

ETHNOMALACOLOGY AND
PALEOECOLOGY OF THE
ROUND BUTTE ARCHAEOLOGICAL
SITES, DESCHUTES RIVER BASIN,
OREGON

By

Ernest J. Roscoe

BULLETIN NO. 6

of the
MUSEUM OF
NATURAL HISTORY

University of Oregon
Eugene, Oregon

July 1967



The *Bulletin* of the Museum of Natural History of the University of Oregon is published to increase the knowledge and understanding of the Natural History of Oregon. Original articles in the fields of Archaeology, Botany, Ethnology, Geology, Paleontology and Zoology appear irregularly in consecutively numbered issues. Contributions arise primarily from the research programs and collections of the Museum of Natural History and the Oregon State Museum of Anthropology. However, in keeping with the basic purpose of the publication, contributions are not restricted to these sources and are both technical and popular in character.

J. ARNOLD SHOTWELL, *Director*
Museum of Natural History
University of Oregon

Communications concerning manuscripts and purchase of copies of the *Bulletin* should be addressed in care of the Museum of Natural History, University of Oregon, Eugene, Oregon 97403. A list of previous issues of the *Bulletin* will be found inside the back cover.

ETHNOMALACOLOGY AND
PALEOECOLOGY OF THE ROUND
BUTTE ARCHAEOLOGICAL SITES,
DESCHUTES RIVER BASIN, OREGON

ETHNOMALACOLOGY AND
PALEOECOLOGY OF THE ROUND
BUTTE ARCHAEOLOGICAL SITES,
DESCHUTES RIVER BASIN, OREGON

by

ERNEST J. ROSCOE



Bulletin No. 6
Museum of Natural History
University of Oregon
Eugene, Oregon
July 1967

FOREWORD

During the summer of 1961 and 1962 the University of Oregon Dept. of Anthropology conducted archaeological excavations in the area to be inundated with the completion of Round Butte Dam, on the Deschutes River in Jefferson County, Oregon. The Dam was being constructed by the Portland General Electric Company of Portland, Oregon, which provided funds for the archaeological excavations.

A report on the results of the archaeological work was presented in *Prehistory of the Round Butte Area, Jefferson County, Oregon*, by Richard Everett Ross, a Master of Arts thesis presented to the University of Oregon, Dept. of Anthropology. It is hoped that his thesis will be published, eventually.

In connection with the Round Butte Project, Ernest J. Roscoe with the Raymond Foundation of the Field Museum of Natural History, Chicago, agreed to analyze the shells recovered during the excavations and write the results of his analysis for an appendix to a final report. Mr. Roscoe's detailed analysis was felt to have pertinence other than for the Round Butte Project so it is being presented as a separate publication.

Tables prepared by Mr. Roscoe, that enumerated the shells found by site and levels within the sites are not included, since they would be best understood in the context for which they were originally prepared. Summary of some of this information occurs in the table accompanying this foreword.

The reservoir area of the Round Butte Dam extends from the Dam, on the Deschutes River about one half mile below the mouth of the Metolius River, eleven miles up the Metolius River, eight miles up the Deschutes River and six miles up the Crooked River. Figure 1 indicates the location of the reservoir and the sites within it. Thirty two sites were located in the reservoir, of which sixteen were excavated. Three types of site occurred, namely; rock shelters (12), lava tubes (4), and open sites (16). Twenty-one sites occurred near the river

while the remaining eleven were situated from 500 feet above the river up to the rim rock. One of three sites situated near the canyon rim contained a few shell fragments, while eleven of thirteen excavated sites near the river contained shells. One rock shelter and one open site did not contain shells. The shell bearing sites near the river included seven rock shelters, one lava tube, and three open sites. From this, it can be seen that preference for a particular type of site, or situation with respect to distance from the river, has no correlation with use of mussel for food, although, those sites containing the greatest quantities of shell were near the river. All six sites which contained specimens of *Goniobiasis* were rock shelters or lava tubes, situated less than 30 feet above the river.

Those sites specifically mentioned by Mr. Roscoe are JE-2, JE-25, JE-41, and JE-47. JE-2 was a small rock shelter on the east bank of the Deschutes River approximately 25 feet above the river. Shells were found throughout the excavation to the depth of excavations at 1.8 m from the surface. Charcoal deposits approximately 90 cm from the surface, produced radiocarbon dates of 2650 ± 185 B.P. (I-500). Of particular interest to archaeologists is Roscoe's observation that shells in the lowers levels of the site were apparently out of place because the weathering characteristics did not conform to their position. This observation helps to explain irregularities in parts of the deposition.

JE-25 was another small rock shelter on the east bank of the Deschutes River and a few feet in elevation above it. This site was very similar to JE-2 in its location relative to the river but had not been as intensively occupied. JE-41, the Three Sheep Site, was a large rock shelter on the west bank of the Deschutes River about two miles south of the mouth of the Crooked River. The shelter was about 30 feet in elevation above the river. Excavations in the site were to a depth of two meters, with charcoal from about the 1.7 m level dating at 7990 ± 220 B.P. (I-806). JE-47, Lava Spring Site #3, was a lava tube cave on the west bank of

the Deschutes River about 1 mile north of the mouth of the Crooked River. The site was about 10 feet above the river. The deposits in the cave were no more than 15 cm deep and included large quantities of mussel shell.

No.	Type of Site	Location	Excavated	No. Specimens	
				<i>Margaritifera</i>	<i>Goniobasis</i>
JE-1	rock shelter	near river	Yes	few	5
JE-2	" "	" "	Yes	746	20
JE-3	open site	" "	Yes	10	0
JE-4	" "	" "	Yes	5	0
JE-5	" "	" "	Yes		
JE-6	" "	" "	No		
JE-7	" "	" "	No		
JE-11	" "	" "	No		
JE-12	rock shelter	rim rock	No		
JE-13	open site	near river	No		
JE-14	" "	" "	No		
JE-15	" "	" "	No		
JE-17	" "	rim rock	No		
JE-18	rock shelter	" "	Yes		
JE-19	lava tube	" "	No		
JE-20	open site	" "	No		
JE-21	" "	" "	No		
JE-22	rock shelter	500' above R.	Yes		
JE-23	" "	rim rock	Yes	4	0
JE-24	" "	near river	Yes	2	0
JE-25	" "	" "	Yes	ca. 100	441
JE-26	open site	" "	No		
JE-27	rock shelter	" "	Yes	21	0
JE-28	lava tube	rim rock	No		
JE-29	" "	" "	No		
JE-41	rock shelter	near river	Yes	113	217
JE-42	" "	" "	Yes		
JE-43	open site	" "	No		
JE-44	" "	" "	Yes	1	0
JE-45	rock shelter	" "	Yes	66	78
JE-47	lava tube	" "	Yes	126	3
JE-48	open site	rim rock	No		

David L. Cole
Curator of Anthropology
Museum of Natural History

ETHNOMALACOLOGY AND PALEOECOLOGY OF THE ROUND BUTTE ARCHAEOLOGICAL SITES, DESCHUTES RIVER BASIN, OREGON

by

ERNEST J. ROSCOE

Field Museum of Natural History

INTRODUCTION

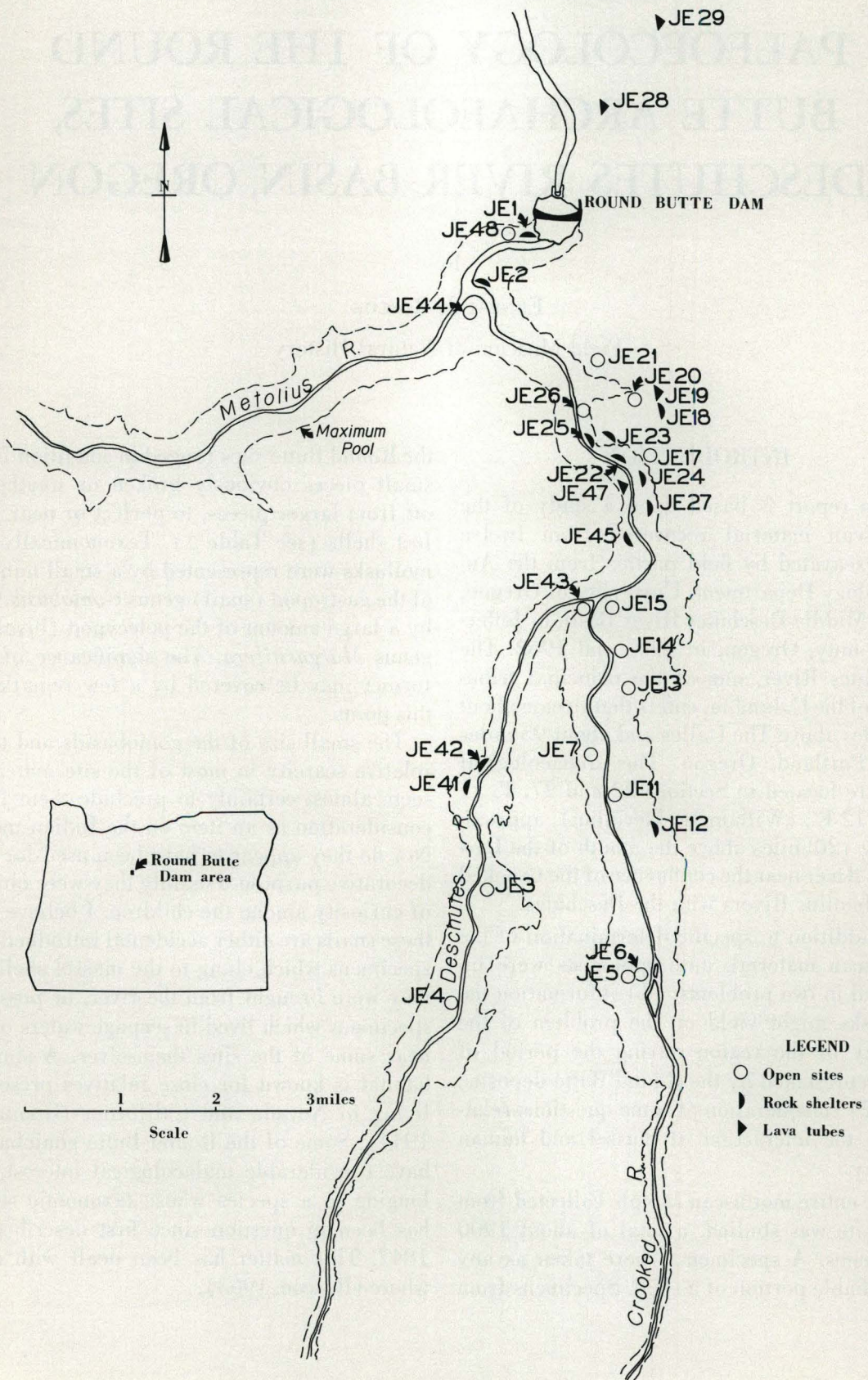
This report is based upon a study of the molluscan material recovered from twelve sites excavated by field parties from the Anthropology Department, University of Oregon, in the Middle Deschutes River Basin in Jefferson County, Oregon, in 1961 and 1962. The Deschutes River, one of the principal tributaries of the Columbia, enters that stream about 15 miles above The Dalles and about 95 miles from Portland, Oregon. The archaeological sites are located in Sections 22 and 27, T. 11 S., R. 12 E., (Willamette Meridian), approximately 120 miles above the mouth of the Deschutes River near the confluence of the Crooked and Metolius Rivers with the Deschutes.

