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PLIOCENE AND PLEISTOCENE SPHAERIIDAE (PELECYPODA) FROM THE CENTRAL UNITED STATES*

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THE Sphaeriidae, finger-nail clams, are one of the two chief groups of freshwater clams. They are abundant and widespread in North America, but an understanding of their relationships has been hindered by the great variation within species and the many names for each species. If knowledge concerning the living members has lagged, this is even more true for the late Cenozoic representatives. Although there are several such European studies, this is the first paper dealing with North American fossil material which does more than list these clams from a particular deposit. The authors' objectives were several: (1) To classify the fossil material in terms of the revised concepts of Recent species and their variation, and to contribute to knowledge of the stratigraphic range of the Pliocene and Pleistocene Sphaeriidae of the High Plains. (2) To gain information on past environments by interpreting the fossils in the light of the habitats of living relatives. (3) To summarize what little is known about late Cenozoic Sphaeriidae from other parts of the North American continent. (4) To correct previous records for the faunas discussed.

Our study was restricted to localities and fossils whose age is known from independent evidence. Only in this way can the geologic ranges of these animals be determined. Although two species of *Pisidium* have survived unchanged from the early Pliocene, a period of perhaps ten million years, the two species of *Sphaerium* from the same beds (Laverne formation) are extinct.

The material on which this study is based consists of over 13,000 valves, mostly collected by Dr. Claude W. Hibbard, University of Michigan Museum of Paleontology, and field parties under his direc-

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tion. Essentially all the shells are in the University of Michigan Museum of Zoology (UMMZ); they are referred to by number only here. A few are in the collections of the U. S. Geological Survey (USGS) and Chicago Natural History Museum (CNHM), with the source indicated. The systematic parts of this paper are entirely the work of the senior author, except for the jointly compiled synonymies. The junior author is responsible for the geologic and stratigraphic portions, and for the catalogue of late Cenozoic Sphaeriidae.

We thank Dr. Henry van der Schalie, University of Michigan Museum of Zoology, for loaning the specimens, and Dr. Claude W. Hibbard for criticizing the manuscript and giving pertinent data.

Fragments of thin-shelled *Sphaerium* are common. This material, as well as some pieces of the thicker-shelled species, was difficult or impossible to identify specifically because the cardinal teeth of *Sphaerium* usually are not diagnostic. A few specimens of large, long, heavy-shelled *Sphaerium* also were difficult to identify. Some are referred to *S. transversum,* others to *S. striatinum.* Certain specimens of *S. transversum* from the southern states are considerably heavier than those from Canada; they are much the same in weight, size, and outline as some present-day *S. striatinum* from Kansas. All specimens were confidently determined except one complete valve and a few fragments.

Many of the shells studied have capped beaks. Not only do these occur on the thin-shelled *Sphaerium,* but there are weak caps on a few of the thicker-shelled species, such as *S. striatinum.* This feature is fairly common on *Pisidium casertanum* throughout the whole period represented by our material. Caps are on some specimens of *P. nitidum* and on almose every individual of *P. obtusale.* Only in *obtusale,* however, are they as sharply defined as in some of the thinner-shelled species of *Sphaerium,* although, as in present-day material, many of such *Sphaerium* lack caps.

FAUNAL SEQUENCE AND LOCALITIES

The age and correlation of the assemblages are shown in Table I. The following information is supplementary and gives the chief references. Numbers given and those in Table I correspond. All localities in Beaver County, Oklahoma, are based on the Cimarron Meridian.

I. Laverne local fauna (Hibbard, 1951; Leonard and Franzen, 1944; Taylor, 1954). In the Laverne formation, Beaver County, Oklahoma. Mammals, mollusks, fishes, and a turtle are known. The mammals indicate a Clarendonian (approximately early Pliocene) age.

LOCALITIES:

1. NW¼SE¼ sec. 1, T. 3 N., R. 27 E.
2. NW¼SE¼ sec. 5, T. 3 N., R. 28 E.
3. W. of center sec. 5, T. 3 N., R. 28 E.
4. Center of N side sec. 5, T. 3 N., R. 28 E.
5. SW¼ sec. 33, T. 4 N., R. 28 E.
6. NE¼ sec. 4, T. 3 N., R. 28 E.

TABLE I

AGE AND CORRELATION OF FAUNAS AND LOCALITIES

Numbers of faunas correspond to those in text.

	Age	Southwestern Kansas and Western Oklahoma		Faunas in Other Areas
		Formation	Fauna and Locality	Fauna and Locality
Pleistocene	Wisconsin	Vanhem	XI. Jones X. Jones Sink (lower level)	
	Sangamon	Kingsdown	IX. Jinglebob	XVI. Slaton XV. Rezabek
	Illinoian		VIII. Berends VII. Bar M VI. Butler Spring	
	Yarmouth	Crooked Creek		
	Kansan		V. Cudahy	
	Aftonian	Ballard		
	Nebraskan			XIV. Sand Draw XIII. Dixon
Pliocene	Late	Rexroad	IV. Rexroad III. Saw Rock Canyon	XII. Red Corral
	Middle	Ogallala	II. Buis Ranch	
	Early	Laverne	I. Laverne	

II. Buis Ranch local fauna (Hibbard, 1954*a*). In the upper part of the Ogallala formation, Beaver County, Oklahoma. Tortoise, mammals, and mollusks make up the assemblage. The mammals indicate a late middle Pliocene age. Only one locality is known, on the west side of Buckshot Arroyo, Buis Ranch, NE¼SW¼ sec. 5, T. 5 N., R. 26 E.

III. Saw Rock Canyon local fauna (Hibbard, 1953). In the XI member in the lower part of the Rexroad formation, Seward County, Kansas. Fishes, amphibians, reptiles, birds, mammals, and mollusks comprise the fauna. The mammals indicate an early late Pliocene age. Only one locality is known, near the center of the west line of sec. 36, T. 34 S., R. 31 W.

IV. Rexroad local fauna (Hibbard, 1950, 1954*b*). In the upper part of the Rexroad formation, below the massive caliche, Meade County, Kansas. Fishes, amphibians, reptiles, birds, mammals, and mollusks make up this fauna—very nearly the largest nonmarine fossil fauna known. The fauna, stratigraphic interpretation, and combined climatic inferences from the Rexroad fauna and formation as well as from the sequence of overlying faunas and rock units all indicate a late Pliocene age.

LOCALITIES:

2. Center of NE¼NW¼ sec. 24, T. 32 S., R. 29 W.
3. W½SW¼ sec. 22, T. 33 S., R. 29 W.

V. Cudahy fauna (Hibbard, 1944, 1949; Leonard, 1950; Frye and Leonard, 1952: 158–59; Johnston and Savage, 1955; Tihen, 1955). The fauna occurs associated with the Pearlette Ash over a wide area from Iowa to Texas. In southwestern Kansas it lies in the middle of the Crooked Creek formation. Fishes, amphibians, reptiles, birds, mammals, and mollusks are known. Stratigraphic position and climatic inferences from the faunal and stratigraphic sequence indicate a late Kansan age.

LOCALITIES:

36. NE¼ sec. 26, T. 32 S., R. 28 W., Meade County, Kansas.
37. W½ sec. 35, T. 33 S., R. 32 W., Seward County, Kansas.
51. SE¼NW¼ sec. 16, T. 6 N., R. 26 E., Beaver County, Oklahoma.

