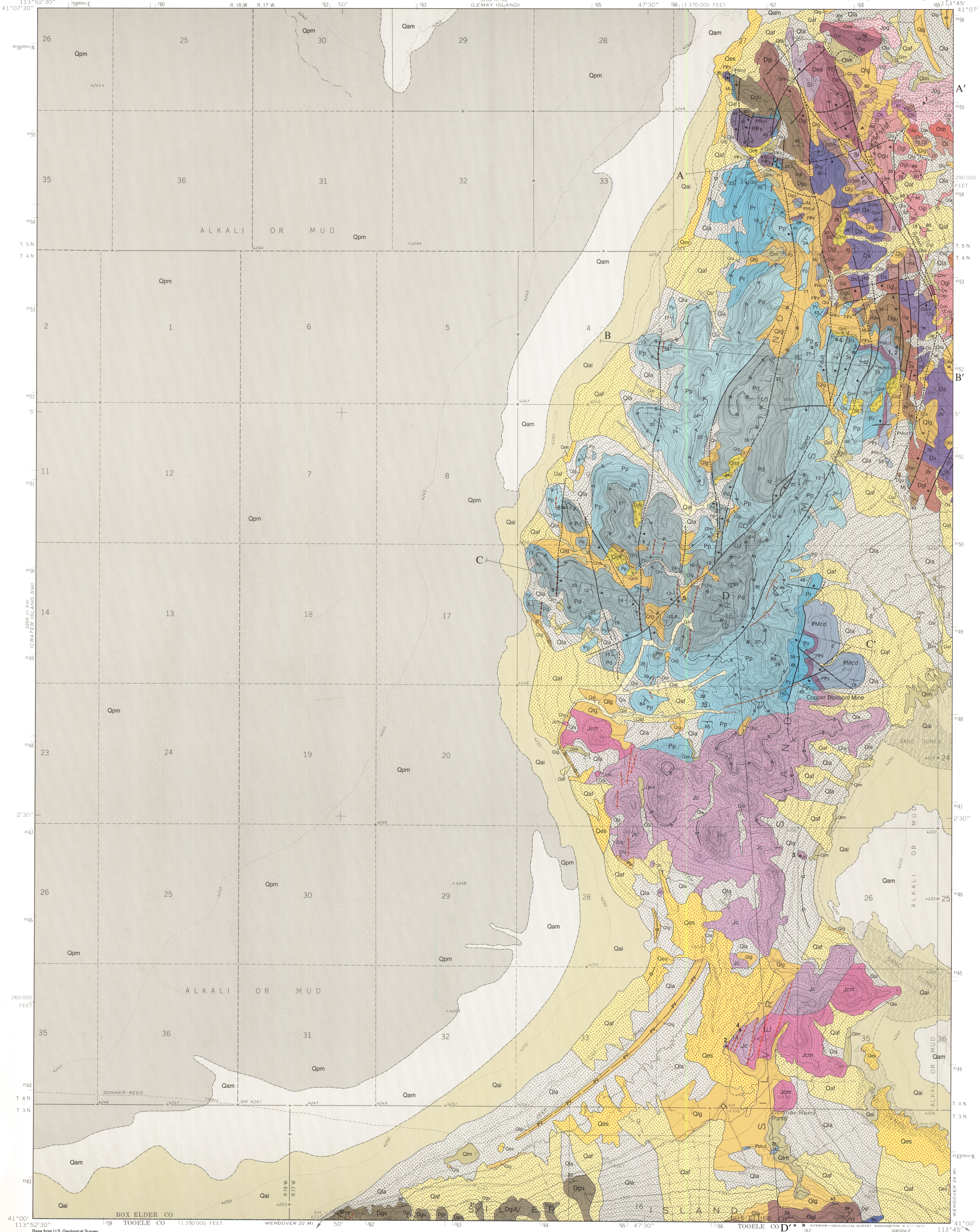
UTAH GEOLOGICAL AND MINERAL SURVEY
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with
THE UNITED STATES GEOLOGICAL SURVEY



Base from U.S. Geological Survey, Crater Island Quadrangle 1970

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

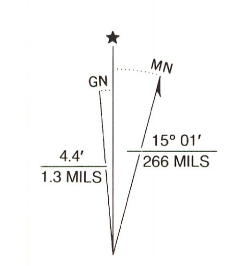
SCALE 1:24 000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL



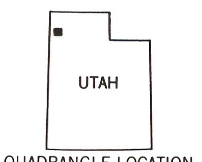
UTM GRID AND 1990 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

GEOLOGIC MAP OF THE CRATER ISLAND QUADRANGLE, BOX ELDER COUNTY, UTAH

by

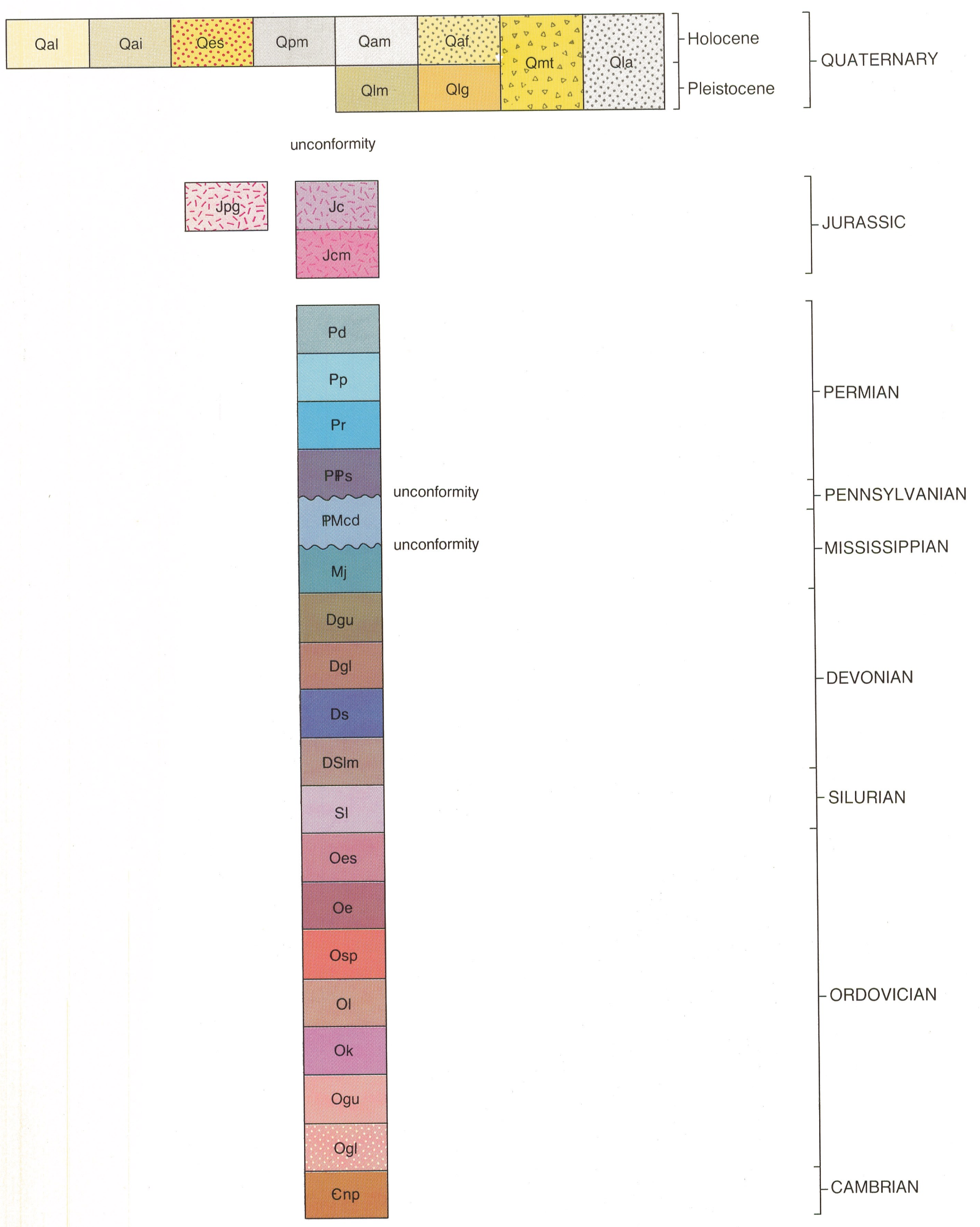
David M. Miller, Teresa E. Jordan,
and Richard W. Allmendinger

1990



QUADRANGLE LOCATION

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 playa; gradational into 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. Forms thin sand sheets and small dunes less than 1.8 meters (6 ft) thick in most places; forms blow-out dunes as much as 6 meters (20 ft) thick near Donner-Reed Pass.*

Qpm Playa mud (Holocene) — *White to tan mud, silt, and halite deposits of plastic consistency underlying nearly flat expanses east and west of Crater Island.*

Qam Alluvial mud (Holocene) — *Tan to brown mud and silt 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.*

Qmt Mass-movement talus (Holocene and Pleistocene) — *Blocky, boulder to cobble deposits on steep slopes. Locally includes colluvium.*

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 interbedded and (or) 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. Locally includes poorly exposed underlying marl.*

Jpg Porphyritic granodiorite (Jurassic) — *Light-gray, porphyritic, biotite granodiorite and monzogranite. Forms light-brown, rounded outcrops in the northern part of the quadrangle.*

Jc Crater Island Quartz Monzonite (Jurassic) — *Light- to dark-gray, coarse-grained, subequigranular to equigranular, biotite-hornblende quartz monzonite. Underlies gray-brown, rugged hills in much of southern part of the quadrangle. Locally includes:*

Jcm Monzodiorite — *Dark-brown, coarse-grained, biotite-augite monzodiorite to monzonite. Conspicuously poikilitic; biotite, as much as 2 inches across, is after augite oikocrysts. Forms dark-colored, low hills.*

Pd Unnamed dolomite (Permian) — *Light-gray, thin-to medium-bedded dolomite and interbedded, medium-brown, quartz sandstone. Dolomite contains white chert interbeds or nodules and brown sand laminae. Forms brown cliffs.*

Pp Pequop Formation of Steele (1960) (Permian) — *Dark-gray limestone and interbedded brown, sandy limestone forming ledgy steep slopes that typically are striped brown and gray. Limestone dolomitized in many areas. Bioclastic beds common.*

Pr Riepetown Sandstone of Steele (1960) (Permian) — *Brown, thin- to medium-bedded, calcareous, quartz sandstone and sandy limestone. Forms brown cliffs.*

PIPs Strathearn Formation (Permian and Pennsylvanian?) — *Well-bedded, brown conglomerate consisting of chert, quartz, sandstone, and limestone clasts in light-gray, clastic, limestone matrix. Forms dark-brown cliffs.*

IPMcd Chainman Shale and Diamond Peak Formation, Undivided (Pennsylvanian and Mississippian) — *Brown quartz sandstone, gray and green siltstone and shale, and gray quartzite; less common siliceous, quartz-chert-quartzite conglomerate. Forms gentle slopes.*

Mj Joana Limestone (Mississippian) — *Black, thin-bedded, coarse-grained, fossiliferous limestone in upper part and light-gray, massive to thick-bedded limestone in lower part. Forms caps of cliffs and steep slopes underlain by Guilmette Formation (Dgu, Dgl).*

Guilmette Formation (Devonian) — Divided into:

Dgu Upper member — *Thick-bedded to massive, light-gray limestone containing common algal heads and* Amphipora. *Forms massive light-colored cliffs.*

Dgl Lower member — *Thick-bedded, black limestone containing common algal heads and* Amphipora. *Forms steep, ledgy slopes.*

Ds Simonson Dolomite (Devonian) — *Laminated dolomite with black and light-gray units interlayered on 1.8- to 6-meter scale (6-20 ft); upper part dominantly black and includes limestone beds. Forms ledgy slopes with alternating light and dark colors.*

DSlm Lone Mountain Dolomite (Devonian and Silurian) — *Light-gray to buff, coarse-grained, thick-bedded to massive dolomite. Characteristically laminated or mottled. Forms pale cliffs.*

Sl Laketown Dolomite (Silurian) — *Thick-bedded, mottled dolomite. Upper part is dark to medium gray, lower part is light gray to buff. Lower part and basal part of upper part contain abundant white chert nodules. Forms steep slopes.*

Oes Ely Springs Dolomite (Ordovician) — *Black, medium- to thick-bedded dolomite. Upper part mottled. Forms prominent cliffs.*