In addition to specific determination of the mollescan material, anthropologists were interested in two problems: (1) information the mollusks might yield on the problem of the ecology of the region during the period of time represented by the Round Butte deposits, and (2) consideration of some questions relating to the interaction of mussel and human ecology.

The entire molluscan sample collected from each site was studied, a total of about 1900 specimens. A specimen is here taken as any identifiable portion of a shell. Specimens from

the Round Butte sites ranged in condition from small pieces obviously broken or weathered off from larger pieces, to perfect or near perfect shells (see Table 1). Taxonomically the mollusks were represented by a small number of the gastropod (snail) genus *Goniobasis*, and by a large amount of the pelecypod (bivalve) genus *Margaritifera*. The significance of the former may be covered by a few remarks at this point.

The small size of the goniobasids and their relative scarcity in most of the site materials seem almost certainly to preclude them from consideration as an item on the Indian menu. Nor do they appear to have been used for any decorative purpose. Possibly they were objects of curiosity among the children. I believe that these snails are either accidental introductions, specimens which clung to the mussel shells as they were brought from the river, or possibly specimens which lived in seepage waters on or near some of the sites themselves. A similar habitat is known for close relatives presently living in Nevada and California (Goodrich, 1944). Some of the Round Butte goniobasids have considerable malacological interest, belonging to a species whose taxonomic status has been in question since first described in 1847. This matter has been dealt with elsewhere (Roscoe, 1963).



As previously mentioned, the bulk of the molluscan material recovered from the Round Butte sites, and the most significant from an ethnomalacological viewpoint, consists of specimens of the bivalve *Margaritifera*. Most of these specimens consist of fairly large pieces of the umbone (beak) areas, lacking a greater or lesser portion of the anterior, posterior, or ventral parts of the shell. Features studied included the length, height, shape, thickness, and degree of "weathering" of the valves, the color and condition of the nacre, and the condition of the periostracum, aided by reference to specimens from the Columbia drainage in the Field Museum collections. No quantitative studies were undertaken, nor was any attempt made to measure or estimate breadth of specimens.

The bivalve *Margaritifera* has been reported from middens from Japan (Okada and Koba, 1953), Wales (fide Kennard, 1922), Saxony (Hertel, 1956), and Czechoslovakia (Petrbok, 1935). In North America members of the U.S. Exploring Expedition (Wilkes Expedition) found large heaps of these "dead" shells in both Oregon and California in 1849-50 (Gould, 1850, 1852), from which fact it was concluded that *Margaritifera* had been used as food by the Indians of this area. Cooper (1860) and Ingersoll (1876) both stated that this mussel was eaten by the Indians of the Cascade Mountains. Henderson (1929) noted finding many badly weathered shells of *M. margaritifera* on the bank of the Columbia River at Vantage Ferry, Kittitas Co., Washington, "some of them in small heaps, undoubtedly old Indian middens. . . ." It is interesting to note, as reflecting a possible change in river ecology, that the ferryman at Vantage stated that he had never been able to find live mussels in the river although he was familiar with the weathered shells on the bank. One set of specimens in the Field Museum of Natural

History collection (#111627), from the recently acquired Eyerdam Collection, undoubtedly are from this Vantage Ferry midden material. The specimens are as badly weathered as any valves from the lower levels of the Round Butte sites.

As shown by Spier (1930) and Cressman (1956), *Margaritifera* was one of the most important sources of food for the Indians of the Klamath area. One of the chief features in the Klamath Indian ecology, and one which marks it off sharply from the Great Basin on which it borders, was the development in the former of the food resources of a stable area.

The paucity of molluscan species from the Round Butte sites is in striking contrast to recoveries from archaeological sites in the Mississippi Basin and in the southeastern United States. It reflects the relative paucity of the native molluscan fauna of the western United States as compared to these other regions. The freshwater mussels, or naiads, attain their greatest diversity in the Mississippi Basin, where the greatest proportion of the 500 or 600 North American species occur (H. and A. van der Schalie, 1950; Pennak, 1953). The western states possess only five or six kinds of naiads, with the Pacific slope being the most favorably disposed (Ingram, 1948). All but one of the mussels of the Columbia drainage belong to the thin-shelled, toothless genus *Anodonta*, whose eating qualities are presumably lower than the heavy-shelled, toothed *Margaritifera*.

SHELL MORPHOLOGY

Since our deductions of mussel ecology must be based on the only part of the animals present in the midden deposits, some preliminary attention must be given to the morphology of the shell.

Size: To a degree at least, size is a reflection of ecological conditions. The largest American specimens on record, from Pennsylvania, range up to 152 mm in length and 67 mm in height (Ortmann, 1911, 1919). The largest European specimen known, from Sweden, deposited

Figure 1. Map of Round Butte area showing location of archaeological sites.

in the Zoological Museum, University Helsingfors, measures 154 mm in length and 63 mm in height (Brander, 1956). Haas (1941) gives no data on either American or European members of this species, but does cite a record of a subspecies, *M. m. dahurica* Middendorff, from the Amur River in eastern Siberia, which measured 177 mm in length and 69 mm in height.

Ortmann (1919) noted that material from the Pacific Coast tended to be smaller than material from eastern North America. The Round Butte specimens fall within the size range exhibited by material from the Columbia drainage in the Field Museum of Natural History collections. The largest Round Butte specimen (JE-2, 140-160 cm level) measures 140 mm in length and 60 mm in height.

Thickness: Although characteristically thicker than *Anodonta*, for its size *Margaritifera* is not excessively thick-shelled. Material from two Round Butte sites are unusual in this regard. Near perfect specimens from JE-2 (140-160 cm level) and fragments from JE-25 (level 7) exceed in thickness anything I have observed in this species. I have had no comparative material available but these specimens are strongly reminiscent of descriptions and illustrations of *M. auricularia* (Spengler), known from the British Pleistocene and Holocene (Kennard, Salisbury and Woodward, 1925; Wenz, 1944; Kerney, 1958). The relationship of the species *margaritifera*, *auricularia*, and *durrovensis* has been discussed (Haas and Wenz, 1914; Phillips, 1928; Haas, 1948), but I believe the subject requires further examination and re-evaluation. The ecological significance of the massive Round Butte specimens remains to be discovered.

Shape: To what extent shell shape reflects environmental conditions, and to what extent it is a factor of age variation is not clear. Two types of shapes have long been recognized. Linnaeus applied the specific name *margaritifera* to the "kidney-shaped," or arcuate type (the presumed type specimens from the Linnaean collection are illustrated by Bloomer,

1937). Lamarck later applied the name *elongata* to the non-arcuate type. Several other variants have been given formal taxonomic status by European writers.

As early as 1823 Barnes published figures of both arcuate and non-arcuate types, noting that "The remarkable change in the form of this species by age as represented in the figures [his Fig. 20, indicating a non-arcuate specimen as "young," an arcuate specimen as "old"] might induce an observer to suppose that the shells belonged to different species; but the specimens in our collections of every variety of form, from those that are straight or even slightly rounded on the base, to those that are deeply arcuated, show clearly that all belong to the same species." [Italics in original] Recently Clarke and Berg (1959, figs. 57, 58) have illustrated both non-arcuate and arcuate specimens of *M. margaritifera* from New York, designating them as immature and mature respectively.

Simpson (1914) related the difference in shape of *Margaritifera* to an "unfavorable environment," while Haas (1948) has specifically ascribed it to the calcium content of the water. Haas believes that specimens living in streams with low calcium content are larger, longer, wider, thicker, and more arcuate than those living in high calcium waters.

Both arcuate and non-arcuate types are present in the Round Butte material, but unfortunately much of this consists of fragments too small to determine the shape of the specimens. There are some non-arcuate individuals that are as large as some arcuate specimens.