VI. Butler Spring local fauna (new name) (Smith, 1940: 102, Locality B; Hibbard, 1943*a*, 1949; Taylor, 1943; Tihen, 1955). Fishes, amphibians, turtle (*Emys twentei* Taylor), and *Microtus pennsylvanicus* are known besides the mollusks (largely undescribed). Inferences from the combined evidence of local stratigraphy and climatic interpretation of this fauna and an undescribed assemblage stratigraphically above it suggest an Illinoian age. Only one locality is known: SE¼ sec. 32, T. 34 S., R. 29 W., Meade County, Kansas (University of Kansas Meade County loc. 7, in part).

VII. Bar M local fauna (Taylor and Hibbard, 1955). Harper County, Oklahoma. An extinct species of armadillo is associated with the mol-

lusks. Climatic inferences suggest a glacial age; molluscan evidence suggests an Illinoian is slightly more probable than a Wisconsin date.

LOCALITIES:

1. NW1/4 sec. 13, T. 28 N., R. 22 W.
2. SE corner sec. 14, T. 26 N., R. 23 W.

VIII. Berends local fauna (Rinker and Hibbard, 1952; Smith, 1954; Taylor, 1954; Taylor and Hibbard, 1955). In a basin deposit, Beaver County, Oklahoma. Fishes, birds, mammals, and mollusks are known. Combined faunal and climatic evidence indicates an Illinoian age. Only one locality is known, in secs. 5 and 6, T. 5 N., R. 28 E.

IX. Jinglebob local fauna (Tihen, 1954; Hibbard, 1955; Taylor and Hibbard, 1955). In the Kingsdown formation, Meade County, Kansas. The fauna is composed of mammals, mollusks, and a tortoise. The mammals indicate a late Pleistocene age, considered Sangamon because of interglacial climatic implications. Only one locality is known, SW1/4 sec. 32, T. 33 S., R. 29 W. The shells reported by Rinker (1949) and van der Schalie (1953) are all from this site.

X. Jones Sink (lower level) fauna (Goodrich, 1940). In the Vanhem formation, Meade County, Kansas. Only mollusks have been recovered so far. Their stratigraphic position close below the Jones fauna and climatic inferences suggest a Wisconsin age. The one locality is in sec. 8, T. 33 S., R. 27 W., in Bed 19 of the section given by Hibbard (1940).

XI. Jones fauna (Hibbard, 1940, 1949; Goodrich, 1940; Tihen, 1942, 1955; Downs, 1954; Taylor and Hibbard, 1955). In the Vanhem formation, Meade County, Kansas. Fishes, amphibians, birds, mammals, and mollusks are known. The fauna is considered of Wisconsin age because of stratigraphic position and climatic implications. Only one locality is known, in sec. 8, T. 33 S., R. 27 W., in Bed 5 of the section given by Hibbard (1940).

XII. Red Corral local fauna (Taylor, MS.). In an unnamed unit, Oldham County, Texas. Both mammals (essentially all undescribed) and mollusks have been found. The fauna indicates an upper Pliocene age. Only one mollusk locality is known, on the west side of the valley drained by Rita Blanca Creek, 10 miles southwest of Channing, Texas.

XIII. Dixon local fauna (Tihen, 1955; Hibbard, 1956). In an equivalent of or in the Ballard formation, Kingman County, Kansas. Mollusks, amphibians, and mammals are known. Combined faunal and climatic evidence indicates a latest Nebraskan age.

LOCALITIES:

1. S1/2 sec. 12, T. 29 S., R. 8 W.
2. SE1/4NE1/4 sec. 23, T. 30 S., R. 5 W.

XIV. Sand Draw local fauna (McGrew, 1944; Taylor, 1954). In an unnamed formation, Brown County, Nebraska. Fishes, turtles, mammals, and mollusks make up the assemblage. Combined faunal and climatic evidence indicates a late Nebraskan age.

LOCALITIES:

1. SW¼SE¼SW¼ sec. 24, T. 31 N., R. 22 W., 75 feet below top of formation.
2. NW¼ sec. 14, T. 31 N., R. 23 W., 38 feet below top of formation.
3. NE¼SW¼ sec. 12, T. 31 N., R. 23 W., 35–40 feet below top of formation.
4. NW¼ sec. 33, T. 31 N., R. 22 W., 21–22 feet below top of formation.
5. Center of N side sec. 34, and SE. corner SW¼ sec. 27, T. 31 N., R. 22 W., 18–20 feet below top of formation.
6. N. side SW¼ and S. side NW¼ sec. 25, T. 31 N., R. 22 W., 8–15 feet below top of formation.
7. Near center SW¼SE¼ sec. 4, T. 30 N., R. 21 W.

XV. Rezabek local fauna (Frye, Leonard, and Hibbard, 1943; Hibbard, 1943*b*; Franzen and Leonard, 1947), Lincoln County, Kansas. Fishes, amphibians, reptiles, birds, mammals, and mollusks make up the fauna. Stratigraphic position indicates a late Pleistocene age, restricted to the Sangamon interglacial by mild-climate indications. Some of the snails may have been reworked. One locality is known, sec. 20, T. 13 S., R. 10 W.

XVI. Slaton local fauna (Meade, 1942, 1952). Both mammals and mollusks are known, but the mollusks are noted for the first time in this paper. The few mammals, *Terrapene llanensis* Oelrich, and the mollusks suggest a Sangamon age. The southern position of the locality means that a late Illinoian age is also possible, even though the fauna is similar to Sangamon assemblages farther north. Only one locality is known, on the W. E. Smart Ranch, 5 miles north of Slaton, Lubbock County, Texas.

SYSTEMATICS

Occurrence of the species of Sphaeriidae in the fossil assemblages is shown in Table II. Specific localities, amount and kind of material, and the geographic distribution and present-day habitats are given under the species heading. References under each species are limited to those which deal with the faunas treated here. The taxonomy of the North American species of *Pisidium* has been revised (Herrington, 1954) and

a more extensive, illustrated monograph in preparation will give additional references.

In the synonymies, any name marked by an asterisk is a misidentification; "in part" (in parentheses) following the citation means that it refers to other species as well. The catalogue number of each lot is followed (in parentheses) by the number of specimens studied. Integers indicate specimens with both valves still together; fractions the number of separate valves. "Distribution" under each species refers to Recent distribution; "Occurrence" to fossil occurrences.

TABLE II

FAUNAL OCCURRENCES OF FOSSIL SPHAERIIDAE FROM THE HIGH PLAINS

Species	Pliocene Fauna					Pleistocene Fauna									
	Laverne	Buis Ranch	Saw Rock Canyon	Red Corral	Rexroad	Sand Draw	Dixon	Cudahy	Berends	Bar M	Butler Spring	Jinglebob	Slaton	Jones Sink, lower level	Jones
Sphaerium lavernense	—														
S. hibbardi	—														
S. partumeium						—	—					—			
S. transversum						—	—				—				
S. lacustre form *ryckholti*							—	—	—						
S. striatinum			—			—		—		—	—	—	—		
S. sulcatum						—			—			—			
S. occidentale												—			
Pisidium casertanum	—	—	—	—	—	—	—	—	—	—		—	—	—	
P. nitidum	—					—	—	—	—	—		—		—	—
P. compressum	1/2					—	—	—	—	—	—	—	—		—
P. obtusale								—	—			—		—	
P. walkeri												—			—
P. lilljeborgi														—	—
P. ferrugineum															—
P. subtruncatum														—	

Sphaerium partumeium (Say), 1822

Musculium partumeium (Say)*, Goodrich, 1940: 78 (Jones fauna, by error; should be Jones Sink, lower level. *Sphaerium* indet.).

Musculium partumeium (Say)*, Hibbard, 1940: 418 (from Goodrich).