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) — *Interlayered brown dolomite, gray silty limestone, brown sandy dolomite, and dolomitic quartzite. Unit is lithologically heterogenous on 6- to 18-meter scale (20-60 ft). 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.*

Garden City Formation (Ordovician) — *Divided into:*

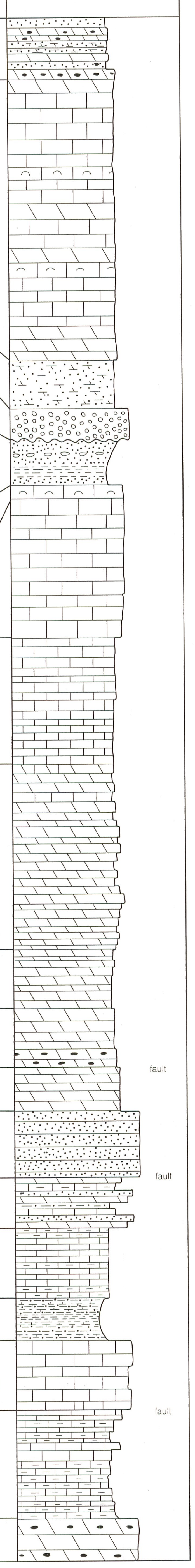
Ogu Upper member — *Light- to medium-gray, thick-bedded to massive, slightly silty limestone forming steep slopes. Where marbleized, unit is alternating bands of yellow, blue-gray, and dark-gray.*

Ogl Lower member — *Medium-gray and tan, thin-bedded, silty limestone. Forms gentle slopes.*

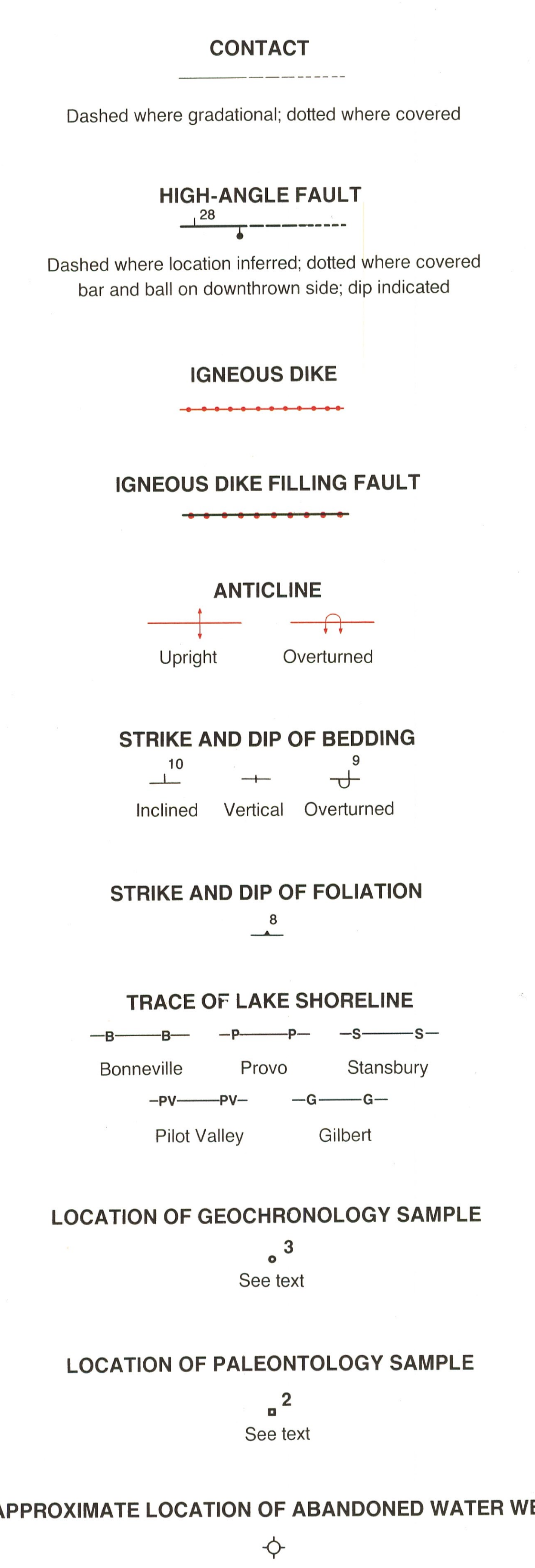
Ꞓnp Notch Peak Formation (Cambrian) — *Dark-gray to black, medium- to thick-bedded dolomite and limestone. Upper part carries abundant chert nodules, commonly black. Forms cliffs and steep slopes.*

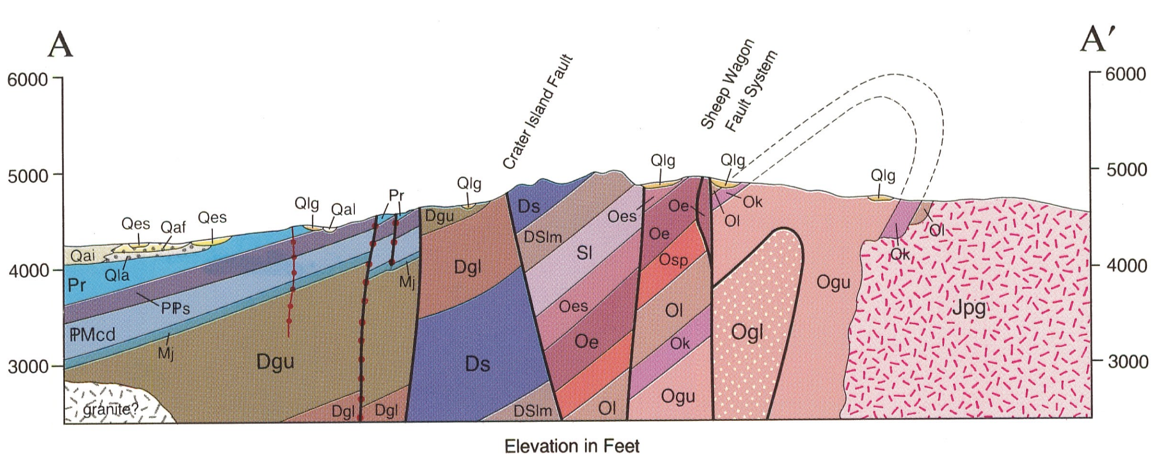
FORMATION		SYMBOL	THICKNESS feet (meters)
Unnamed dolomite		Pd	400+ (120+)
Pequop Formation		Pp	1800+ (549+)
Riepetown Sandstone		Pr	300 (90)
Strathearn Formation		PIPs	200 (60)
Chainman Shale and Diamond Peak Formation, undivided		IPMcd	255 (80)
Joana Limestone		Mj	85 (26)
Guilmette Formation	Upper member	Dgu	900+ (274+)
	Lower member	Dgl	810+ (247+)
Simonson Dolomite		Ds	1170 (355)
Lone Mountain Dolomite		DSlm	370 (113)
Laketown Dolomite		Sl	380+ (115)
Ely Springs Dolomite		Oes	280 (85)
Eureka Quartzite		Oe	430+ (130+)
Swan Peak Quartzite		Osp	325+ (100+)
Lehman Formation		Ol	440 (134)
Kanosh Shale		Ok	280 (85)
Garden City Formation	Upper member	Ogu	450+ (137+)
	Lower member	Ogl	700+ (210+)
Notch Peak Formation		Ꞓnp	260+ (78+)

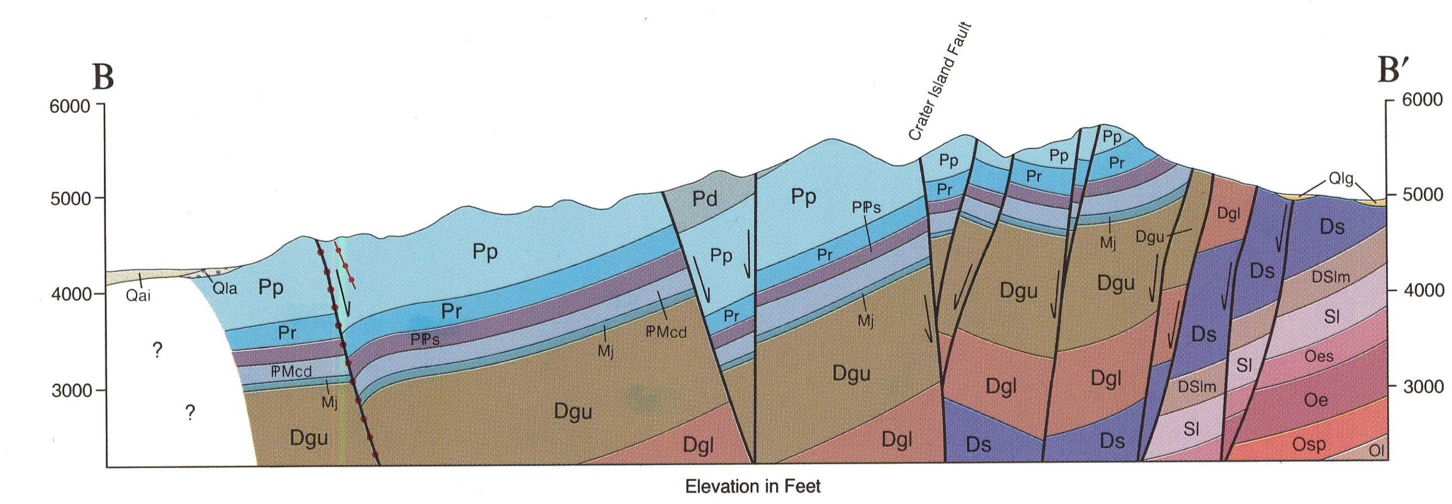
LITHOLOGY

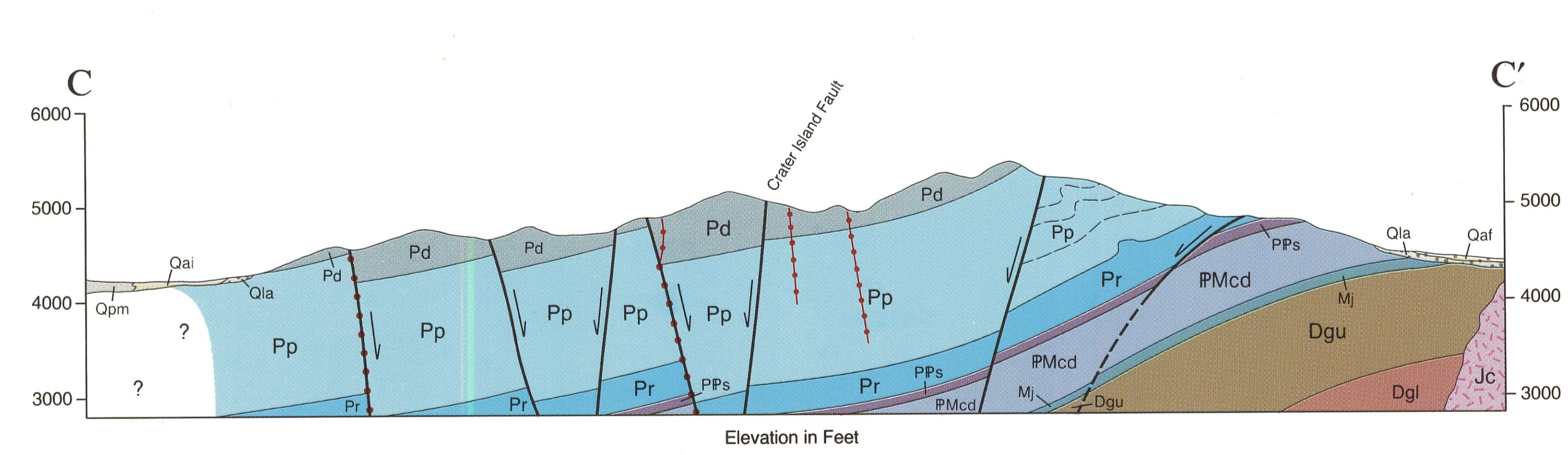


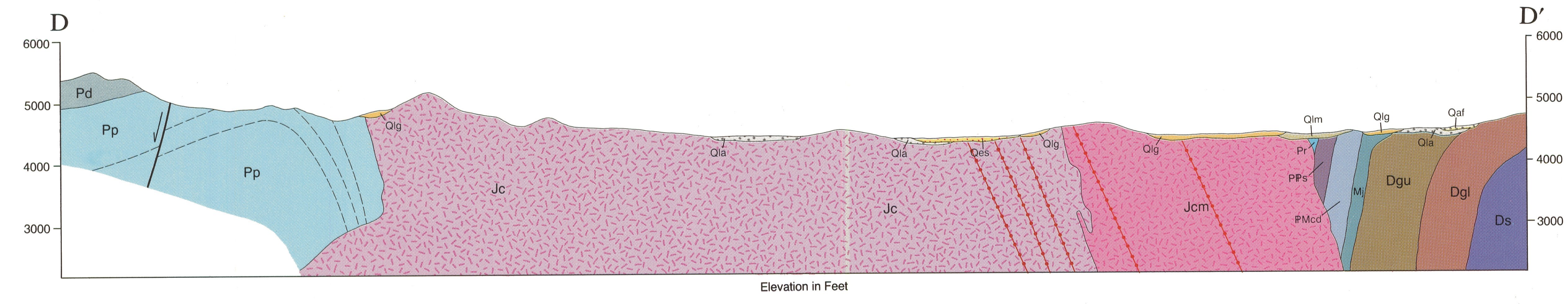
MAP SYMBOLS











GEOLOGIC MAP OF THE CRATER ISLAND QUADRANGLE, BOX ELDER COUNTY, UTAH

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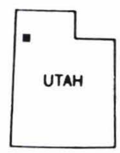
and Richard W. Allmendinger