Sculpture: This consists of longitudinal ridges, sometimes a little broken. The surface is marked by rude growth lines. The Round Butte specimens afford nothing unusual in this regard.

Periostracum: Sometimes, but incorrectly, called the epidermis, the outer horny covering of the shell is thick, blackish or brownish, and somewhat shiny. Below a depth of about 60-70 cm the Round Butte specimens have generally lost their periostraca. All Round Butte speci-

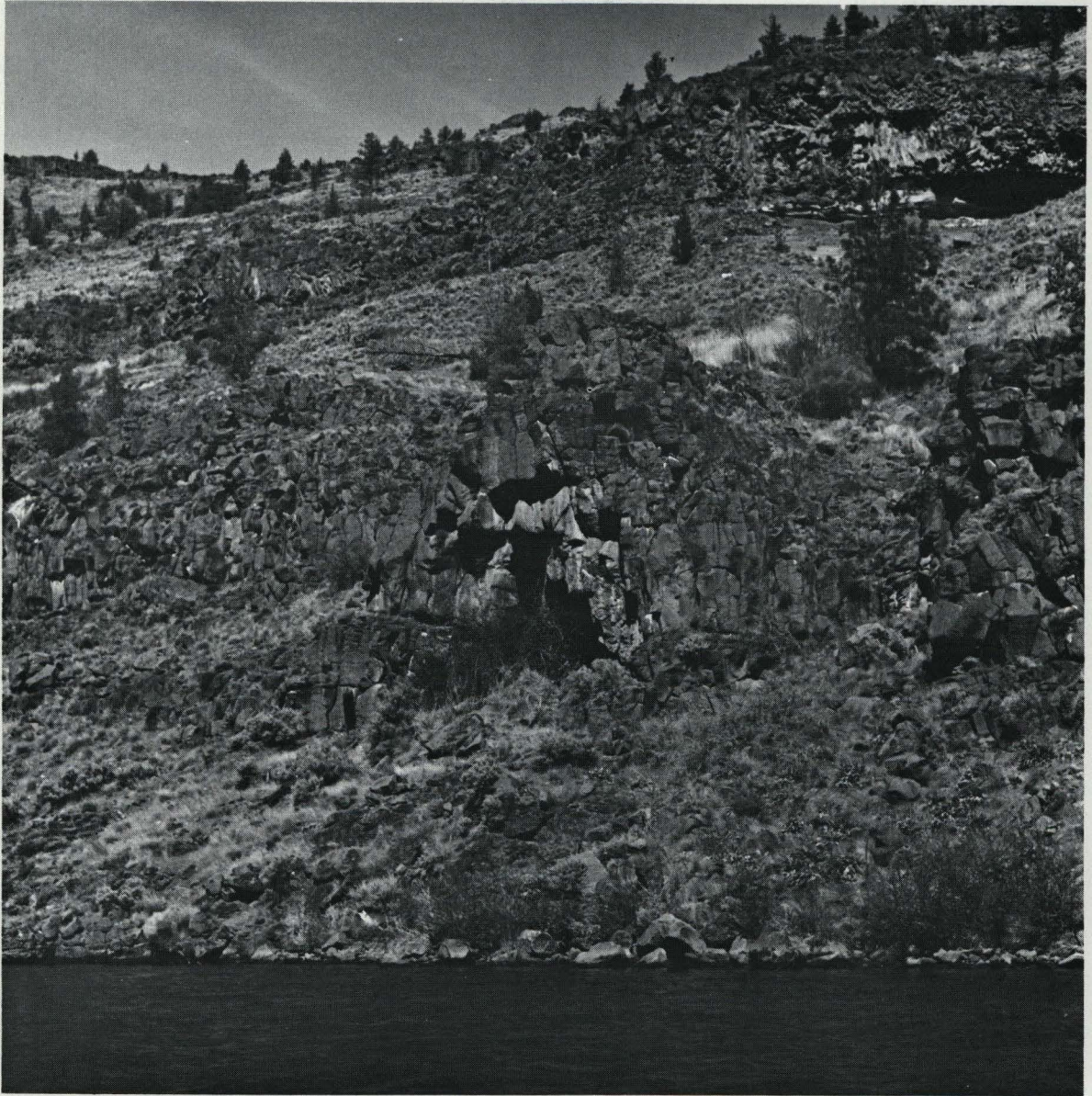


Figure 2. Rock shelter JE1 near Round Butte Dam. Back water from Pelton Dam had reached this point when the picture was taken.

mens which retained any portion of the periostracum exhibit the typical black or brownish color.

Nacre: The inner lining of the valves, or nacre which may make up to half of the entire thickness of the shell (Jeffreys, 1862), is shiny in fresh material, and varies in color from whitish to purple. Much of the western United

States material has a decided purplish or reddish-purple, and this was the basis for the nominal subspecies *M. m. falcata* described by Gould from the Columbia River material collected by the Wilkes Expedition. Most naiad specialists are now of the opinion that this is merely a color variation not worthy of even a varietal name. Nacre color tends to fade even

in recently collected museum specimens, and is generally absent in fossil and subfossil material. The most extensive discussion of variation in nacre color in naiades is that of Grier (1920) on the Ohio drainage basin fauna.

The nacre of the Round Butte specimens retained the pristine characteristics better than the periostracum. Specimens to a depth of 1.7-2.0 m (JE-41) have a shiny nacre but with most of the periostracum lacking. Where color is exhibited it is of the typical purple to reddish-purple type.

Teeth and Muscle Scars: The left valve of *Margaritifera* has two stumpy pseudocardinal teeth; the right valve has one tooth. Lateral teeth are generally absent in adult specimens, although often well developed in juveniles and occasionally occurring in mature individuals. Muscle scars are impressed, the anterior one rough, the posterior one smoother, elliptical.

Most of the valves from the Round Butte sites were those of adult specimens, as would be expected from material selected for food. They show no outstanding differences from typical conditions as regards either teeth or muscle scars. Seemingly a considerable amount of variation may occur in the degree of development of the pseudocardinal teeth among comparable sized specimens.

ECOLOGY OF *MARGARITIFERA MARGARITIFERA*

The American literature contains very little ecological information on *Margaritifera*, most of the data coming from European sources. Major summaries in English are those of Jackson (1925) and Boycott (1936). A succinct summary of bivalves in general is that of van der Schalie and Robson (1963). Extended observations on a population of *M. margaritifera* in the Kettle River, Stevens Co., Washington, have been made by Roscoe and Redelings (1964) and are included in the present report where pertinent.

Margaritifera margaritifera has the widest range of any naiad in the world (Simpson,

1914). It is found throughout the Palaerctic as far south as Japan: in eastern North America from Canada to Pennsylvania and New York, in the central states in the upper Missouri River only, and in western North America to below the 40th parallel. Its distribution in North America is detailed by Walker (1910), while a more recent summary of its distribution in the Pacific Coast area is given by Ingram (1948). The zoogeographic significance of *Margaritifera* is discussed by Scharff (1907, 1911) and Beauford (1951).

Margaritifera is essentially, although not exclusively, a river inhabitant. Lake dwelling *M. margaritifera* have been reported from Nova Scotia (Clarke and Rick, 1963). Boycott (1936) speaks of *M. margaritifera* as living in "a well-defined river habitat, though it is a little difficult to specify the essential qualities. . . Most of its habitats are places in which fishermen would expect to get trout and hope for salmon. . . ." The species occurs in water of a depth of from 1½ to 5 feet, preferring a depth of about 3 feet (Boycott and Howell, 1898; Haas, 1908; Harms, 1907; Ortmann, 1919; Jackson, 1925). It is said to particularly like the accumulations of sand behind large stones (Boycott, 1936), and to be generally absent from deep holes and muddy localities (Boycott and Howell, 1898; Ortmann, 1919). While usually reported from natural streams, *Margaritifera* has been found in lakes (Boycott, 1936) and in millstreams in the vicinity of artificial stone weirs (Harms, 1907). A preference for situations where the banks are shaded by trees and shrubs has been noted (Ortmann, 1919).

Confirmation of most of the above data was made by observations on a population of *M. margaritifera* in the Kettle River, Washington (Roscoe and Redelings, 1964). Here a single bed of *margaritifera* was noted extending over an area of about 1500 square feet. The mussels were mostly confined to one side of the stream just above a sharp bend. The bottom material consisted of a mixture of boulders and gravel with some sand. The current was

fairly rapid, although at the time of the original observation (September 1962) the stream was a low-water stage. The mussels were covered by water from a depth of about 2 feet to over 4 feet. At the upper margin of the bed the mussels tended to occur singly, but further downstream they were grouped together in clumps of from 2 to about 8 individuals, often in sand-mud behind larger stones and boulders. Just below the bed a deep hole occurs, in which no mussels could be detected. The stream is not shaded by trees or shrubs at the site of the bed. Despite the fact that seemingly identical conditions could be found in the stream for a distance of about a mile both above and below the clam bed, no additional live specimens were found. Following the high water stage of 1963 a second smaller bed of *margaritifera* was observed about 1,000 feet below the original bed. We believe that these specimens were washed down from the main bed.