Musculium partineium [sic] Say, Rinker, 1949: 110 (Jinglebob fauna).
Musculium transversum Say*, Rinker, 1949: 110 (Jinglebob fauna; in part).
S.[phaerium] transversum (Say)*, Taylor and Hibbard, 1955: 12 (Jinglebob fauna; from Rinker).
S.[phaerium] cf. *truncatum* (Linsley)*, Taylor and Hibbard, 1955: 12 (Jinglebob fauna).

Distribution.—Most of the United States; less common in mountainous areas. Southern Canada from Saskatchewan to Quebec.

Ecology.—Ponds and eddies in rivers where there is considerable vegetation and a soft bottom.

Occurrence.—Sand Draw, Dixon, and Jinglebob local faunas.

Material.—Sand Draw, Loc. 1, 186369 (77/2); Dixon, Loc. 2, 191501 (114/2), 191502 (17/2); Jinglebob, 171578 (3/2).

Sphaerium transversum (Say), 1829

Musculium transversum Say*, Rinker, 1949: 110 (Jinglebob fauna. *S. partumeium* and *S. sulcatum*).
S.[phaerium] transversum (Say)*, Taylor and Hibbard, 1955: 12 (Jinglebob fauna, from Rinker. Berends fauna, by error).

Distribution.—North America east of the Rocky Mountains from México to the Northwest Territories.

Ecology.—In Meade County, southwestern Kansas, Taylor collected this species at several localities in Crooked Creek. It lives in both sand and mud, in slow current or quiet water. Information on labels in Herrington's collection suggests still water and a muddy bottom as the usual habitat.

Occurrence.—Sand Draw, Dixon, and Butler Spring local faunas.

Remarks.—A large specimen in the Dixon fauna seems to be *transversum*. One complete, full-grown valve was found in the Butler Spring fauna. A dwarf form of this species which occurs in the Sand Draw fauna resembles certain living individuals that appear in unfavorable habitats.

Material.—Sand Draw, Loc. 3, 186378 (43/2); Dixon, Loc. 1, 186385 (10/2); Butler Spring, 177368 (1/2).

Sphaerium lacustre (Müller), 1774, form *ryckholti* (Normand), 1844

Sphaerium sp., Frye and Leonard, 1952: 151, Kingman County locality (Dixon fauna).
Sphaerium cf. *lacustre* (Müller), Taylor and Hibbard, 1955: 12 (Berends fauna).

Distribution.—North America from southern United States to the Northwest Territories. This form of *lacustre* is also found in Europe and Brazil.

Ecology.—It seems to have a preference for ponds where there is considerable vegetation and even bog ponds that have a bottom of muck, rotting wood, grasses, and the like.

Occurrence.—Dixon, Cudahy, and Berends faunas.

Remarks.—The reference by Frye and Leonard is attributed to this species because *S. lacustre* is the commonest *Sphaerium* in the Dixon fauna.

Material.—Dixon, Loc. 1, 186386 (31/2); Cudahy, Loc. 36, 177250 (1/2), 186414 (6/2), 186417 (4/2); Loc. 51, 186420 (3/2); Berends, 177519 (4/2).

Sphaerium striatinum (Lamarck), 1818

Sphaerium sulcatum (Lamarck)*, van der Schalie, 1953: 84 (Jinglebob fauna; in part).
Sphaerium sp., Taylor and Hibbard, 1955: 8, 13 (Bar M, Loc. 2).
S.[phaerium] striatinum (Lamarck), Taylor and Hibbard, 1955: 12 (Jinglebob fauna; Berends fauna, by error).

Distribution.—This species ranges widely over North America, from Panamá to Great Slave Lake, Northwest Territories. The form represented by the fossils is long and moderately heavy; this variation has been seen in individuals from the central states (including Kansas) but not in those from the northern part of the border states or from Canada. Canadian specimens are smaller and the heavier ones among them have a shorter outline than the fossil specimens.

Ecology.—*S. striatinum* can adapt itself to many kinds of habitats, from the Great Lakes and small lakes to rivers and creeks, in gravel, sand, or mud. We have never found it in ponds, lagoons, bog ponds, or swamps. Within a radius of 10 miles from Keene, Ontario, Herrington collected many individuals from (*a*) sand and gravel in the cracks of bare rock forming the bed of the Indian River, (*b*) soft mud in the Ouse River, and (*c*) soft to hard sand in Rice Lake.

Occurrence.—Saw Rock Canyon, Sand Draw, Cudahy, Butler Spring, Bar M, Jinglebob, and Slaton faunas.

Material.—Saw Rock Canyon, 186408 (1/2); Sand Draw, Loc. 1, 186368 (5/2); Loc. 3, 181125 (3/2); Cudahy, Loc. 37, 177287 (59/2); Butler Spring, 177367 (24/2); Bar M, Loc. 2, 186404 (682/2); Jinglebob, 181143*a* (1/2); Slaton, 186403 (353/2).

Sphaerium sulcatum (Lamarck), 1818

Musculium transversum Say*, Rinker, 1949: 110 (Jinglebob fauna; in part).
Sphaerium sulcatum (Lamarck), van der Schalie, 1953: 84 (Jinglebob fauna).
S.[phaerium] sulcatum (Lamarck), Taylor and Hibbard, 1955: 12 (Jinglebob and Berends faunas).
S.[phaerium] transversum (Say)*, Taylor and Hibbard, 1955: 12 (from Rinker, 1949).

Distribution.—Northeastern North America from Quebec to Virginia, west to Iowa, Montana, and Alberta.

Ecology.—This species is much more restricted in habitat than *striatinum.* Herrington always found it in the soft bottom of a perennial small lake, river, or creek.

Occurrence.—Sand Draw, Berends, and Jinglebob local faunas.

Remarks.—The only specimen of the form *crassum* Sterki seen comes from the Berends local fauna (177547), associated with typical ***sulcatum.***

Material.—Sand Draw, Loc. 1, 186370 (3/2); Berends, 177518 (2/2), 177547 (1/2); Jinglebob, 171575*c* (1/2), 171578*a* (1/2), 177627 (1/2), 181143 (26/2).

Sphaerium occidentale Prime, 1856

Pisidium abditum Haldeman*, Rinker, 1949: 110 (Jinglebob fauna; in part).
Sphaerium occidentale Prime, van der Schalie, 1953: 84 (Jinglebob fauna).
S.[phaerium] occidentale Prime, Taylor and Hibbard, 1955: 12 (from van der Schalie).

Distribution.—Northern North America; New Brunswick, Quebec and Ontario; northeastern United States; Colorado, Wyoming, Montana, Utah, Idaho, Oregon, and Washington.

Ecology.—This species lives in swamps, lagoons, flood plains, and ponds, among leaves or grass. Most of its stations dry up for part of the year; at such times the clam stays under dry leaves or in the grass and keeps its shells tightly closed. At the end of the dry season when the rain begins again, it once more opens up and resumes life as usual.

Occurrence.—Jinglebob local fauna.

Material.—Jinglebob, 171575*a* (2/2), 181142 (10/2).

Sphaerium lavernense Herrington, new species
(Pl. I, Figs. 4–7)

Musculium sp., Leonard and Franzen, 1944: 18, Pl. 4, Fig. 3.
Pisidium abditum Haldemann*, Leonard and Franzen, 1944: 18, Pl. 4, Fig. 2.

Holotype.—186390, Laverne Loc. 1, NW¼SE¼ sec. 1, T. 3 N., R. 27 E., Beaver County, Oklahoma. Lower Pliocene; Laverne formation. Collected by C. W. Hibbard and party, July 24, 1950.

