GEOLOGICAL SURVEY RESEARCH 1971

Chapter C

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Scientific notes and summaries of investigations in geology, hydrology, and related fields

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GEOLOGICAL SURVEY RESEARCH 1971

This collection of 40 short papers is the second published chapter of "Geological Survey Research 1971." The papers report on scientific and economic results of current work by members of the Geologic and Water Resources Divisions of the U.S. Geological Survey.

Chapter A, to be published later in the year, will present a summary of significant results of work done in fiscal year 1971, together with lists of investigations in progress, reports published, cooperating agencies, and Geological Survey offices.

"Geological Survey Research 1971" is the twelfth volume of the annual series Geological Survey Research. The eleven volumes already published are listed below, with their series designations.

Geological Survey Research	*Prof. Paper*
1960	400
1961	424
1962	450
1963	475
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CLARK'S TERTIARY MOLLUSCAN TYPES FROM THE YAKATAGA DISTRICT, GULF OF ALASKA

By WARREN O. ADDICOTT; SABURO KANNO[1]; KENJI SAKAMOTO, and DON J. MILLER[2], Menlo Park, Calif.; Tokyo, Japan; Menlo Park, Calif.

Abstract.—Forty-six molluscan taxa described and illustrated by Clark in 1932 from the Oligocene and Miocene part of the Poul Creek and Yakataga Formations, Gulf of Alaska Tertiary province, Alaska, are reillustrated. One species from the Poul Creek Formation, *Turritella* sp., figured by Merriam in 1941 is also reillustrated. Clark's generic assignments have been reevaluated, in most cases necessitating changes in the generic classification of his species. Some of the collections used by Clark contain mixtures of species from both the Poul Creek and Yakataga Formations, and therefore the stratigraphic occurrence of these mollusks has also been restudied.

The Gulf of Alaska Tertiary province, extending in an arcuate belt from Prince William Sound (lat 60.5° N.) southeastward to the Fairweather Range (lat 58.5° N.), includes a thick sequence of marine and nonmarine strata that has been divided into two broad units: (1) indurated, strongly deformed rocks of early Tertiary age, and (2) less deformed and indurated rocks of middle and late Tertiary age (Plafker, 1967, 1971). Marine strata of Eocene through Pliocene age are characterized by abundant molluscan fossils. Although poorly known, these assemblages have provided the framework for age determination and correlation of the marine sequence of this province (MacNeil and others, 1961; Plafker, 1971).

Descriptive paleontologic documentation of the marine Tertiary sequence is limited to a very few reports (Clark, 1932; MacNeil, 1961, 1965, 1967). Other systematic studies, principally monographs of Pacific coast molluscan genera, touch on one or two taxa from the Gulf of Alaska Tertiary province (Schenck, 1931, 1936; Merriam, 1941; Parker, 1949; Keen, 1954; Smith, 1970). However, the only systematic treatment of Tertiary molluscan faunas was by Clark (1932), who described material from the Oligocene and Miocene part of the Poul Creek and Yakataga Formations of the Yakataga district (lat 60° N.). The collections were made by Taliaferro (1932) during the course of geologic mapping of the district. A systematic study of mollusks from the Yakataga district, principally from the Miocene section at Cape Yakataga, is being prepared by Kanno. It will treat many, but not all, of the species illustrated by Clark (1932), in addition to several species not previously recorded from the Yakataga district.

Clark's report stands as the principal reference for faunal correlation of the upper Oligocene to middle Miocene marine strata of this area. It has taken on added significance during the past few years on account of heightened geological exploration of the Gulf of Alaska Tertiary province by petroleum companies. Yet this unique report has proven to be difficult and in many ways unsatisfactory to use for biostratigraphic work, because of the exceptionally poor quality of the fossil illustrations, and because of the stratigraphic misallocation of many of the collections. Many of the illustrations are so poor that the specimens cannot even be determined generically. For example, divaricate sculpture cannot be detected on the figure of "*Nucula hamiltonensis*" [*Acila taliaferroi*] Clark (1932, pl. 14, fig. 14). The problem of stratigraphic assignment of collections was what led Clark (1932) to the incorrect conclusion that the mollusks from the Poul Creek and Yakataga Formations represented a single faunal unit or zone, and that none of his species were limited in stratigraphic occurrence to the Yakataga Formation. To the contrary, subsequent biostratigraphic studies have clearly indicated that several distinctive faunal units are indeed represented in these formations (MacNeil, in Miller, 1957 sheet 2, table 1; Plafker, 1971) and that there is a very pronounced faunal change at or near the Poul Creek-Yakataga Formation boundary.

The purpose of the present report is to make available high-quality photographs of Clark's molluscan types, to place these species in a modern framework of taxonomic classification, and, finally, to indicate as accurately as possible the stratigraphic occurrence of these specimens.

The photography in this report is by Sakamoto; stratigraphic allocation of Taliaferro's (1932) collections is by Miller; and taxonomic revisions are by Kanno and Addicott.

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[2] Deceased, August 1961, formerly of U.S. Geological Survey.

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Acknowledgments. —We are indebted to Wayne L. Frye and Joseph H. Peck, Jr., Museum of Paleontology, University of California, Berkeley, for permission to borrow and to photograph the fossil material included in this report. J. Wyatt Durham also of the University of California, Berkeley, provided assistance in evaluating the species of *Liracassis*. The report has been critically read by George Plafker, Richard C. Allison, and Ellen J. Moore. We appreciate their helpful comments.

STRATIGRAPHIC ALLOCATION OF COLLECTIONS

Neither Taliaferro's (1932) nor Clark's (1932) reports included locality descriptions. The localities were shown, however, on an index map by Clark (1932, fig. 1) at a scale of about 1 inch = 3 miles. Miller's formational assignments and notes on geographic occurrence of the fossil localities are shown in table 1. According to Joseph H. Peck, Jr., Museum of Paleontology, University of California, Berkeley (oral commun., December 1970), Miller searched Taliaferro's field notes and discussed the problems with Taliaferro during the early 1950's. Miller's comments, therefore, represent as thorough an evaluation as possible of the stratigraphic position of the fossil localities. The localities are from the coastal area between Yakataga Reef, on the west, and the head of Icy Bay, on the east. The geology of this part of the Yakataga district has been mapped by Miller (1957).

