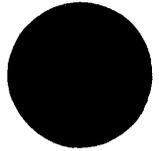


BISHOP, 1985

J. Martin

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FERRUGINOUS MEMBER, PIERRE SHALE (EARLY CAMPANIAN),  
BLACK HILLS, SOUTH DAKOTA



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FOSSIL DECAPOD CRUSTACEANS FROM THE GAMMON  
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**ABSTRACT**—Four hundred twenty-five fossil decapods, preserved in apatite concretions, were collected from the Early Campanian Gammon Ferruginous Member of the Pierre Shale in Butte County, South Dakota. The fauna, confined to a 4.3 meter interval of rock and mapped over eight square kilometers, is dominated by the mud shrimp *Protocallianassa russelli* n. sp. (74.5% of decapod fauna), the crab *Necrocarcinus davisii* n. sp. (14.6%), and the lobster *Hoploparia mickelsoni* n. sp. (9.5%), but includes four other crabs: *Dioratiopus hearttailensis* n. sp. (1.2%), *Raninella oaheensis* Bishop, 1978 (0.5%), *Xanthosia elegans occidentalis* n. sp. (0.5%), and *Rugafarius frederichi* n. gen., n. sp. (0.2%). This group of decapods is considered to be an assemblage, the *Protocallianassa-Necrocarcinus-Hoploparia* Assemblage, because of similarities to the *Dakoticancer* Assemblage in faunal characteristics, mode of preservation, and geographic and stratigraphic distribution. This assemblage predates the migration of *Dakoticancer overanus* Rathbun into the Western Interior and the consequent development of the *Dakoticancer* Assemblage, which contains descendants of taxa in the *Protocallianassa-Necrocarcinus-Hoploparia* Assemblage, repeatedly present in the Upper Pierre Shale.

INTRODUCTION

**Background.**—The Heart Tail Ranch locality (GAB 36) was discovered by myself and H. C. "Card" Smith on September 2, 1976, while collecting fossil crabs under the sponsorship of the National Geographic Society (Grant #1629). The locality has been recollected 12 times over the last five years, with approximately 20 man-days of collecting yielding 425 fossil crabs, lobsters, and mud shrimp.

Prior to the development as a decapod locality the exposures had been mapped by Knechtel and Patterson (1956) and described by Gill and Cobban (1961), Knechtel and Patterson (1962), Robinson, Mapel, and Bergendahl (1964), and Shurr (1976).

**Distribution.**—The distribution of fossil decapods at the Heart Tail Ranch locality (GAB 36) was mapped (Figure 1) through all or parts of secs. 7, 8, 16-18, 20-22, 27, and 28, T11N, R2E, Butte County, South Dakota.

A measured section (Figure 2) documents the stratigraphic distribution of the decapod fauna as occurring about 30.5 m (about 100 feet) above the Groat Sandstone and 8.2 m (27 feet) below Bentonite "H" of Knechtel and Patterson (1955), through an interval of 4.3 m (14 feet) of silty shale in the Gammon Ferruginous Member of the Pierre Shale.

Large grayish red (10R 4/2) to blackish red (5R 2/2) ferruginous concretions (about 30 cm) and small grayish orange (10 YR 7/4) apatite concretions (about 1 cm) occur abundantly below, through, and above the decapod zone. The silty shale below and through the crab zone is light olive in color (5 Y 5/2), differing slightly from lighter gray silty shale from the top of the crab zone to Bentonite "H." The base of the decapod zone was mapped at the top of an abundance of smooth *Baculites* sp., an index to early Campanian rocks, present everywhere immediately below the zone of abundant decapods. The top of the decapod zone was mapped at the color change from darker to light gray shale, which coincides with a subtle steepening in slope. A few decapods occur above and below the decapod zone but not in the same abundance as within the zone.

**The fauna.**—The published fauna reported from the Gammon (Robinson et al., 1964) is quite diverse, consisting of six decapods, nine gastropods, one scaphopod, nine cephalopods, twenty bivalves, worms, mosasaurs, bony fish, and sharks. The fauna associated with the decapods is sparse, both in terms of this expected diversity and in terms of numbers of individuals (Table 1). Of special note at this locality are: 1) the abundance of fish remains, similar to decapod-fish assemblages

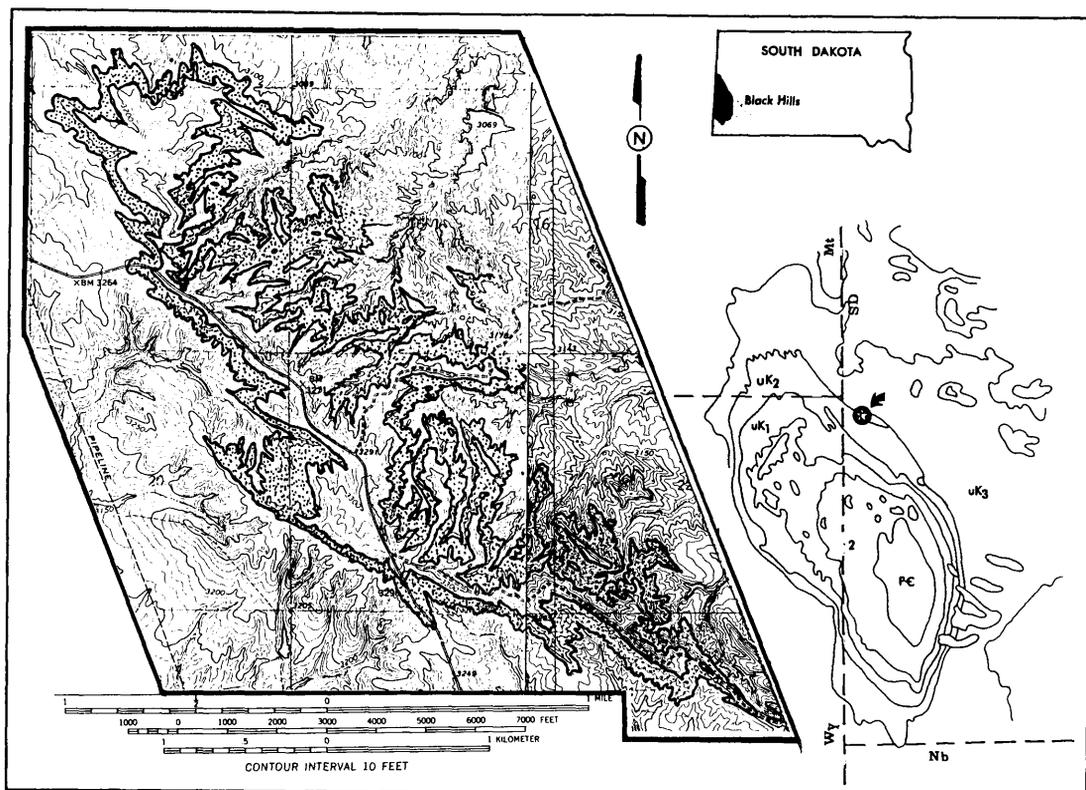


FIGURE 1—The Heart Tail Ranch locality (GAB 36) is located in western South Dakota, on the northeastern flank of the Black Hills uplift (star). The distribution of the locality is shown (in stipple) in T11N, R2E, on parts of the U.S.G.S. Antelope Butte and Mud Buttes, NW, topographic quadrangles.

elsewhere in the Western Interior (e.g., the Carlile Shale, GAB 24) and 2) the presence of the rudistid bivalve *Titanosarcolites coralloidea* (Hall and Meek), which is very rare in the Western Interior.

**Preservation.**—The fossils described from the Heart Tail Ranch locality occur in grayish orange (10 YR 7/4) apatite concretions. One pterid bivalve occurred in siderite. The original occurrence of the rudistids and oysters is unknown. Most apatite concretions from this locality are barren and occur as nuclei in siderite concretions. All specimens were collected as float from the surface, so their true occurrence in the rock must be deduced from circumstantial and fragmentary evidence. The fact that neither oyster fragments nor rudistid fragments occur in concretions leads to the conclusion that they are preserved directly in the shale. The baculites occur as steinkerns in concretions and unassociated with concre-

tions. Bivalves and gastropods are preserved as steinkerns of concretionary material. Fish remains are invariably preserved in concretions as single scales, single vertebrae, other isolated bones (including a jaw fragment), or unidentifiable masses of “bone.”

The decapods are all preserved within the apatite concretions, either completely enclosed, or, more often, with carapace edges or appendages exposed at the surface. Very often the concretion has cracked open, exposing the carapace or claw surface. A number of decapods were collected broken free of the concretions. The preservation of exoskeleton varies from excellent to poor (in the case of steinkerns). Most of the crabs are incomplete. Distal appendages are almost always missing, as is the sternum on all the necrocarcinids (which is common and testifies to the fragility of the sternum and abdomen). The differential preservation poten-