MAP 128 **1990**
UTAH GEOLOGICAL AND MINERAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

UTAH GEOLOGICAL AND MINERAL SURVEY
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

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GEOLOGIC MAP OF THE CRATER ISLAND QUADRANGLE BOX ELDER COUNTY, UTAH

by
David M. Miller[1], Teresa E. Jordan[2], and Richard W. Allmendinger[2]

ABSTRACT

The Crater Island 7.5-minute quadrangle lies in northwestern Utah and includes part of the northern Silver Island Mountains and the adjacent Pilot Valley Playa. A thick sequence of miogeoclinal Paleozoic rocks, ranging from Cambrian to Permian in age, underlies the Silver Island Mountains 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 area covered by the quadrangle; shorelines cut into bedrock and alluvial fans indicate that the lake reached about 1589 meters (5210 ft) in elevation at its maximum depth. Mining operations in several locations have explored skarn mineralization associated with the Jurassic granitoids.

INTRODUCTION

The Crater Island quadrangle encompasses vast flatland in its western part and mountains in its eastern part. The eastern part is underlain by Crater Island, which is the northernmost mountain of the Silver Island Mountains (figure 1). The western two-thirds of the quadrangle is a part of Pilot Valley playa. Crater Island ranges in elevation from 1750 meters (5743 ft) at its crest to about 1295 meters (4250 ft) at the margin. The adjacent playa is about 1292 to 1295 meters (4240-4250 ft) in elevation within the quadrangle. 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.

Rainfall is scarce at Crater Island and the surrounding Great Salt Lake Desert, and there is sparse vegetation. A single spring was noted during investigations. The desert climate provides superb, little-weathered outcrops.

Early studies of parts of Crater Island and vicinity by Stansbury (1853) and Gilbert (1890) dealt chiefly with the surrounding desert. Anderson and Schaeffer conducted the only previous systematic geologic mapping studies of the range (Anderson, 1957; many articles in Schaeffer, 1960). They identified Cambrian to Permian strata, several granitoid plutons, and several units of surficial deposits including extensive sediments deposited in Lake Bonneville. Doelling (1980) described the economic geology of Crater Island.

Our detailed geologic mapping has updated several aspects of the stratigraphy and structure of Paleozoic rocks exposed at Crater Island, and we have firmly established the age of the granitoids as Jurassic. The basic map pattern of the stratigraphic units and portrayal of the 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 Allmendinger, in preparation.).

This report on the Crater Island quadrangle and its companion report on the adjacent Lucin 4 SW quadrangle represent continuations of geologic-map studies in the northwestern Utah area (figure 2).

GEOLOGIC SETTING

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

Thick accumulations of miogeoclinal Paleozoic sediments, predominantly carbonate, were deposited in northwestern Utah. Ensuing Mesozoic tectonism included plutonism, metamorphism, folding and faulting, and was followed by Cenozoic normal faulting associated with regionwide 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.

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[1]*U.S. Geological Survey*
[2]*Cornell University and U.S. Geological Survey*

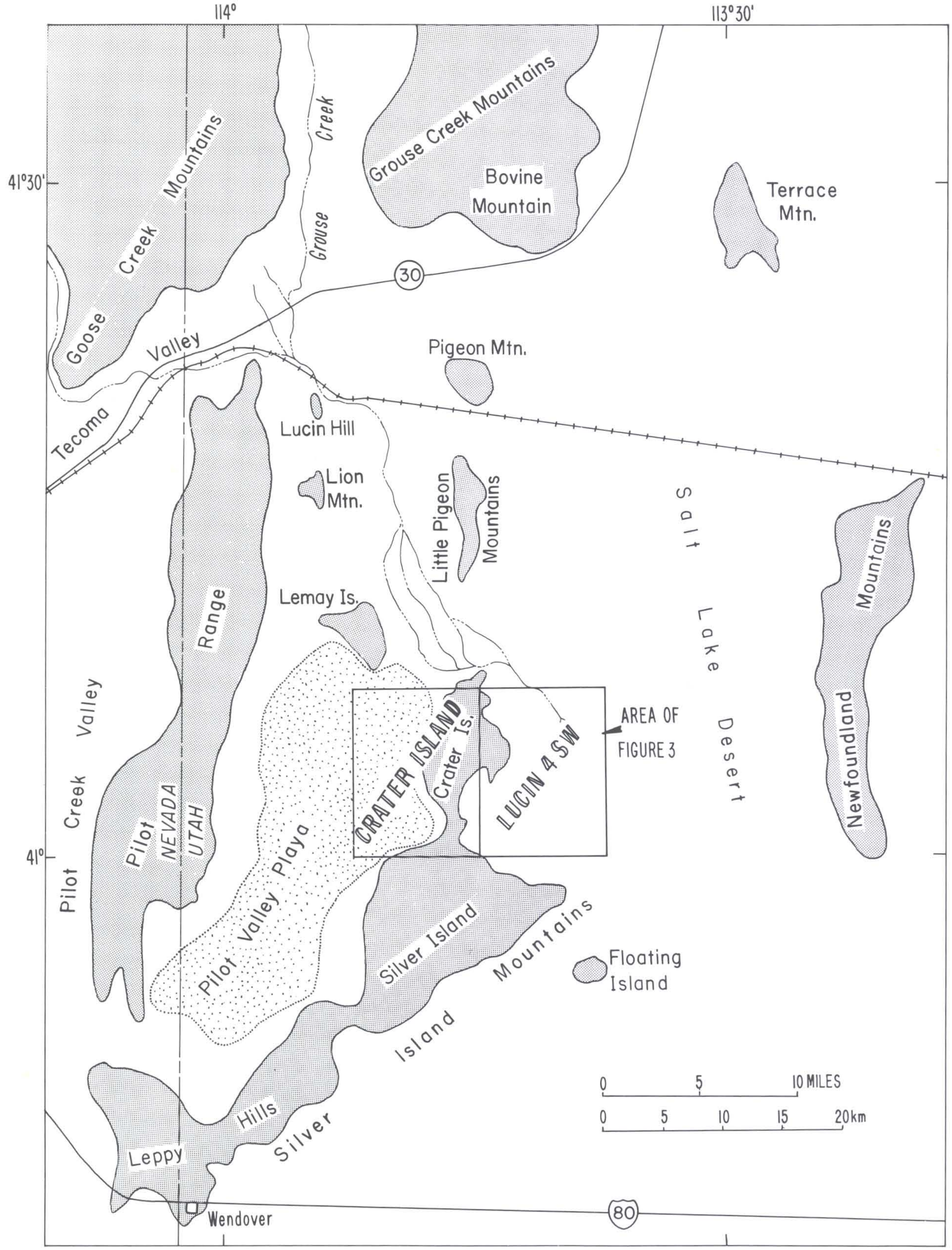

Figure 1. Location of Crater Island in northwestern Utah. The Crater Island quadrangle and companion-report Lucin 4 SW quadrangle are outlined.

MAP UNITS

Cambrian Rocks

Notch Peak Formation: The Notch Peak Formation is a limestone and dolomite unit, thick-bedded, ridge-forming, and approximately 335 meters (1100 ft) thick. Only its upper part, consisting of chert-rich, dark-gray dolomite interbedded with dark-gray limestone, occurs in the Crater Island quadrangle. In the adjacent Lucin 4 SW quadrangle, the unit is also 335 meters (1100 ft) thick.

The Notch Peak Formation at Crater Island is correlated with the unit elsewhere in eastern Nevada and western Utah on the basis of stratigraphic position and lithology. The Notch Peak Formation (Ꞓnp) at Crater Island may include a few beds in its uppermost part that are Early Ordovician in age, but studies by John Repetski (1985, personal communication) have not as yet verified the presence of such strata locally; therefore, its age here is regarded as Late Cambrian.

Ordovician Rocks

Lower and Middle Ordovician strata at Crater Island represent mappable parts of two widely distributed stratigraphic sections. The stratigraphic nomenclature used for units occurring in the eastern, thin margin of the miogeocline in northeastern Utah can be applied at Crater Island. However, mappable subdivisions within these units correlate more closely with parts of the Pogonip Group 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) applied a similar nomenclature to these rocks. The Garden City Formation and part of the Swan Peak Quartzite, units defined in northeastern Utah, are used herein; other unit names derive from Pogonip Group terminology.

Garden City Formation: The Garden City Formation is a thick, predominantly silty, limestone unit lying above the massive dolomite and limestone of the Notch Peak Formation. The Garden City is herein informally divided 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 of this unit are orange-colored sand and silt laminae, and intraformational conglomerate. The lower member is truncated in several places by normal faults, reaching 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 in places. The upper member is structurally truncated at its base and has a minimum thickness of 137 meters (450 ft). Where metamorphosed, it is composed of yellow, white, and blue-gray marble.

Conodonts from the lower member of the Garden City Formation confirm an Early Ordovician age at Crater Island (John Repetski, personal communication, 1985). The Garden City Formation at Crater Island is correlated with the unit in northeastern Utah on the basis of age, stratigraphic position, and lithology. Formations of the lower Pogonip Group that are time equivalent to the Garden City Formation cannot be differentiated at Crater Island.

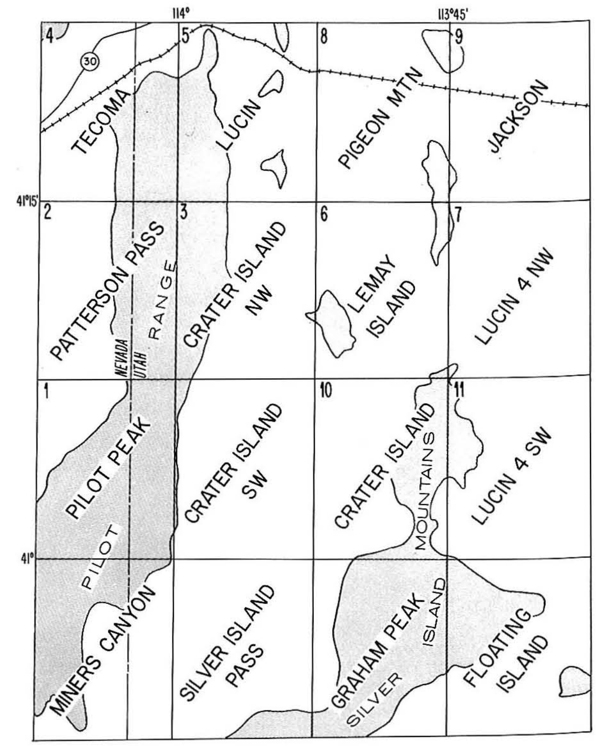

Figure 2. *Quadrangle index for Crater Island and vicinity, showing geologic maps published at 1:24,000. 1. Miller and Lush, 1981; 2 & 3. Miller, Lush, and Schneyer, 1982; 4. Miller and Schneyer, 1985; 5. Miller, 1985; 6. Miller and Glick, 1986; 7. Glick and Miller, 1986; 8. Glick and Miller, 1987; 9.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

Kanosh Shale: The Kanosh Shale (Ok) at Crater Island consists predominantly of dark-brown siltstone and shale and grayish-brown calcareous siltstone. Thin, gray bioclastic limestone beds of ostracods are diagnostic. Where metamorphosed, the unit consists of dark-brown hornfels. The Kanosh here is about 85 meters (280 ft) thick. The Kanosh is presumed to be Middle Ordovician in age at Crater Island. The Kanosh Shale at Crater Island is correlated with the formation elsewhere in western and central Utah and eastern Nevada, where it is part of the Pogonip Group, on the basis of lithology and stratigraphic position. It is probably laterally correlative with the lower part of the Swan Peak Quartzite in northeastern Utah (Oaks and others, 1977).