Margaritifera is a burrowing form. A very early account by Redding (1693) states that they may be found "laying on their sides or set up in the sand like eggs in salt, with the sharp edge downwards, and the opening side turned from the torrent." Generally *Margaritifera* does not bury its shell as deeply as does *Anodonta*, a fact probably correlated with the usually harder substrate in which *Margaritifera* lives, but it has been noted as burrowing nearly two-thirds of its length into sand and gravel (Okada and Koba, 1953), at angles of from 25° to 80° (Harms, 1907; Haas, 1908; Okada and Koba, 1953). In the Kettle River population (Roscoe and Redelings, 1964) generally only a short part of the anterior end of the shell was imbedded in the substrate, although in places almost one-half of the clam was buried. The angle of repose varied from 0° to 90°, i.e., almost parallel with the substrate to upright. In transplants some individuals would lie almost parallel to the bottom with much of the shell being covered by stones. Occasionally an individual would be found laying on its side for a short period of time. Most of the clams in the bed had the siphons

directed upstream, but among transplants the clams assumed every angle from siphons directed toward the current to siphons directed away from the current. In eddies there is a tendency to orient the siphons toward the current.

There is little published information on population density in *Margaritifera*. In a half mile of stream at the trout rearing ponds near Truckee, California, Murphy (1942) estimated the number of individuals of *M. margaritifera* over 40 mm in length at about 20,000. At a locality on the Sprague River just below the point where Kawumkan Springs empty into the stream D. L. Cole, curator of Anthropology, Museum of Natural History, University of Oregon (personal communication, Feb. 1, 1962) relates that he and his companions found that they could obtain 15 to 20 mussels in an evening through the use of fish hooks. Presumably hand picking would have resulted in a much higher yield. A rough estimate of the main Kettle River population indicates a density of a few thousand individuals in an area of about 1500 square feet, while the secondary population (established after high-water in 1963) number about 60 individuals over an area of 9 square feet.

Data on associated species is likewise scant. In Europe *Margaritifera* has been reported associated with *Anodonta anatina* and *Unio crassus* (Haas, 1948). In New York, Clarke and Berg (1959) found *Margaritifera* in association with *Elliptio complanatus* and a few other unspecified species. At the Kettle River bed a single specimen of *Anodonta*, seemingly a juvenile specimen of *A. oregonensis*, was found near the water's edge where the bottom was somewhat muddy (Roscoe and Redelings, 1964). At the Round Butte sites *Margaritifera* was apparently associated with the snail *Goniobasis*, but if other species of mussels were collected by the Indians they were not brought to the midden sites. No snails were observed on or among the Kettle River population. Small crayfish were observed near the Kettle River population, and a single claw of

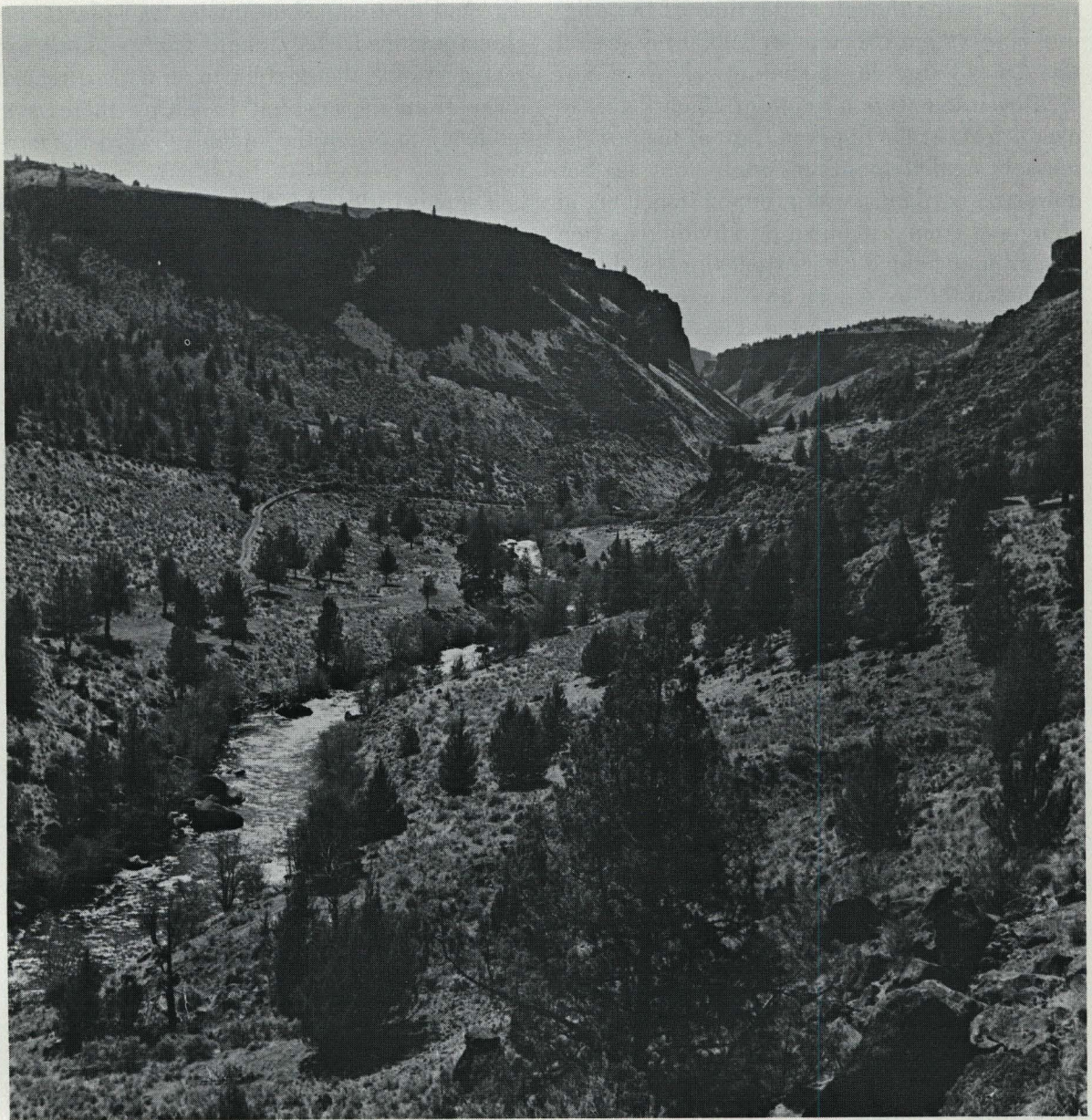


Figure 3. Looking north from JE2.

a crayfish was found in one of the Round Butte samples (JE-47). Fish associates are discussed later in connection with reproduction.

Margaritifera is apparently quite tolerant of cold temperatures, being known to live in mountain streams off the Arctic Ocean coast of Europe where the summer water temperatures reach only about 13° C (55.4° F) (Jack-

son, 1925). Nothing has been published on the activity of *Margaritifera* during the winter months. Ice has hampered our observations (Roscoe and Redelings, 1964) on the Kettle River population, but apparently the clams remain in the same position during the winter.

In contrast to its response to temperature, *Margaritifera* is very sensitive to drought, not

frequenting streams subject to drying. This characteristic makes it difficult to ship live specimens (Boycott, 1921a). In the Kettle River one transplant was observed (Roscoe and Redelings, 1964) to remain partially embedded in the substrate for a period of three days during which the water gradually lowered until over one-half of the shell was exposed to the atmosphere.

In its reaction to light, *Margaritifera* is said to emerge under full sun and to protrude a portion of a mantle through the partly opened valves. If the sun becomes overcast or the water muddied, the mantle is withdrawn and the valves close (Jackson, 1925). Our limited observations (Roscoe and Redelings, 1964) show no consistent pattern in regard to response to light. During periods of high water in the Kettle River the stream becomes so full of sediment as to render observations of the clams difficult to impossible.

In discussing unionids in general Eager (1948) has noted that there is seemingly an upper limit to the stream velocity in which the various river forms can live. For the non-burrowing forms it is suggested that this may be determined merely by the rate at which the shells are washed away in time of flood. Eager does not feel that such is the case in the large burrowing species, such as *Margaritifera*. Altnöder (1926) has noted a limiting velocity for *Margaritifera* in small brooks in Germany. Some of our observations (Roscoe and Redelings, 1964) on transplants suggest that individuals use currents as an aid in shifting position, and the establishment of the secondary population in 1963 indicates that strong currents do not damage individuals as much as might be thought. In fact, these currents may assist in the distribution of the species.

Working with *M. margaritifera* from several small streams in Germany, Altnöder (1926) found some correlation between obesity and relative height, and a negative correlation between relative height and the fall or gradient,

of the stream. Obese, relatively high forms with rounded lower borders were present where the fall of the stream was least, while in more rapid water the shell become less obese and more elongate with straight and finally "bighted" (arcuate?) or reflected lower borders. There has been some additional work on shell morphology of *M. margaritifera* (Dyak, 1942) which I have not seen. Eager (1948, fig. 5) reproduces a series of illustrations of the shape of *M. margaritifera* shells from streams of various velocities.

A seasonal pattern has been ascribed to the distribution of *Margaritifera* in the stream bed (Jackson, 1925). In the spring the clams are reported to be found in the shallow water near the bank. Here they are said to move about freely, their long curving tracks being very conspicuous on the bottom. These tracks are described as forming a very nearly regular circle, and it is estimated that they travel from 12 to 15 feet each day. Stoppages are said to be clearly visible on the tracks. Later in the year, mid- to late-summer, the mussels are reported to be distributed over the entire width of the river (Harms, 1907). No seasonal pattern of distribution has been detected for the Kettle River population (Roscoe and Redelings, 1964). Observation of individual transplants reveals straight and "L" shaped tracks, over stony bottom, but no circular or curving tracks.