Description.—The shell is of medium size, heavy, and short; the beaks are central, moderately narrow and very prominent; striae fine and regularly spaced; dorsal margin moderately to rather steeply curved. In specimens that have a dip in front of the beaks the height of the shell is much less in front of the beaks than behind. The anterior end is usually truncate or slightly rounded, but not quite vertical; posterior end truncate, sometimes vertical, but there is some variation

in the ends; ventral margin but little curved; hinge almost as long as the shell; hinge plate rather narrow but widened at the cardinals; laterals all short, little more than cusps, and heavy; proximal ends of the posterior lateral of the left valve and the outer posterior lateral of the right valve remain on top of the hinge plate, in all the other laterals it dips under the hinge plate; cusps of the left valve distal and very prominent, and sometimes flattened on top; laterals of right valve very low and flat on top, hence, the cusps are not easy to locate. Ligament pit heavy, of moderate length; there is usually a ridge along its inner edge. The cardinals are central or subcentral; of right valve short, almost parallel with the hinge plate, the posterior end slightly nearer the inner edge of the plate, deeply bifurcate, the ends of the arms being moderately wide apart, the anterior end of the cardinal of the right valve about one-half the length of the cardinal, and slightly to very steeply curved; inner cardinal of left valve back from inner edge of hinge plate, very short, the posterior end being usually the longest, in some cases the anterior end is merely a hook; outer cardinal very weak, frequently broken off, its anterior end begins above the outer part of the inner cardinal. Outer cardinal is usually straight and lying parallel with the hinge plate, but it varies, sometimes curving slightly outward so that it is directed through the ligament pit, and sometimes curving inward, and even pointing inside the posterior cusp.

Remarks.—One juvenile valve has distinct striae radiating from the beak to the margin of the shell and covering the whole shell. These striae show somewhat on the inside of the shell. Some specimens have reversed hinges. The species is named for the Laverne formation, in which it occurs.

Measurements.—Thirteen valves (186390) were arranged according to size, and specimens 1, 5, 9 and 13 measured, and diameter doubled.

Length	Height	Diameter
8.2;	7.1;	5.3 mm.
7.0	6.2	4.2
4.6	3.9	2.9
2.4	1.8	1.0

Comparisons.—To *Sphaerium lacustre.* The prominent, centrally placed beaks give *Sphaerium lavernense* an outline altogether unlike any living species I have seen except some specimens of *S. lacustre* (Müller) form *ryckholti* (Normand). But *lavernense* is heavy and *ryckholti* usually very fragile. To *S. striatinum.* The dip in the hinge of many of the specimens is suggestive of this feature in one short, heavy form of *S. striatinum* (Lamarck). To *S. bulleni* Kennard. *S. La-*

vernense approaches the fossil *S. bulleni* Kennard, from the lower Pleistocene Cromer Forest Bed, England. But C. P. Costell of the Department of Geology, British Museum (Natural History), London, who compared specimens with syntypes and topotypes of *bulleni,* wrote that he "could not see any close agreement."

Occurrence.—Known only from the lower Pliocene Laverne fauna of Oklahoma.

Material.—Twenty-nine plus 1426/2 specimens were examined: Laverne, Loc. 1, 186390 (21+918/2); Loc. 2, 186395 (2+400/2); Loc. 3, 181084 (4+29/2); Loc. 4, 186400 (13/2); Loc. 5, 183636 (1/2); Loc. 6, 181092 (2+65/2).

Sphaerium hibbardi Herrington, new species
(Pl. 1, Figs. 1–3)

Pisidium noveboracense Prime*, Leonard and Franzen, 1944: 18, Pl. 4, Fig. 1.

Holotype.—186391, Laverne Loc. 1, NW¼SE¼ sec. 1, T. 3 N., R. 27 E., Beaver County, Oklahoma. Lower Pliocene; Laverne formation. Collected by C. W. Hibbard and party, July 24, 1950.

Description.—Shell small, walls thin, moderately inflated, rhomboid; beaks low, subcentral; anterior and posterior ends roundly truncate, dorsal and ventral margins gently curved, the ventral being slightly the longer: hinge long, gently curved; hinge plate moderately narrow, of uniform width; laterals rather short; cusps of right valve low and distal or on distal side of center; of left valve moderately high, anterior cusp central, posterior central or on distal side of center: cardinals near anterior cusps; of right valve moderately long, gently curved and almost parallel with hinge plate; of left valve, inner back from inner edge and parallel to the hinge plate, evenly curved; outer curving downward toward center of inside of shell: ligament pit long, and about half width of hinge plate.

The species is named for Dr. Claude W. Hibbard.

Measurements.—Taken from single valves, the diameter doubled to give full shell diameter.

Length	Height	Diameter	Cat. No.
3.3;	2.9;	2.0 mm.	186391
2.1	1.6	1.1	186396

Compare these dimensions with those of the following two specimens of *S. rhomboideum* (Say) from Selby Creek, Richmond Town-

ship, Lennox and Addington County, Ontario (Herrington Collection, S-478). The larger is an adult of usual size, the other an embryo.

Length	Height	Diameter
14.0;	10.5;	9.3 mm.
4.9	4.1	2.0

Comparison.—*S. hibbardi* is like *S. rhomboideum* (Say) in shell outline. The hinge plate of very young specimens is exactly as in the very young juvenile *rhomboideum,* and the adults have a hinge plate much the same, including the teeth. The species differs in smallness of size (adults are smaller than the embryo of *rhomboideum*), in having the hinge plate flat, and in lacking the dip near the cusps found in present-day *rhomboideum* (Say). The degree of inflation and development of the cusps and cardinals of both adults and juveniles indicates that it is not just an embryonic *S. rhomboideum,* for the teeth of specimens of that species show their immaturity.

Occurrence.—Known only from the lower Pliocene Laverne fauna of Oklahoma.

Material.—Loc. 1, 186391 (4/2); Loc. 2, 186396 (4/2).

Sphaerium indet.

Musculium partumeium (Say)*, Goodrich, 1940: 78 (Jones fauna, by error; from Jones Sink, lower level).

Musculium partumeium (Say)*, Hibbard, 1940: 418 (from Goodrich).

Sphaerium sp., Frye, *et al.,* 1943: 41 (Rezabek fauna).

Sphaerium sp., Frye and Leonard, 1952: 151, Meade County localities (Rexroad fauna).

Occurrence.—Laverne, Saw Rock Canyon, Sand Draw, Cudahy, and Butler Spring local faunas; Jones Sink, lower level.

Remarks.—Some specimens from several localities are unidentifiable specifically, because they are immature or too fragmentary. They may well represent the thinner-shelled species, *partumeium, lacustre,* and *transversum.* That the specimens reported by Goodrich (1940) from the Jones fauna actually came from a stratigraphically lower level in Jones Sink is inferred from the University of Michigan Museum of Zoology Catalogue. Our collections contain no *Sphaerium* from either the Rezabek or Rexroad faunas, so that the specific identity of such records remains in doubt.

Material.—Laverne, Loc. 1, 186392 (6/2); Loc. 2, 186397 (10/2); Saw Rock Canyon, 177553 (6/2); 177514 (1); Sand Draw, Loc. 2, 184168 (1/2); Loc. 3, 181124 (2/2), 186379 (31/2); Loc. 4, 186373 (8/2); Loc. 5,

186374 (18/2), 186366 (263/2); Loc. 7, 186381 (1/2), 177225 (5/2); Cudahy, Loc. 37, 186419 (1/2); Butler Spring, 186410 (1/2); Jones Sink, lower level, 137801 (16/2).