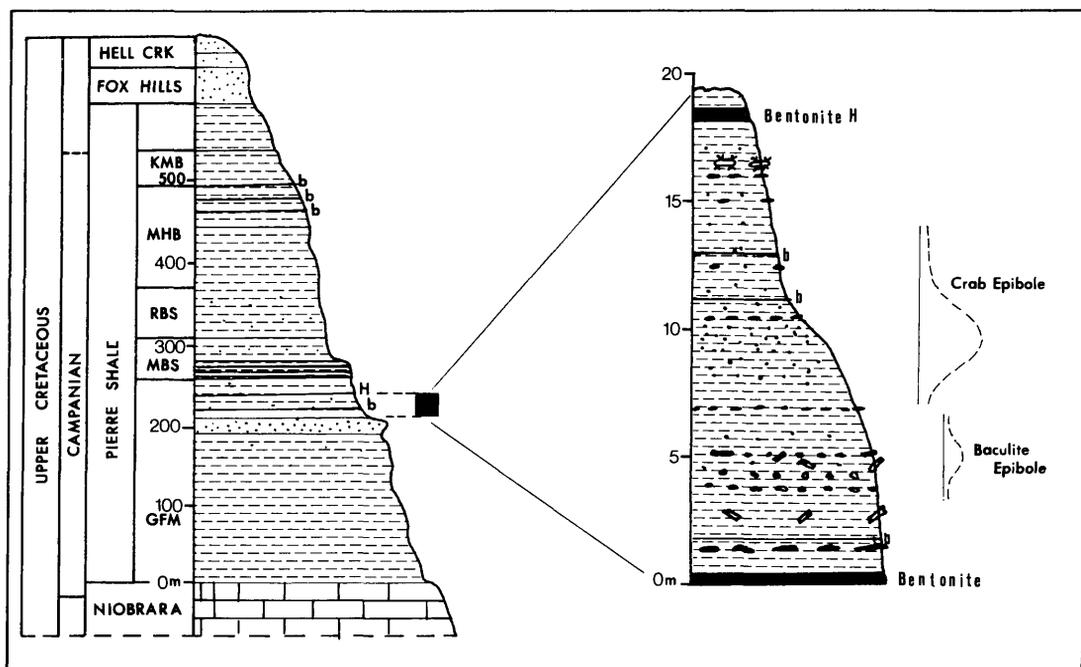


FIGURE 2—Stratigraphic setting of the Pierre Shale (left) and the Heart Tail Ranch locality (GAB 36), which lies near the top of the Gammon Ferruginous Member above the Groat Sandstone Bed and below Bentonite “H.” GFM, Gammon Ferruginous Member; MBS, Mitten Black Shale Member; RBS, Red Bird Silty Member; MHB, Monument Hill Bentonitic Member; KMB, Kara Bentonitic Member.

tial of different parts of different taxa is emphasized by the presence of 312 claws of *Protocallianassa*, and no body parts; 62 carapaces of *Necrocarcinus* with no sterna or claws, five carapaces of *Dioratiopus* preserving two sterna and an impression of one claw, and an abundance of major body parts of *Hoploparia mickelsoni* n. sp. Virtually every

fossil encountered was collected and was tabulated in this study (Table 1).

*Decapod assemblages.*—Several decapod assemblages are known from the North American Cretaceous. The best known of these decapod faunas, the *Dakoticancer* Assemblage, is found at four distinct levels and at seven distinct localities in the Pierre Shale.

TABLE 1—The *Protocallianassa*–*Necrocarcinus*–*Hoploparia* Assemblage.

Infauna	No.	%*	Epifauna	No.	%*	Nekton	
<i>Protocallianassa russelli</i>	317	74.0	<i>Necrocarcinus davisi</i>	63	14.6	<i>Baculites</i> sp.	24
<i>Raninella oahensis</i>	2	0.5	<i>Hoploparia mickelsoni</i>	41	9.5	Sharks	3
“Worms” (fecal pellets and burrows)			<i>Dioratiopus hearttailensis</i>	5	1.2	Bony Fish	173+
“Serpula”	14		<i>Xanthosia elegans occidentalis</i>	2	0.5		
			<i>Rugafarius fredrichi</i>	1	0.2		
			<i>Titanosarcolithes coraloidea</i>	12			
			<i>Ostrea</i> sp.	11			
			<i>Graphidula</i> cf. <i>aubertsoni</i>	4			
			<i>Trachytriton vinculum</i>	1			
Silty claystone			Pierre Shale, Gammon Ferruginous Member				
1 Distribution			Lower Campanian				
3m+ thick, areal distribution = 550 km <sup>2</sup>			Zone of <i>Baculites</i> sp. (smooth)				

\* % of decapod fraction.

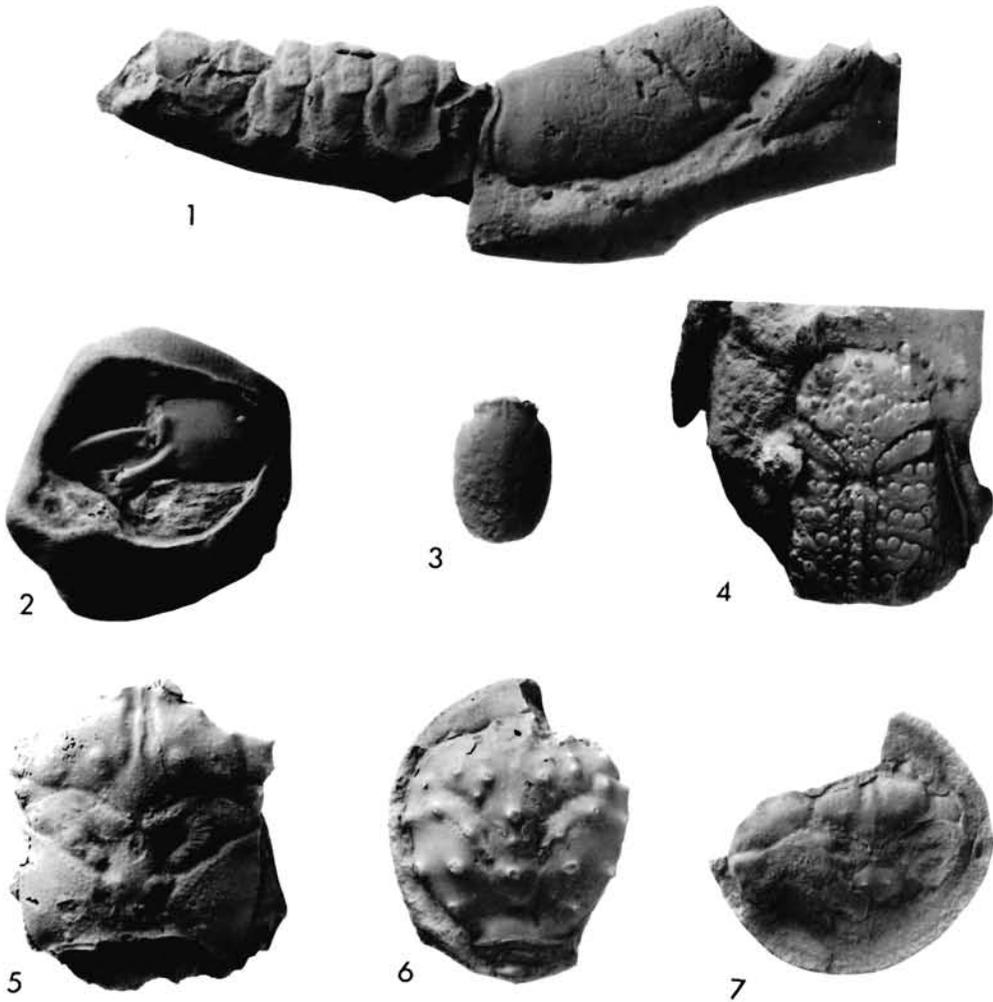


FIGURE 3—The Heart Tail Ranch decapod Assemblage: 1, *Hoploparia mickelsoni* (SDSM 10,023); 2, *Protocallianassa russelli* (GAB 36-310); 3, *Raninella oaheensis* (GAB 36-101); 4, *Rugafarius fredrichi* (SDSM 10,029); 5, *Dioratiopus hearttailensis* (SDSM 10,030); 6, *Necrocarcinus davisi* (SDSM 10,033); and 7, *Xanthosia elegans occidentalis* (SDSM 10,036); 1, 2,  $\times 1.5$ ; 3-7,  $\times 2.0$ .

In each case, decapods dominate the fauna, show a consistent faunal composition, and are distributed over broad areas (up to 1,500 sq. km) while being restricted to thin intervals of rock (3-5 m). Because of the consistency of faunal composition and its distribution, it is felt that these assemblages constitute preserved fractions of Cretaceous decapod communities (Bishop, 1971, 1972, 1981).

The Heart Tail Ranch fauna (Figure 3) is similar to the *Dakoticancer* Assemblages, which occur higher in the Pierre Shale (Bish-

op, 1981), by having similar faunal characteristics, modes of preservation and geographic and stratigraphic distributions. They are dominated by decapods, usually by a single decapod taxon, and they have one or two sub-dominant decapod taxa with numerous other crabs as occasional members of the decapod fauna.

The fauna, named the *Protocallianassa-Necrocarcinus-Hoploparia* Assemblage, is characterized (Table 1) by abundant *Protocallianassa russelli* (74.5%), numerous *Necrocarcinus davisi* (14.6%), and *Hoploparia*

*mickelsoni* (9.5%), while *Dioratiopus heart-tailensis*, *Raninella oaheensis*, *Xanthosia elegans occidentalis*, and *Rugafarius fredrichi* make up a small proportion (2.4%) of the decapod fauna. Associated with the decapods are numerous fossils of fish (teeth, bones, vertebrae, and scales), a few bivalves (including oysters and rudistids), baculites, and gastropods.

The *Notopocorystes* Assemblage (Bishop, 1983) is similar in that the fauna is consistently dominated by a single crab taxon and has many other taxa (mostly not decapods) present, some in smaller numbers. This assemblage is known from the Campanian Bearpaw Shale of northern Montana (GAB 31) and from the Cenomanian Eagle Ford Formation (GAB 18) of north-central Texas. Several other decapod assemblages are being described from the North American Cretaceous.

The assemblage described here is of utmost interest as it is only slightly older than the first appearance of the *Dakoticancer* Assemblage in the Western Interior (Zone of *Exiteloceras jennyi*) and the subsequent occurrences of the *Dakoticancer* Assemblages in four of the overlying 11 zones. This appears to document the migration of *Dakoticancer overanus* into the Western Interior (Zone of *Exiteloceras jennyi*) and its subsequent domination of most of the succeeding decapod communities in the Pierre Shale.