The most controversial point in the ecology of *Margaritifera* centers around the chemistry of the waters it inhabits. The absence of this genus from lime-rich regions in Europe has been frequently commented upon. In North America Stearns (1907) raised the question of whether the absence of much of the unionid fauna of the Mississippi basin from the Columbia and Pacific Coast region was due to a smaller proportion of lime in the waters of the latter areas, which would imply a favorable chemical environment in these waters for *Margaritifera*.

In a long list of chemical analyses of waters from which *Margaritifera* has been found,

Boycott (1936) shows that they occur in Scotland in waters with a hardness (Ca ppm) of 1 to 79, with the majority running below 30 ppm. Analyses of rivers in the south of England in which the mussels *do not* occur show hardness of from 70 to 115 ppm. At Cleveland, New York, Clarge and Berg (1959) obtained *Margaritifera* at only one locality, Black Creek, in the softest stream water analyzed in their survey. This locality had a hardness of 46 ppm CaCO_3 .

Several workers (Von Hessaling, 1859; McKean, 1882-3; Haas, 1910) have experimentally placed this species in hard waters with no success. However, Boycott (1925) concluded after a series of experiments with waters of varying degrees of hardness that hard water *per se* is by no means necessarily quickly fatal to *Margaritifera*. He subsequently (Boycott, 1927) recorded its presence in British waters with a calcium content as high as 79 mgs. per liter. Haas (1948) has since conceded that this mussel is able, "under conditions not yet known," to exist in water in which considerable lime is present. His views as to the influence of calcium on shell shape have already been noted.

Boycott (1936) notes that "the case for soft water is up to a point impressive. . . . It would almost [be] equally easy to argue that the thing that is requisite and necessary is a quick flowing cool river with clean water and the right kinds of bottom, and that it is as it were a physiographical accident that such rivers are nearly always soft. . . . Perhaps the solution of this very interesting question may come when someone discovers where the young mussels live after they fall off the fish till they are about 2 inches long—a matter of several years; at present this is quite unknown."

The Round Butte material, presumably derived from the same stream(s) throughout the period of time represented by the midden deposits, shows considerable variation in both shape and thickness. The waters of the Deschutes River and its tributaries are now relatively soft (Henshaw, Lewis, and McCaustland,

1914), and there is no reason to suspect that this factor has varied appreciably during the time interval in question. Under such circumstances the extraordinary thickness of the specimens from JE-2 (140-160 cm level) and JE-25 (level 7) is exceptionally noteworthy.

As noted previously, it is an unresolved problem as to how much of the variation in shell morphology is attributable to age and how much to environmental factors. The lack of growth series and of adequate population samples make most museum collections of little use in such studies. In some experiments on the effect of various salts on freshwater mussels Ellis et al. (1931) found calcium salts to be less toxic than other groups of salts, and also that there was some difference in tolerance between adult clams and young stages of the same species. The entire matter of calcium metabolism is a physiological problem which bears much further investigation. H. B. Baker (1956), for example, has called attention to the relationship between calcium carbonate and resistance to drought in mussels.

In seeking some explanation to account for the demonstrable absence of *Margaritifera* from most high-calcium waters, I am personally inclined to agree with Boycott (1925, 1927) and Kennard, Salisbury and Woodward (1925) that we should look for a correlative factor or factors.¹

Before leaving the topic of lime, it should be noted that the excess of carbon dioxide in most waters in which *Margaritifera* live results in severe erosion of the shells, especially around the beak area. Variation in degree of erosion from stream to stream has been noted (Jackson, 1925). "Bones" frequently have nothing left but the periostracum, and these

¹ In the brine shrimp, *Artemia salina*, Gilchrist (1954) has shown that concentration of the haemoglobin in the blood may be correlated with degree of salinity of the water which these organisms inhabit. He points out that this is a false correlation, however, as haemoglobin concentration is directly related to O_2 , which is inversely related to degree of salinity. Thus salinity is an indirect factor which acts by reducing the amount of O_2 the water can hold, the organism responding by an increase in haemoglobin in the blood.

"shell skins" have been reported from Holocene repositis in Scotland (Bennid, 1866) and from midden heaps in the Klamath region (Cressman, 1956). No such "skins" were observed in the Round Butte material, although most of the specimens did show extensive erosion. As noted previously, in the Round Butte material the nacre and prismatic layers of the shell held up better than did the periostracum. Several "bones" observed in the bed of the Kettle River as well as along the flood plain showed the calcium layers to be more eroded than the periostracum, a situation that would lead to the production of "shell skins" (Roscoe and Redelings, 1964).

Freshwater mussels always attest to the presence of fish in streams from which they are collected since these mussels are obligatory parasites on fish during their young, or glochidial, stages. According to Morrison (1955) the mantle flaps of the freshwater mussel *Lampsilis* are spotted and resemble small fish. These flaps "pulsate or jerk intermittently like a wounded minnow, to attract fish during the glochidia shedding season." *Margaritifera* does not possess such specialized mantle flaps, however.

In Europe *Margaritifera* is reported to breed in mid-summer, July to early August (Harms, 1907). The process may occur as early as the end of May (Schierholz, 1888). In eastern North America breeding is suspected to occur during approximately the same period, June to August (Conner, 1909; Ortmann, 1919). The European *Margaritifera* (Harms, 1907) produce a relatively large quantity of ova in a season. The duration of a single brood is about 16 days in very warm weather, but may extend to about 4 weeks in cold temperature. Unlike *Anodonta*, the ripe glochidia are not retained in the gills of the parent *Margaritifera* over the winter, but are expelled during late July and August within a period of a few days. The mussel is said to frequently change position during the course of expelling its ova.

According to Jackson (1925) the glochidia of *Margaritifera* are extremely small (diam-

eter 0.0475 mm) as compared to *Anodonta* (0.35 mm). They are without true hooks, possessing six or seven small teeth only. *Margaritifera* glochidia become attached to the gills of the host fish, not to the fins as in *Anodonta*. Within 2-4 hours the glochidia become shut in by a thick cyst. The duration of the parasitic stage on the gills depends upon the temperature of the water. It generally occupies about 14 or 15 days, but may be prolonged to 4 or 5 weeks. The larvae then fall to the bottom of the stream and become free-living. Illustrations of the glochidial stages of over 50 species of North American freshwater mussels may be found in Surber (1912, 1915). He does not illustrate *M. margaritifera*, but does include *M. monodonta*. Juvenile stages of *M. margaritifera* are discussed and illustrated by Alverdes (1918).

The morphological development of the glochidia and young mussel stages of *Margaritifera* are discussed in detail by Harms (1909). A study of the growth of marked specimens over a two-year period was made by Rubbel (1913). He failed to detect consistent growth rings, which are rather ill-defined in *Margaritifera*. Growth rate is more rapid in the younger stages, falling regularly from 1 mm/year in shells 60 mm long to 0.4 mm/year in shells 100 mm long. As might be expected, growth rate varies from place to place. Altnöder (1926) found that specimens from one locality bearing 20 annuli measured 11.6 mm in length, while from another they measured 12.4 mm with 60 annuli. He also found that the size relative to the number of annuli increased in a downstream direction. Saldau (1939) found that the specimens from some rivers had reached 60 mm in length by 10 years of age and 70 mm by 13 years, 13 year-old specimens from other rivers measured less than 50 mm. Saldau (1939) noted that while growth in *Unio* from the European part of Russia continued in some waters after the 8th year, *M. margaritifera* was growing steadily without any evident falling-off in rate at the 13th year.

In discussing the duration of life in various mollusks, Comfort (1957) notes that it has long been suspected that *M. margaritifera* has by far the longest life-span of any European species. Various inferences and estimates range from 60 to 100 years. Assuming a 60 mm specimen to be at least 10 years old, Rubbel (1913) concluded that it should take another 20 years to reach 80 mm, and a further 40 years to reach 100 mm. On this basis the natural life-span could not be less than 70-80 years. Comfort (1957) notes that in general, large naiad shells represent a high growth-rate rather than extreme age. The normal maximum age in *Unio* and *Anodonta* is probably not much more than 20-30 years.

Comfort (1957) remarks that, if the 100 years estimate of Israel's for *M. margaritifera* is correct, it is the longest-lived invertebrate known. (A similar age has been guesstimated for the giant clam *Tridacna*). Comfort thinks that a life span of this order in the wild would imply an exceedingly low adult mortality. Freshwater mussels are known to be attacked by rodents and birds, and *M. margaritifera* has been fished for many centuries by man, often in a destructive manner. A direct determination of age-group mortality in marked shells does not seem to have been undertaken, either in fished or unfished rivers.

More information is needed on the fish hosts of *Margaritifera*. Trout have been observed naturally infected with *Margaritifera* glochidia (Wilson, 1916; Murphy, 1942), and experimental infection has been established in Brown, Rainbow, and Brook trout (Murphy, 1942) and several kinds of minnows (Harms, 1907; Murphy, 1942). Judging from the wide distribution of this mussel, several kinds of fish must be capable of serving as hosts. It was early recognized that the Deschutes River was an excellent trout stream, and salmon were noted in its lower portions (Henshaw, Lewis, and McCaustland, 1914).

STREAM CHARACTERISTICS

Because of the perishable nature of these mussels it seems highly probable that the *Margaritifera* were gathered from one or more of the three streams in the immediate vicinity of the Round Butte sites, viz., Deschutes, Metolius, and Crooked rivers. The following information on these streams is abstracted from Henshaw, Lewis and McCaustland (1914), van Winkle (1914), and Stearn (1931).

The Metolius River rises on the eastern slopes of the Cascades in the western part of Crook County, Oregon. Its course is through a deep canyon and its average fall from headwaters to confluence with the Deschutes is about 35 feet to the mile. Its flow is derived largely from springs and is well maintained throughout the year. Its water is clear, carrying practically no drift.