Lehman Formation: The Lehman Formation (Ol) at Crater Island consists of dark bluish-gray, silty limestone that exhibits thin regular bedding. Thin bioclastic beds contain gastropods and ostracods. The unit is about 134 meters (440 ft) thick. The age of the formation is here considered Middle Ordovician.

The Lehman Formation at Crater Island is correlated with the formation elsewhere in western and central Utah and east-central Nevada where it is part of the Pogonip Group. However, at the type locality the Lehman 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 Formation type section or the Eureka Quartzite at Crater Island may be younger than at the type section.

Swan Peak Quartzite: The rock-unit occurring between the Lehman Formation and the Eureka Quartzite at Crater Island is lithologically heterogeneous, consisting of brown, gray, and black dolomite, gray and black silty limestone, and brown and white sandstone. The proportions and stratigraphic positions of these rock types change along strike; the causes of these changes are partly depositional and partly structural. Orthoquartzite and calcareous sandstone form lens-shaped bodies in several places, and faults duplicate and truncate section in other places. Orthoquartzite in places is as pure as that in the overlying Eureka Quartzite, but it 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 consist of dark-gray calcareous dolomite. The unit is greater than 100 meters (325 ft) thick here. The Swan Peak is considered Middle Ordovician in age at Crater Island.

The Swan Peak Quartzite (Osp) at Crater Island is correlated with the middle part of the Swan Peak Quartzite exposed at the type locality in northeastern Utah on the basis of lithology and stratigraphic position. Conodonts recovered from the unit in the adjacent Lucin 4 SW quadrangle are considered Middle Ordovician in age, further supporting this stratigraphic assignment. The unit also correlates broadly with the Crystal Peak Dolomite of Webb (1956), which occurs stratigraphically between the Lehman Formation and Eureka Quartzite in central Utah.

Eureka Quartzite: The Eureka Quartzite (Oe) at Crater Island is a prominent, cliff-forming, white orthoquartzite unit . It consists of medium sand grains that are extremely well size sorted, well rounded, and cemented by silica. Locally occurring gray ellipsoidal patches are caused by dolomitic cement. Color variations in the rocks include blue, yellow, and gray-blue tones. The Eureka is fault-bounded in all exposures at Crater Island; its minimum thickness is 130 meters (430 ft); a structurally complex occurrence at the north end of Crater Island has a structural thickness of nearly 475 meters (900 ft). The age of the unit here is considered to be Middle Ordovician.

The Eureka Quartzite at Crater Island is correlated with the type Eureka 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 (Oaks and others, 1977).

Ely Springs Dolomite: The Ely Springs Dolomite (Oes) at Crater Island consists of dark-colored dolomite that is recognizable as three distinct lithic intervals. The lower interval consists of medium-bedded, very dark-gray dolomite. The middle interval consists of dark-gray dolomite with a variety of 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). The total thickness of the Ely Springs Dolomite here is about 85 meters (280 ft). The formation is considered to be Late Ordovician in age at Crater Island.

The Ely Springs Dolomite at Crater Island is correlated with Ely Springs Dolomite 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 probably stratigraphically equivalent to, the Fish Haven Dolomite of northeastern Utah.

Silurian Rocks

Laketown Dolomite: The Laketown Dolomite (Sl), which is here geographically extended to Crater Island, is a chert-bearing light- and dark-colored dolomite. The lower one-fourth of the unit bears abundant white chert nodules; this part of the unit is medium-gray dolomite in its upper part and light-gray dolomite in its lower part. The upper three-fourths of the unit consists of medium- to dark-gray dolomite that is mottled and contains burrows. Approximately 10% of this upper part of the unit consists of thick beds of dolomite. The Laketown is a minimum of 115 meters (380 ft) thick, but its lower part is in all cases cut by a fault. The unit is considered to be Silurian in age at Crater Island.

The Laketown Dolomite at Crater Island is correlated with the formation elsewhere in the central Silver Island Mountains (Sheehan, 1979) on the basis of stratigraphic position, lithology, and the presence of *Halycites* sp.

Silurian and Devonian Rocks

Lone Mountain Dolomite: The Lone Mountain Dolomite (DSlm) at Crater Island 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 of the unit. The unit is about 113 meters (370 ft) thick here. Its age at Crater Island is regarded as Silurian and Early Devonian.

Sheehan (1979) described a shelf-to-slope transition for Upper Silurian strata in the Silver Island Mountains area. This transition is reflected by a change in nomenclature from the Sevy Dolomite (shelf facies) used south and east of the Silver Island Mountains to Lone Mountain Dolomite (slope facies) at the Silver Island Mountains and west. Both formations are light-colored dolomite, but the Sevy is lighter with strongly developed laminations, whereas the Lone Mountain is nearly featureless. The transitional strata at Crater Island are assigned to the Lone Mountain Dolomite because laminations are developed in only part of the unit exposed there and are nowhere as pronounced as in the Sevy. Neither the Sevy nor the Lone Mountain were recognized by Schaeffer (1960) in the Silver Island Mountains.

Devonian Rocks

Simonson Dolomite: The Simonson Dolomite (Ds) at Crater Island consists of thick-bedded, superbly laminated dolomite and subordinate limestone that is divided into upper and lower parts. The lower part of the unit is ledgy, alternating light and dark dolomite. The dolomite ranges from black, dark brown, and dark gray to light gray and light-medium gray. The lighter beds constitute about 20% of the lower part of the unit. Some beds show intraclasts, scour features, and cross stratification. Sedimentary breccia beds also occur. One characteristic bed in the lower part of the unit 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 Dolomite at Crater Island is considered to be Middle Devonian in age, and is about 355 meters (1170 ft) thick.

The Simonson Dolomite at Crater Island is correlated with the formation elsewhere in eastern Nevada and western Utah on the basis of stratigraphic position and lithology. The sharp contact between dolomite of the Simonson and limestone of the overlying Guilmette Formation in the Pilot Range (Miller and Schneyer, 1985) is blurred by transitional lithologies and interbedding at Crater Island and not definable farther east in the Newfoundland Mountains (Allmendinger and Jordan, 1989).

Guilmette Formation: The Guilmette Formation, which is here geographically extended to Crater Island, consists of cliff-forming silt-free limestone that is divided into a lower, black limestone member and an upper light-gray-weathering massive limestone member. Both members contain common beds of *Amphipora*, stromatolite "heads," and "hash" of bryozoan, crinoid, and coral debris. The lower member (Dgl) is well bedded and black with the exception of 2 or 3 white to light-gray beds. Lamination is poorly developed, in marked contrast with the underlying Simonson Dolomite. Several interbeds of dolomitic limestone also occur within the lower member. The upper member (Dgu) forms massive pale gray cliffs. Thick bedding in the fossiliferous limestone is less distinct than in the lower member. Although quartz sand occurs in the upper part of the Guilmette Formation at Silver Island (Schaeffer, 1960), the Pilot Range, and many other locations, it is not present at Crater Island. The limestone is light gray to black when fresh. The lower member is about 247 meters (810 ft) thick, and the upper member is a minimum of 274 meters (900 ft) thick from incomplete sections. The Guilmette Formation is regarded as Middle and Late Devonian in age at Crater Island.

The Guilmette Formation at Crater Island is correlated with the unit elsewhere in Nevada and western Utah on the basis of stratigraphic position and lithology. As with the underlying Simonson Dolomite, the Guilmette at Crater Island appears to be transitional between an easily recognizable massively bedded limestone unit exposed in the Pilot Range to the west (Miller and Schneyer, 1985) and the limestone, dolomite, and shale in the Newfoundland Mountains without Guilmette and Simonson equivalents (Allmendinger and Jordan, 1989).

The top of the Guilmette Formation is not precisely defined at Crater Island and requires further study. As described by Schaeffer (1960), the Devonian Pilot Shale and Mississippian Joana Limestone overlie the Guilmette in the southern Silver Island Mountains, but the Pilot Shale thins northward until the Joana Limestone rests directly on the Guilmette Formation at Silver Island and at Crater Island. These relations were interpreted as an erosional unconformity beneath the Joana by Schaeffer (1960). However, Mississippian conodonts collected from strata slightly below rocks typical of Schaeffer's Joana Limestone indicate that the uppermost part of Schaeffer's Guilmette is actually much younger than the remainder of his Guilmette. Upon further study, we have tentatively placed the Joana-Guilmette contact at the base of a zone 0.15 to 0.9 meters (0.5-3 ft) thick of brown silty limestone, below which is thick-bedded *Amphipora*-bearing limestone. Above this silty interval is medium- to thick-bedded limestone that is darker gray than that typical of the Guilmette. This contact requires paleontologic verification. These relations indicate either a disconformity at the base of the Joana, or a facies change with continuous sedimentation.

Mississippian Rocks

Joana Limestone: The Joana Limestone (Mj), which is here geographically extended to Crater Island, consists of distinctively black, thick-bedded, abundantly fossiliferous limestone in its upper part and dark-gray limestone in its lower part. The lower part is similar to, but darker than, limestone in the underlying Guilmette Formation. The upper part of the unit carries abundant crinoid debris, as is typical for the unit elsewhere, but is chert-free, unlike the Joana exposed farther south in the Silver Island Mountains (Schaeffer, 1960). The Joana is about 26 meters (85 ft) thick at Crater Island; its age here is Early Mississippian (table 1, locations 1 and 2).

The Joana Limestone at Crater Island is correlated with the formation elsewhere in eastern Nevada and western Utah on the basis of stratigraphic position, lithology, and age. These rocks were previously called the Madison Limestone by Anderson (in Schaeffer, 1960, p. 114).

Karst solution cavities as much as 4.5 meters (15 ft) thick formed within the Joana Limestone and (or) upper Guilmette Formation. Clastic dikes composed of the coarsely fossiliferous upper part of the Joana occur within the lower part of the Joana. At the northernmost exposures of the Joana Limestone, solution cavities within rocks belonging to the upper Guilmette Formation and lower Joana contain jumbled clasts composed of the upper part of the Joana Limestone and jasperoid and sandstone clasts from the undivided Chainman Shale and Diamond Peak Formations. Some of these clasts are rimmed by thick concentric layers of calcite deposits. Features indicative of karst development within the upper part of the Guilmette Formation previously were noted in the region (Schaeffer, 1960; Miller and others, 1982; Miller and Schneyer, 1985).

Mississippian and Pennsylvanian Rocks

Chainman Shale and Diamond Peak Formation, undivided: The (undivided) Chainman Shale and Diamond Peak Formations (IPMcd) cannot be mapped separately at Crater Island. This composite unit is best exposed below the highest peak at Crater Island, where it is crudely recognizable as consisting of a lower sandstone interval, a middle shale interval, and an upper sandstone interval. The lower sandstone interval is brown, about 6 meters (20 ft) thick, and heterogeneous; its lithology ranges from siltstone to coarse sandstone. The middle shale interval is also heterogeneous, consisting of gray papery shale, dark-gray blocky shaly limestone, and fine quartz sandstone and siltstone. The upper sandstone interval consists of gray impure subarkosic sandstone, gray orthoquartzite, and a few beds of conglomerate. Sandstone in the upper sandstone interval is medium to coarse grained. Conglomerate clasts are chert, quartz, and quartzite, with diameters under 2.5 centimeters (1 in). The middle and upper intervals vary considerably in thickness. Jasperoid is common at or near the base of the composite unit. Feldspar is a common constituent of sandstone and conglomerate beds throughout the unit. The composite unit is about 80 meters (255 ft) thick at its northern outcrops. Near Copper Blossom mine the unit consists of metamorphosed sandstone and hornfels. At this location, the unit could be structurally thickened; it is greater than 113 meters (370 ft) thick in the structure section. South of Donner-Reed Pass, conglomerate and orthoquartzite of