#### SYSTEMATIC PALEONTOLOGY

Family NEPHROPIDAE Dana, 1852  
 Subfamily HOMARINAE Huxley, 1879  
 Genus HOPLOPARIA M'Coy, 1849

*Type species.*—“*Astacus longimanus* Sowerby, 1826; subsequent designation by Rathbun, 1926. [= *Palaeno* Robineau-Desvoidy, 1849 (type, *P. roemeri*).” Glaessner, 1969, p. 459.

*Discussion.*—The genus *Hoploparia* contains a series of lobsters with a diverse morphology, particularly in their carapace grooves. Woods (1923, 1931) presented a comprehensive list of Cretaceous species assigned to *Hoploparia* and *Homarus*, genera between which he could see no real difference (Woods, 1930, p. 87). Glaessner (1969, p. 459) stated, “The distinction between some species of *Hoploparia* and *Homarus* is diffi-

cult and disputed.” Secretan (1964) presented a comprehensive summary of macruran carapace groove evolution and descriptions of three new species of *Hoploparia* from the Campanian of Madagascar. She has suggested (1964, p. 112) that there are three evolutionary tendencies producing hoploparids similar to astacids, to homarids, and to nephropsids. Carapace grooves of these three groups are quite different. Feldmann (1974, p. 591) re-emphasized the difficulties of generic assignment in his discussion of observations made on *Hoploparia*, some *Nephrops*, and *Homarus* at the British Museum (Natural History) and suggested *Hoploparia* may be ancestral to *Homarus* and *Nephrops*.

#### HOPLOPARIA MICKELSONI n. sp.

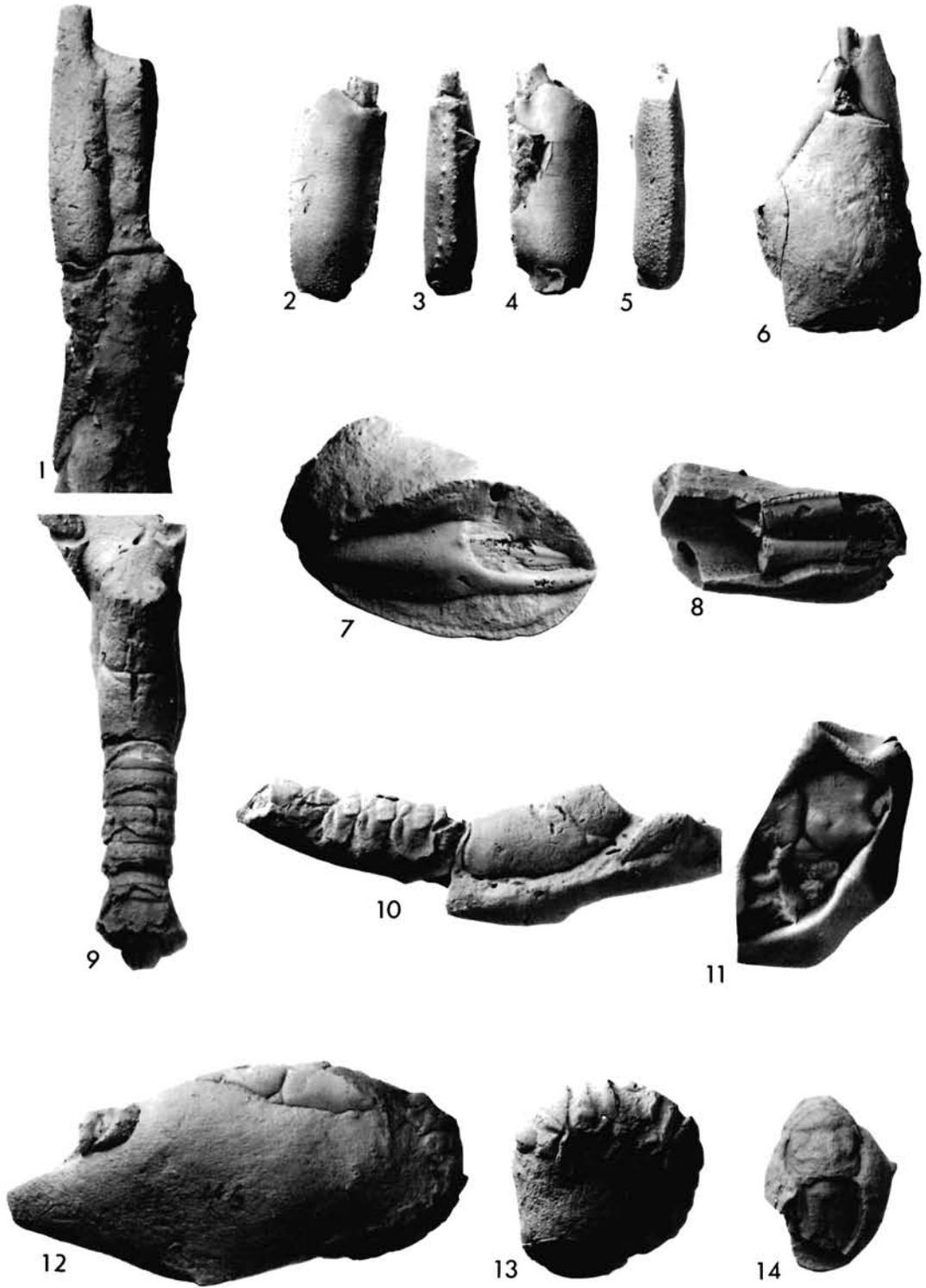
Figures 3.1, 4, 5; Table 2

*Etymology.*—*Hoploparis mickelsoni* is named in honor of Dr. John C. Mickelson, stratigrapher and paleontologist at South Dakota School of Mines.

*Types.*—The holotype of *Hoploparia mickelsoni* (SDSM 10,023) and the paratypes (SDSM 10,024, 10,025, 10,026, and 10,027) are deposited in the collection (SDSM) of The Museum of Geology, South Dakota School of Mines and Technology, Rapid City, South Dakota 57701.

*Occurrence, sample size, and preservation.*—The 41 specimens of *Hoploparia mickelsoni* were all collected from the Heart Tail Ranch locality and are preserved in apatite concretions.

*Description.*—Carapace small; about twice as long as wide; abdomen longer than carapace; chelipeds about as long as cephalothorax (Table 2). Carapace grooves discontinuous. Postcervical and branchiocardiac grooves parallel, crossing dorsum behind midpoint, merging and swinging forward as they disappear about 1/3 the way to carapace margin. Cervical groove about 1/4 distance from front, beginning about 1/4 down on carapace side swinging forward forming antennar groove (a) which disappears before meeting carapace margin. Short hepatic groove (b) swings downward and slightly backward delineating, with antennar groove, the prominence omega (w). Rostrum unknown. Orbits bordered by fine ridge above and subtle antennar spine below; supraorbital and suborbital spines (Stenzel, 1945, p. 402) repre-



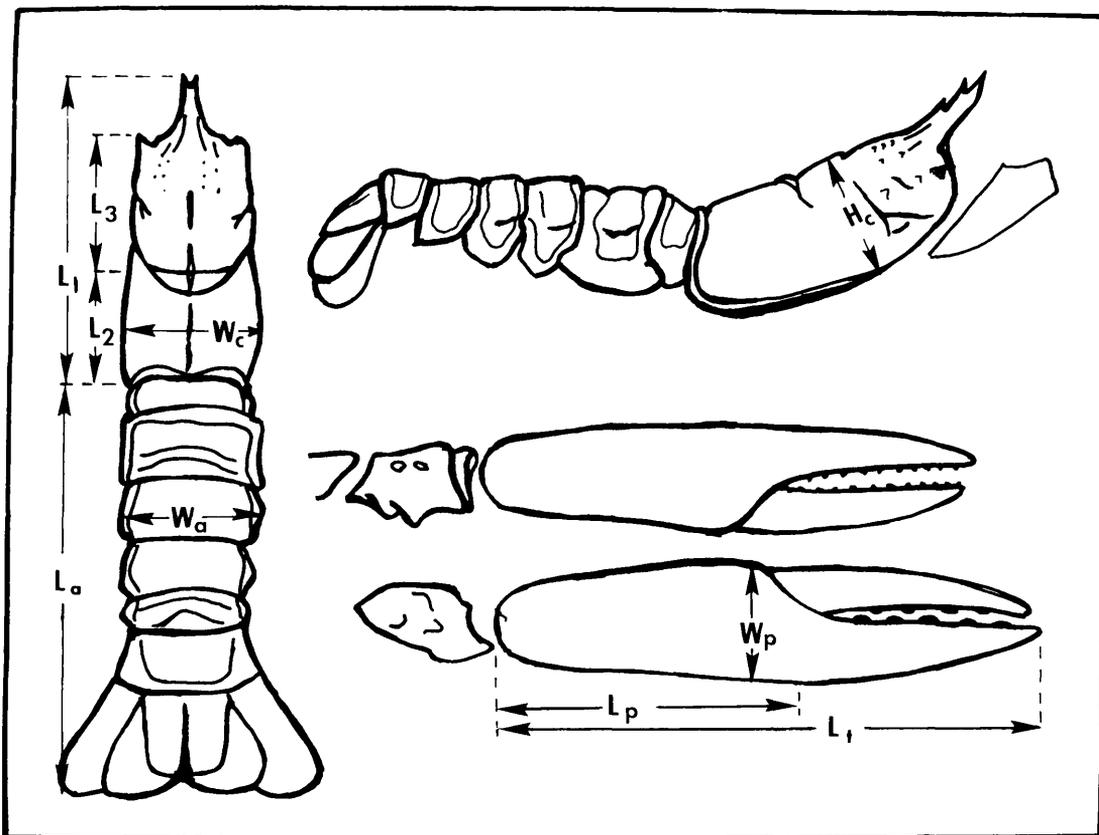


FIGURE 5—Line drawing of reconstruction of *Hoploparia mickelsoni* n. sp. showing measurements made in Table 2.