Crooked River, in marked contrast, arises in a number of warm springs scattered along a narrow two-mile belt about 10 miles east of Hampton Butte. The temperature of these springs range from 60° to 87° F. In its upper portion Crooked River is warm and alkaline, but soon picks up large contributions from numerous springs. Between Prineville and Forest the stream diminishes in volume. In late summer its bed near Forest is frequently dry, a condition largely attributable to irrigation. Marked seasonal variations are, however, said to have occurred under natural conditions. Near Forest the stream received additions from several springs, the largest of which is known as Opal Spring, which quickly change the river into a torrent of clear, cool water. The trout of Crooked River are said to be famous for their size and abundance.

The Deschutes proper is described by Henshaw et al. (1914) as "a swift-flowing stream of conspicuously clear, greenish-blue water, broken by many rapids and cascades, and is a delight to the beholder on account of its beautiful colors, refreshing coolness, and the picturesque and impressive scenery of its canyon walls." Three waterfalls occur in the area,

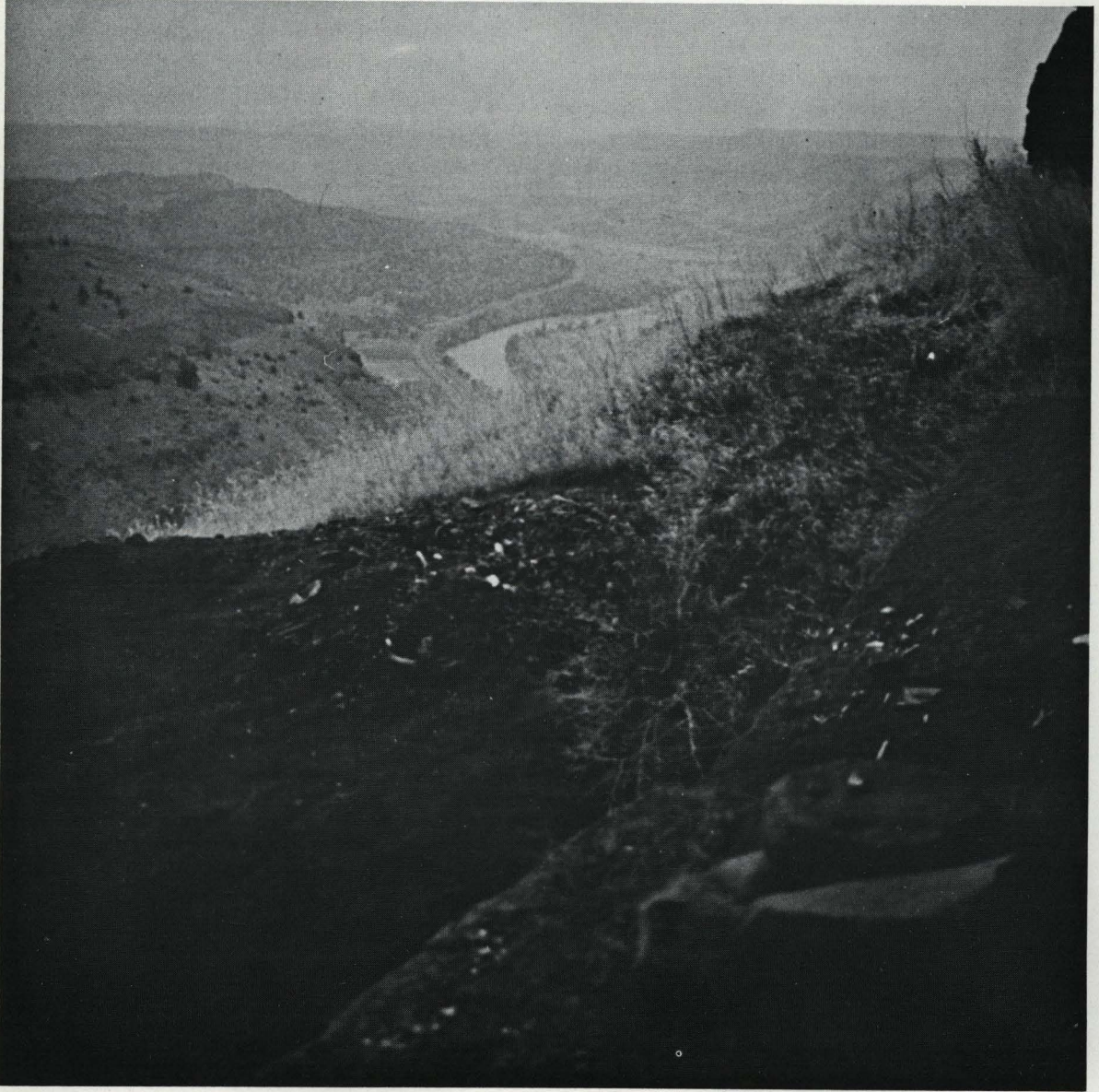


Figure 4. *View of the river from a high rock shelter. Shell and other material from site in the foreground.*

Steelhead, Big, and Odin, with drops of 15, 30, and 10 feet respectively. These authors mention that its waters are abundantly stocked with trout and that salmon ascend its lower portion to the falls. The Deschutes is remarkably uniform, the maximum discharge being only six times the minimum at its mouth. Be-

tween the mouth of Crooked River and Benham Falls, a distance of about 50 miles, the river varies in height no more than 8 to 10 inches during the year. High stages occur in July, resulting from melting snows in the mountain headwaters. Winter temperatures are low, but ice does not affect the flow of the stream

as the winter flow is derived largely from springs. All of the above refers to conditions prior to the construction of Pelton Dam in 1957. This dam, located about 5 miles above the mouth of Shitike Creek and 9 miles northwest of Madras, had backed water at the time of excavation 200 to 300 feet upstream from the mouth of Metolius River (Cole, personal communication, February 1, 1962; cf. Campbell, 1963).

The total dissolved matter in the Deschutes River averages between 65 and 75 ppm at Bend, and about an additional 25 ppm at its mouth. The mineral matter consists largely of salts of sodium, chiefly bicarbonate. Seasonal variation in mineral content, at least about the mouth of Crooked River, are very small. During high water stages the chemical composition of Crooked and Deschutes are almost the same, but during low stages Crooked River contributes an increased mineral content. The water of the Deschutes is classified as soft, and is said (in 1914) to be almost ideal for domestic use. At times of greatest turbidity, the Deschutes carries no more than 150 ppm of suspended solids.

The cool, clear, soft waters of the Metolius and Deschutes rivers, and of the lower portion of Crooked River, with their highly uniform flows, would seem to make these streams ideal habitats for *Margaritifera*. Unfortunately, no recent specimens from any of these streams has been available for comparison with the Round Butte material. Shells from the majority of the Round Butte sites compare favorably in size and thickness with specimens from elsewhere in the Columbia drainage which I have studied. It would seem plausible, therefore, to conclude that these streams afforded as favorable *Margaritifera* habitats during the period represented by the midden deposits as that afforded by the same streams prior to the construction of Pelton Reservoir. A greater knowledge of the effects of environment on shell morphology is necessary before more detailed ecological analyses can be made.

MARGARITIFERA AS A FOOD SOURCE

How much of the mussel ecology was known to the Indians who collected *Margaritifera* for food? To what extent did it affect the manner and time of gathering of the mussels?

Ortmann (1911) states that "the art of collecting mussels has to be learned, because, while it is easy enough to pick them up, it can only be done after a thorough knowledge of the proper places and seasons has been acquired. . . . Their discovery cannot be accomplished under all conditions. Part of the season [in Pennsylvania] our creeks and rivers have too much water, or the water is too muddy to locate the mussels . . . but as soon as their whereabouts is discovered, it is easy enough to get them." It is related (Forbes and Hanley, 1853) that in Ireland the poor people gathered *Margaritifera* in the warm months before harvest time, when the rivers were low. They collected them with their toes, or with wooden tongs, or by thrusting a stick into the partially opened valves as they lay on the bottom. Canadian lumbermen, as related by Kunz (1898:422), caught them by fastening bushes to the rear of a raft so that as they pass over a mussel shoal the shells close on the leaves and thin branches. That such a technique would be successful with *Margaritifera* is seen in the comment of Cole (personal communication, February 1, 1962) that he and his companions were able to obtain 15 to 20 mussels in an evening by the use of fish hooks on which the mussels would close as the hooks drifted along the bottom.

Speaking of the Klamath Indians, Cressman (1956) states that "We have no reports on any patterned behavior for the gathering of mussels, but they could be secured easily enough by the hands from the shallow waters of the rivers. If they were gathered from the deeper waters, and how, we do not know. Nor do we know whether men or women gathered them. Fishing was a man's occupation and gathering of roots and seeds a woman's."

The technique of preparing the mussels for food is not known. In some of the Round Butte samples a few charred fragments were present. Whether these came into contact with fire before or after the animal was removed is impossible to determine. Since the large majority of the shells bear no evidence of charring, it may be concluded that roasting was not a common practice at the Round Butte sites. In answer to a query, Cole (personal communication, February 15, 1962) stated that "At this particular level (RB2B2a) shells were found in association with a rather extensive cooking area. The mussels could have been placed in the fire for cooking or an empty shell could have come into contact with the fire by some means. I would suspect that if it was customary to cook mussels to the extent that the shells became charred, then uncharred shells would be the exception rather than the rule. This does not rule out the possibility that someone may have occasionally desired a roasted mussel."