Pisidium casertanum (Poli), 1791

Pisidium sp., Baker, 1938: 131 (Sand Draw, Loc. 6).
Pisidium noveboracense Prime, Goodrich, 1940: 78 (Jones Sink, lower level; in part).
Psidium sp., Hibbard, 1941*a*: 265 (Rexroad, Loc. 3).
Pisidium sp., Hibbard, 1941*b*: 95 (Rexroad Loc. 3).
Pisidium sp., Frye and Hibbard, 1941: 408 (Rexroad, Loc. 3).
Pisidium sp., McGrew, 1944: 36 (from Baker, 1938).
Pisidium abditum Haldeman, Rinker, 1949: 110 (Jinglebob fauna).
Pisidium noveboracense Sterki, Rinker, 1949: 110 (Jinglebob fauna).
Pisidium sp., Frye and Leonard, 1952: 151, Meade County localities (Rexroad fauna).
Pisidium casertanum (Poli), van der Schalie, 1953: 84 (Jinglebob fauna).
Pisidium casertanum (Poli), Hibbard, 1954*a*: 342 (Buis Ranch fauna).
Pisidium spp., Taylor and Hibbard, 1955: 8, 13 (Bar M, Loc. 2; in part).
Pisidium casertanum (Poli), Taylor and Hibbard, 1955: 12 (Berends and Jinglebob faunas).

Distribution.—Almost cosmopolitan: Eurasia, New Zealand, and Australia; in the Western Hemisphere from Patagonia to Alaska.

Ecology.—This species, even more adaptable than *Sphaerium striatinum,* lives in a wide range of habitats and shows a corresponding variation in shell. It can maintain itself wherever any other *Pisidium* does, except in deep water. The form *roperi* Sterki, as well as somewhat similar shells with thin walls and smooth outlines, comes from ponds, swamps, lagoons, bog ponds, and small lakes that are filling up with marl. The heavier-shelled, typical *casertanum* lives in rivers or fairly large creeks.

Occurrence.—Laverne, Buis Ranch, Saw Rock Canyon, Red Corral, Rexroad, Sand Draw, Dixon, Cudahy, Berends, Bar M, Jinglebob and Slaton local faunas; Jones Sink, lower level.

Remarks.—These shells vary from short and thin to long and thin (the form *roperi*) and to heavier, with some even of the form *noveboracense* Prime.

Material.—Laverne, Loc. 1, 186394 (88/2); Loc. 2, 186399 (2+426/2); Buis Ranch, 181119 (1/2); Saw Rock Canyon, 173587 (51/2), 177553 (1+1398/2); Red Corral, 182992 (58/2); Rexroad, Loc. 2, 186388 (3/2); Loc. 3, 186387 (11/2); Sand Draw, Loc. 3, 186377 (8/2); Loc. 4, 177311 (58/2); Loc. 5, 186367 (32/2), 181134 (11/2); Loc. 6, CNHM PE3439 (2/2); Loc. 7, 177226 (25/2); Dixon Loc. 1, 186383 (11/2); Cudahy, Loc. 36, 186411 (4/2), 186415 (2/2); Loc. 37, 177286 (312/2); Berends,

177520 (15/2); Bar M, Loc. 2, 186406 (10/2); Jinglebob, 171575 (910/2), 171576 (7/2), 181144 (1741/2); Slaton, 186402 (329/2); Jones Sink, lower level, 137802c (1/2).

Pisidium nitidum Jenyns, 1832

[*Pisidium*] *noveboracense* Prime*, Goodrich, 1940: 78 (Jones fauna; in part).
Pisidium noveboracense Prime*, Goodrich, 1940: 78 (Jones Sink, lower level; in part).
Pisidium noveboracense Prime*, Hibbard, 1940: 418 (Jones fauna; from Goodrich).
Pisidium abditum Haldeman*, Rinker, 1949: 110 (Jinglebob fauna; in part).
Pisidium contortum Prime, van der Schalie, 1953: 84 (Jinglebob fauna).
Pisidium spp., Taylor and Hibbard, 1955: 8, 13 (Bar M, Loc. 2; in part).
P.[*isidium*] *nitidum* Jenyns. Taylor and Hibbard, 1955: 12 (Jones, Jinglebob, and Berends faunas).

Distribution.—Holarctic; Eurasia and North Africa; in North America from México to Hudson Bay, except for southeastern United States.

Ecology.—The typical form of this species occurs in lakes and ponds. The form *pauperculum* Sterki lives in lakes, rivers, and large creeks, where it thrives in soft sand.

Occurrence.—Typical form: Laverne, Sand Draw, Dixon, Cudahy, and Bar M faunas; Jones Sink, lower level. Form *pauperculum:* Sand Draw, Cudahy, Berends, Jinglebob, and Jones faunas.

Remarks.—The typical form of *Pisidium nitidum* is angular in outline. It is found in postglacial deposits under as much as 20 feet of peat, or in lakes now filling up with marl. Shells from rivers or lakes without marl are not so high and usually have more rounded angles. The form *pauperculum* Sterki is shorter and higher than typical *nitidum*. It comes from postglacial marl, lakes now filling up with marl, and rivers, lakes, and large creeks, and is fairly plentiful in debris on the shore on Lake Ontario. Unlike the typical form, *pauperculum* seems not to occur in ponds.

Material.—Form *nitidum*. Laverne, Loc. 1, 186393 (2/2); Loc. 2, 186398 (1/2); Sand Draw, Loc. 3, 186375 (347/2); Loc. 7, 186380 (1/2); Dixon, Loc. 1, 186384 (8/2); Cudahy, Loc. 36, 177239 (1005/2), 177341 (868/2); Bar M, Loc. 2, 186407 (22/2); Jones Sink, lower level, 137802b (7/2).

Form *pauperculum* Sterki. Sand Draw, Loc. 3, 186376 (7/2); Berends, 186389 (1/2); Jinglebob, 171575d (6/2), 181146 (14/2); Jones, 137790a (2/2).

Pisidium compressum Prime, 1851

Pisidium compressum Prime, Frye, *et al.*, 1943: 41 (Rezabek fauna).
Pisidium compressum: Frye, *et al.*, 1948: 516 (Cudahy, Locs. 36, 37).
Pisidium abditum Haldeman*, Rinker, 1949: 110 (Jinglebob fauna; in part).

Pisidium compressum Prime, Leonard, 1950: 40, 41, Pl. 1, Figs. G, H (Cudahy, Locs. 36, 37).

Pisidium sp., Frye and Leonard, 1952: 151, Kingman County locality (Dixon fauna), p. 159 (Cudahy Locs. 36, 37); Pl. 15, Fig. K.

Pisidium compressum Prime, van der Schalie, 1953: 84 (Jinglebob fauna).

Pisidium spp., Taylor and Hibbard, 1955: 8, 13 (Bar M, Loc. 2; in part).

P.[isidium] compressum Prime, Taylor and Hibbard, 1955: 12 (Berends, Jinglebob, and Jones faunas).

Distribution.—North America, from México to Great Slave Lake, Northwest Territories.

Ecology.—In lakes, rivers, and creeks; never in ponds, swamps, lagoons, or bog ponds.

Occurrence.—Sand Draw, Dixon, Cudahy, Bar M, Berends, Butler Spring, Jinglebob, Rezabek, Slaton, and Jones faunas.

