarily constitute active fans downslope from the mouths of canyons along the margin of Crater Island. The deposits overlie Lake Bonneville deposits in most places, indicating that they are Holocene in age.

METAMORPHISM

Metamorphism of sedimentary rocks at Crater Island is expressed in several manners: skarn-mineral assemblages adjacent to plu-

tons; bleaching and recrystallization adjacent to plutons, dikes, and unexposed plutons(?); and by widespread elevation of conodont alteration indices (table 1). Of these expressions, the former two are local and probably directly related to igneous thermal sources, whereas elevated alteration indices occur widely in the Silver Island Mountains-Pilot Range-Toano Range area.

Paleozoic rocks are visibly altered adjacent to the porphyritic granodiorite pluton over distances as great as 1.5 kilometers (0.6 mi). Occurring close to the pluton are wollastonite, diopside, and garnet. Farther from the pluton, the rocks are coarsely marbled and bleached in places. The Ordovician strata adjacent to the porphyritic granodiorite display a penetrative cleavage nearly parallel to the pluton contact; the spatial relation suggests cleavage development during emplacement. Elsewhere, cleavage is less well developed. Recrystallization, bleaching, and skarn development minerals also are present adjacent to the porphyritic monzogranite body and in narrow zones adjacent to some mafic dikes.

Rocks in the eastern part of Crater Island show significant recrystallization, color change, and local andalusite, suggesting nearby but unexposed heat sources such as plutons (figure 3).

STRUCTURE

The structure of Crater Island is basically that of a homocline with strata dipping westward about 30°. A major fault system (the Sheepwagon fault of Schaeffer, 1960) that passes from the north end of the island to the south-southeast (figure 3) cuts the homoclinal strata. This fault system displaces strata down to the west, with a small component of right-lateral offset. Faults with smaller displacements are approximately north- and east-striking; they are probably kinematically related to the Sheepwagon fault. Many faults are intruded by Jurassic granitoids. Other structures include megascopic folds and cleavage developed in strata adjacent to plutons (best expressed in the adjacent Crater Island quadrangle but probably also expressed at the eastern tip of Crater Island), and a small-separation thrust(?) fault within the Swan Peak Quartzite. These structures and the entire Crater Island structural block were probably tilted westward as a somewhat coherent block by Cenozoic extensional structures that bound deep basins east and west of Crater Island.

High-Angle Faults

High-angle faults belong to two sets with basically north and east strikes. Faults in the north-striking set show larger separations and have longer strike lengths than those in the east-striking set. Faults in both sets are steeper than 75° in nearly all cases. The north-striking fault set consists of the major Sheepwagon fault system and numerous faults with less than 152 meters (500 ft) dip separation (figure 3). The Sheepwagon fault system is sinuous, north-northwest-striking, with splays at several points. Maximum stratigraphic throw is about 91 to 1220 meters (300-4000 ft), and apparent dextral separation of the Eureka Quartzite is about 4 kilometers (2.5 mi) (figure 3). Faults within the Sheepwagon system dip steeply west and in places are marked by highly foliated rock rather than breccia. Strata in the vicinity of the fault system commonly dip 40° to 70° west, contrasted with 15° to 35° dips elsewhere.

Minor north-striking faults are down to the west and dip steeply both east and west. Faults with north-northeast strikes displace Cambrian strata down to the east and appear to be cut by the north-striking faults.

Most east-striking faults occur in the adjacent Crater Island quadrangle (figure 3), where they form short segments between northerly faults or are cut by northerly faults. Easterly faults dip between 75° north and 75° south and show both reverse and normal separations. Two major easterly faults are inferred to lie within canyons in the Lucin 4 SW quadrangle. They show 245 meters (800 ft) (northern fault) and 335 meters (1100 ft) (southern fault) of down-to-the-south dip separation, or apparent sinistral separation of 488 meters (1600 ft) and 670 meters (2200 ft). A few smaller subparallel faults show separations of generally less than 60 meters (200 ft). The east-striking faults may be kinematically coordinated with the Sheepwagon system because changes in displacements along that system appear to be partitioned to east-striking faults.

Kinematic interpretation of high-angle faults suggests approximately east-west extension. Striae on fault planes in breccia zones of two minor north-striking faults show rakes of 70° to 80° north, indicating oblique slip for part of the fault movement. Sigmoid flexures between minor north-striking faults reinforce the hypo-

thesis of a dextral slip component on these faults. However, steep striae rakes indicate a predominance of dip slip on the minor faults. Deformation was predominantly caused by roughly horizontal extension oriented about WNW-ESE, with a component of subsidiary dextral slip along north-striking faults. Vertical igneous dikes strike north to north-northeast, indicating that least compressive stress was oriented roughly west to west-northwest during intrusion at about 155 Ma, a stress orientation appropriate for the fault patterns.