In his extensive work on Klamath ethnology, Spier (1930) noted that in this region crawfish were prepared by boiling, while insects, particularly moth chrysalida, were pit-roasted between layers of grass with a covering of bits of bark and earth. Boiling was accomplished by dropping hot stones into baskets of water (the Klamath had a separate designation for boiling baskets). Roasting was a common method of opening shells for pearls by the Indians of the southeastern United States (Kunz, 1898).

Aside from food, what use did the Indians make of the mussel? Cressman (1956) illustrates a pendant made from a *Margaritifera* shell, and Spier (1930) relates that spoons and knives were fashioned from "river shells," presumably *Margaritifera* as the thin shelled *Anodonta* would seem unsuitable for these purposes. None of the Round Butte specimens appear to have been utilized in any way, the shells being discarded after the animal was extracted. Although many of the naiads produce pearls of varying quality *Margaritifera* is especially noted for the production of these

objects as denoted by its scientific name (*margarites*, Gr., a pearl; *fero*, L., to bear; Jaeger, 1944). There seems to be no information as to the use of *Margaritifera* pearls by the Northwest Coast Indians. *Margaritifera* pearls are generally white, but may be green or brown. A colored illustration of these is given by Jeffreys (1862, frontispiece). A specimen of *M. margaritifera* from the Botova River, Bohemia showing a pearl in place between the mantle and shell was a featured exhibit at the Columbian Exposition of 1893. This specimen is illustrated by Kunz (1898, Pl. II), who discusses pearl fisheries, including use by Indians, at length. Physiology of pearl secretion in *Margaritifera* is discussed by von Hessling (1856), Rubbel (1911), and Haas (1931), while the natural history of pearls, including the freshwater types is treated at length by Haas (1955).

It is anticipated that these and related questions will be discussed at greater length by the archaeologist and anthropologist, but this does not mean to say that the malacologist and ecologist has no interest in such matters.

REFERENCES CITED

- Altnoder, K.**, 1926, Beobachtungen uber die biologie von *Margaritana margaritifera* und uber die okologie ihres wohnorts: Arch. Hydrobiol., v. 17, p. 423-451
- Alverdes, F.**, 1918, Uber die jugendschale von *Margaritana margaritifera*: Mitteilungen der Naturforschenden Gesellschaft zu Halle add. S., 5
- Baker, H. B.**, 1956, Review of "Bivalvia," by F. Haas: Nautilus, v. 69, p. 107
- Baldwin, E. M.**, 1959, Geology of Oregon: Univ. Ore. Cooperative Book Store, Eugene, Ore. 136 pp. Deschutes-Umatilla Plateau, pp. 72-75
- Barnes, D. W.**, 1823, On the genera *Unio* and *Alasmodonta*; with introductory remarks: Amer. Jour. Sci., v. 6(2), p. 258-280, pls. 1-18, 11-13. Reprinted, with plates, in Sterkiana, Nos. 6 and 7, 1962
- Beaufort, L. F. de.**, 1651, Zoogeography of the Land and Inland Waters: Sidwick and Jackson, Ltd., London. 208 pp.

- Bloomer, H. H.**, 1927, *Margaritifera margaritifera*. Notes on the variation of British and Irish forms: Proc. Malac. Soc. London, v. 17, p. 208-216, pls. xxx-xxxii
- , 1928, *Margaritifera durrouensis*, anatomical notes; Proc. Malac. Soc. London, v. 18, p. 74-76
- Boettger, C. R.**, 1954, Fussperlmuschel und perlenfischerei in der Lüneberger Heide Abh. braunsch. Wiss. Ges., v. 6, p. 1-40. English summary
- Boycott, A. E.**, Ecological notes 3. *Margaritana margaritifera* out of water: Proc. Malac. Soc. London, v. 14, p. 130
- , 1921b, Notes on the distribution of land and freshwater mollusca from the point of view of habitat and climate: Proc. Malac. Soc. London, v. 14, p. 163-167
- , 1925, Tolerance of hardwater by *Margaritifera margaritifera*: Jour. Conch., v. 17, p. 210-211
- , 1927, Ecological notes 7. *Margaritana margaritifera* in hard water: Proc. Malac. Soc. London, v. 17, p. 184
- , 1936, The habitats of freshwater mollusca in Britain: Jour. Animal Ecol., v. 5, p. 116-186
- Boycott, A. E.**, and **E. B. Bowell**. 1898, Wooihope Naturalists' Field Club, Trans., 1898:98-99. Not seen, in Jackson, 1925
- Brander, T.**, 1956, Über dimensionen, gewicht, volumen und alter grosswüchsiger europäischer Unionazeen: Arch. Molluskenk., v. 85, 65-68
- , 1957, Aktuelles über die flusspermuschel, *Margaritana margaritifera* (L.) in Finnland: Acta Societatis pro Fauna et Flora Fennica, v. 74(2), p. 1-29
- Campbell, D.**, 1963, Geology and its application to engineering on the Round Butte hydroelectric development, Deschutes River, Oregon: Geol. Soc. Amer., Spec. Paper 73, p. 30 (Abstract)
- Carl S.**, 1910, Die Flussperlmuschel und ihre Perlen: Karlsruhe, Not seen, in Ortmann, 1919
- Clarke, A. H., Jr.**, and **C. O. Berg**, 1959, The freshwater mussels of central New York: Cornell Univ., Agr. Exp. Sta., N.Y. State Coll. Agr., Memoir 367
- Clarke, A. H., Jr.**, and **A. M. Rick**, 1963, Supplementary records of Unionacea from Nova Scotia with a discussion of the identity of *Anodonta fragilis* Lamarck: Nat. Mus. Canada, Bull. 199, p. 13-27
- Comfort, A.**, 1957, The duration of life in Mollusca: Proc. Malac. Soc. London, v. 32, p. 219-241
- Conner, C. H.**, 1909, Supplementary notes on the breeding season of the Unionidae: Nautilus, v. 22, p. 111-112
- Cooper, J. G.**, 1860, Report upon the Mollusca collected on the Survey: Pacific Railroad Survey Report, 12, pt. 2, p. 269-386
- Cressman, L. S.**, 1956, Klamath prehistory. The prehistory of the culture of the Klamath Lake area, Oregon: Trans. Amer. Phil. Soc. (n.s.), v. 46, pt. 4, p. 374-513
- Dyak, V.**, 1942, Zur morphologie der Flanzflussperlmuschel: Arch. Hydrobiol., v. 39, p. 63-69
- , 1957, Kleinste loklitäten der Flussperlmuschel: Cas nar. Mus., v. 126, p. 69-72, German summary
- Eager, R. M. C.**, 1948, Variation in shape of shell with respect to ecological station. In review dealing with Recent Unionidae and certain species of the Anthracosiidae in Upper Carboniferous times: Proc. Royal Soc. Edinburgh, ser. B, v. 63, p. 130-148
- Ellis, M. C.**, **A. D. Merrick**, and **M. D. Ellis**, 1931, The blood of North American fresh-water mussels under normal and adverse conditions: U.S. Bur. Fish., Bull. no. 46, p. 507-542, Doc. 1097
- Fiedler, F.**, 1937, Die gegenwartge verbreitung der flussperlmuschel, *Margaritana margaritifera* L. in Vogtlande: Mitt. Vogtland Ges. Natur., v. 3, p. 53-60
- Forbes, Edward** and **Sylvanus Hanley**, 1953, A History of British Mollusca, and their Shells, vol. 2: London, *Unio margaritifera* L., pp. 146-153
- Gilchrist, B. M.**, 1954, Haemoglobin in *Artemia*: Proc. Roy Soc., B., v. 143, p. 136-146
- Gould, A. A.**, 1850, Descriptions of shells collected by the U.S. Exploring Expedition: Proc. Boston Soc. Nat. Hist., v. 3, p. 292-296
- , 1852, U.S. Exploring Expedition Reports, vol. 12, Mollusca:
- Goodrich, C.**, 1935, A species of *Goniobasis* new to the Great Basin: Nautilus, v. 49, p. 66
- , 1944, Pleuroceridae of the Great Basin: Occ. Pap., Mus. Zool., Univ. Mich. No. 485
- Grier, N. M.**, 1920, Variation in nacreous color of certain species of naiades inhabiting the upper Ohio drainage and their corresponding ones in Lake Erie: Amer. Midl. Nat., v. 6, p. 211-243
- Haas, F.**, 1909, Die vergreitung der Flussperl-