Remarks.—Shells found in creeks and rivers tend to be high and to bear well-developed beak ridges. In marl-forming lakes, slow-moving rivers, and in the deep water of large lakes they are longer, the ventroanterior angle is blunter, and the beak ridges are weaker. The species is usually abundant if present.

Material.—Sand Draw, Loc. 1, 186371 (579/2); Loc. 2, 184169 (8/2); Loc. 3, 177328 (1172/2); Loc. 6, 186372 (1/2), 177422 (3/2); Dixon Loc. 1, 186382 (240/2); Cudahy, Loc. 36, 186412 (4/2); Bar M, Loc. 2, 186405 (163/2); Berends, 177522 (9/2); Butler Spring, 186409 (3/2); Jinglebob, 171575b (28/2), 181145 (81/2); Rezabek, 177447 (24/2); Slaton, 186401 (105/2); Jones, 177344 (30/2).

Pisidium obtusale C. Pfeiffer, 1821, form *rotundatum* Prime, 1851

Pisidium noveboracense Prime*, Goodrich, 1940: 78 (Jones Sink, lower level; in part).

Pisidium abditum Haldeman*, Rinker, 1949: 110 (Jinglebob fauna; in part).

Pisidium obtusale C. Pfeiffer, van der Schalie, 1953: 84 (Jinglebob fauna).

P.[isidium] obtusale Pfeiffer, Taylor and Hibbard, 1955: 12 (Jinglebob and Berends faunas).

Distribution.—Holarctic; in North America from New Jersey and New York west through Ohio, Indiana, and Minnesota to Montana; northward to Great Slave Lake and Hudson Bay; a single record for México.

Ecology.—The form *rotundatum* prefers shallow water and it is principally in ponds, bog ponds, lagoons, and flood plains.

Occurrence.—Cudahy, Berends, and Jinglebob local faunas; Jones Sink, lower level.

Remarks.—This species occurs in North America in two ecologic

forms, *rotundatum* Prime and *ventricosum* Prime; *ventricosum* (a lake form) is not represented by our fossils. The Eurasian form differs somewhat from that of North America. Inasmuch as this small species is not common at any one place today, it is not surprising that only a few fossils were found.

Material.—Cudahy, Loc. 36, 186413 (1/2), 186416 (1/2); Loc. 37, 186418 (3/2); Berends, 177521 (9/2); Jinglebob, 171575*e* (6/2), 181147 (23/2); Jones Sink, lower level, 137802*a* (1/2).

Pisidium walkeri Sterki, 1895

Pisidium noveboracense Prime*, Goodrich, 1940: 78 (Jones fauna; in part).
Pisidium noveboracense Prime*, Hibbard, 1940: 418 (from Goodrich).
Pisidium casertanum (Poli)*, van der Schalie, 1953: 84 (Jinglebob fauna; in part).
P.[isidium] walkeri Sterki, Taylor and Hibbard, 1955: 12 (Jones? and Jinglebob? faunas).

Distribution.—Northern North America; Canada from Ontario to Alberta, northward to James Bay and Northwest Territories; in the United States, Maine to Virginia, and Michigan, Ohio, Missouri, Iowa, South Dakota, Minnesota, Montana, and Arizona.

Ecology.—In rivers, creeks, and small lakes.

Occurrence.—Jinglebob and Jones local faunas.

Material.—Jinglebob, 181144a (8/2); Jones, 137790 (8/2); 177345 (253/2).

Pisidium lilljeborgi Clessin, 1886

Pisidium noveboracense Prime*, Goodrich, 1940: 78 (Jones Sink, lower level; in part).
P.[isidium] lilljeborgi Clessin, Taylor and Hibbard, 1955: 12 (Jones fauna?).

Distribution.—Holarctic; in North America from the Aleutian Islands and Great Bear Lake, Northwest Territories, southward to the northernmost United States; eastward to Quebec; also, California, Utah, Colorado, and Massachusetts.

Ecology.—In rivers and lakes, even the Great Lakes, but never in small creeks or ponds.

Occurrence.—Jones local fauna; Jones Sink, lower level.

Remarks.—The northern distribution of this species suggests that it has been unable to move southward because of the warm summers.

Material.—Jones Sink, lower level, 137802 (1+103/2); Jones, 177343 (6/2).

Pisidium ferrugineum Prime, 1851

Pisidium abditum Haldeman*, Goodrich, 1940: 78 (Jones fauna).
Pisidium abditum Haldeman*, Hibbard, 1940: 418 (from Goodrich).
P.[isidium] ferrugineum Prime, Taylor and Hibbard, 1955: 12 (Jones fauna).

Distribution.—Northern North America; Newfoundland to British Columbia, Hudson Bay and Great Slave Lake south to the states adjacent to Canada and the Great Lakes; also, New Jersey.

Ecology.—In lakes, creeks, and rivers.

Occurrence.—Jones local fauna.

Material.—137789 (1/2).

Pisidium subtruncatum Malm, 1855

Pisidium noveboracense Prime*, Goodrich, 1940: 78 (Jones Sink, lower level; in part).

Distribution.—Very scarce in North America, but more plentiful in Eurasia. The fossil specimens represent the typical, rather than the western American form. The species as a whole is found from the Northwest Territories south to states bordering Canada and the Great Lakes, as well as in Colorado.

Ecology.—In rivers and lakes, including the Great Lakes.

Occurrence.—Jones Sink, lower level.

Remarks.—The northern distribution of this species suggests it has not been able to move southward because of the warm summers.

Material.—137802*d* (3/2).

Pisidium indet.

Pisidium sp., Frye *et al.*, 1943: (Rezabek fauna).
Pisidium spp., Taylor and Hibbard, 1955: 13 (Bar M fauna; in part).

Material.—Bar M, Loc. 1, 184423 (2/2).

PALEOECOLOGY

Assuming that these Sphaeriidae lived in the same habitats in the past as they do today and that their distributions were controlled by the same factors, something about the habitat and climate when they lived can be inferred. The faunas are discussed in the order listed under Faunal Sequence and Localities. The species of *Pisidium* now living only in northern North America appear in the later parts of the sequence. *P. lilljeborgi, P. ferrugineum,* and *P. subtruncatum,* which have markedly northern ranges, are known only from Wisconsin deposits (Jones fauna; Jones Sink, lower level). Perhaps this distribution reflects increasingly severe glaciations.

I. Laverne local fauna. Judging the species of *Sphaerium* by their living relatives, they lived in comparatively still water, as a sheltered lake cove or the widening of a river or creek. The *Pisidium casertanum,* of moderate weight, and the *P. nitidum* could also live in such a situation. They do not belong to a swamp or pond.

II. Buis Ranch local fauna. The single broken *Pisidium* valve yields few data.

III. Saw Rock Canyon local fauna. The Sphaeriidae here are almost entirely *Pisidium casertanum:* 1449/2 compared to the six or seven other valves. Of these, one valve seems to be a rather young *Sphaerium striatinum;* the others may also be that same species, for the fragments are heavy. The *Pisidium casertanum* are of moderate weight, and some are pitted by solution. The general impression of the environment is that of a small lake or stream enlargement; nothing suggests a swamp, pond, or lagoon habitat.

IV. Rexroad local fauna. Although Frye and Leonard (1952) recorded a *Sphaerium,* this fauna is represented in our collections only by 14/2 *Pisidium casertanum* from Localities 2 and 3. The heavy hinge of the *Pisidium* suggests a perennial stream environment, not a pond, lagoon, or swamp.