Table 1. *Paleontology data for the Crater Island quadrangle*

Map Number	*Field Number*	*USGS Collection*	*Rock Unit*	*Fossil Age*	*Date of Report*	*Paleontologist*	*Faunal Description*	*Location Latitude*	*Longitude*
1	M82CI-02	28895-PC	Joana Limestone	Kinderhookian (Early Mississippian)	7/6/83	Anita G. Harris	2 Pa elements of *Siphonodella* cf. *S. Obsoleta* Hass 3 juvenile Pa elements of *Siphonodella* sp. indet. 1 Pa element of *Ozarkodina* sp (long-bladed morphotype) 1 M element 10 indet. bar, blade, and platform fragments *Siphonodella Obsoleta* ranges from the Upper *Duplicata* zone through the lower part of the *Isosticha*—Upper *Crenulata* Zone. CAI = 5 Age is Kinderhookian.	41°05′25″	113°45′27″
2	M82CI-03	28896-PC	Joana Limestone	Kinderhookian (Early Mississippian)	7/6/83	Anita G. Harris	10 Pa elements of *Ozarkodina Crassidentatus* (Branson and Mehl) 1 Pa element of *Polygnathus Communis Communis* Branson and Mehl 28 Pa elements of *Siphonodella Isosticha* (Cooper) 1 M element 4 Sc elements 49 indet. bar, blade, and platform fragments Age is late Kinderhookian *(Isosticha*—Upper *Crenulata* Zone). CAI = 5	41°05′25″	113°45′27″
3	T82-40	f14554	Riepetown Sandstone	Wolfcampian (Early Permian)	6/7/83	R.C. Douglass	Two slightly different lithologies were included. The first one is a silty limestone with abundant crushed fusulinids. The rock has been altered by dolomitization, destroying many details. Rare specimens of *Psuedofusulinella* sp. are present. The more common form present is either a *Pseudofusulina* sp. or a primitive *Parafusulina* sp. The rock is definitely of Permian age and is probably of late Wolfcampian age. The second sample does not show alteration. The fusulinid is an advanced *Schwagerina* sp. characteristic of the late Wolfcampian.	41°05′22″	113°45′50″
4	T82-41	f14555	Pequop Formation	Wolfcampian (Early Permian)	6/7/83	R.C. Douglass	Silty limestone with abundant organic debris and large subcylindrical fusulinids. The fusulinid bears considerable resemblance to *Schwagerina Jeffordsi* Skinner & Wilde, 1966, described from the Quinn River Crossing area of NW Nevada. The age is probably late Wolfcampian.	41°05′28″	113°45′57″
5	T82-42	f14556	Pequop Formation	Leonardian or Wolfcampian (Early Permian)	6/7/83	R.C. Douglass	Crinoidal, fusulinid packstone with calcareous siltstone matrix. Three genera of fusulinids are present in this sample: *Pseudofusulinella* sp. is rare. *Schwagerina?* sp. is uncommon. *Parafusulina?* sp. is the most common form. The stage of development suggests a very early Leonardian form, but latest Wolfcampian cannot be ruled out.	41°05′26″	113°46′09″
6	83C5	f14659	Unnamed dolomite	Leonardian (Early Permian)	1/3/84	R.C. Douglass	This sample contains *Schwagerina?* sp. and *Parafusulina* sp., and suggest a Leonardian age.	41°04′26″	113°48′13″

the unit crop out in isolated exposures and black quartzite cuttings from a water well drilled near BM 4398 in the pass (plate 1), suggesting that the unit underlies much of the southern part of the pass.

The Chainman Shale and Diamond Peak Formation, which are both herein geographically extended to Crater Island, are correlated with the units in eastern Nevada on the basis of stratigraphic position and lithology. This composite unit is bounded by unconformities at Crater Island; its overall age at Crater Island is regarded as Late Mississippian to Early Pennsylvanian based on regional relations. Unconformities bounding the composite unit have been described in the Silver Island Mountains (Schaeffer, 1960), at Lemay Island (Miller and Glick, 1986), and in the Pilot Range (Miller, 1984). Unconformities in other parts of the northwest Utah area may be correlative (e.g., Allmendinger and Jordan, 1984; Douglas and Oriel, 1984; D.M. Miller, unpublished mapping, 1988).

Pennsylvanian and Permian Rocks

Strathearn Formation: The Strathearn Formation (PPs), which is here geographically extended to Crater Island, consists of conglomerate and sandstone. It rests with marked unconformity on Mississippian rocks; an angularity of 5 degrees with underlying rocks is common and channels as deep as 4.6 meters (15 ft) are cut into underlying rock units. The basal few beds of the Strathearn contain clasts derived from the Chainman Shale and Diamond Peak Formation, undivided, such as rounded dark chert and quartzite pebbles. Higher in the section, clasts are predominantly derived from the Pennsylvanian Ely Limestone and include angular white chert, fossiliferous gray limestone, dolomite, and white to pink quartzite. The Ely Limestone was probably once present at Crater Island but was eroded by modest uplift. Clast diameters are 25 centimeters (10 in) maximum. The conglomerate is clast supported. Its matrix is composed of clastic limestone and silt. Thin bedding is marked by changes in clast size. Size sorting is poor and grading within beds is lacking. Shallow channels and cross stratification occur in the upper part of the formation, where it is finer grained and shows better bedding. The formation grades upward into calcareous sandstone, which contains lenses of gravel and pebble conglomerate near Copper Blossom mine at the northernmost exposures. Because this calcareous sandstone facies is local, it is not divided at Crater Island. The total unit is about 60 meters (200 ft) thick here. Although all Strathearn Formation outcrops occur north of the Crater Island pluton, float blocks from the unit occur at Donner-Reed Pass, suggesting that the Strathearn underlies some of the pass (plate 2, section DD').

The Strathearn Formation at Crater Island is correlated with the unit elsewhere in eastern Nevada and western Utah on the basis of stratigraphic position and lithology. As detailed by Schneyer (1984), the unit is chiefly, if not entirely, Permian (Wolfcampian) in age in the southern Silver Island Mountains; its age at Crater Island is regarded as Late Pennsylvanian(?) to Early Permian. At Crater

Island, the unit contains abundant clasts derived from the Ely Limestone, which in the nearby ranges is Lower to Middle Pennsylvanian in age (Miller, 1984; Schneyer, 1984). This lithology is in sharp contrast to similar-appearing conglomerate 13 kilometers (8 mi) north at Little Pigeon Mountain assigned to the Strathearn(?) Formation (Miller and Glick, 1986) that predominantly contains clasts recycled from the Chainman Shale and Diamond Peak Formation. The northernmost exposures of the Strathearn at Crater Island show increased amounts of dark chert and quartzite clasts, suggesting a lithology transitional between central Crater Island and Little Pigeon Mountain. Clasts in the Strathearn were derived from epiorogenic highlands to the north (Schneyer, 1984).

Permian Rocks

We recognize three Permian formations at Crater Island. Permian strata in the Silver Island Mountains previously were not divided into separate units by Schaeffer (1960) because of complex facies changes.

Riepetown Sandstone: The Riepetown Sandstone (Pr) of Steele (1960) at Crater Island consists of medium- to thick-bedded, fine-grained dolomitic or calcareous quartz sandstone and forms brown-weathering cliffs. Intervals of thick-bedded, bioclastic dolomite or limestone are also common. The basal part of the unit is gradational with pebbly sandstone of the Strathearn Formation, and the uppermost part is gradational with sandy limestone or dolomite of the overlying Pequop Formation. The Riepetown has been dolomitized in many places, but it probably was originally a calcareous sandstone. The unit is about 90 meters (300 ft) thick at Crater Island; its age is here regarded as Early Permian.

The Riepetown Sandstone is correlated with the Riepetown Sandstone named by Steele (1960) at Rib Hill near Ely, Nevada. At its type locality at Rib Hill, the Riepetown consists of yellowish-gray quartz sandstone with interbedded gray silty limestone. It is late Wolfcampian (Early Permian) in age. Steele (1960) defined the Riepetown as consisting of the basal sandstone member of the Rib Hill Formation of Pennebraker (1932), and abandoned the name Rib Hill since that term was previously used in Wisconsin. Nevertheless, the name Rib Hill has continued to be used by some authors (see Marcantel, 1975). At Ely, the Riepetown underlies the Pequop Formation and overlies a limestone unit that, in turn, overlies the Strathearn Formation. A fusilinid sample (table 1, number 3) indicates a late Wolfcampian age for the upper part of the Riepetown at Crater Island. The Riepetown at Crater Island is, therefore, correlated with the unit at Rib Hill and elsewhere in eastern Nevada and western Utah on the basis of stratigraphic position, lithology, and age.

In the southern Silver Island Mountains, Schneyer (1984) identified the Ferguson Mountain Formation of Berge (1960), which intertongues with and overlies the Strathearn Formation and underlies the Pequop Formation. The silty limestone of the Ferguson Mountain Formation could conceivably represent a less clastic facies of the Riepetown Sandstone at Crater Island.

Pequop Formation: The Pequop Formation (Pp) of Steele (1960) at Crater Island consists of three lithic intervals: a lower, ledgy sandy limestone interval; a middle, thinner bedded cherty limestone interval; and an upper, thick-bedded coarsely bioclastic cherty limestone interval. As with the underlying Riepetown Sandstone, the unit is variably dolomitized. The lower interval consists of pale-brownish-gray-weathering, light-medium-gray fresh, thickly bedded limestone or dolomite. Many beds contain fine-grained quartz sand, and a few beds are calcareous quartz sandstone. Prominent gray bioclastic limestone beds also occur. The middle interval consists of thin- to medium-bedded, fine-grained, light and medium-gray limestone and thinly bedded, dark-gray, siliceous or cherty bands. The limestone is commonly fetid and coarsely bioclastic, and reddish-brown very fine-grained sandstone beds occur throughout this interval. The upper interval consists of medium- to thick-bedded, ledgy, coarsely bioclastic limestone or dolomite. Dark-gray, black, and medium-gray colors predominate. Although cherty, the upper interval contains less chert than does the middle interval. Crinoid fragments, fusilinids, bryozoans, and brachiopods are locally abundant throughout the Pequop. The unit has an observed thickness of between 425 to 550 meters (1400-1800 ft) at Crater Island, but its stratigraphic thickness is unknown due to structural complexities.

The Pequop Formation at Crater Island is correlated with the unit elsewhere in eastern Nevada and western Utah on the basis of stratigraphic position, lithology, and age. Fusilinids recovered from its basal part and from the middle interval indicate a late Wolfcampian to Leonardian (Early Permian) age for the unit at Crater Island (table 1 , numbers 4, 5). In the southern Silver Island Mountains the Pequop is over 732 meters (2400 ft) thick (Schneyer, 1984), and elsewhere in the region it ranges from 914 to 1067 meters (3000-3500 ft) thick (Marcantel, 1975).

Unnamed dolomite: An unnamed dolomite unit (Pd) rests conformably on the Pequop Formation at Crater Island. The unit consists of light-gray dolomite and brown dolomite (containing quartz sand) interbedded on a medium to thick scale. The dolomite is typically laminated and cross-laminated. White chert constitutes about 10-20% of the unit except in its upper part, where the chert content typically increases to 40%. Dolomite beds occur locally that are rich in crinoids, fusilinids, and brachiopods. The unit is a minimum of 120 meters (400 ft) thick, and the top is not exposed.

The unnamed dolomite unit is Leonardian (Early Permian) in age on the basis of fusilinids (table 1, numbers 6, 7) and is probably broadly correlative with the cherty and sandy dolomite of the Grandeur Formation of the Park City Group cropping out at Lemay Island (figure 1) and in areas to the northwest (Miller and Glick, 1986).

Jurassic Rocks

Several plutons and numerous dikes that are Jurassic in age (Miller and others, 1990) are exposed at Crater Island. These intrusive rocks show many modal, chemical, and textural affinities and are considered to represent a magmatically related suite. Unifying features include overlapping modal and chemical compositions, broadly collinear variations of oxides with respect to SiO_2, similar xenolith suites, ubiquitous dikes, and features such as broad metamorphic aureoles indicating a moderately deep (lower epizonal) level of emplacement. All plutons and dikes yield K-Ar biotite isotopic ages of 150 to 155 Ma, and muscovite from an altered dike yielded a 148 Ma K-Ar isotopic age. Because similar K-Ar data are reported for a pluton in the Toano Range that yielded a 162 Ma U-Pb date on zircon, Miller and others (1990) inferred pluton emplacement ages at Crater Island of 160 to 165 Ma.

The igneous suite within the Crater Island quadrangle is represented by two plutonic centers that are located at the north end of Crater Island and at Donner-Reed Pass, and by dike swarms and scattered dikes throughout Crater Island. The two plutonic centers are composite; the northern one consists of granodioritic fine-grained and porphyritic phases (Miller and Glick, 1986), and the pluton at Donner-Reed Pass consists of a mafic monzodiorite phase intruded by widespread quartz monzonite. A small pluton cropping out in the adjacent Lucin 4 SW quadrangle consists of porphyritic monzogranite; although it is close by the pluton at Donner-Reed Pass, it is compositionally distinct. Dikes range widely in composition and texture, but seem to mirror the compositional variations seen in the plutonic centers.