- muschel in Odenwald: Nach. Bl. Deutsch Malac. Zoo. Ges., 1908. Suppl., 8-16
- , 1910, On *Unio*, *Margaritana*, *Pseudanodonta* and their occurrence in the Thames Valley: Proc. Malc. Soc. London, v. 9, p. 106-112
- , 1931, Bau und Bildung der Perlen: Akademische Verlagsgesellschaft, M.B.H., Leipzig, 116 pp.
- , 1941a, Records of large fresh-water mussels: Field Mus. Nat. Hist., Zool. Ser., v. 24(2), p. 259-270
- , 1941b, Bivalvia, Teil II, Lief 3: Bronn's Klass. Ordn. Tierreichs, v. 3, p. 467-678
- , 1948, On *Margaritifera durrovensis* Phillips and its affinities: Jour. Conch., v. 23, p. 6-8
- , 1955, Natural History of Pearls: Comunicaciones del Instituto Tropical de Investigaciones Cientificas de la Universidad de El Salvador, v. 4, p. 113-126, In English with Spanish summary
- Haas, F., and W. Wenz**, 1914, *Unio pachyoden* Ludwig=*Margaritana auricularia* (Splenger): Jahresberichten und Mitteilungen des oberrheinischen geologischen vereines, n.s., v. 4(2), p. 88
- Harms, W.**, 1907, Zur biologie und entwicklungsgeschichte der Flussperlmuschel: Zool. Anz., v. 31, p. 821-822
- , 1909, Postembryonale entwicklungs-geschichte der Unioniden: Zool. Jahr., v. 28, p. 325-328
- Henderson, J.**, 1929, Non-marine Mollusca of Oregon and Washington: Univ. Colo. Studies, v. 17, p. 47-190
- Henshaw, F. F., J. H. Lewis, and E. J. McCaustland**, 1914, Deschutes River, Oregon, and its utilization: U.S. Geol. Surv., Water Supply Paper 344
- Hertel, R.**, 1956, Prehistorische fund von *Margaritana auricularia* Spglr. und *Margaritan margaritifera* L. in Saxony: Abh. Mus. Tierk. Dresden, v. 23, p. 1-7
- Ingersoll, E.**, 1876, Special report on the Mollusca: Eighth Ann. Rept., U.S. Geol. Surv. Terr. (Hayden Survey) for 1874, pp. 389-410
- Ingram, W. J.**, 1948, The larger freshwater clams of California, Oregon and Washington: Jour. Ent. and Zool., v. 40, p. 72-92
- Israel, W.**, 1910, Beitrage zur Kenntnis der Fauna des Weissen Elster: Nachr. Bl. Beutsch Malkozool. Ges., 1910, p. 173-181
- , 1913, Beilogie der Süsswassermuscheln: Stuttgart
- Jackson, J. W.**, 1925, The distribution of *Margaritifera margaritifera* in the British Isles: Jour. Conch., v. 17, p. 195-211, 270-278
- Jadin, V. I.**, 1939, Contribution to the ecology of Pearl-shell *Margaritana margaritifera* L.: Bull. Inst. Freshwater Fish., Leningrad., v.2, p. 351-358 In Russian with English summary
- Jaeger, E. C.**, 1944, A Source Book of Biological Names and Terms: Charles C. Thomas, Springfield, Illinois
- Jeffreys, J. G.**, 1862, British Conchology, vol. 1, London, *Unio margaritiferosus* L.: pp. 37-39
- Kennard, A. S.**, 1923, The Holocene non-marine mollusca of England: Proc. Malac. Soc. London, v. 15, p. 241-259
- Kennard, A. S., A. E. Salisbury, and B. B. Woodward**, 1925, Notes on the British Post-Pliocene Unionidae, with more especial regard to the means of identification of fossil fragments: Proc. Malac. Soc. London, v. 16, p. 267-285, pls. xii-xxii
- Kerney, M. P.**, 1958, On the occurrence of *Margaritifera auricularia* (Spengler) in the English Pleistocene: Jour. Conch., v. 24, p. 250
- Kunz, G. F.**, 1898, The fresh-water pearls and pearl fisheries of the United States: U.S. Fish Comm. Bull. for 1897, art. 9, pp. 373-426
- McKean, K.**, 1882-3, Proc. Croydon Micr. and Nat. Hist. Club, p. 143, Not seen, in Jackson 1925
- Morrison, J. P. E.**, 1955, Family relationships of the North American fresh-water mussels: Amer. Malac. Union Ann. Report, 1955, p. 16-17
- Murphy, G.**, 1942, Relationship of the fresh-water mussel to trout in the Truckee River: Calif. Fish and Game, v. 28, p. 89-102
- Okada, Y., and K. Koba**, 1933, Notes on the distribution of the fresh-water pearl mussel *Margaritifera margaritifera* in Japan: Proc. Imperial Acad., v. 9(7), p. 337-339, In English
- Ortmann, A. E.**, 1911, Monograph of the Naiades of Pennsylvania, Part I, II: Memoirs, Carnegie Mus., v. 4(6), p. 279-347
- , 1919, Ibid, Part III: Memoirs Carnegie Mus., v. 8(1), p. 2-6
- Pennak, R. W.**, 1953, Fresh-water Invertebrates of the United States: Ronald Press, N.Y. Chapter 37, Pelecypoda, pp. 694-726, by Henry van der Schalie

- Petrbok, J.**, 1935, *Margaritifera margaritifera* L. dans la prehistoire de la Boheme: Jour. de Conch., v. 79, p. 152-154
- Phillips, R. A.**, 1928, On *Margaritifera durrovensis*, a new species of pearl mussel from Ireland: Proc. Malac. Soc. London, v. 18, p. 69-74
- Redding, R.**, 1963, Account of British fresh-water pearl mussel fisheries: Phil. Trans. Royal Soc., v. 18, p. 659-663, Not seen, in Forbes and Hanley, 1853
- , 1963, Some goniobases in western United States: Nautilus, v. 77(2), pp. 43-47, pl. 4, figs. 5-8.
- Roscoe, E. J.**, and **S. Redelings**, 1964, Ecology of the fresh-water pearl mussel *Margaritifera margaritifera* (L): Sterkiana No. 16, pp. 19-32
- Rubbel, von A.**, 1911, Über perlen und perlbildung bei *Margaritana margaritifera*: Zool. Jahrb. (anat. abl.) v. 32, p. 287-366, pls. 17, 18, 60 test figs
- , 1913, Beobachtungen über das Wachstum von *Margaritana margaritifera*: Zool. Anz., v. 41, p. 156-162
- Saldau, M. P.**, 1939, Rate of growth of commercially valuable mollusks in the European part of U.S.S.R. in relation to ecologic conditions: Bull. Inst. Freshw. Fish., Leningrad, v. 22, p. 244-269
- Scharff, R. F.**, 1907, European Animals: Archibald Constable & Co., London
- , 1911, Distribution and Origin of Life in America: Archibald Constable & Co., London
- Schierholz, C.**, 1888, Ueber entwicklung der Unioniden: Denks. d. kais. Acad. d. Wiss. math.-naturw. Classe, v. 55, p. 183-214, Not seen, in Jackson, 1925
- Simpson, C. T.**, 1899, The pearly fresh-water mussels of the United States: U.S. Fish Comm. Bull. for 1898, p. 279-288
- , 1914, Descriptive Catalog of the Naiads: Bryant Walker, Detroit, Mich. 1540 pp.
- Spier, L.**, 1930, Klamath Ethnology: Univ. Calif. Publ. in Amer. Arch. and Ethnol., v. 30, p. 1-388
- Stearns, H. T.**, 1931, Geology and water resources of the middle Deschutes River basin, Oregon: U.S. Geol. Surv., Water Supply Paper 637-D
- Stearns, R. E. C.**, 1907, On the composition and decomposition of fresh-water mussel shells with notes and queries: Proc. Biol. Soc. Wash., v. 20, p. 67-70
- Surber, T.**, 1912, Identification of the glochidia of fresh-water mussels: U.S. Bur. Fish., Doc. 771
- , 1915, Identification of the glochidia of fresh-water mussels: U.S. Bur. Fish., Doc. 813
- van der Schalie, H.** and **G. C. Robson**, 1963, Article "Bivalve," Ency. Britannica, 1963 ed.
- van der Schalie, H.** and **A. van der Schalie**, 1950, The mussels of the Mississippi River: Amer. Midl. Nat., v. 44, p. 444-446
- van Winkle, W.**, 1914, Quality of the surface waters of Oregon: U.S. Geol. Surv., Water Supply Paper 363
- von Hesaling, T.**, 1859, Perlmuscheln und ihre Perlen: Leipzig, Not seen, in Jackson, 1925
- Walker, B.**, 1910, Distribution of *Margaritifera margaritifera* in North America: Proc. Malac. Soc. London, v. 9, p. 126-145, pl. ii
- Ward, H. B.**, and **G. C. Whipple**, 1959, Fresh-water Biology, 2nd ed: Chapter 43, Mollusca, by W. J. Clench, pp. 1117-1160
- Wenz, W.**, 1944, Unsere fluss-perlmuscheln in ver-gangenheit und gegenwart: Natur und Volk, v. 74, p. 155-157
- Wilson, C. B.**, 1916, Copepod parasites of fresh-water fishes and their economic relations to mussel glochidia: U.S. Bur. Fish., Bull. v. 34, p. 331-374
- Wilson, D.**, 1830, On fresh-water pearls: Loudon's Magazine of Nat. Hist., June, 1830, Not seen, in Forbes and Hanley, 1853

PUBLICATIONS

Museum of Natural History
University of Oregon
Eugene, Oregon

<i>Bulletins</i>	<i>Titles</i>	<i>Price</i>
No. 1	Cenozoic Stratigraphy of the Owyhee Region, Southeastern Oregon; Kittleman, L. R. <i>et. al.</i> , 45 pp., 9 plates 11 figures, (December 1965)	\$1.50
No. 2	Notes on some Upper Miocene Shrews from Oregon, Hutchison, J. H., 23 pp., 17 figures, (March 1966)	\$1.25
No. 3	A New Archaic Cetacean from the Oligocene of Northwest Oregon, Emlong, D., 51 pp., 15 figures, (October 1966)	\$1.50
No. 4	The Archaeology of a Late Prehistoric Village in Northwestern California; Leonhardy, Frank C., 41 pp., 17 figures, (March 1967)	\$1.00
No. 5	<i>Peromyscus</i> of the Late Tertiary in Oregon; Shotwell, J. Arnold, 11 figures, (June 1967)	\$1.25
No. 6	Ethnomalacology and Paleoecology of the Round Butte Archaeological Sites, Deschutes River Basin, Oregon; 4 figures; Roscoe, Ernest J. (July 1967)	\$.75