Table 1.—*Stratigraphic assignment of Taliaferro's collections from the Poul Creek and Yakataga Formations, Yakataga district, Alaska*
[Clark, 1932, fig. 1]

University of California (UCMP) locality No.	Description
3850	Poul Creek Formation, about 700 feet below top (locality approximate).
3851	Float, probably Poul Creek Formation. Not plotted on map; location of "Salmon Creek" not known.
3852	Float, probably Yakataga Formation; could include uppermost Poul Creek Formation.
3853	Yakataga Formation, lower part (locality approximate).
3854	Poul Creek Formation, about 2,000 feet below top.
3855	Probably Poul Creek Formation. Not plotted on map; locality not given in catalog. May be field number Y-9, float, Little River?
3856	Float, Poul Creek Formation and (or) Yakataga Formation. Not plotted on map; locality indefinite.
3857	Poul Creek Formation, middle or lower part (locality approximate).
3858	Float, Poul Creek Formation and (or) Yakataga Formation.
3859	Yakataga Formation, about 350 feet above base.
3860	Poul Creek Formation, upper 50 feet?
3861	Float, Poul Creek Formation and (or) Yakataga Formation. Not plotted on map; locality indefinite.
3863	Probably Poul Creek. Not plotted on map; locality not given in catalog.
3864	Unknown, Poul Creek Formation and (or) Yakataga Formation. Not plotted on map; locality not given in catalog. Locality is "Lawrence Creek" on Clark's list.
3868	Poul Creek Formation at least in part. Not plotted on map; locality not given in catalog. Locality is "Lawrence Creek" on Clark's list.
3869	Yakataga Formation(?) Locality indefinite; as plotted on Clark's map it falls in outcrop of Yakataga Formation, but list of fossils is more suggestive of Poul Creek Formation.
3870	Probably lower part of Yakataga Formation (locality approximate).
3871	Float, largely Poul Creek Formation, but may include some Yakataga Formation. Not plotted on map; locality indefinite.
3872	Float, Poul Creek Formation and (or) Yakataga Formation. Not plotted on map; locality indefinite.

BIOSTRATIGRAPHIC EVALUATION OF COLLECTIONS

Biostratigraphic criteria can also be used to evaluate the stratigraphic assignment of Clark's material. There is a very pronounced faunal change at or near the Poul Creek-Yakataga boundary, contrary to Clark's (1932, p. 799) conclusion that all the species in the Yakataga Formation range downward into the Poul Creek Formation. The diverse, relatively warm water fauna of the upper part of the Poul Creek is replaced, in the lower part of the Yakataga Formation, by a cool-water fauna of much different composition and of very low species diversity. The faunal change is striking as relatively few species are common to both formations (MacNeil, in Miller, 1957). This change is attributed to the onset of local glaciation and resultant cooling of shallow-water, nearshore marine environments.

Using stratigraphic ranges shown by MacNeil (in Miller, 1957), it seems clear that at least six of Clark's collections (UCMP locs. 3857, 3858, 3864, 3868, 3869, and 3870) contain stratigraphically anomalous associations. In other words, these collections contain species with mutually exclusive stratigraphic ranges. Kanno's unpublished biostratigraphic studies support these inferences. Two of the largest collections (UCMP locs. 3850 and 3854), however, do not appear to be mixed. Both are from the upper part of the Poul Creek Formation. Almost half the molluscan taxa figured by Clark (1932) are from these two localities. One of the three collections that Clark (1932, p. 799) maintained were from the Yakataga Formation (UCMP loc. 3859) also does not appear to be mixed, according to currently known stratigraphic ranges of the seven species listed by Clark.

This form of evaluation is limited, however, by the changing concepts for recognition of the Poul Creek-Yakataga boundary. The boundary recognized by Miller (1957) and MacNeil

(in Miller, 1957; MacNeil, 1961), for example, falls within the lower part of the Yakataga Formation as it is now recognized by Kanno and other geologists working in this area (George Plafker, oral commun., October 1970). The lowering of the boundary places it at or near the lowest occurrence of cool-water molluscan assemblages in the Poul Creek-Yakataga sequence at Cape Yakataga.

TAXONOMIC REVISION OF CLARK'S NAMES

Species described and illustrated by Clark (1932) are listed systematically in table 2. One of Clark's (1932) types, *Cancellaria alaskensis* (UCMP No. 12395), has been missing from the University of California type collection since 1933 (Joseph H. Peck, Jr., oral commun., October 1970). Taxonomic revisions are indicated in the right-hand column of the table and in brackets in the captions for figures 1-6. Systematic arrangement of gastropods is after Keen (1963); of pelecypods after McCormick and Moore (1969).

FOSSIL PHOTOGRAPHS

The initial entry on the plate descriptions (figs. 1-6) is the name used by Clark (1932, pls. 14-21). The spelling is as

Table 2.—*Correlation of Clark's (1932) names with names used in this report*

[Species preceded by an asterisk (*) are considered to be restricted, in stratigraphic occurrence, to the Yakataga Formation]