sented by exceedingly subtle swellings. Dorsal midline marked by line of weakness. Anterior of carapace ornamented by four anteriorly convergent ridges, central pair longest. Probably in line with ridges are four rows of very fine granulations, each represented by 4-5 granules. Posterior of carapace concave, bordered by deep marginal groove. Abdomen about four times longer than wide; widest across the 2nd somite, decreasing in width very little posteriorly. Pleuron of 2nd somite

large, rounded at both ends, other pleura triangular and squared off; slight ridges progress from the articulating processes of pleura. Telson longer than wide with medial groove. Chelipeds, heterochelous, probably slightly longer than cephalothorax, rotated so that plane of opening is horizontal. Heterochely exhibited by slight size difference (mostly length), right normally longer, and right claw with heavier crushing teeth, left with fine cutting teeth. Merus moderate in length, bring-

FIGURE 4—*Hoploparia mickelsoni* n. sp. showing the chelipeds (1-8), the carapace (9-12), and the abdomen (9-10, 12-14). 1, dorsal view of left cheliped (SDSM 10,025); 2-5, top, inner edge, bottom, and outer edge of right propodus (SDSM 10,027); 6, dorsal view of both claws (SDSM 10,024); 7, right propodus and dactylus (GAB 36-90); 8, fingers of right claw (GAB 36-85); 9-10, dorsal and right lateral view of carapace and abdomen (SDSM 10,023); 11, lateral carapace spines on hepatic region (GAB 36-78); 12, left lateral view of specimen in concretion (GAB 36-45); 13, left side of abdomen (SDSM 10,026); and 14, telson (GAB 36-89). 1-8 and 11-14,  $\times 1.5$ ; 9-10,  $\times 1.0$ .

TABLE 2—Measurements of *Hoploparia michelsoni* (mm).

Specimen	Carapace				Abdomen				
	Length			Width	Height	Length	Width	Telson	
	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>	Wc	He	La	Wa	Length	Width
SDSM 10,023	28.5	10.5	—	13.4	14.0	40.2	12.5	8.0	8.1
SDSM 10,026	—	—	—	—	—	41.9	11.5	—	—
36-1	20.7	8.5+	—	18.5	—	34.6+	9.7	8.5	9.7
36-45	22.1+	10.6+	11.7?	6.5+	—	38.2+	7.8	5.1+	7.8
36.89	—	—	—	—	—	49.2	8.5	8.2+	6.4
36.94	26.6+	13.2	—	10.9+	10.3	—	—	—	—

Specimen	Side	Chelipeds									
		Merus		Carpus		Propodus			Dactylus		
		Length	Width	Length	Width	Length	Width	Thick	Length	Width	
SDSM 10,023	L	13.8+	5.1	10.4	8.2	Lt	Lp	Wp	T	—	—
SDSM 10,025	R	15.3	5.8+	10.3	7.6	—	22.2	—	—	—	—
SDSM 10,025	L	13.6	6.7	9.6	7.2	28.3+	21.5	7.1	—	—	—
SDSM 10,027	R	—	—	—	—	—	21.1	10.3	6.0	—	—
36-1	L	—	—	—	—	—	18.1	7.9	—	—	—
36-23	R	—	—	—	—	26.8+	22.7	8.2	—	—	—
36-23	L	—	—	—	—	20.8	17.1	4.0	—	—	—
36-32	R	—	—	—	—	21.4	16.9	7.4	—	—	—
36-78	R	—	—	—	—	27.4+	21.2	9.9	—	—	—
36-83	L	—	—	6.2	4.9	20.8+	16.0	7.3	—	—	3.5
36-84	?	—	—	—	—	22.3+	12.3	4.1	—	—	—
36-85	R?	—	—	—	—	—	—	—	—	16.4+	2.9
36-87	R	—	—	—	—	—	14.6	11.2	6.2	—	—
36-90	R	—	—	—	—	30.7	17.3	18.1	—	12.0	3.5

ing cheliped from beneath carapace, somewhat ridged along innerside and coarsely granulate. Carpus short with three (?) spines on inner edge and two on upper surface. Propodus 3.5 times longer than wide, dorsoventrally flattened, biconvex in plane view. Manus about twice as long as wide, slightly flatter on upper surface, which meets more convex lower surface and finely granulate outer edge in an angulation (offset toward upper side; inner side slightly ridged with parallel edges of ridge coarsely tuberculate). Walking legs slim (about 1 mm in maximum diameter).

*Comparison.*—*Hoploparia mickelsoni* is readily distinguished from *H. georgeana* Rathbun, 1935; *H. dentonensis* Rathbun, 1935; and *H. blossomana* Rathbun, 1935, by having much less tuberculate claws. *Hoploparia gabbi* Pilsbry, 1901, is much stouter, has a stouter claw, the postcervical groove (c) is continuous and connects with the hepatic, and the branchiocardiac groove is absent. *Hoploparia mcnairyensis* Rathbun, 1926, is complemented by a much more complete set

of carapace grooves. *Hoploparia tennesseensis* Rathbun, 1926, has no branchiocardiac groove, the postcervical groove is more complete, the orbital spines are much more prominent, and the stout, prominently ridged, tuberculate claw is very different. *Hoploparia tarrentensis* Rathbun, 1935, has no branchiocardiac groove, the postcervical groove is more complete, the orbital spines are much more prominent, and the stout, prominently ridged, tuberculate claw is very different. *Hoploparia tarrentensis* Rathbun, 1935, still poorly known, has a more ridged abdomen, as does *H. westoni* Woodward 1900, (in addition to its different carapace grooves). *Hoploparia gladiator* Pilsbry, 1901, is most similar to *H. mickelsoni* but differs in that the branchiocardiac groove is longitudinal rather than transverse, the postcervical groove is more complete, the orbital spines are better developed, and the claws are even slimmer and with prominent tubercles. *Hoploparia bearpawensis* Feldmann, 1977, has more continuous grooves so it can be easily distinguished from the only slightly older *H. mick-*

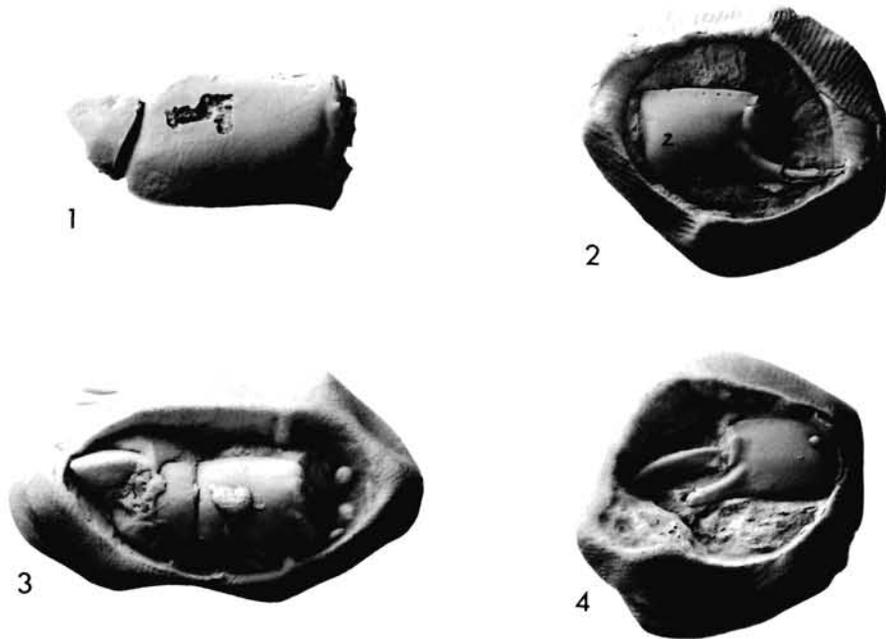


FIGURE 6—Chelae of *Protocallianassa russelli*. 1, outer face of right carpus and propodus of holotype (SDSM 10,028); 2, inner face of left propodus (GAB 36-137); 3, outer face of right manus, carpus, and propodus and a pereopod (GAB 36-158); 4, inner face of right propodus and dactylus (GAB 36-310). 1,  $\times 2.0$ ; 2-4,  $\times 1.5$ .

*elsoni*. *Hoploparia mickelsoni* only vaguely resembles *H. intermedia* Secretan, 1964, in carapace grooves and does not resemble *H. collignoni* Secretan, 1964, nor *H. sculptata* Secretan, 1964.

Family CALLIANASSIDAE Dana, 1852  
Subfamily CALLIANASSINAE Dana, 1852  
Genus PROTOCOLLIANASSA Beurlen, 1930

*Type species*.—*Callianassa archiaci* A. Milne-Edwards, 1860, by original designation.

*Remarks*.—The callianassids are a difficult group to study. The different genera are remarkably similar in fossil material. The fossil callianassids are often represented just by numerous claws. Glaessner (1969, p. 478) remarked in his description of *Protocallianassa* that "Single chelae are hardly distinguishable from those of *Protaxius* or *Callianassa*." Rathbun (1935, p. 29) commented on the morphologic variation of claws shown within species of *Callianassa (sensu lato)*: "In identifying chelae of *Callianassa* it must be taken

into consideration that the major and the minor chela of the same specimen may differ not only in size but in form and ornamentation; that those of the female differ from those of the male and the old from the young. The wide distribution of a species also promotes diversity of form."

PROTOCOLLIANASSA RUSSELLI n. sp.  
Figures 3.2, 6

*Etymology*.—*Protocallianassa russelli* is named in honor of (the late) William L. Russell of the South Dakota Geological Survey who collected the 17 specimens from the Pierre Shale that Mary J. Rathbun described as *Callianassa cheyennensis* Rathbun, 1930.

*Type*.—The holotype of *Protocallianassa russelli* n. sp. is a right, major chela (carpus and most of propodus) collected at the Heart Tail Ranch and is deposited in the South Dakota School of Mines Museum of Geology (SDSM 10,028).