All high-angle faults appear to be Late Jurassic or older in age because they are intruded by Jurassic granitoids. North-striking faults in several parts of Crater Island are filled or cut by dikes representing the three compositional groups. In the Lucin 4 SW quadrangle, dikes emanating from the porphyritic monzogranite pluton cut a fault that juxtaposes the Lehman and Swan Peak units.

Low-Angle Faults

A cryptic thrust(?) fault approximately parallel to bedding is mapped in the southern exposures of the Swan Peak Quartzite (figure 3). This fault truncates beds in the Swan Peak, climbing gradually in the stratigraphic section northward. Duplication or attenuation of beds is difficult to demonstrate because of the poorly known stratigraphy, but 12 to 18 meters (40-60 ft) of stratigraphic duplication is probable. Similar relations may occur in the northern exposures of the Swan Peak, but structural complexities and the small outcrop area preclude definitive relations. The thrust(?) fault is cut by the Sheepwagon fault system, establishing its age as Late Jurassic or older.

Cleavage

Cleavage is sporadically developed in areas of recrystallized rocks that may indicate nearby subsurface plutons (figure 3). Ordovician strata typically bear a spaced cleavage within 15° of bedding; both strike northwest. Cambrian strata generally exhibit similar relations, but none of these strata were studied systematically for cleavage relations.

Structural Configuration of the Basins

Cenozoic high- and low-angle normal faults associated with generally easterly extension have been documented in several ranges in the area, chiefly on the basis of tilted and faulted Cenozoic strata (e.g., Schneyer, 1984; Miller and Schneyer, 1985; Miller, 1985; Miller and Glick, 1986). Although neither Cenozoic strata nor normal faults of proven Cenozoic age occur at Crater Island, Bouguer gravity anomalies indicate thick sequences of low-density (Cenozoic?) material in basins east and west of Crater Island, virtually requiring large Cenozoic faults buried by playa sediments (Cook and others, 1964). At the south side of Donner-Reed Pass (figure 3) is a north-facing gravity gradient that suggests shallow Cenozoic basins and/or low-density granitoids occur on both sides of the pass. East of Crater Island is a larger gravity gradient suggesting that a north-trending fault system (figure 3) bounds a Cenozoic basin on the east that is about 1066 meters (3500 ft) deep. The eastern basin probably is a composite of two grabens (Cook and others, 1964). The positions of these fault systems are poorly constrained by the reconnaissance gravity data.

Near the southern margin of the quadrangle, seismic reflection and refraction studies by Rene and others (1988) have more accurately delineated the Cenozoic basins. Along an east-northeast-trending line extending about 6 kilometers (4 mi) from an origination in the Floating Island quadrangle (south of the Lucin 4 SW quadrangle), a shallow basin was interpreted from reflection and refraction data. This basin contains about 275 meters (900 ft) of unconsolidated sediments underlain by about 152 meters (500 ft) of consolidated (Miocene?) sediments. The Paleozoic bedrock floor of the basin dips gently northeast near outcrops in the Silver Island Mountains, but reverses dip and thins out near the northeast end of the line in the Lucin 4 SW quadrangle. René and others (1988) interpreted these data as indicating a shallow Cenozoic basin east of Donner-Reed Pass but west of the major Cenozoic fault (figure 3) identified by Cook and others (1964). René and others conducted another seismic reflection experiment east of Silver Island 3.5 kilometers (2 mi) south of the Lucin 4 SW quadrangle to determine the geometry of the southern extrapolation of the major Cenozoic basin and fault (figure 3). They concluded that at least 1610 meters (5300 ft) of Cenozoic sediments lie in this basin and that its western margin consists of several faults and a steep bedrock erosional surface. Similar geometry may hold for the basin inferred by Cook and others (1964) to lie in the easternmost Lucin 4 SW quadrangle.

SUMMARY

Four events comprise the structural history of Crater Island: (1) minor low-angle faulting within the Swan Peak Quartzite, (2) high-angle faulting that accomplished west-northwest extension of strata, (3) pluton emplacement about 160-155 Ma (Miller and others, 1990b) accommodated by lateral shortening and ductile deformation of contact-metamorphosed wallrocks, and (4) Cenozoic down-faulting to form basins adjacent to Crater Island, and possibly tilting the Crater Island rocks as a block. Late Jurassic or older structural development at Crater Island parallels that described at the Newfoundland Mountains (Allmendinger and others, 1984), where a similar Late Jurassic pluton cuts the structures (Allmendinger and Jordan, 1984, 1989).