Porphyritic granodiorite: A granodiorite pluton (Jpg) underlying the northern end of Crater Island was referred to as the North stock and the Sheepwagon stock by Schaeffer (1960), and the northern composite parts were described by Glick and Miller (1986) and Miller and Glick (1986). The fine-grained phase is exposed north of the Crater Island quadrangle. The part of the pluton within the northeastern Crater Island 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 centimeters (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. Mafic segregations are biotite rich and in rare cases show size grading suggestive of magma-current deposits. Pink aplite dikes and pink pegmatite dikes are common; they typically strike N20°W and dip moderately northeast. Locally common, porphyritic, fine-grained granodiorite dikes may represent a fine-grained phase of the plutonic suite (Miller and Glick, 1986). Quartz veins are common at pluton contacts with metamorphosed Ordovician strata. Xenoliths occur widely and are of two types: (1) porphyritic, biotite quartz monzodiorite that 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 centimeters (1 ft) in diameter and are rounded or oval in shape.

A K-Ar cooling age of 150.3 ± 3.8 Ma on biotite (Miller and others, 1990) established the granodiorite as Jurassic in age (table 2, number 1). 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 N50°E to N60°E create a blocky outcrop appearance.

Crater Island Quartz Monzonite: A composite pluton underlies tan to dark-brown hills throughout much of the southeastern part of the Crater Island quadrangle. The pluton is herein named the Crater Island pluton for its location at Crater Island. The pluton is composed of the herein-named Crater Island Quartz Monzonite, consisting of quartz monzonite and subordinate dark monzodiorite phases. Additional minor constituents of the pluton are intermediate-composition granitoids and dike swarms. Schaeffer (1960) separated the pluton into two geographically separate stocks—Crater Island and South stocks—but recognized that they represent a single igneous body. Aeromagnetic data (Zietz and others, 1976) suggest that the Crater Island pluton is extensive in the subsurface. The data indicate a prominent magnetic high centered just west of, and encompassing, outcrops of the Crater Island pluton. The pattern suggests that the magnetite-bearing pluton extends in the shallow subsurface for several miles west of Donner-Reed Pass and underlies an area of at least 70 kilometers^2 (30 mi^2).

***Table 2.** K-Ar sample locations*

Map Location	Sample Number	Rock Type	Age (Ma)	Material Dated
1	M84CI-65	Porphyritic granodiorite	150.3 ± 3.8*	Biotite
2	YAG-88	Quartz monzonite	143 ± 3**	Biotite and hornblende
3	SI-1	Quartz monzonite	152.2 ± 3.9*	Biotite
4	F84SI-58	Granodiorite dike	152.2 ± 3.9*	Biotite
5	M85CI-27	Granodiorite dike	154.6 ± 3.9*	Biotite

*Data reported by Miller and others (1990)
**Data reported by Armstrong and Suppe (1973); revised with new decay constants

The Crater Island Quartz Monzonite is here named for exposures of plutonic rocks occurring in the southern part of Crater Island. The unit consists principally of quartz monzonite (Jc) and a more areally restricted monzodiorite phase (Jcm). The type locality of the Crater Island Quartz Monzonite is designated as the exposures located in section 34, T. 4 N., R. 17 W. of the Crater Island 7.5-minute quadrangle, where intrusive relations between the two phases of the pluton are particularly instructive.

The quartz monzonite phase of the Crater Island Quartz Monzonite underlies about 13 kilometers^2 (5 mi^2) of southern Crater Island. This phase is homogenous and consists of medium- to coarse-grained, biotite-hornblende quartz monzonite to monzogranite. It is light-grayish-pink where fresh, and typically forms tan-colored weathered hills with blocky to rounded outcrops. The rock is subequigranular, with major mineral phases of clear quartz, gray plagioclase, pink orthoclase, and clusters of biotite and hornblende. Sphene is a ubiquitous accessory mineral, and augite, zircon, and apatite are less common. Orthoclase ranges in size from 2 mm to 6 mm (.08-0.2 in) and rarely to 10 mm (0.4 in). Mafic minerals range from 12 to 24 percent modally. Rare, pink aplite dikes are generally less than 2 centimeters (0.7 in) wide.

The Crater Island Quartz Monzonite bears a xenolith suite similar to that of the porphyritic granodiorite. Two common types are (1) equigranular, hornblende-biotite-plagioclase-sphene quartz diorite to tonalite xenoliths that generally are less than 10 cm (3.9 in) diameter, and (2) porphyritic, biotite-hornblende-sphene quartz monzodiorite xenoliths with abundant plagioclase phenocrysts and less common biotite phenocrysts. The second type is similar to the monzodiorite phase of the pluton. Both xenoliths in places carry fine-grained, black diorite xenoliths.

A biotite and hornblende mixture from the Crater Island Quartz Monzonite at its type locality (table 2, number 2) was K-Ar dated by Armstrong and Supper (1973) as 143 ± 3 Ma (recalculated using new decay constants). Miller and others (1990) reported a K-Ar age for biotite from the unit as 152.2 ± 3.9 Ma (table 2, number 3). The impure mineral separate dated by Armstrong and Suppe (1973) may have caused the much younger age (Miller and others, 1990). The Crater Island Quartz Monzonite was emplaced in Jurassic time.

A dark-colored monzodiorite phase (Jcm) underlies the northwestern and southeastern parts of the Crater Island pluton. The monzodiorite phase is dark-gray, medium- to coarse-grained, poikilitic biotite-augite monzodiorite to monzonite. It contains gray plagioclase, white to pink orthoclase, quartz, biotite, and augite. Sphene, olivine, zircon, and apatite are accessory minerals. Biotite typically occurs as clusters of small crystals after augite and, in hand specimen, exhibits single cleavage orientations over areas as large as 60 cm^2 (9.4 in^2), the size of augite oikocrysts along which it has grown. In some samples the feldspar-dominated matrix between the mafic mineral clusters is very fine grained and appears to be recrystallized. Mafic minerals total 24 to 30% modally.

The monzodiorite phase is cut by rare aplite and pegmatite dikes and contains rare mafic schlieren. The monzodiorite phase in many places exhibits sharp contacts with the quartz monzonite phase, but in some places a compositionally transitional rock-type intervenes. This transitional phase is a dark-gray, medium-grained, sometimes poikilitic, biotite-hornblende quartz monzodiorite. The transitional phase is well exposed at the northeasternmost part of the pluton, near the road to the Copper Blossom mine. The transitional quartz monzodiorite appears to grade into monzodiorite over distances of 3 to 6 meters (10-20 ft), and locally this quartz monzodiorite phase and the monzodiorite phase are included as xenoliths within the quartz monzonite phase. These relations indicate that the monzodiorite phase is slightly older than the quartz monzonite phase, but petrographic and petrologic affinities indicate a close relationship between these rock types. By these relations, the monzodiorite phase is inferred to be Jurassic in age.

Dike rocks: Other than aplite and pegmatite dikes associated with plutons, igneous dikes at Crater Island consist of three general types: (1) common granodioritic dikes occurring as swarms cutting the Crater Island pluton and most sedimentary rocks, (2) rare mafic dikes occurring 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, respectively. Representatives of all three dike types cut faults in several places at Crater Island. Dikes generally strike northerly.

Granodioritic dikes: At the type locality of the Crater Island Quartz Monzonite, 0.8 kilometers (0.5 mi) north of Donner-Reed Pass, a swarm of dark-brown-weathering dikes cuts the pluton. These dikes are approximately granodiorite in composition, are medium- to dark-gray where fresh, and have a fine- to medium-grained matrix bearing, medium- and coarse-grained phenocrysts of quartz, plagioclase, orthoclase, hornblende, and biotite. The dikes are as much as 12 meters (40 ft) wide, have sharp contacts, and locally constitute about 20% of the bedrock. Although the dikes vary somewhat texturally and in the relative abundance of hornblende and biotite, they are quite uniform in their mineralogy, orientation, and relations to plutonic rocks. A K-Ar cooling age of 152.2 ± 3.9 Ma on biotite (table 2, number 4) from a dike at this location indicates that the dikes were emplaced shortly after pluton emplacement. The similarity between pluton and dike mineralogies suggest that these intrusive bodies belong to a single magmatic event.

Similar granodioritic dikes cut sedimentary rocks in many places. About 2 kilometers (1.2 mi) west of Copper Blossom mine, fine-grained, hornblende-biotite granodiorite intrudes along a fault. Biotite from this dike (table 2, number 5) yielded a K-Ar age of 154.6 ± 3.9 Ma, which is consistent with the interpretation that these dikes are related to dikes in the Crater Island pluton. Dikes occurring west of the porphyritic granodiorite pluton carry larger orthoclase phenocrysts, creating trimodal grain sizes: groundmass, medium grains, and orthoclase up to 3.8 centimeters (1.5 in) in diameter. In a few locations, granodioritic dikes are highly sericitized. One such dike in the Lucin 4 SW quadrangle was dated by K-Ar at 148.1 ± 3.7 Ma (sericite), indicating that alteration probably occurred shortly after emplacement.

Mafic dikes: Black to dark-greenish-gray dikes and pods are locally common within Ordovician strata in the Lucin 4 SW quadrangle and are sparse in rocks within the Crater Island quadrangle. Most dikes are composed predominantly of augite, with accompanying hornblende, biotite, and plagioclase together constituting less than 50% of the dikes by volume. Mafic dikes are generally highly altered; sericite after plagioclase and chlorite after mafic minerals are common. The dikes are as wide as 5.5 meters (18 ft). One dike only 1.5 meters (5 ft) wide caused a bleached zone in wallrock limestone 4.6 meters (15 ft) wide on either side. A solitary mafic dike cutting Permian strata has intruded a north-striking fault.

Felsite dikes: Light-colored aphanitic felsite dikes cut Permian strata about 1 to 2 miles (1-3 km) west of Copper Blossom mine. Phenocrysts of feldspar and quartz are common in these rocks; biotite is rare. Sericitic and silicic alteration is intense in these dikes, many of which contain hematite after pyrite. The felsite dikes have intruded granodioritic dikes and several faults in this area.

Quaternary Deposits

Quaternary deposits in the Crater Island quadrangle are primarily alluvial and lacustrine. Lacustrine deposits are widespread and varied, and possibly represent one of the best records of Lake Bonneville history in the northwestern part of the ancient lake. The lake nearly covered Crater Island, leaving only a narrow island at the highstand, and the lake deposits therefore record all stages of the lake history: its rise to the highest level (represented by the Bonneville shoreline), its decline, and its return to its last widely developed shoreline (Gilbert). Subsequent extremely shallow stages of the lake may be expressed as well.

Lacustrine and alluvial deposits, undivided: Pre-Lake Bonneville alluvial units of sandstone and gravel at Crater Island are commonly overlain by gravels that are slightly reworked along paleo-lake shorezones or by irregular sheets of lacustrine marl. These deposits are mapped as an undivided unit (Qla) where exposures are complex or poor.

Lacustrine gravel: Gravel deposited at the shore lines of Lake Bonneville (Qlg) is widely represented at Crater Island (Schaeffer, 1960). Gravel deposits associated with five regionally mappable shorelines, including the herein informally designated Pilot Valley shoreline, are summarized in table 3. The Bonneville and Provo (Gilbert, 1890) shorelines are represented by broad erosional platforms and gravel constructions where they cut Permian strata. Shorelines from about the Provo level and below typically display tufa-cemented gravel.

In a series of outcrops along two stream channels in the northeastern part of the quadrangle (NE ¼ of section 34, T. 5 N., R. 17 W.), gravel associated with the Stansbury shoreline lies between two marl accumulations (the lower marl and overlying Stansbury gravel deposits are shown by Schaeffer (1960, figures 33 and 35). These relations indicate a lake-level oscillation and development of the Stansbury shoreline early in the transgressional history of Lake Bonneville.

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 shorezone gravel accumulation about 1306 meters (4285 ft) elevation. This shoreline also is prominently developed at southern Crater Island, and farther south in the Silver Island Mountains, warranting its informal designation for exposures bordering Pilot Valley. West of Donner-Reed Pass, where Pilot Valley shoreline gravels are dissected by streams, these exposures display an internal structure of alternating sand, pebbly sand, and pebble beds, all cross stratified. The deposits, over 3.6 meters (12 ft) thick, possibly represent multiple small-scale transgressions and regressions. Along the west side of Silver Island (figure 1), the white marl overlies gravel of the Pilot Valley shoreline, indicating that the gravel represents shorelines of the early transgressional phase of Lake Bonneville.