V. Cudahy fauna. Locality 36. The *Sphaerium lacustre* form *ryckholti* and *Pisidium obtusale* suggest shallow water, as a pond, small lake, or widening in a creek; the large number (1873/2) of *P. nitidum,* a small lake or river-lake. The *P. casertanum* are all of form *roperi* and indicate a swamp, lagoon, or bog pond habitat. Locality 37. The *P. casertanum* belong to a light form, with a heavy hinge. These could live any place where there was not too much water action, except in a swamp or lagoon. The *P. obtusale* implies shallow water. *Sphaerium striatinum* frequents a wide variety of situations. Locality 51. The *Sphaerium lacustre* form *ryckholti* suggests shallow water, as a pond, small lake, or widening of a creek.

The present northern distribution of living *Pisidium obtusale* suggests that the Cudahy fauna lived when summers were somewhat cooler than those on the High Plains today. This corroborates similar inferences drawn from the snails and mammals.

VI. Butler Spring local fauna. The *Sphaerium striatinum, S. transversum,* and *Pisidium compressum* all suggest a stream, small lake, or similar perennial body of water.

VII. Bar M local fauna. The *Sphaerium striatinum* (682/2) and *Pisidium compressum* (163/2), some of which have thin shells, suggest a large, slow stream or small lake. The *P. casertanum* are fragile (but not of form *roperi*) and hence confirm this inference. The *P. nitidum* also fits such a habitat.

VIII. Berends local fauna. The *Pisidium casertanum* form *roperi* and *P. obtusale* suggest still water like a lagoon or a swamp-pond which is permanent or nearly so. *Sphaerium sulcatum* and *P. compressum* re-

quire a continuous supply of water, like a creek with enlargements or eddies, or a small lake. The *P. nitidum* (1/2) and *S. lacustre* (4/2) could have come from such situations. Since *P. obtusale* is a northern species, it may be inferred that the summers in Oklahoma were cooler when the Berends fauna lived. This supposition agrees with evidence derived from the fishes, mammals, and snails, and from pollen.

IX. Jinglebob local fauna. The specimens from this site suggest two different kinds of habitat (1) a stream and (2) quiet pools or lagoons along shore. The *Pisidium obtusale,* thinner-shelled *P. casertanum,* and *Sphaerium occidentale* belong to a shallow, still-water environment, such as a swamp near a larger water body or a lagoon. *S. occidentale* is rare except where the water dries up for part of the year; these particular specimens are of the thicker form found in ponds and lagoons, not of the more fragile variety which lives in swamps lacking water action.

Pisidium compressum, P. nitidum form *pauperculum, P. walkeri,* the heavier-shelled *P. casertanum, Sphaerium sulcatum* and *S. striatinum* could all have come from a small lake or from a stream with sheltered spots. The heavier *P. casertanum* are worn, and seem to have been brought down stream and deposited, along with the thinner-shelled valves, from quieter water. The *S. sulcatum* and *S. partumeium* require a soft bottom, but are never found in summer-dry ponds. They live in the eddies of streams or in sheltered coves of lakes where they are protected from most of the water action.

The area where the Jinglebob fossils were collected is presumed to have had a permanent creek with a bottom of soft mud (at least locally), and shallow pools or lagoons along the edges, where the water dried up for part of the year. *S. occidentale* and *P. obtusale* may have lived among the leaves or in grass or the like in these pools. Two of the species, *Pisidium obtusale* and *P. walkeri,* now have northern distributions in the United States. This suggests that the Jinglebob fauna lived when summers were much less hot and dry than those of southwestern Kansas today.

X. Jones Sink, lower level. The combination of species here suggests a small lake. It probably had a different sort of bottom from that of the stratigraphically higher Jones fauna (see below), for *Pisidium walkeri* and *P. compressum* of the younger assemblage are absent. Three species now have northern distributions in the United States: *Pisidium obtusale* and to an even greater extent *P. lilljeborgi* and *P. subtruncatum.* They imply much cooler summers than those of

today and, in conjunction with stratigraphic and other faunal evidence, indicate a Wisconsin glacial age.

XI. Jones local fauna. All living forms representing this fauna are found in lakes, rivers, and creeks. *Pisidium lilljeborgi,* however, is rare in the smaller streams. Occurrence of the sediments as a basin fill indicates a lake environment. *P. lilljeborgi* and *P. ferrugineum* now live only in the northern United States; *P. walkeri* ranges slightly farther south. Summer extremes of temperature must have been much reduced when the Jones fauna lived; and this corroborates similar inferences from data on snails.

XII. Red Corral local fauna. The *Pisidium casertanum* (58/2) are longer and slightly thinner-shelled than those of the Laverne local fauna. Their habitat was probably still water, for they are most like forms from either small slow-moving creeks that dry up for part of the year, or from lakes filling with marl.

XIII. Dixon local fauna. Locality 1. The *Sphaerium transversum* and *S. lacustre* form *ryckholti* are quite heavy. The *Pisidium compressum* have thinner shells than the usual creek form. Together these suggest a small lake or river-lake. The *P. casertanum* are light and could be from a lake or other still water.

XIV. Sand Draw local fauna. The general impression given by the Sphaeriidae here is of more than one kind of habitat. Most of the *Pisidium casertanum* are of the form *roperi* Sterki, a rather long, thin-shelled, low-beaked form with a short hinge. We never collected these except in a swamp, bog pool, flood plain, or lagoon. They do not live in running water or where there is much water action. All the specimens of this species might have come from the same habitat. The *Sphaerium transversum* and *S. partumeium* require a little more water than the *P. casertanum* form *roperi.* The *P. compressum, P. nitidum* and *S. sulcatum* could have come from the same water as the *S. transversum* and *partumeium,* for the *compressum* are of the long, light form. *S. striatinum* could have come from the same place, but it is usually found in sand, more or less hard, and only rarely in mud; it also occurs in clear running water or in lakes. If this assemblage of species had come from a single locality, one would think of a widening in a stream, where the water has slowed down and where it is bordered on the sides by a lagoon.

XV. Rezabek local fauna. The *Pisidium compressum* (24/2) could be from a creek, river, or lake.

XVI. Slaton local fauna. The *Sphaerium striatinum* are the large, long, moderately heavy form, like the individuals living in the area

today. The shape approaches that of *S. sulcatum*. Both the *Pisidium compressum* and *P. casertanum* seem to have come from water without much action, certainly not from a rapid stream.

COMPARISON OF FOSSIL AND RECENT FAUNAS

The Pliocene and Pleistocene Sphaeriidae of the High Plains show some interesting contrasts with those living in North America. Eight species of *Pisidium* are found among our fossils, all of which live in North America today. Sixteen living species are not represented. Absence of some of these is readily understandable, but that of others is inexplicable. Of those not present in the fossil material, *P. amnicum* (Müller), *P. henslowanum* (Sheppard) and *P. supinum* Schmidt have probably been introduced into North America since Columbus. Some of the smaller species, such as *P. insigne* Gabb, *P. cruciatum* Sterki and *P. punctiferum* Guppy are not very plentiful and easily broken, and although is not likely, could be overlooked.

Pisidium ultramontanum Prime is a local species found only in California. Both *P. aequilaterale* Prime and *P. mainense* Sterki are not very widely distributed. *P. idahoense* Roper and *P. conventus* Clessin require cold water, at high elevations, or deep lakes or the far north, which helps explain their absence. *P. dubium* (Say) does not occur west of the Mississippi River today, but *P. adamsi* Prime does range into the western states, so failure to find it is curious. Why, too, are *P. fallax* Sterki and *P. milium* Held not in the fossil collections? Especially strange is the lack of *P. variabile* Prime, the companion of *P. compressum* in many localities.