Clark (1932)	This report
Gastropods	
Turcicula turbonata n. sp.	*Bathybembix turbonata* (Clark).
Natica (Cryptonatica) n. sp	*Cryptonatica* aff. *C. clausa* (Broderip and Sowerby).
Polinices (Euspira) ramonensis Clark.	*Euspira ramonensis* (Clark).
Galeodea apta Tegland (pl. 21, figs. 1, 3).	*Liracassis apta* (Tegland).
Galeodea apta Tegland (pl. 21, figs. 2, 9, 15).	*Liracassis* aff. *L. petrosa* (Conrad).
Turritella hamiltonensis n. sp.	*Turritella hamiltonensis* Clark.
Turritella n. sp.	*Turritella* n. sp. Clark.
Turritella cf. *porterensis* Weaver.	*Turritella* aff. *T. diversilineata blakeleyensis* Weaver.
Colus rearensis n. sp.	*Ancistrolepis rearensis* (Clark).
**Neptunea* aff. *tabulatus* Baird	*Neptunea* aff. *N. tabulata* (Baird).
Fusinus cf. *hannibali* Clark and Arnold.	*Priscofusus* aff. *P. hannibali* (Clark and Arnold).
Psephaea corrugata n. sp.	*Musashia (Miopleiona) corrugata* (Clark).
Cancellaria (Progabbi) alaskensis n. sp.	*Cancellaria (Crawfordina) alaskensis* Clark.
Haminoea n. sp.?	*Haminoea* n. sp.? Clark.
Scaphander alaskensis n. sp.	*Scaphander alaskensis* Clark.
Pelecypods	
Nucula (Acila) gettysburgensis Reagan.	*Acila (Acila) gettysburgensis* (Reagan).
Nucula (Acila) gettysburgensis alaskensis n. var.	*Acila (Acila) gettysburgensis* (Reagan).
Nucula (Acila) hamiltonensis n. sp.	*Acila (Truncacila) taliaferroi* Schenck.
Nucula (Acila) yakatagensis n. sp.	*Acila (Truncacila) yakatagensis* (Clark).
**Leda fossa* Baird	*Nuculana (Borissia) olferovi sachalinensis* Krishtofovich.
**Pecten (Patinopecten) yakatagensis* n. sp.	*Patinopecten (Lituyapecten) yakatagensis* (Clark).
Thyasira bisecta Conrad	*Conchocele disjuncta* Gabb.
Venericardia hamiltonensis n. sp.	*Cyclocardia hamiltonensis* (Clark).
Venericardia yakatagensis n. sp.	*Cyclocardia yakatagensis* (Clark).
Cardium (Serripes) hamiltonensis n. sp.	*Papyridea? hamiltonensis* (Clark).
Cardium (Laevicardium) alaskensis n. sp.	*Nemocardium (Keenae?) alaskense* (Clark).
Cardium (Papyridea) brooksi n. sp.	*Clinocardium brooksi* (Clark).
Cardium (Ceratoderma) yakatagensis n. sp.	*Clinocardium yakatagensis* (Clark).
Mactra (Mactrotoma) californica equilateralis n. subsp.	*Spisula californica equilateralis* (Clark).
Spisula ramonensis Packard (pl. 14, figs. 1, 4; pl. 19, fig. 3).	*Spisula ramonensis* Packard.
Spisula ramonensis Packard (pl. 14, fig. 5).	*Spisula* aff. *S. ramonensis* Packard.
Schizothaerus? trapezoides n. sp.	*Spisula trapezoides* (Clark).
**Tellina* sp.	*Macoma?* cf. *M. arctata* (Conrad).
Macoma cf. *secta* Conrad (pl. 16, fig. 3).	*Macoma* aff. *M. calcarea* (Gmelin).
Macoma cf. *M. middendorffii* Dall.	*Macoma* cf. *M. incongrua* (von Martens).
Heterodonax? sp.	*Macoma* cf. *M. incongrua* (von Martens).
Macoma cf. *secta* Conrad (pl. 16, fig. 2).	*Macoma (Rexithaerus)* sp.
Macrocallista pittsburgensis Dall.	*Macrocallista pittsburgensis* (Dall).
Macrocallista? rearensis Clark	*Macrocallista rearensis* Clark.
**Chione securis alaskensis* n. subsp.	*Securella alaskensis* (Clark).
Mya salmonensis n. sp.	*Mya (Mya) salmonensis* Clark.
**Mya truncata* Linnaeus n. subsp.?	*Mya (Mya) truncata* Linné
Schizothaerus nuttallii Conrad n. subsp.?	*Mya* sp.
**Panomya (Arctica) turgida* Dall.	*Panomya arctica* (Lamarck).
**Panomya* n. sp.?	*Panomya* cf. *P. arctica* (Lamarck).
Saxicava pholadis Linnaeus	*?Panomya* sp.
Pandora (Kennerlia) yakatagensis n. sp.	*Pandora yakatagensis* Clark.
Thracia schencki Tegland (1933)	*Thracia schencki* Clark (1932).
Cephalopods	
Aturia angustata (Conrad) *alaskensis* Schenck.	*Aturia alaskensis* Schenck.

originally used and may contain typographical errors or lapses. If the name is followed by another one in brackets, that name represents our reevaluation of generic classification and of specific identification. Not all the species have been assigned to subgenera, in part owing to the poor quality of preservation and, in the case of some pelecypods, to the fact that hinges have not been exposed on most of the specimens. The intent of this report is to provide a current generic classification of Clark's (1932) taxa and not to evaluate the validity of his specific names. Nevertheless, some of the obvious misidentifications and synonyms are indicated by revised specific identifications in table 2. It is recognized that detailed systematic study of his material may prove that some of the other species are also synonyms.

In preparing his plates Clark (1932) cropped the matrix from around many of the photographs, and on some plates the resultant outline does not accurately depict the fossil specimen. In the interest of reproducing the type material as objectively as possible, this practice has not been followed in preparing illustrations of this report.