The Gilbert shoreline is underlain by pebbly sand in most locations. The beach crest was hand-leveled at 4262 ± 1 feet (1299 m) elevation along the southernmost prong of Crater Island within the adjacent Lucin 4 SW quadrangle.

Table 3.
Elevations of prominent shorelines at Crater Island

Shoreline	Feature	Elevations This report feet	Elevations This report meters	Elevations Schaeffer (1960) feet
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

Lacustrine marl: The white marl unit (Qlm) of Gilbert (1890) is present widely at Crater Island and is represented by thick accumulations in many valleys that were sheltered from storm action when under water and by thinner accumulations along flats. In the valleys it typically includes silt and sand beds derived from nearby bedrock sources, as well as extremely shelly intervals. At lower elevations along the margin of the flats, the marl typically is composed of mud, 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 regressive deposits following the transgression of the lake to the Gilbert shoreline. Poorly to well-sorted gravel representing terminal regressive lacustrine gravel and (or) alluvial gravel typically overlies the marl along the flanks of the range.

Alluvial mud: Alluvial-mud deposits (Qam) predominantly occur along the margin of Pilot Valley playa in the distal parts of Grouse Creek and small ephemeral streams emanating from Crater Island (figure 1). Sediments in parts of the Grouse Creek drainage system reaching the Crater Island quadrangle have travelled at gradients averaging 75 centimeters (2.5 ft) per mile, and consequently primarily consist of mud and silt. The alluvial-mud deposits commonly display scars of meandering-stream channels in aerial photographs. These deposits are gradational with playa mud, which represents alluvial-derived mud as well as mud deposited from suspension during periods of standing water.

Playa mud: Mud and silt deposited by a combination of alluvial and lacustrine processes (Qpm) underlie broad flats west of Crater Island. These mud deposits contain varying amounts of salt crystals. Although Scaheffer (1960) described a mappable salt pan in the center of Pilot Valley playa, the feature is probably only present during dry years. During our studies, when standing water persisted nearly year round on parts of playas east and west of Crater Island, no salt pans were observed. Dessication polygons are common on the playas.

Playa-mud deposits are gradational with alluvial-mud deposits to the north, where Miller and Glick (1986) distinguished the units on the basis of paler color in the playa-mud deposits there.

Mass-movement talus: Talus and scree (Qmt) form steep slopes commonly associated with the Permian unnamed dolomite unit and the Riepetown Sandstone. Small talus deposits are abundant; only large deposits are depicted on the geologic map. In many locations, talus slopes are cut by Lake Bonneville shorelines.

Eolian sand: Twin sheets of tan eolian silt and fine sand lie along the margins of playas east and west of Crater Island. Irregular mounds, probably representing degraded dunes, in these sand sheets are locally as much as 1.2 meters (4 ft) thick. A larger field of eolian sand occurs at Donner-Reed Pass, where blow-out dunes are hundreds of feet long and as much as 12 meters (40 ft) thick. The dune crescents open westward, indicating easterly transport of material. The blow-out dunes primarily consist of locally derived clasts of fine- to medium-sand size: quartz, feldspar and chert. In addition, about 30% of the clasts are ooids, both rod- and sphere-shaped. These dunes rest on a thin zone of pebbles, representing the Bonneville regression, which in turn rests on lacustrine silt and sand.

Alluvial silt: Bordering the range, along the margins of Pilot Valley playa and the desert east of Crater Island, extensive sheets of alluvial silt (Qai) constitute a facies transitional between the coarse alluvial deposits of the mountains and the 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 was probably deposited both as low-gradient alluvial sheets and as delta-like deposits within the margins of standing water bodies.

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: Alluvial-fan deposits (Qaf) primarily form active fans downslope from the mouths of canyons along the margin of Crater Island. The deposits overlie lacustrine deposits in most places, indicating that they are Holocene in age. South of Donner-Reed Pass, on the north flank of Silver Island, alluvial-fan deposits form sheets of coalesced fans.

Older alluvial-fan deposits are coalesced as broad, sloping bajada surfaces in the east-central part of the Crater Island quadrangle. These deposits are overlain by patches of Bonneville lacustrine deposits in many areas and have been reworked along Bonneville shorezones in others. The older fan deposits are mapped as the undivided lacustrine and alluvial deposits unit.

METAMORPHISM

Metamorphism of sedimentary rocks is expressed in several manners at Crater Island: skarn-mineral assemblages adjacent to plutons; bleaching and recrystallization adjacent to plutons, dikes, and unexposed plutons(?); and by widespread elevation of conodont alteration indices. 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, and other nearby ranges.

Paleozoic rocks are visibly altered adjacent to the Crater Island Pluton and to the porphyritic granodiorite pluton over distances as great as 0.8 kilometers (0.5 mi). Within about 30 meters (100 ft) of the plutons, wollastonite, diopside, and garnets occur. Farther from the plutons, rocks are coarsely marbleized and bleached in places. The Ordovician strata adjacent to the porphyritic granodiorite acquire a penetrative cleavage that is axial planar to the fold adjacent to the pluton, suggesting cleavage development and folding occurred during emplacement. Elsewhere, cleavage is sporadically expressed. Metamorphic calc-silicate minerals also occur adjacent to the porphyritic monzogranite body (of the Lucin 4 SW quadrangle) and in narrow zones adjacent to some mafic dikes.

Rocks in some areas show significant recrystallization and (or) bleaching, suggesting nearby, but unexposed, heat sources such as subsurface plutons (figure 3). Most strata in sections 27 and 34, T. 5 N., R. 17 W. are bleached and recrystallized. Alteration increases to the northwest, suggesting the presence of a westward extension of porphyritic granodiorite exposed to the northeast.

STRUCTURE

The structure of Crater Island is basically that of a homocline, with strata dipping westward about 30° on the east side of the range and 15° on the west. A major normal fault system (the Sheepwagon fault of Schaeffer (1960), cuts the homoclinal strata at passes from the north end of the island south-southeast to the central part of the island. This fault system displaces strata down to the west and in an apparent right-lateral sense. Faults with relatively smaller displacements are approximately north- and east-striking; they appear to merge with the Sheepwagon fault system. Many faults, primarily from the north-south set, are intruded by Jurassic igneous dikes (cross sections AA' and CC'). Other structures include megascopic folds and cleavage developed in strata adjacent to plutons and locally elsewhere, and a small-separation low-angle fault within the Swan Peak Quartzite in the Lucin 4 SW quadrangle. 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 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, another larger fault, the Crater Island fault of Schaeffer (1960), and numerous faults with less than 150 meters (500 ft) of dip separation (figure 3). The Sheepwagon fault system separates structural blocks with differing fault styles. The eastern block (mostly on the Lucin 4 SW quadrangle) contains two major faults striking within 30° of east and minor north-striking faults. The western block contains numerous minor north-striking faults that curve and splay into the Sheepwagon fault system, and several minor east-striking faults.

The Sheepwagon fault system is sinuous, north-northwest-striking, and splays at several points. Maximum stratigraphic throw is about 914 to 1219 meters (3000-4000 ft), and apparent dextral separation of the Eureka Quartzite is about 4 kilometers (2.5 mi)(figure 3). The faults within the 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, in contrast to 15° to 35° dips elsewhere.

Faults striking northerly in the block west of the Sheepwagon fault system dip steeply west for the most part, although one east dip was measured and many faults are not exposed sufficiently for structural measurements. Faults that are down to the east comprise a significant subset of the western block faults (figure 3). The Crater Island fault shows about 488 meters (1600 ft) of stratigraphic throw (down to the west) at the north end that decreases to about 90 meters (300 ft) southward at two east-striking faults (figure 3). West of the Crater Island fault is a fault with 457 meters (1500 ft) of stratigraphic throw that also decreases rapidly southward (figure 3). This western fault is cut by the Crater Island fault at its south end.

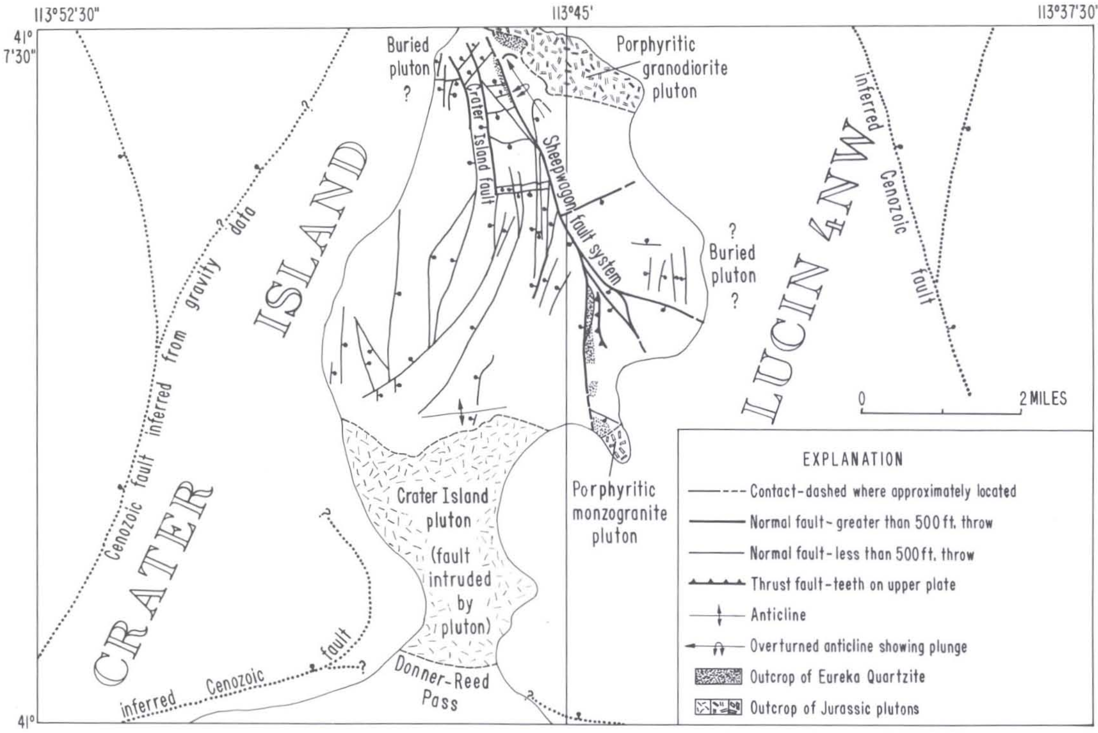

Figure 3. *Generalized structure map of Crater Island and Lucin 4 SW quadrangles, outlining areas above the surrounding flats and showing plutons. Buried Cenozoic faults are inferred from gravity data (Cook and others, 1964). Possible buried plutons inferred from distribution of metamorphosed rocks.*

East-striking faults 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. Although dip separations are generally less than 60 meters (200 ft), two east-striking faults at the south end of the zone of major separation on the Crater Island fault (figure 3) show greater separations. These relations suggest that the east-striking faults translate part of the separation on the Crater Island fault to the Sheepwagon system. The east-striking faults are therefore kinematically coordinated with the north-striking faults.

An inferred major east-striking fault in Donner-Reed Pass likely was intruded by the Crater Island pluton. Evidence for the fault is the juxtaposition of two structural domains. Strata exposed in the southern domain at Silver Island dip moderately to steeply to the northwest and north-northwest in the southernmost part of the Crater Island quadrangle and are shown by Schaeffer (1960). Dips in this homoclinal domain are nearly perpendicular to those in the northern domain of Crater Island, a relation we interpret as requiring a major fault between the blocks. Scraps of outcrop in the Donner-Reed Pass area suggest an unfaulted stratal sequence at the margin of the Crater Island pluton, requiring that the inferred fault was intruded by the pluton (plate 2, section DD').

Kinematic interpretation of the high-angle faults is complicated by the possibility of rejuvenation of the Sheepwagon fault system. Striae on fault planes in breccia zones of two minor north-striking faults show a rake of 70 to 80 degrees north, indicating oblique slip for part of the fault movement. Sigmoid flexures between minor north-striking faults reinforce the hypothesis of a dextral slip component on these faults. However, steep striae rakes and horst-and-graben faulting patterns in the west block indicate a predominance of dip slip on the minor faults. Our preferred interpretation is that deformation within the east and west blocks was caused predominantly by roughly horizontal extension oriented about WNW-ESE, with a component of subsidiary dextral slip along north-striking faults. Nearly vertical igneous dikes strike north to north-northeast, indicating that least compressive stress was oriented roughly west to north-northwest around 155 Ma, a stress orientation appropriate for the fault patterns.