*Occurrence, sample size, and preservation*.—The 311 specimens assigned to *Pro-*

*tocallianassa russelli* are all from the Heart Tail Ranch locality. The claws are often broken free of the concretions yielding both isolated claws and external molds. They are commonly somewhat crushed into irregular surfaces and show a mottled color pattern when fresh that subsequently weathers differentially, forming a mottled surface on some claws. The external molds bearing impressions of the claws are difficult to interpret directly, but an impression of these molds in dental wax rapidly produces a positive replica which can be studied and photographed.

*Diagnosis.*—Chela longer than high, relatively thick, rectangular. Outer face roundly convex, unornamented. Inner face relatively flat, upper margin rounded, lower margin sharp, unkeeled. Approximately eight setal pits parallel the upper edge, three or four lie just below fixed finger ridge on manus, one pit on inside of manus below its center.

*Description.*—Cheliped typical of callianassids, merus triangular twice as long and half as high as rectangular carpus which is same height and  $\frac{1}{3}$  length of manus. Propodus rectangular, twice as long as high, manus longer than high. Outer face convex; inner face flat on lower  $\frac{2}{3}$  rounding on upper  $\frac{1}{3}$  into broadly rounded upper margin. Lower margin sharp and wedge-shaped. Fixed finger long and slim, dactylus stout. Outer face unornamented except for vertical ridge along articulation of dactylus and subdued ridge which runs off manus onto fixed finger. Inner face with row of seven to nine setal pits just below upper margin, vertical ridge along articulation with dactylus, and pronounced ridge from manus onto fixed finger. About four setal pits lie beneath this ridge and another in line with top of fixed finger midway across manus. Second(?) pereopod small, slim, and chelate.

*Comparison.*—*Protocallianassa russelli* differs from *Protocallianassa cheyennensis* (Rathbun), 1930, by being much longer, thicker, and lacking the row of setal pits along the lower margin of the inner face. *Protocallianassa russelli* differs more dramatically from *P. mortoni* (Pilsbry), 1901, by being slimmer and lacking the setal pits and granulations so prominent on the outer face of *P. mortoni*. *Protocallianassa russelli* has the shape of *P. praecepta* Roberts, 1962, but lacks the setal pits along the lower margin of the outer face, the second carina of the manus,

the “acute but bluntly rounded” upper margin, and the lower margin “erect, crenulated, raised line along the crest of the lower margin.” *Protocallianassa russelli* is thinner and lacks the crests of *P. cretacea* (Rathbun), 1935; is more rectangular than *P. aquilae* (Rathbun), 1935 and *P. valida* (Rathbun), 1935; and is longer and less ornamented than *P. pilsbryi* (Rathbun), 1935.

*Remarks.*—The variable morphology of the chelae of callianassids makes them a real challenge to study. Until somebody applies mechanized shape analyses to large suites of the claws of callianassids, the true systematic relationships of these abundant fossils will continue to remain obscure and confusing. Mertin (1941, p. 200–201) began this sort of analysis on European species.

The variation in the shape of *P. russelli* seems minimal with only a few variants that are nearly square, very slim, or have an oblique proximal edge, a very high fixed finger, and an ornamented dactylus.

Superfamily GALATHEOIDEA  
Samouelle, 1819

Family GALATHEIDAE Samouelle, 1819  
(nom. correct. White, 1847)

(pro Galathedae Samouelle, 1819)

Subfamily GALATHEINAE Samouelle, 1819  
nom. transl. Ortmann, 1898

(ex Galatheidae Samouelle, 1819)

Genus RUGAFARIUS n. gen.

*Etymology.*—This taxon takes its name from *ruga*, Latin, for the wrinkles, and *farius*, suffix meaning multiplication of parts.

*Type species.*—*Rugafarius fredrichi* is the type species by monotypy.

*Diagnosis.*—Carapace much longer than wide, widest across flaring branchial regions. Rostrum very reduced and bifurcating. Carapace with prominent transverse cervical groove and shallow indistinct grooves ahead and behind it. A sagittal ridge marked by paired tubercles on the cephalic gastric region of the arch and by a distinct sagittal ridge on the scapular arch; entire surface covered by 6–7 rows of coarse forward-facing squamae alternating with 6–7 rows of small tubercles.

*Discussion.*—This new genus is necessary as none of the described galatheid crabs has a well-developed sagittal ridge on the scapular arch nor a rostrum as reduced as that of *Rugafarius*. The strong transverse ornamen-

tation suggests the taxon belongs in the Galatheinae. Of the four genera in the subfamily, *Rugafarius* most resembles *Munida* with its reduced rostrum. The possibility remains, however, that this unique carapace may prove to be that of a palinurid lobster.

The term "cephalic arch" refers to the area of the dorsum, ahead of the cervical furrow and "scapular arch" to the area of the dorsum behind the cervical furrow. These terms are most useful in describing carapace morphology.

*RUGAFARIUS FREDRICHII* n. sp.

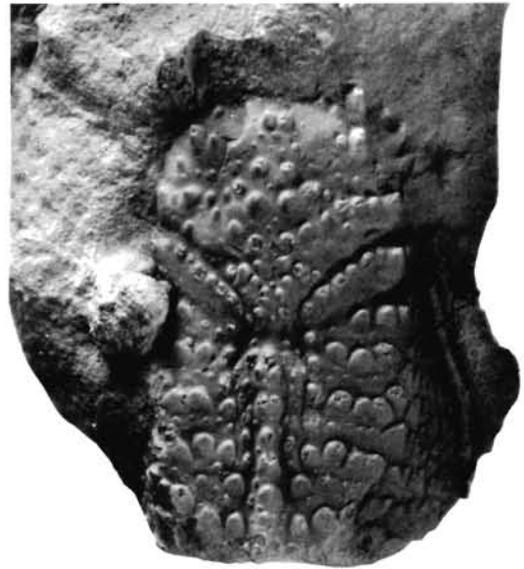
Figures 3.4, 7

*Etymology.*—This taxon is named in honor of Dr. Frederick J. Rich of the South Dakota School of Mines and Technology who accompanied me in the field on numerous occasions and found the holotype.

*Holotype.*—The holotype and only known specimen (SDSM 10,029) is deposited in the collection of the Museum of Geology, South Dakota School of Mines.

*Description.*—Carapace rectangular, longer than wide ( $L/W = 1.19+$ ), widest across branchial regions, sides converging and steepening toward front, dorsum fairly level. Carapace crossed near its middle by three parallel grooves oriented obliquely forward and outward. The cervical groove continuous and deepest, crossing sagittal area in broadened transverse furrow. Just behind it is the equally well developed postcervical furrow, which joins the cervical where it crosses the sagittal line. A less distinct furrow lies ahead of the cervical furrow; becomes indistinct toward the sagittal axis. All three grooves continue onto the nearly vertical side of the anterior of the carapace. From where the cervical-postcervical groove crosses sagittal axis, two parallel branchiocardiac grooves proceed to posterior edge of preserved part of carapace.

Cephalic arch differentiated into a frontal lobe and ridge-shaped hepatic lobes. Gastric lobes poorly delineated but represented by three pairs of tubercles on "gastric region" ahead of hepatic groove. Hepatic ridge fairly narrow and surmounted by a row of six tubercles. Rostrum very short, bifurcated and bordered by broad orbital spines, then large, forward-pointing spines. The anterolateral margin is just outside these large spines and



1



2

FIGURE 7—Carapace of *Rugafarius fredrichi* seen in 1, dorsal and 2, right lateral view (SDSM 10,029),  $\times 3.5$ .

carries four forward-facing spines, two small and two large. The scapular arch is divided by the prominent, parallel branchiocardiac grooves into a narrow, continuous cardiac-intestinal ridge and the branchial regions. Branchial regions differentiated by distinct postcervical furrow into an epibranchial ridge (surmounted by a row of 6–7 tubercles) and the large, undifferentiated meso- and meta-branchial region.

Carapace ornamentation on cephalic region consists of the three pairs of gastric spines, the hepatic ridges with rows of six spines, four frontal spines, and the two pairs

of anterolateral spines as well as numerous small tubercles. Ornamentation on the scapular arch consists of epibranchial ridges with rows of 6–7 tubercles, the cardiac-intestinal ridge with a row of forward-facing shingle-like squamae. Each meso-, metabranchial lobe is covered by alternating rows of forward-facing shingle-like squamae and very tiny tubercles. The carapace side flares outward, becoming less vertical posteriorly, covered by continuous forward-facing squamae increasing in density and decreasing in size downward. Carapace edge not visible. Ventral side, posterior margin, and most pereopods not preserved. One walking leg, preserved along right margin of carapace. It is long and slim.

*Remarks.*—*Rugafarius fredrichi* is very unusual in its morphology, as is its presence in the Western Interior (where only one other galatheid is known). The likelihood of finding a second specimen seems so slim and the importance of publishing on a complete decapod fauna so great that I feel obligated to name and describe this taxon even though it is partly known.

Superfamily TYMOLOIDEA Alcock, 1896  
Family TORYNOMMIDAE Glaessner, 1980  
Genus DIORATIOPUS Woods, 1953

*Type species.*—*Dioratiopus salebrosus* Woods, 1953.

*Remarks.*—Glaessner (1980, p. 182) synonymized *Glaessnerella* Wright and Collins, 1975 (= *Glaessneria* Wright and Collins, 1972) with *Dioratiopus* Woods, 1953; assigning the genus to the Family Torynommidae Glaessner, 1980, and Superfamily Tymoloidea Alcock, 1896. I concur with this reassignment.

DIORATIOPUS HEARTTAILENSIS n. sp.  
Figures 3.5, 8, 9

*Etymology.*—This species is named after the Heart Tail Ranch, where it was first found, and the locality that has yielded all known specimens.