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[Figures 1–6 follow on pages C22–C33]

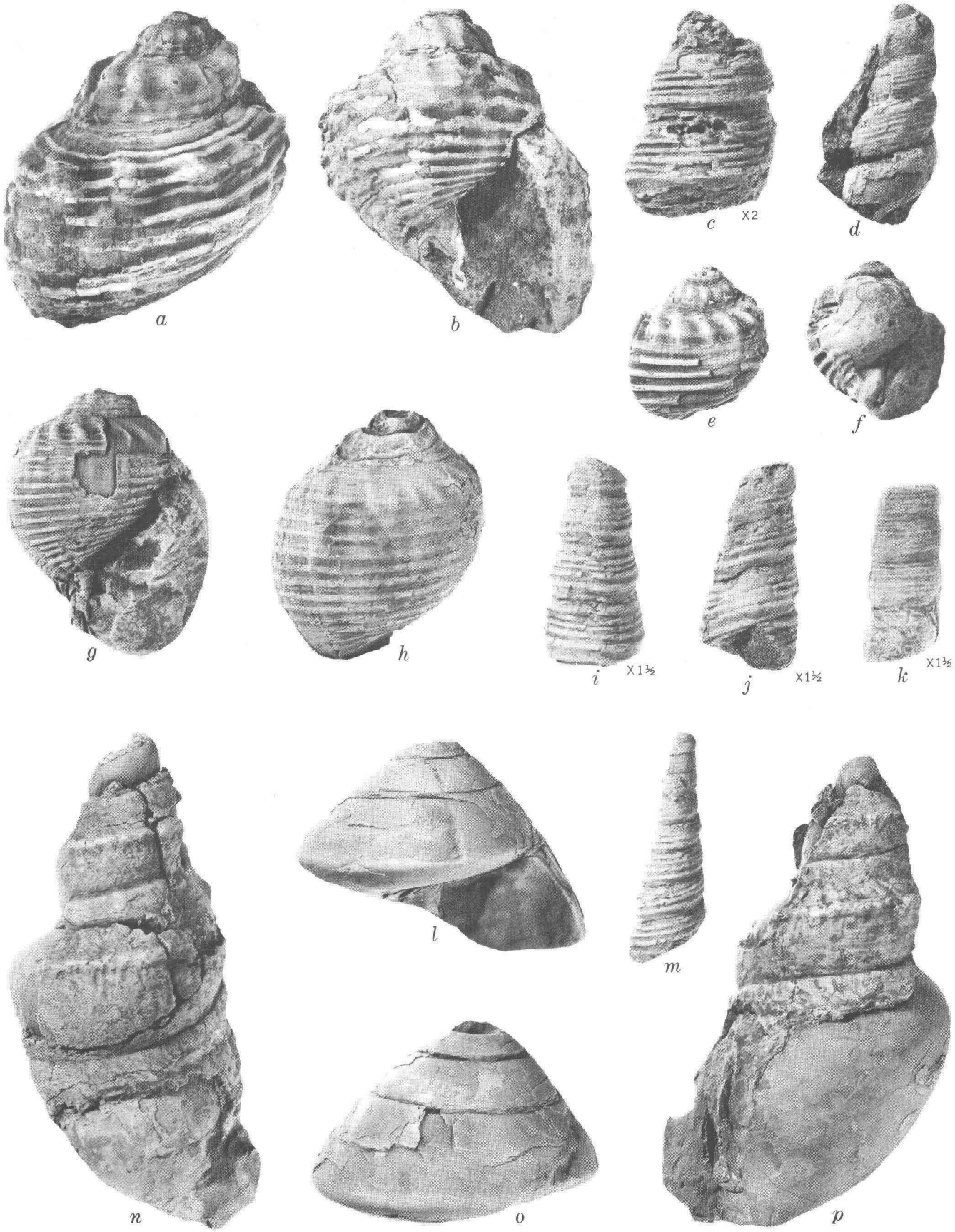

Figure 1.

Figure 1.–Molluscan fossils, from the Yakataga district, described by Clark (1932). All photographs natural size unless otherwise indicated.

a, b, e, f. Galeodea apta Tegland [*Liracassis* aff. *L. petrosa* (Conrad)].

a, b. UCMP 12404. UCMP loc. 3871. Clark (1932, pl. 21, fig. 15).

e, f. UCMP 12405. UCMP loc. 3871. Clark (1932, pl. 21, fig. 9).

c, k. Turritella cf. *porterensis* Weaver [*Turritella* aff. *T. diversilineata blakeleyensis* Weaver].

c. UCMP 31361. UCMP loc. 3868. Clark (1932, pl. 21, fig. 10).

k. UCMP 31440. UCMP loc. 3858. Clark (1932, pl. 21, fig. 16). A crushed specimen.

d. Turritella n. sp. Clark UCMP 31360. UCMP loc. 3871. Clark (1932, pl. 21, fig. 8).

g, h. Galeodea apta Tegland [*Liracassis apta* (Tegland)]. UCMP 12392. UCMP loc. 3850. Clark (1932, pl. 21, figs. 1, 3).

i, j, m. Turritella hamiltonensis Clark.

i, j. Holotype. UCMP 30281. UCMP loc. 3850. Clark (1932, pl. 21, fig. 14).

m. Paratype. UCMP 30280. UCMP loc. 3850. Clark (1932, pl. 21, fig. 13).

l, o. Turcicula turbonata Clark [*Bathybembix turbonata* (Clark)]. Holotype. UCMP 32420. UCMP loc. 3857. Clark (1932, pl. 20, fig. 11).

n, p. Neptunea aff. *tabulatus* Baird [*Neptunea* aff. *N. tabulata* (Baird)]. UCMP 12406. UCMP loc. 3870. Clark (1932, pl. 20, fig. 13).