Six species of *Sphaerium* now living are recognized in the fossil record, besides the two extinct species described here. Five other Recent North American forms are not represented in the material examined. They are *S. corneum* (Linné), apparently introduced, which is not native to North America; *S. patella* (Gould) found only west of the Rocky Mountains; and *S. tenue* (Prime) which requires the cold water of higher elevations, the far north, or deep lakes. The absence of *S. fabale* (Prime) and *S. securis* (Prime) is curious.

GEOLOGIC VALUE OF SPHAERIIDAE

As is true of other nonmarine mollusks, the Sphaeriidae may furnish two sorts of information of geologic value: (1) Determination of age of strata by restricted ranges of species and (2) knowledge concerning environment, especially local habitat and climate. Ranges of North American fossil nonmarine mollusks are so poorly known that only a

few of them are of much stratigraphic value. Certainly many, perhaps including the Sphaeriidae, will prove to be of great use in the future. About all that can be now said of this family is that the occurrence of the extinct species demonstrates that the group is of potential use. Lack of data concerning Recent species has greatly handicapped work on late Cenozoic Sphaeriidae. One conclusion to be drawn from the present study is that some species of *Pisidium* have a very short geologic range in the Pleistocene of the High Plains. But is this the result of sampling error? Or does it mean that these species evolved or immigrated into the area recently? This is one of the problems that needs to be solved.

Any environmental inferences to be drawn from fossil Sphaeriidae will necessarily depend on a knowledge of the habitat preferences of closely related, if not the same, species. For this reason reliable habitat data can probably only be obtained from the late Cenozoic forms which continue to exist or else are close to living species. The Sphaeriidae bury themselves and do not move around as much as the snails, which crawl about on the bottom and on vegetation. Nevertheless, because they are also sensitive to their environment, they provide data on the nature of the bottom and on habitat (whether mud, sand; bog pond, creek), data which often cannot be gained from snails.

CATALOGUE OF LATE TERTIARY SPHAERIIDAE

The original reference and type locality for all the late Tertiary (Miocene and Pliocene) Sphaeriidae known to us in addition to those described herein are given in the list below. The age if assigned in the original publication is given; that which now seems most probable is enclosed in parentheses. Some species described as Eocene are known to be late Tertiary. Many other Sphaeriidae are recorded from early Tertiary and Mesozoic deposits. Henderson (1935) has summarized the published data.

Sphaerium (Amesoda) andersonianum Hannibal, 1912: 132, Pl. 6, Fig. 11. Badland Hills, 1 mile east of Sand Hollow, Oregon. Pliocene. (Pliocene, probably middle Pliocene.)

Sphaerium (Amesoda) catherinae Hannibal, 1912: 132, Pl. 7, Fig. 20. Hill near Hawthorne on the Belmont Stageroad, Nevada. Eocene. (Late Miocene or early Pliocene.)

Sphaerium cooperi Arnold, 1910: 94, Pl. 30, Fig. 2. SW¼NE¼ sec. 30, T. 21 S., R. 17 E., Fresno County, California. Basal part of Tulare formation, Pliocene. (Late Pliocene.)

Sphaerium cynodon Hanna, 1923: 35, Pl. 1, Figs. 4–6. Haggin Creek, about 200 feet below bridge, 1 mile southeast of Penn Grove,

Sonoma County, California. Late Miocene. (Petaluma formation; Pliocene, probably middle Pliocene. Haggin Creek is now Willow Brook.)

Sphaerium? idahoense Meek, 1870: 57. Hot Spring Mountains, at Fossil Hill, Idaho Territory.

The type specimens (USNM 12520) were examined by Taylor. The originally published type locality is wrong, for the matrix in which the holotype of *S. idahoense* is preserved is distinct from that of other fossils described by Meek from Fossil Hill. Furthermore, the block also contains the fossil shells *Orygoceras* and *Ceriphasia taylori* (Gabb), species unknown outside the late Pliocene of southwestern Idaho. From this and from field experience in southern Idaho, Taylor believes the types of *S. idahoense* probably came from the vicinity of Castle Creek, Owyhee County, Idaho. Clarence King, who collected fossils in that area about 1869, may have obtained these specimens there.

Sphaerium kettlemanensis Arnold, 1910: 94, Pl. 30, Fig. 1. NW¼NE¼ sec. 35, T. 21 S., R. 17 E., Kings County, California. Basal part of Tulare formation. Pliocene. (Late Pliocene.)

Sphaerium malheurense Henderson and Rodeck, 1934: 266, Pl. 37, Fig. 2. Sand Hollow, 16 miles southwest of Vale, Malheur County, Oregan. Pliocene. (Middle Pliocene.)

Sphaerium meeki Dall, 1924: 111, Pl. 26, Fig. 8. Castle Creek, Owyhee County, Idaho. (Late Pliocene.) Not *Corneocyclas meeki* Hannibal, 1912, also a *Sphaerium*. We delay renaming this form until better material is known.

Corneocyclas (Pisidium) meeki Hannibal, 1912: 135, Pl. 6, Fig. 12. Hill near Hawthorne, on Belmont Stageroad, Nevada. Eocene. (Late Miocene or early Pliocene.) The large size and central beaks show this is a *Sphaerium*.

Cytherea parvula Hall, in Frémont, 1845: 308, Pl. 3, Fig. 10, 10*a*. Longitude 115°, latitude 43°.

The narrative of Frémont's expedition clearly describes several recognizable landmarks in the vicinity of the fossil locality. From field experience in the immediate area, Taylor feels confident that this locality is within the Pasadena Valley Quadrangle (1948) 1:62500, Idaho. Most probably it is in Deer Gulch, sec. 28, T. 6 S., R. 11 E. Frémont (1845:169) recorded collecting in a ravine crossed by what later became the Oregon Trail. Deer Gulch fits this description, and fossil shells are abundant there.

Cytherea parvula is misidentified. It is certainly a *Sphaerium,* but the description and figures are inadequate to show whether it is *S.*

idahoense or another, and as yet undescribed, species collected in this area by Taylor. Since the types have apparently been destroyed (Henderson, 1935: 36), the species must be considered unrecognizable.

Sphaerium rugosum Meek, 1870: 56. Hot Spring Mountains, at Fossil Hill, Idaho Territory. (Truckee formation; early or middle Pliocene.)

Pisidium compressum praecompressum Pilsbry, 1935: 546, Pl. 18, Fig. 8. NE¼ sec. 30, T. 21 S., R. 17 E., Fresno County, California. Basal part of Tulare formation. Pliocene. (Late Pliocene.)

Pisidium curvatum Hanna, 1923: 36, Pl. 1, Fig. 7; Pl. 2, Fig. 1–2, 4. Same locality as *Sphaerium cynodon* (above).

Pisidium woodringi Yen, 1945: 34. New name for *P. exiguum* Yen (1944: 108, Fig. 4) not Sterki. Near Hammett, Elmore County, Idaho. (Late Pliocene.)

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PLATE I

Sphaerium hibbardi Herrington, new species

FIGS. 1–2. Left valve. Holotype, 186391. Length, 3.3 mm.; height, 2.9 mm. × 10.

FIG. 3. Right valve. Paratype, 186396. Length, 3.2 mm.; height, 2.7 mm. × 10.

Sphaerium lavernense Herrington, new species

FIGS. 4–5. Left valve. Paratype, 186390. Length, 6.4 mm.; height, 5.5 mm. × 5.

FIGS. 6–7. Right valve. Holotype, 186390. Length, 8.1 mm.; height, 6.9 mm. × 5.