*Types.*—The holotype (SDSM 10,030) is a nearly complete carapace preserved in an apatite concretion. The paratype is an eroded carapace preserving the abdomen of a female (SDSM 10,031). The types are deposited in the Museum of Geology, South Dakota School of Mines. Three additional specimens were collected from the Heart Tail Ranch locality.

*Description.*—Carapace pentagonal slight-

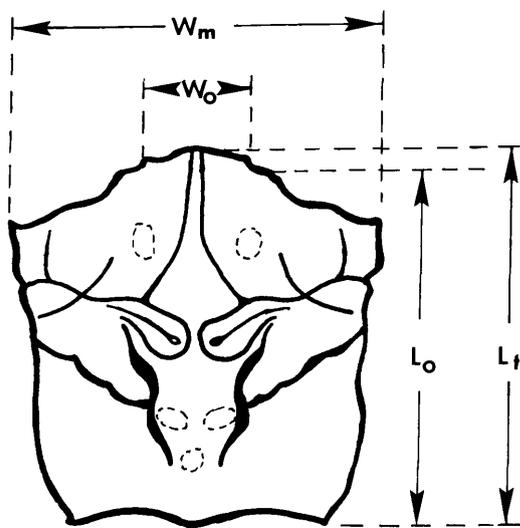


FIGURE 8—Line drawing of carapace of *Dioratiopus hearttailensis*. ( $W_m$ , maximum width;  $W_o$ , orbital width;  $L_t$ , total length; and  $L_o$ , orbital length).

ly longer than wide (Table 3), widest near front across hepatic regions which are produced into anterolateral angles, and slightly arched. Anterolateral margins concave; lateral margins concave behind anterolateral angle, convex on branchial regions. Posterior margin concave. Carapace well differentiated by grooves into regions. Rostrum not completely preserved but appears narrow, grooved, and distally downturned. Frontal region poorly differentiated but with orbital and part of hepatic regions forms a nearly vertical anterolateral wall. Orbits opening upward and forward, width about one-third carapace width. Mesogastric lobe triangular with narrow anterior process. Protogastric lobe large with three gentle bosses, two on a line oriented outward and forward and one on the anterolateral edge. Hepatic region forms anterolateral angle and part of anterolateral wall; separated from protogastric lobe by shallow groove parallel to sagittal axis. Urogastric lobe discontinuous across sagittal axis, forming urogastric peninsulas. Branchiocardiac groove well defined, better so proximally where it bends forward and outward forming epimeral peninsulas just behind urogastric lobes. Postcervical furrow subtle but present. Cardiac region arrow-

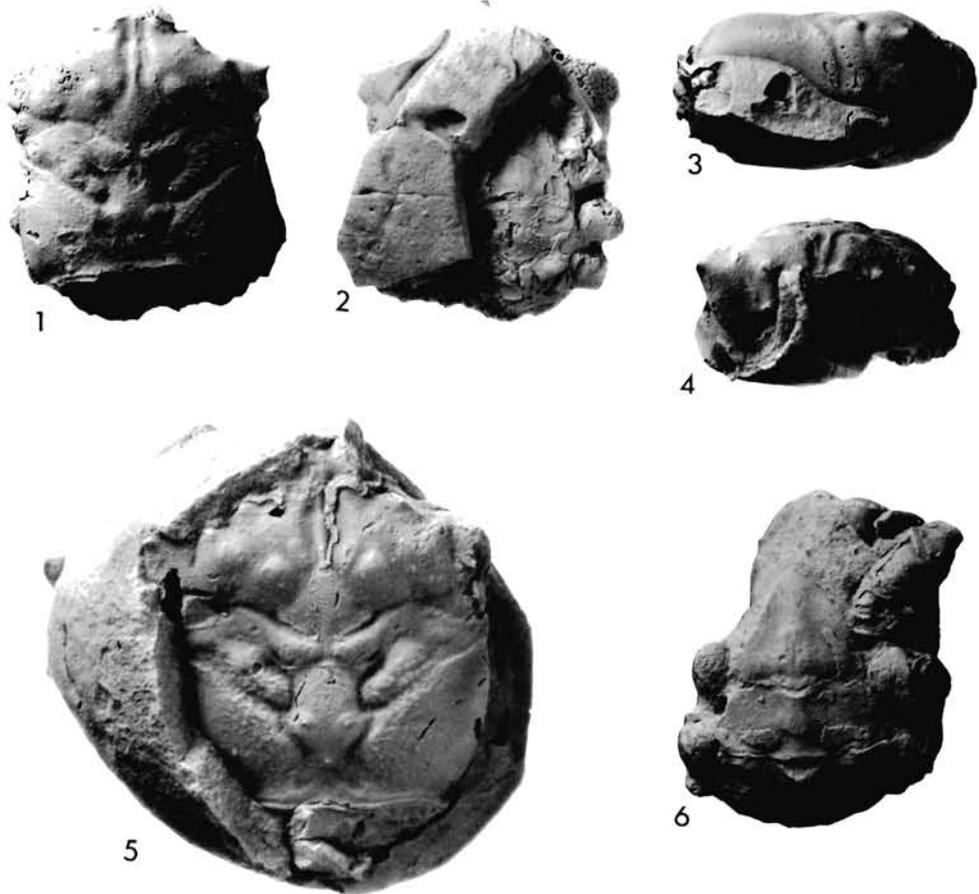


FIGURE 9—*Dioratiopus hearttailensis*. 1-4, dorsal, ventral, right lateral, and anterior views of carapace of holotype (SDSM 10,030); 5, dorsal view of carapace of specimen (GAB 36-26); 6, ventral view of abdomen and proximal pereopods, paratype 1 (SDSM 10,031). 1-4, 6,  $\times 2.0$ ; 5,  $\times 3.0$ .

head-shaped pointing posteriorly, three small bosses near each apex. Intestinal region small. Branchial region well separated from cardiac by branchiocardiac furrow and differentiated into epibranchial, mesobranchial, and metabranchial lobes by shallow postcervical grooves. The epibranchial groove joins the branchiocardiac groove on the carapace edge then slants downward and forward, parallel to the cervical furrow on the lateral margin. Posterior margin paralleled by posterior marginal groove. Sides nearly vertical. The carapace is ornamented everywhere by a very fine granulation.

The sternum is unknown. Abdomen, with broad medial ridge, increasing in length posteriorly and increasing in width to the 6th somite; the telson is triangular.

Cheliped stout, almost as long as carapace width. Propodus and dactylus about same length, latter incurved with row of 5-7 tubercles (teeth) on opposing margin, propodus transversely convex on inner side and probably so on outer face. Pereiopods 2-4 progressively decrease in size, pereopod 5 possibly absent or reduced, lengths of leg segments unknown.

*Comparison.*—*Dioratiopus hearttailensis* n. sp. is easily distinguished from the European species *D. balli* (Wright and Collins), 1972, and *D. latteri* (Wright and Collins), 1972, by distinctive ornamentation on the scapular arch; from *D. kennedyi* (Wright and Collins), 1972, by its more pentagonal shape; from *D. spinosa* (Van Straelen), 1936, by its less triangular cephalic arch and more highly

TABLE 3—Measurements (mm) of the carapace, abdomen, and claw of *Dioratiopus hearttailensis* n. sp.

Specimen	Carapace					Abdomen			
	Total length	Orbital length	Maximum width	Orbital width	Height	A1		A2	
						L	W	L	W
SDSM 10,030	20.7+	17.6	18.5	6.0	10.0	2.3	4.4	1.9?	4.1?
SDSM 10,031	—	—	—	—	12.8	—	—	—	—
36-26	16.2	14.3	15.4	—	—	—	—	—	—
36-28	13.2	11.2	12.4	—	—	—	—	—	—
36-366	—	—	(20.3)	6.6	—	±	—	—	—

differentiated branchial regions; and from *D. depressa* (Carter), 1898, by its shorter cephalic arch and differently ornamented protogastric region. *Dioratiopus hearttailensis* is similar to *D. decipiens* (Wright and Collins), 1972, but differs from it by having bilobed urogastric lobes, three instead of two protogastric bosses, and a differently oriented hepatic furrow.

*Dioratiopus hearttailensis* is narrower than its only North American congener *D. dawsonensis* (Bishop), 1973, is more highly ornamented, is widest across the cephalic arch rather than across the scapular arch, and lacks the groove that swings backward and outward from the mesogastric corner on the mesobranchial region. *Dioratiopus hearttailensis* is broader than the Australian *D. salebrosus*, has a more pentagonal shape, a broader cardiac region, differently oriented hepatic furrows, and gentle bosses on the protogastric lobes and cardiac region.

*Remarks.*—The geologic range of *Dioratiopus* in North America is extended from the early Maastrichtian, Zone of *Baculites baculus*; *Dioratiopus dawsonensis* (Bishop, 1973), back into the early Campanian by *D. hearttailensis*.

The presence of well-defined rectangular orbits necessitates a modification of the generic diagnosis given by Wright and Collins (1972, p. 34). A sixth specimen may be represented by the "*Homolopsis* sp." collected by W. A. Cobban for his thesis from Owl Creek and now in the collections of The Johns Hopkins University (Robinson et al., 1964, p. 80).

Section OXYSTOMATA

H. Milne-Edwards, 1834

Family CALAPPIDAE Alcock, 1896

Genus NECROCARCINUS Bell, 1863

*Type species.*—*Necrocarcinus labeschei*

(Deslongchamps, 1835) Cenomanian, Northern France.