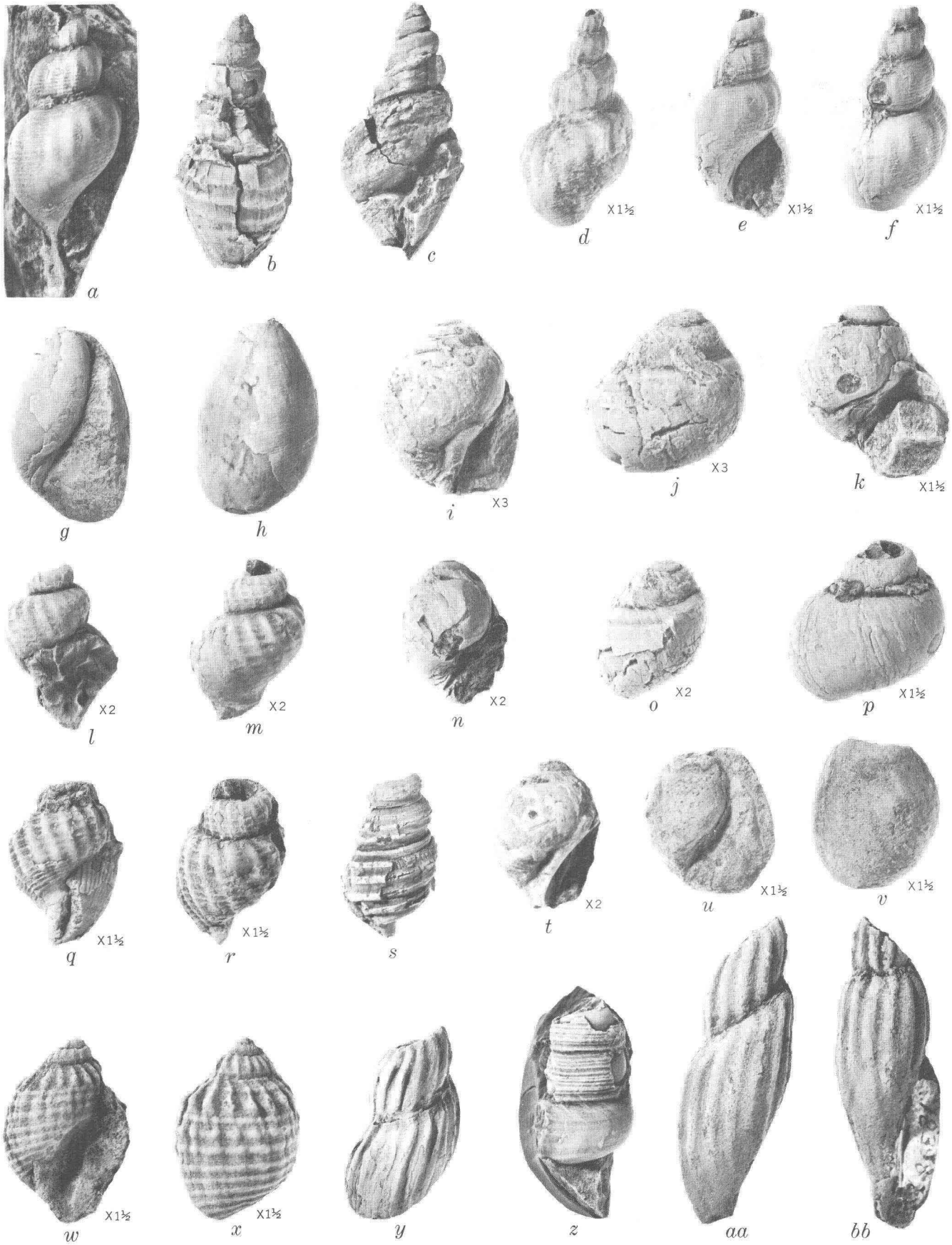
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Figure 2.

Figure 2.—Molluscan fossils, from the Yakataga district, described by Clark (1932). All photographs natural size unless otherwise indicated.

a, d-f. Fusinus cf. *hannibali* Clark and Arnold [*Priscofusus* aff. *P. hannibali* (Clark and Arnold)].

a. UCMP 31356. UCMP loc. 3850. Clark (1932, pl. 20, fig. 1).

d. UCMP 31358. UCMP loc. 3868. Clark (1932, pl. 20, fig. 2).

e, f. UCMP 31357. UCMP loc. 3868. Clark (1932, pl. 20, fig. 3).

b, c, s. Colus rearensis Clark [*Ancistrolepis rearensis* (Clark)].

b, c. Holotype. UCMP 12402. UCMP loc. 3868. Clark (1932, pl. 20, fig. 14).

s. Paratype. UCMP 12401. UCMP loc. 3868. Clark (1932, pl. 20, fig. 15).

g, h. Scaphander alaskensis Clark. Holotype. UCMP 12382. UCMP loc. 3854. Clark (1932, pl. 21, figs. 6, 7).

i, j, n, o, t Polinices (Euspira) ramonensis Clark [*Euspira ramonensis* (Clark)].

i, j. UCMP 12381. UCMP loc. 3854. Clark (1932, pl. 20, figs. 4, 5).

n, o. UCMP 12384. UCMP loc. 3854. Clark (1932, pl. 20, fig. 9). Specimen crushed, callus missing.

t. UCMP 12396. UCMP loc. 3854. Clark (1932, pl. 20, fig. 8).

k, p. Natica (Cryptonatica) n. sp. Clark [*Cryptonatica* aff. *C. clausa* (Broderip and Sowerby)]. UCMP 31359. UCMP loc. 3850. Clark (1932, pl. 20, figs. 6, 7).

l, m, q, r. Cancellaria (Progabbi) alaskensis Clark [*Cancellaria (Crawfordina) alaskensis* Clark]. The holotype of this species is lost.

l, m. Paratype. UCMP 31353. UCMP loc. 3868. Clark (1932, pl. 20, fig. 12).

q, r. Paratype. UCMP 31354. UCMP loc. 3868. Clark (1932, pl. 20, fig. 10).

u, v. Haminoea n. sp.? Clark UCMP 12397. UCMP loc. 3850. Clark (1932, pl. 21, fig. 12).

w, x. Galeodea apta Tegland [*Liracassis* aff. *L. petrosa* (Conrad)]. UCMP 12383. UCMP loc. 3860. Clark (1932, pl. 21, fig. 2).

y, aa, bb. Psephaea corrugata Clark [*Musashia (Miopleiona) corrugata* (Clark)].

y. Paratype. UCMP 12399. UCMP loc. 3871. Clark (1932, pl. 21, fig. 4).

aa, bb. Holotype. UCMP 12398. UCMP loc. 3850. Clark (1932, pl. 21, figs. 5, 11).

z. Turritella sp. Merriam. UCMP 15445. UCMP loc. 3854. Merriam (1941, pl. 40, fig. 6).