The Sheepwagon fault system shows a greater magnitude of separation than other faults and separates blocks of differing structural style, suggesting that it is a primary structure. It may have had earlier fault movement (possibly Paleozoic in age) or it may have been controlled by boundary conditions such as deep-seated basement faults.

All high-angle faults (with the exception of one near the Copper Blossom mine) appear to be Late Jurassic or older because they are intruded by undeformed Jurassic granitoids or are deformed by structures related to pluton emplacement. North-striking faults in several parts of Crater Island are filled or cut by dikes representing the three compositional groups. North-striking faults in and splaying from the Sheepwagon system at its northern end we interpret as folded at the time of pluton emplacement. These relations indicate that no fault at Crater Island is demonstrably or plausibly younger than approximately 155 Ma. Allmendinger and Jordan (1984) described similarly oriented Jurassic dikes and plutons cutting normal faults in the Newfoundland Mountains.

The fault at Copper Blossom mine cuts folded and cleaved strata that are marginal to the pluton, structures that developed synchronously with pluton emplacement. These relations suggest that the fault was synchronous with or postdated pluton emplacement, but the fault has not been identified within pluton outcrops.

The Jurassic or older age for widespread normal faults at Crater Island indicates that localized faulting may have accompanied intrusion, or that a period of upper-crustal extension took place during the Jurassic in northern Utah. The similarity of these faults with those produced by Cenozoic crustal extension suggests caution in assigning all normal faults to "Basin-and-Range" tectonics.

Low-Angle Faults

Brecciated jasperoid common near the base of the undivided Chainman Shale and Diamond Peak Formation may indicate a fault zone controlled by bedding. However, breccia exposures are sporadic and no stratigraphic disruptions were observed. We interpret these features as indicating minor, local dislocations and hydrothermal alteration, rather than the presence of a through-going low-angle fault.

In the adjacent Lucin 4 SW quadrangle, a small low-angle fault cuts units within the Swan Peak Quartzite. Within the Crater Island quadrangle, the Swan Peak Quartzite occurs in a structurally complex zone near the porphyritic granodiorite pluton. At that location the Swan Peak is juxtaposed with the lower member of the Garden City Formation along a presumed fault that is covered by Quaternary deposits. This fault is unlike the normal faults elsewhere in the quadrangle, because the stratigraphic units are older on the west side. The structure bounding the Swan Peak on the west may represent the low-angle fault mapped in the adjacent quadrangle at a slightly different stratigraphic level.

Deformation Adjacent to Plutons

In contrast to the generally brittle behavior exhibited by faults, megascopic and mesoscopic folds and cleavage in the metamorphosed strata adjacent to plutons indicate plastic behavior. The close association of these structures to the visibly recrystallized contact-metamorphic rocks indicates deformation during Late Jurassic plutonism.

Strata describe anticlines with half-wavelengths of 0.8 kilometers (0.5 mi) adjacent to both the porphyritic granodiorite pluton and the Crater Island pluton. Fold limbs adjacent to the plutons dip steeply and axes parallel the pluton borders (figure 3), suggesting steepening or overturning of strata as the plutons were emplaced. Cleavage in folded Ordovician strata is well developed and parallel to the axial plane of the overturned fold. Overturned strata in the east limb, adjacent to the pluton, dip 60 to 80 degrees southwest. A fault between the upper and lower members of the Garden City Formation along the west limb of the fold appears to be folded parallel to strata. Similar relations may obtain farther north where the Sheepwagon fault system separates the Lehman Formation and Eureka Quartzite. An isolated block of the Eureka and Ely Springs Dolomite to the northwest structurally mirrors the overturned limb of the Kanosh Shale: steep dips and west-northwest strikes occur adjacent to the pluton. The Sheepwagon fault is not exposed, and could pass northward between the Eureka outcrops or it could curve to the east, consistently separating the Lehman and the Eureka. We prefer the latter interpretation for structural simplicity; otherwise an additional north-northwest striking fault with significant down-to-the-north separation would be required. According to this hypothesis, the faults are strongly curved; the curvature is consistent with folding during pluton emplacement.

A broad, asymmetric, upright fold in the marbleized Permian units borders the Crater Island pluton and trends east. Cleavage is axial-planar, striking N 75° W to westerly and dipping 65 to 70 degrees south. Chocolate-tablet boudinage in strata near the pluton indicate nearly uniaxial shortening perpendicular to the pluton. Cleaved strata are broken by many small faults in the Copper Blossom mine area, perhaps as a consequence of late stages of magma emplacement.

Cleavage is sporadically developed in areas of recrystallized rocks that may indicate nearby buried plutons (figure 3). Devonian to Permian strata in northwestern Crater Island show cleavage parallel to bedding.

Anticlines formed by adjacent plutons are not easily attributed to common models for pluton emplacement, because they suggest downward and outward inflation of the pluton. Similar relations were described by Allmendinger and Jordan (1984) adjacent to a Late Jurassic pluton in the Newfoundland Mountains.

Structural Configuration of the Basins

Cenozoic high- and low-angle normal faults associated with generally east-oriented 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 demonstrably of 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). In several ranges Paleozoic strata are subparallel to Cenozoic strata, and tilts in both indicate the tilting is associated with Cenozoic extension. North and west of Crater Island, Paleozoic and Cenozoic strata dip east, whereas east of Crater Island, Paleozoic strata dip west (Allmendinger and Jordan, 1984) and south of Crater Island northwest and southeast dips are observed in different structural blocks of Paleozoic and Cenozoic strata. These inconsistent regional relations may result from Mesozoic as well as Cenozoic faulting. Nevertheless, the best indication for Cenozoic tilting is given by the westerly dips of Paleozoic strata at Crater Island. Assuming that the 15° to 30° dips of strata resulted from Cenozoic tilting, the Jurassic high-angle faults were moderately to steeply west-dipping and chiefly normal prior to Cenozoic tilting, consistent with kinematic inferences based on their structural geometry.

In a regional gravity investigation west of Great Salt Lake, Cook and others (1964) described subsurface faults near Crater Island. A north-facing gravity gradient at the south side of Donner-Reed Pass (figure 3) suggests that shallow Cenozoic basins lie on both sides of the pass (Cook and others, 1964). Farther northwest a major gradient indicates that the western one-fourth of the Crater

Island quadrangle (figure 3) is underlain by a Cenozoic basin. The basin, estimated by Cook and others (1964) as about 760 meters (2500 ft) deep, has a generally north-trending eastern margin controlled by an inferred major fault zone. The position of this fault system is poorly constrained by the reconnaissance gravity data.

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 that primarily were displaced down to the west, (3) pluton emplacement at 160 to 155 Ma accommodated by folding 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).

ECONOMIC GEOLOGY

Mineral deposits have been worked at Crater Island since 1901 or earlier, producing copper, silver, gold, and lead. During the past 30 years or so, exploration for tungsten resulted in a few newer developments (Doelling, 1980), now abandoned. Most producing areas are associated with igneous rocks as exoskarn zones, with a few exceptions that are associated with quartz and calcite veins. The five principal areas of exploration were described by Doelling (1980) and are only briefly mentioned below. In addition to the established workings, several unworked metallic and non-metallic mineral occurrences are worthy of description.

Occurrences Associated with Plutons

Exoskarn zones along the northern border of the Crater Island pluton (Copper Blossom mine) and the southwestern border of the porphyritic granodiorite pluton contain pyrite, andradite, grossularite, calcite, epidote, tremolite, actinolite, wollastonite, and quartz, as well as minor amounts of copper minerals (chalcopyrite, chrysocolla, bornite, malachite, azurite) and scheelite, powellite, and molybdenite (Schaeffer, 1960; Doelling, 1980). These zones are formed in Lower Permian strata and the Lehman Formation, respectively, adjacent to the plutons, and have produced copper, silver, gold, lead, and tungsten. Additional prospects for tungsten were in the Swan Peak Quartzite exposed south of the porphyritic granodiorite pluton. Similar exoskarn occurrences may exist in positions buried by alluvium or lake sediments. Especially promising areas are: (1) the southeastern side of Donner-Reed Pass, where the Crater Island Pluton probably intruded Devonian limestone and Mississippian clastic rocks, (2) the northwestern extreme of Crater Island, where Ordovician to Devonian strata are marbleized, suggesting that a pluton is shallowly buried, and (3) the broad valley along the northwestern margin of the Crater Island pluton, where the pluton intruded Permian strata.

Occurrences Associated with Dikes

Several dikes show alteration and mineralization. Felsite dikes cutting Permian strata in many places carry hematite after pyrite. These dikes commonly show silicified wallrocks, as well. Sericitic alteration of granodioritic dikes was noted locally.

Occurrences Associated with Veins

Workings in Ordovician and Devonian strata, east-central Crater Island quadrangle, follow quartz and calcite veins showing copper minerals (Schaeffer, 1960; Doelling, 1980). Similar quartz veins occur in the igneous rocks near the border of the porphyritic granodiorite pluton.

Stratigraphically Controlled Jasperoid

Jasperoid is prevalent at or near the base of the undivided Chainman Shale and Diamond Peak Formation. The jasperoid is brown to black, as much as 2.1 meters (7 ft) thick, and locally contains azurite, malachite, and chalcopyrite. Fragments of sandstone and calcareous sandstone within the jasperoid suggest a replacement origin. The jasperoid locally occurs within karst fillings in the upper part of the Joana Limestone. In many locations, the jasperoid is brecciated and is thicker where east-striking faults intersect Mississippian strata. Although the jasperoid may mark low-angle faults, as described in the Pilot Range (Miller and Schneyer, 1985), such faults are unlikely to be through-going structures of large separation. Douglas and Oriel (1984) described disseminated gold mineralization in jasperoid in a similar stratigraphic context in an area just north of the Pilot Range.

Structurally Controlled Silicification

Fault zones are silicified in several locations. The Strathearn Formation is widely silicified where several faults merge in northwestern Crater Island (NE ¼, section 34, T. 5 N., R. 17 W.). Silicification in these and other faults possibly may be associated with disseminated gold.

Silica, Calcite, and Barite

The Eureka Quartzite and some beds of the Swan Peak Quartzite are nearly pure silica in composition. The uppermost part of the Guilmette Formation, which is quarried for clean limestone in the Toano Range (just west of figure 1), is widely exposed in the Crater Island quadrangle. Other limestone rock-units at Crater Island contain silt, sand, or dolomite. Barite veins were noted in the Guilmette immediately south of the Crater Island quadrangle (Schaeffer, 1960). Similar veins may continue into the Crater Island quadrangle.

Brine

Concentrated minerals 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

Gravels that accumulated in beaches and tombolos abound at Crater Island. The gravels are moderately to well size sorted and are sources of construction materials. The larger accumulations lie southwest of Donner-Reed Pass, and at Pilot Valley and Provo shore zones in several places.

HYDROLOGY

Mountainous and flatland areas of the Crater Island quadrangle are extremely arid and support much less vegetation than do ranges west of the Great Salt Lake Desert. A single spring, about 1.5 kilometers (1 mi) south of Copper Blossom mine, was observed in the quadrangle. Washes near the spring support more dense vegetation than typical for Crater Island, suggesting that they contain near-surface ground water. However, over most of Crater Island even canyons draining large upland areas apparently have little discharge within their alluvial fans because no springs occur at the alluvium-playa boundary, as is typical of the southern Pilot Range.

Two attempts at drilling water wells in the Donner-Reed Pass area apparently failed. The Silver Island well, drilled near the intersection of roads in Donner-Reed Pass (BM 4398) in April 1977, penetrated 45 meters (150 ft) of metamorphosed Chainman Shale and Diamond Peak Formation. The metamorphosed condition of these rocks near the Crater Island pluton may be the cause of the apparent lack of water. A hole was also drilled in the center of the pluton (plate 1) during the 1980s, but also was apparently non-productive. Attempts to exploit ground-water flow at the base of alluvium within canyons draining large watersheds may be more fruitful.

GEOLOGIC HAZARDS

Flooding is the primary hazard in the Crater Island quadrangle. Narrow canyons and washes issue onto alluvial cones, all of which show evidence of youthful intermittent activity. Intense rainstorms are capable of initiating devastating floods and debris flows in these geologic environments. Periodic flooding by standing water or by shallow sheet floods is indicated by playa and alluvial deposits on the flat lands surrounding Crater Island.

Eolian dunes in the Donner-Reed Pass area and in places 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.

Karst formation involving sinkhole collapse and other processes affected some rocks in the quadrangle, but no karst is demonstrably younger than Paleozoic.

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