*Discussion.*—Two taxonomic positions have been recently developed in the literature by Förster, 1968, and Wright and Collins, 1982. Förster, in a major revision of the phylogeny of the Necrocarcinids, maintained six genera in the Family Calappidae Alcock, 1896, in the Subfamily Necrocarcininae Förster, 1968; including *Paranecrocarcinus* van Straelen, 1936, *Necrocarcinus* Bell, 1863, *Cenomanocarcinus* van Straelen, 1936, *Orithopsis* Carter, 1872, *Protonecrocarcinus* Förster, 1968 and *Pseudonecrocarcinus* Förster, 1968. Wright and Collins (1972, p. 62) synonymized *Orithopsis* and *Cenomanocarcinus* with *Necrocarcinus*, but maintained four genera within the Necrocarcininae, including: *Necrocarcinus* Bell, 1863 [synonyms *Orithopsis* Carter, 1872, and *Cenomanocarcinus* (van Straelen nom. nud., 1936) Stenzel, 1945], *Paranecrocarcinus* van Straelen, 1936, *Protonecrocarcinus* Förster, 1968 and *Pseudonecrocarcinus* Förster, 1968. The more conservative position of Wright and Collins has been supported by Feldmann et al., 1976 (p. 986) and Kues (1980, p. 863), even though both of these papers allude to the greater similarity of their described taxa [*N. siouxensis* Feldmann et al., and *N. vanstraeleni* (Stenzel) to the synonymized genus *Cenomanocarcinus*]. As a compromise position to reconcile the apparent validity of points made by Wright and Collins, and yet maintain an apparently useful morphologic distinction, I propose the genus *Necrocarcinus* (of Wright and Collins) be subdivided into subgenera to recognize the distinctions described by Förster and observed by many other authors (Feldmann et al., 1976; Kues, 1980) as follows: *Necrocarcinus* (*Necrocarcinus*) Bell, 1863, *N. (Cenomanocarcinus)* (Stenzel), 1945, and *N. (Orithopsis)* (Carter), 1872.

TABLE 3—Extended.

Abdomen													Lt	Lr	H
A3		A4		A5		A6		T							
L	W	L	W	L	W	L	W	L	W						
1.6	6.6	2.3	9.2	2.6	8.4	4.5	8.04	6.9	7.3	—	—	—	—	—	—
—	10.3	2.8	12.7	3.5	11.4	4.8	11.5	8.8	8.7	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	10.0	6.6	3.9	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

NECROCARCINUS (NECROCARCINUS)

DAVISI n. sp.

Figures 3.6, 10–12

*Etymology.*—*Necrocarcinus* (*N.*) *davis* is named in honor of the Davis family, especially Peggy and Chance Davis, who have extended their hospitality to me over more than five years of collecting on the Heart Tail Ranch.

*Types.*—The holotype (SDSM 10,032) and paratypes (SDSM 10,033, 10,034) are de-

posited in the collection of South Dakota School of Mines Museum of Geology. The 62 specimens of *N. (N.) davis* were all collected at the Heart Tail Ranch locality.

*Diagnosis.*—*Necrocarcinus* (*N.*) *davis* is circular, spinose; has strongly developed cervical, hepatic, and branchiocardiac furrows and weakly developed postcervical and gastric furrows. The sagittal axis is surmounted by a row of four spines, one mesogastric, one urogastric, and two cardiac.

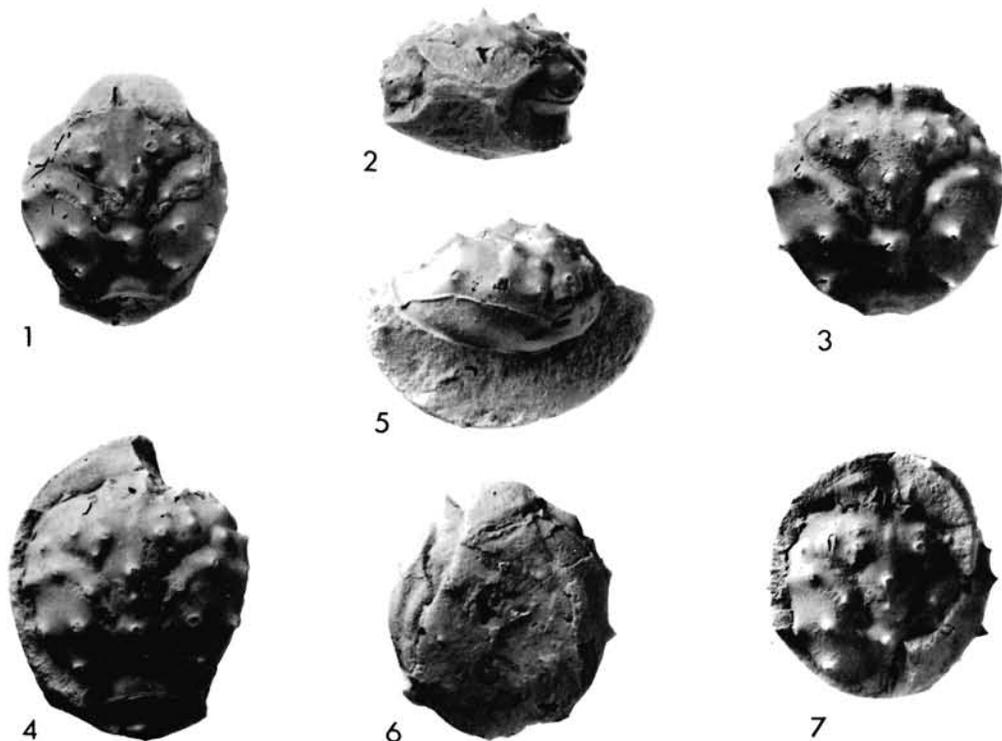


FIGURE 10—*Necrocarcinus davis*. 1–2, dorsal and anterior views of holotype (SDSM 10,032); 3, dorsal view of carapace (GAB 36-61); 4–5, dorsal and right lateral view of paratype enclosed in a concretion (SDSM 10,033); 6, ventral view of pterygostomial regions (GAB 36-69); 7, dorsal view of specimen with rostrum preserved in a concretion (SDSM 10,034). All  $\times 2.0$ .

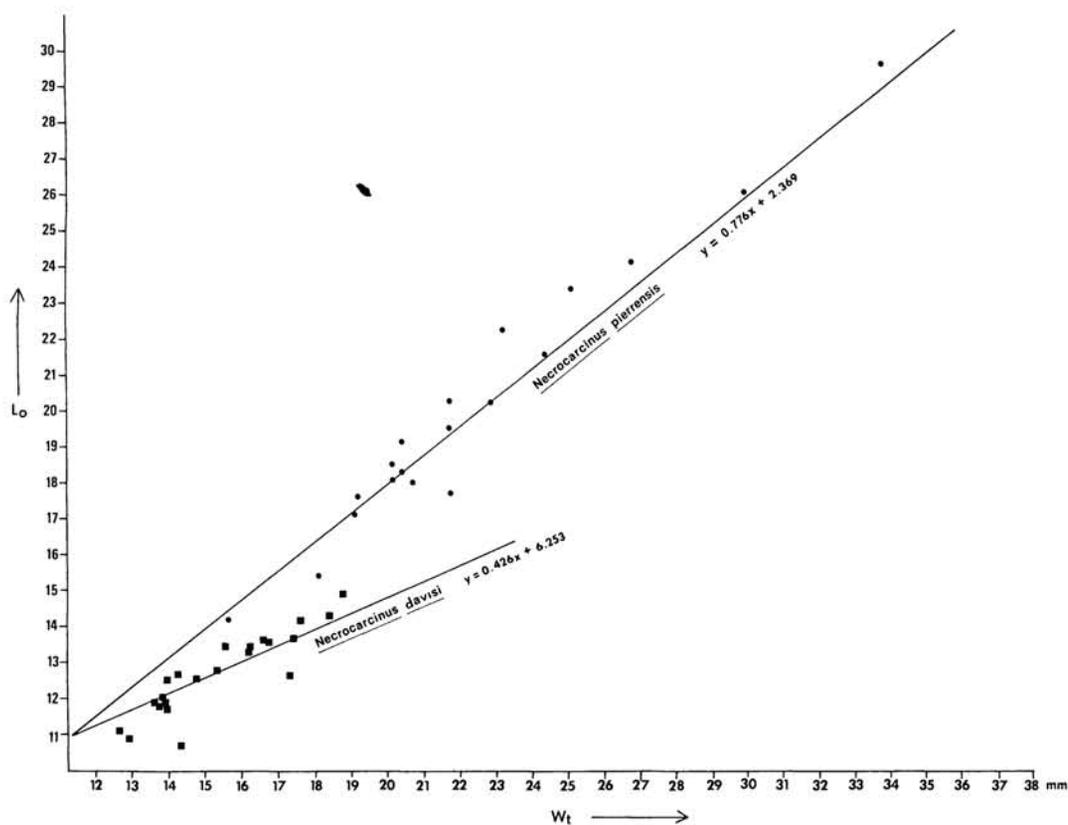


FIGURE 11—Scatter diagram of carapace length ( $L_o$ ) against carapace width ( $W_t$ ) for *Necrocarcinus davisi* (squares),  $n = 22$ ; and *Necrocarcinus pierrensis* (dots),  $n = 19$  with linear regression lines computed for each.

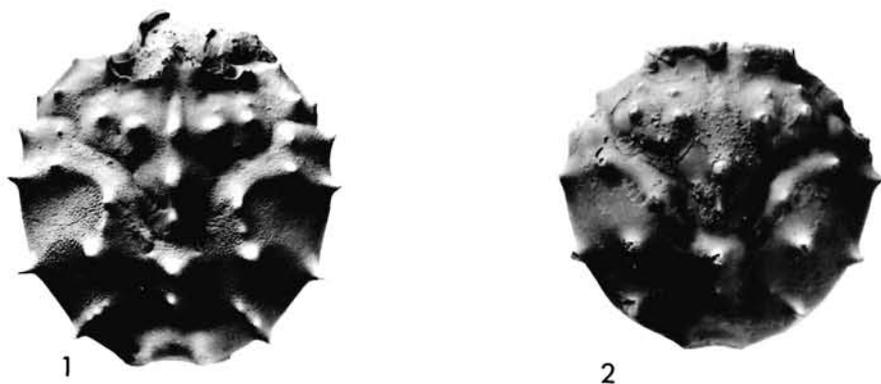


FIGURE 12—Comparative photographs of 1, *Necrocarcinus pierrensis* (GAB 4-509) and 2, *Necrocarcinus davisi* (GAB 36-61) showing the lack of an anterior mesogastric spine and a straight row of four transverse gastric spines. 1,  $\times 1.6$ ; 2,  $\times 2.7$ .