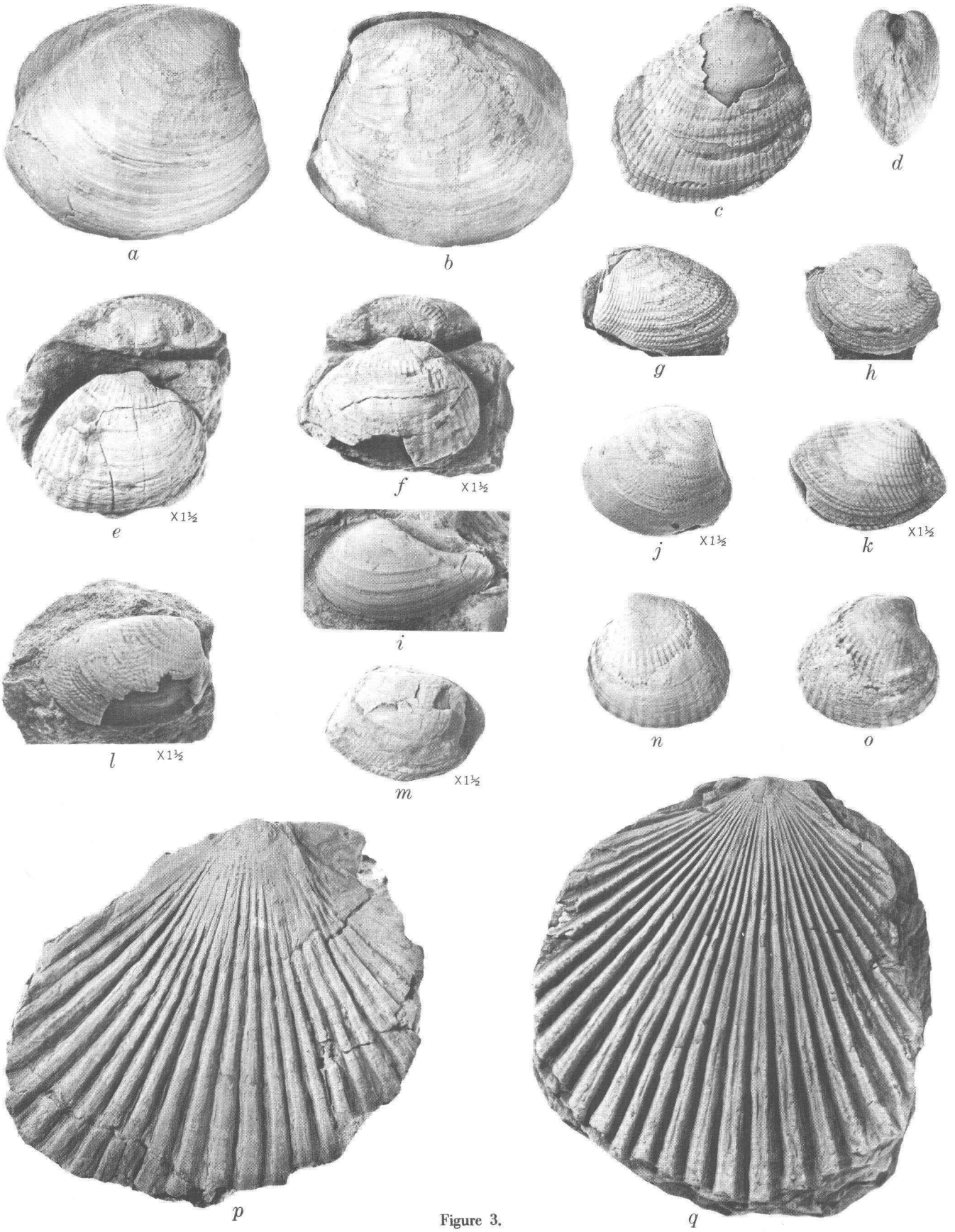

Figure 3.

Figure 3.—Molluscan fossils, from the Yakataga district, described by Clark (1932). All photographs natural size unless otherwise indicated.

a, b. Thyasira bisecta Conrad [*Conchocele disjuncta* Gabb]. UCMP 30385. UCMP loc. 3860. Clark (1932, pl. 14, fig. 2).

c. Cardium (Serripes) hamiltonensis Clark [*Papyridea? hamiltonensis* (Clark)]. Holotype. UCMP 30405. UCMP loc. 3855. Clark (1932, pl. 18, fig. 7).

d, n, o. Venericardia yakatagensis Clark [*Cyclocardia yakatagensis* (Clark)]. Holotype. UCMP 12409. UCMP loc. 3854. Clark (1932, pl. 14, figs. 6, 7).

e, f. Venericardia hamiltonensis Clark [*Cyclocardia hamiltonensis* (Clark)]. Holotype. UCMP 12408. UCMP loc. 3858. Clark (1932, pl. 14, figs. 9, 10.)

g. Nucula (Acila) gettysburgensis var. *alaskensis* Clark [*Acila (Acila) gettysburgensis* (Reagan)]. Holotype. UCMP 30388. UCMP loc. 3871. Clark (1932, pl. 14, fig. 15).

h, j. Nucula (Acila) hamiltonensis Clark [*Acila (Truncacila) taliaferroi* Schenck].

h. Paratype. UCMP 30375. UCMP loc. 3854. Clark (1932, pl. 14, fig. 11).

j. Holotype. UCMP 30376. UCMP loc. 3850. Clark (1932, pl. 14, fig. 14).

i. Leda fossa Baird [*Nuculana (Borissia) olferovi sachalinensis* Krishtofovich]. UCMP 12403. UCMP loc. 3858. Clark (1932, pl. 14, fig. 3).

k, m. Nucula (Acila) gettysburgensis Reagan [*Acila (Acila) gettysburgensis* (Reagan)]. UCMP 30400. UCMP loc. 3871. Clark (1932, pl. 14, fig. 12).

l. Nucula (Acila) yakatagensis Clark [*Acila (Truncacila) yakatagensis* (Clark)]. Holotype. UCMP 30393. UCMP loc. 3871. Clark (1932, pl. 14, fig. 13).

p, q. Pecten (Patinopecten) yakatagensis Clark [*Patinopecten (Lituyapecten) yakatagensis* (Clark)].

p. Paratype. UCMP 30382. UCMP loc. 3859. Clark (1932, pl. 15, fig. 8).

q. Holotype. UCMP 30381. UCMP loc. 3859. Clark (1932, pl. 16, fig. 1).