HYDROLOGY

Mountainous and flatland areas of the Lucin 4 SW quadrangle are extremely arid and support much less vegetation than do ranges west of the Great Salt Lake Desert. No springs were observed in the quadrangle. Even at the mouths of canyons, alluvial fans draining large upland areas apparently discharge little ground water because no springs are observed at the alluvium-playa boundary, as is typical of the southern Pilot Range.

ECONOMIC GEOLOGY

Mineral deposits have been worked at Crater Island since 1901 or earlier and have yielded copper, silver, gold, and lead. During the past 30 years or so, exploration for tungsten resulted in a few newer developments (Doelling, 1980), all of which were abandoned. Most producing areas are associated with igneous rocks as tactite zones or mineralization adjacent to dikes, with a few exceptions

that are associated with quartz and calcite veins. The five principal areas of exploration at Crater Island were described by Doelling (1980); those within the Lucin 4 SW quadrangle are briefly summarized below. In addition to the established workings, several unworked non-metallic mineral occurrences are worthy of description.

Occurrences Associated with Plutons

Tactite zones along pluton borders contain a prolific skarn mineral assemblage (Doelling, 1980), as well as copper and tungsten (scheelite or powellite) minerals and limonite. Prospects for tungsten include: (1) the Eureka Quartzite close by the porphyritic monzogranite pluton, and (2) the Swan Peak Quartzite exposed south of the porphyritic granodiorite pluton. These tactite zones may have potential for copper, gold, and silver. Similar occurrences may exist in positions buried by alluvium or lake sediments. Especially promising areas are: (1) the areas near the exposures of the porphyritic monzogranite pluton, and (2) along the eastern margin of Crater Island, where highly recrystallized and iron-stained Cambrian strata may indicate a nearby pluton in the subsurface.

Occurrences Associated with Dikes

Granodiorite dikes cutting Paleozoic strata in many places are strongly sericitized. Most sericitized dikes were observed within 1 kilometer (0.6 mi) of the Sheepwagon fault system. Some of these granodiorite dikes are limonite-stained and carry hematite after pyrite. Prospects in wallrocks to mafic dikes cutting the lower part of the Garden City Formation (Doelling, 1980) have encountered malachite, chrysocolla, azurite, bornite, and chalcopyrite.

Occurrences Associated with Veins

Small prospects explored a calcite vein in the Johns Wash Limestone in the central Lucin 4 SW quadrangle. A brown, extremely coarse-grained, calcite vein cuts the host marble. Local red alteration of the marble may be related to the vein, but no metallic minerals were noted at this locality.

Structurally Controlled Silicification

High-angle faults cutting Middle Ordovician strata in the west-central part of the quadrangle are variably silicified; red-brown jasperoid has been prospected in places, and black silica masses are present in some faults. Silicification in these and other faults may be associated with disseminated gold or other mineralization.

Silica

The Eureka Quartzite and some beds of the Swan Peak Quartzite are composed of nearly pure silica; these units are locally abundant in the quadrangle.

Brine

Concentrated elements in brines within the saturated playas adjacent to Crater Island may be economically retrievable. Nolan (1927) described potash composition of brines in the area and Lines (1979) compared brines of Pilot Valley playa with those of the Bonneville Salt Flat.

Gravel

Gravel deposited in beaches and tombolos abounds at Crater Island. The gravel is moderately to well sorted and is a source of construction materials.

low-gradient sheet floods is indicated by playa and fine-grained alluvial deposits on flats surrounding Crater Island. During 1987 to 1989, water pumped from Great Salt Lake flooded part of the southeastern Lucin 4 SW quadrangle.

Eolian dunes fringing Crater Island are active. They may migrate across improperly located roads, building sites, or other constructions.

Quaternary faults were mapped in the Pilot Range (Miller and others, 1982; Miller and Schneyer, 1985). Although the frequency and magnitude of earthquakes along these faults are unknown, large earthquakes in the Pilot Range could severely shake the Crater Island area.

GEOLOGIC HAZARDS

Flooding is the primary hazard at Crater Island. Narrow canyons and washes concentrate water onto alluvial cones which show evidence of youthful, intermittent activity. Intense rainstorms are capable of initiating devastating floods and debris flows in these geologic environments. Bulldozer tracks only one or two decades old have been destroyed where they traverse washes and fans in the quadrangle. Periodic flooding by standing water or by

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