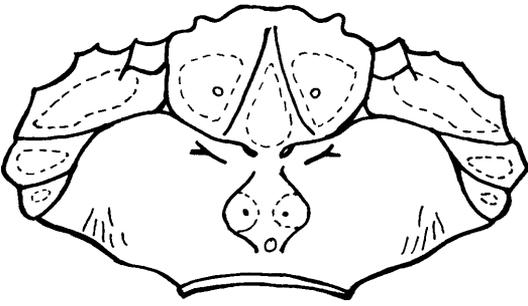


FIGURE 13—Line drawing of a reconstruction of the carapace of *Xanthosia elegans occidentalis*.

*Description.*—Carapace circular to oval, slightly wider than long (Figure 10), widest across metabranchial spines, transversely and longitudinally convex, ornamented by large spines. Cervical and branchiocardiac furrows deep; gastric, hepatic, branchial furrows poorly defined. Carapace outline broken by cervical notch, forward protruding frontal region, more or less protruding posterior margin, and five pairs marginal spines (two hepatic and three branchial). Rostrum broad and grooved medially, orbits 48% of carapace width, each with two fissures in the upper margin, the outermost deep. Anterolateral margin concave at orbit, convex to cervical notch with two marginal (hepatic) spines. Lateral margins evenly rounded to posterolateral angles with three marginal, branchial spines. Posterior margin narrow, concave, and more or less protruding.

Cephalic arch poorly differentiated into mesogastric lobe with a single large spine near its posterior; a urogastric lobe separated from mesogastric by shallow furrow terminating in a pair of gastric pits, carrying a small medial spine; large protogastric lobes occupying most of the dorsal surface each with two large spines (the four forming a straight line) and three small spines, two on each region ahead of larger spines forming a parallel line and one behind larger spines placed nearer sagittal axis. Hepatic regions small and form anterolateral margin, carrying two marginal spines.

Scapular arch well differentiated into cardiac region with two medial spines, the anterior far larger, and poorly defined intestinal region consisting of broad depression. Branchial regions differentiated into short epi-

branchial ridge-like lobes (with one marginal and one interior spine), ridge-like mesobranchial lobes with a marginal spine and two interior spines, and metabranchial lobes with three spines; one marginal (near anterior), one nearly marginal (near posterior), and one interior on line with anterior marginal, metabranchial spine. The row of sagittal spines is consistently dominated by the very large mesogastric and anterior cardiac spines (the largest on the carapace) and the very small urogastric and posterior cardiac spines (the smallest on the carapace). The pterygostomial regions are wedge-shaped and carry the pleural suture along the base of the hepatic region, anteriorly, and along the dorsal edge, posteriorly.

The carapace is ornamented by the grooves, spines, and very dense, small, round, flat-topped tubercles with many setal pits interspersed between them.

Abdomen, sternum, and appendages unknown.

*Comparison.*—*Necrocarcinus davisii* is extremely similar to *Necrocarcinus pierrensis* (Rathbun, 1917), from which it consistently differs in: 1, lacking the anterior mesogastric spine (present on every specimen of *N. pierrensis*); 2, having the posterior metabranchial spine single and in the interior instead of multiple and on the carapace margin; 3, having a more distinct postcervical groove, which is absent on *N. pierrensis*; 4, lacking the upper hepatic spine of *N. pierrensis*; 5, lacking the fourth (and most posterior) metabranchial spine of *N. pierrensis*; and 6, having the orbits a little less upturned. *Necrocarcinus davisii* and *Necrocarcinus pierrensis* differ from *N. rathbunae* Roberts, 1962, by having more circular carapaces, the transverse row of gastric spines concave forward or straight, instead of convex forward; and the row of medial spines less well developed. *Necrocarcinus davisii* is not as finely spinose or longitudinally ridged as *Necrocarcinus (Cenomanocarcinus) siouxensis* Feldmann and others, 1976 (which occurs nearby geographically and stratigraphically) and is further removed from *N. (Cenomanocarcinus) vanstraeleni* Stenzel, 1945 (from Texas and New Mexico) and stratigraphically more distant, being Turonian in age (Kues, 1980, p. 862). *Necrocarcinus (N.) davisii* cannot be confused with the Early Cretaceous necrocarcinids of Texas, nor the Eu-

ropean forms, as documented by Förster (1968, p. 181).

*Remarks.*—The morphologic similarity between *N. (N.) davisi* and *N. (N.) pierrensis* is so close that I had trouble deciding at what taxonomic level to make a distinction between these two crabs. The consistent lack of the anterior mesogastric sagittal spine, in conjunction with the numerous more minor differences (including size), finally swayed my opinion to make the nomenclatorial distinction at the species level. It seems likely that *N. davisi* is ancestral to *N. (N.) pierrensis* because of their close morphologic similarity and stratigraphic relationship.

Superfamily RANINOIDEA de Haan, 1833

Family RANINIDAE de Haan, 1833

Subfamily RANININAE

Serene and Umali, 1972

Genus RANINELLA A. Milne-Edwards, 1862

*Type species.*—*Raninella trigeri* A. Milne-Edwards by original designation (Glaessner, 1969, p. 501).

RANINELLA OAHEENSIS Bishop, 1978

Figure 3.3

*Raninella oaheensis* BISHOP, 1978, p. 612, Pl. 1, figs. 7–11, Pl. 2, figs. 1–20, text-fig. 5, table 3.

*Remarks.*—The two specimens of *Raninella* collected from the Heart Tail Ranch locality (GAB 36-100, 36-101) agree in most respects with *Raninella oaheensis* Bishop, 1978. They differ in that they lack the small, but prominent, lateral spine present on specimens from higher in the Pierre Shale. The absence of this lateral spine on these early forms of *Raninella oaheensis* is not deemed of sufficient importance to name a new species or subspecies.

Section BRACHYRHYNCHA Borradaile, 1907

Superfamily XANTHOIDEA Dana, 1852

Family XANTHIDAE Dana, 1852

Genus XANTHOSIA Bell, 1863

*Type species.*—Subsequent designation by Glaessner (1929a, p. 401); *Xanthosia gibbosa* Bell, 1863 (p. 3, Pl. 1, figs. 4–6); =*Podophthalmus buchii* Reuss, 1845.

XANTHOSIA ELEGANS Roberts, 1962

*Xanthosia elegans* ROBERTS, 1962, p. 177–179, Pl. 89, figs. 1, 3; WRIGHT and COLLINS, 1972, p. 98.

XANTHOSIA ELEGANS OCCIDENTALIS n. subsp.

Figures 3.7, 13

*Etymology.*—“Occidentalis” to represent the western form of *Xanthosia elegans*.

*Types, occurrence, sample size, and preservation.*—The holotype (SDSM 10,036) and paratype (SDSM 10,037), the only specimens, are from the Heart Tail Ranch locality and are deposited in the Museum of Geology, South Dakota School of Mines.

*Description.*—The general aspects of the carapace agree with the description provided by Roberts. Carapace much wider than long ( $L/W = 0.52 \pm$ ), oval, concave posterolateral and posterior margins. Anterolateral margin thin, crenulate, produced into a series of “teeth.” Carapace separated into regions by shallow grooves. Mesogastric, proto gastric, hepatic, and branchial lobes slightly swollen into bosses. Cardiac lobe domed and surmounted with three tubercles in form of equilateral triangle, base transverse and anterior. Orbits large, occupying about half carapace width. Anterolateral and posterolateral margins sharp and reflexed beneath. Deflexed portion of carapace occupying about half of ventral side of cephalothorax. Subhepatic and subbranchial lobes separated from wide pterygastomial regions by narrow groove (pleural suture), which parallels the anterolateral margin.

*Comparison.*—*Xanthosia elegans occidentalis* differs from *X. elegans elegans* by possessing three cardiac tubercles, lacking a metabranchial ridge, and two elongated subhepatic tubercles. As pointed out by Roberts (1962, p. 178), and confirmed by Wright and Collins (1972, p. 98–99), *Xanthosia elegans* is similar to *X. buchii* (Reuss, 1845) (= *X. gibbosa* Bell, 1863) but “is more distinctly areolated, has a completer system of furrows and has rather distinct ridges on the hepatic and epibranchial lobes.”

*Remarks.*—The two specimens (SDSM 10,036 and 10,037) are both poorly preserved partial carapaces. It might be necessary to elevate this new subspecies to species-level rank as better material becomes available.

#### ACKNOWLEDGMENTS

I thank Peggy and Chance Davis for granting permission and extending their hospital-

ity to collect on the Heart Tail Ranch during the five-year interval, and to Billy McIlvain of the Bureau of Land Management for helping me gain access to BLM land leased to the Heart Tail Ranch. The assistance of numerous collectors (Card Smith, Fred Rich, Philip Bjork, Charlie Harris, Rob Priestley, Nelda, Kim, and Eric Bishop) expedited the accumulation of this fine collection of fossil decapods. Direct support for this research was received from the National Geographic Society (NGS 1629) and National Science Foundation (DEB 8011570) and indirect support from the Faculty Research Committee and Department of Geology and Geography at Georgia Southern College. The final manuscript was typed by Ms. Susan Kerns and Mrs. Rebecca Granade Lewis. Nanny Carder drafted some of the figures. The manuscript was reviewed by J. S. H. Collins, Reinhard Förster, and Rodney Feldmann.

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