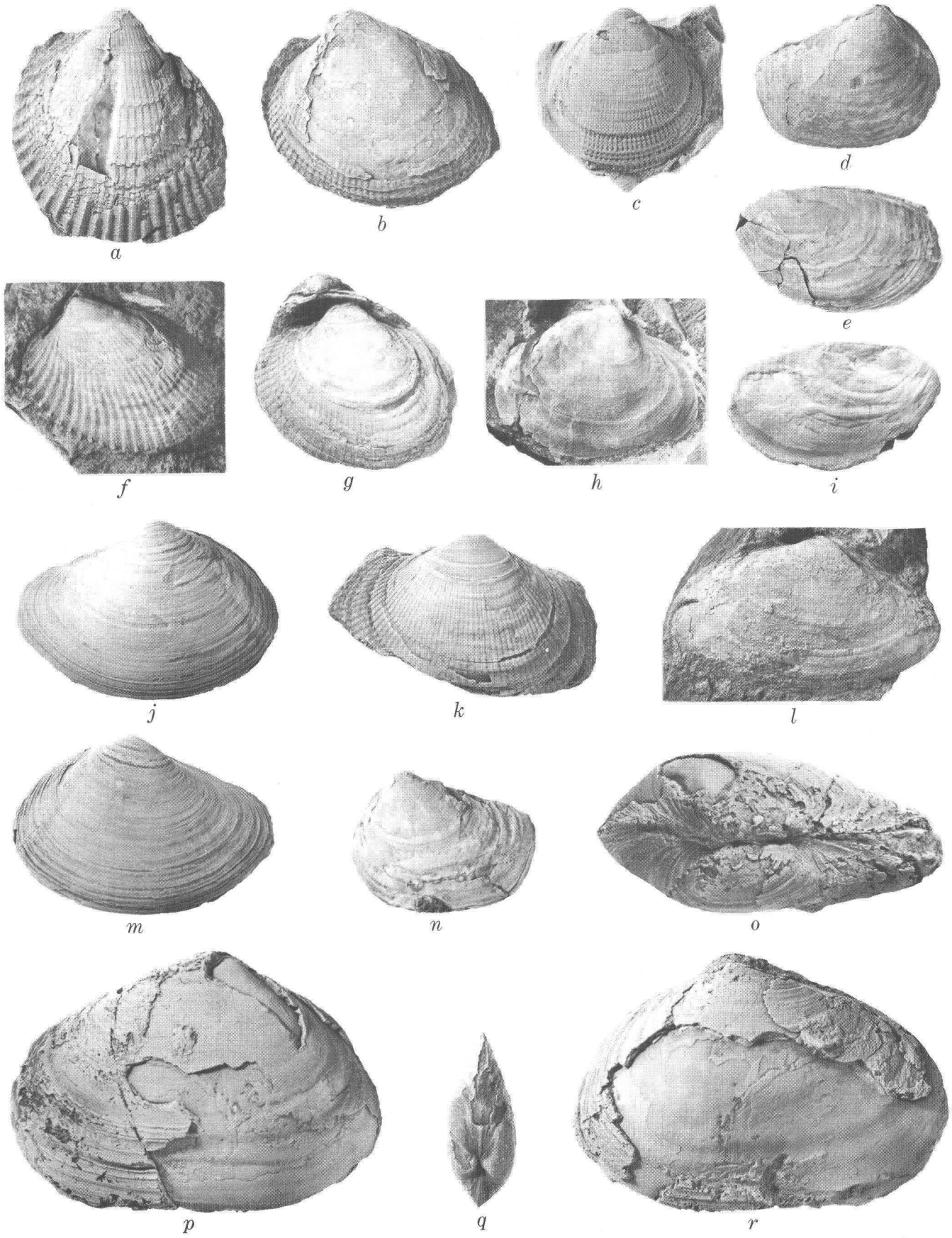

Figure 4.

Figure 4.—Molluscan fossils, from the Yakataga district, described by Clark (1932). All photographs natural size.

a. Cardium (Ceratoderma) yakatagensis Clark [*Clinocardium yakatagensis* (Clark)]. Holotype. UCMP 30384. UCMP loc. 3860. Clark (1932, pl. 18, fig. 8).

b, g, k. Cardium (Serripes) hamiltonensis Clark [*Papyridea? hamiltonensis* (Clark)].

b. Paratype. UCMP 30391. UCMP loc. 3850. Clark (1932, pl. 18, fig. 6).

g. Holotype. UCMP 30405. UCMP loc. 3855. Clark (1932, pl. 18, fig. 7).

k. Paratype. UCMP 30392. UCMP loc. 3850. Clark (1932, pl. 18, fig. 10).

c. Cardium (Laevicardium) alaskensis Clark [*Nemocardium (Keenae?) alaskense* (Clark)]. Holotype. UCMP 30389. UCMP loc. 3868. Clark (1932, pl. 18, fig. 4).

d, n, q. Schizothaerus? trapezoides Clark *[Spisula trapezoides* (Clark)]. Holotype. UCMP 30374. UCMP loc. 3850. Clark (1932, pl. 15, fig. 9). Specimen crushed along posterior dorsal margin.

e, i. Pandora (Kennerlia) yakatagensis Clark [*Pandora yakatagensis* Clark]. Holotype. UCMP 30399. UCMP loc. 3869. Clark (1932, pl. 17, figs. 1, 2).

f. Cardium (Papyridea) brooksi Clark [*Clinocardium brooksi* (Clark)]. Holotype. UCMP 30402. UCMP loc. 3850. Clark (1932, pl. 18, fig. 5).

h. Spisula ramonensis Packard. UCMP 32302. UCMP loc. 3850. Clark (1932, pl. 19, fig. 3).

j, m. Spisula ramonensis Packard [*Spisula* aff. *S. ramonensis* Packard]. UCMP 30394. UCMP loc. 3861. Clark (1932, pl. 14, fig. 5).

l.Mactra (Mactrotoma) californica equilateralis Clark [*Spisula californica equilateralis* (Clark)]. Holotype, UCMP 30390. UCMP loc. 3870. Clark (1932, pl. 14, fig. 8).

o, p, r. Schizothaerus nuttallii Conrad n. subsp.? Clark [*Mya* sp.]. UCMP 30380. UCMP loc. 3870. Clark (1932, pl. 15, figs. 1, 4).

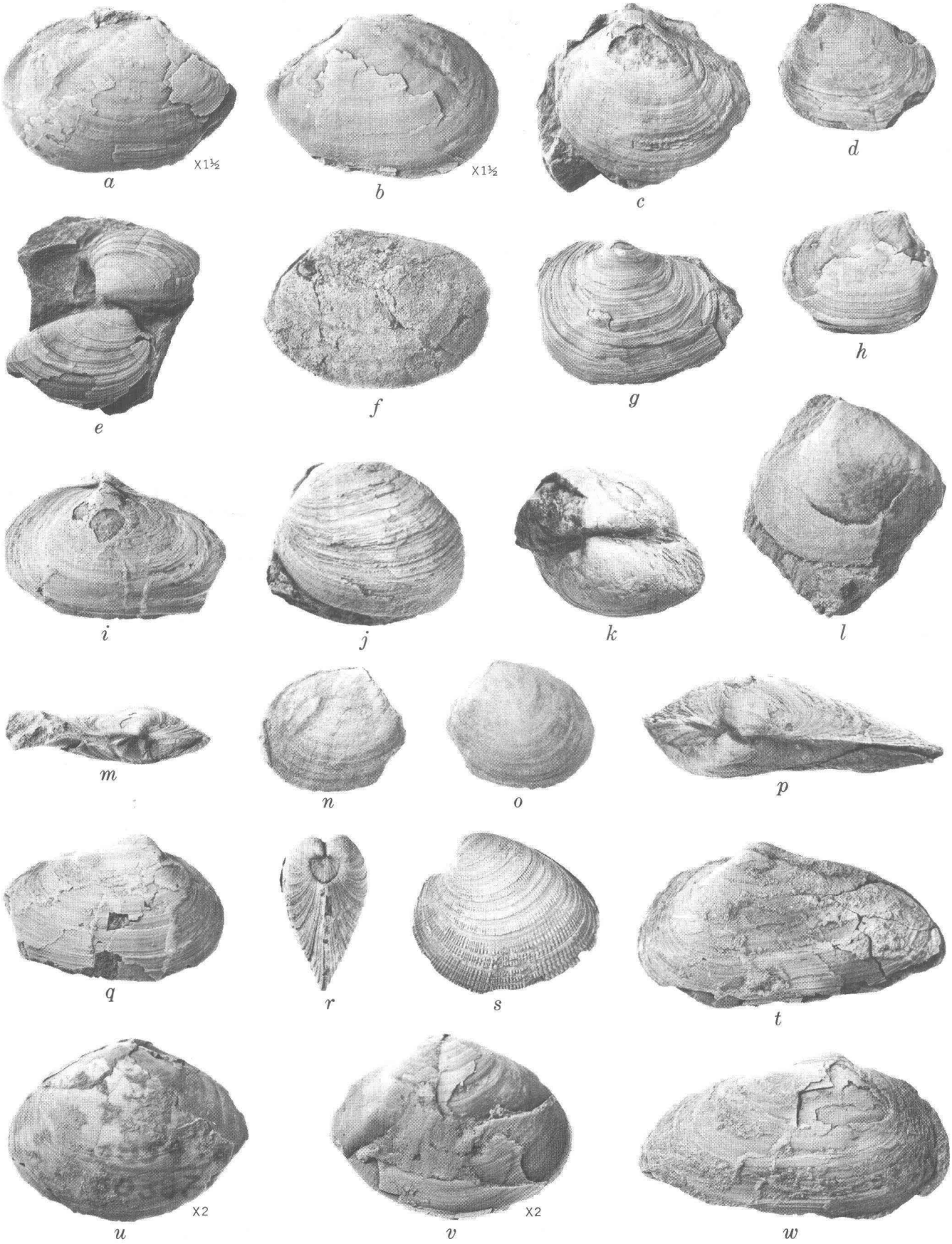

Figure 5.

Figure 5.—Molluscan fossils, from the Yakataga district, described by Clark (1932). All photographs natural size unless indicated otherwise.

a, b. Macoma cf. *secta* Conrad [*Macoma* aff. *M. calcarea* (Gmelin)]. UCMP 30386. UCMP loc. 3854. Clark (1932, pl. 16, fig. 3).

c, l. Spisula ramonensis Packard.

c. UCMP 30404. UCMP loc. 3850. Clark (1932, pl. 14, fig. 1).

l. UCMP 32301. UCMP loc. 3850. Clark (1932, pl. 14, fig. 4).

d, h. Heterodonax? sp. Clark [*Macoma* cf. *M. incongrua* (von Martens)]. UCMP 30383. UCMP loc. 3850. Clark (1932, pl. 15, figs. 6, 7).

e. Macrocallista pittsburgensis Dall [*Macrocallista pittsburgensis* (Dall)]. UCMP 31345. UCMP loc. 3854. Clark (1932, pl. 19, figs. 1, 2).

f. Tellina sp. Clark [*Macoma?* cf. *M. arctata* (Conrad)]. UCMP 31351. UCMP loc. 3859. Clark (1932, pl. 15, fig. 10).

g, m. Mya (Mya) truncata Linnaeus n. subsp.? Clark [*Mya (Mya)* truncata, Linné]. UCMP 30379. UCMP loc. 3868. Clark (1932, pl. 17, fig. 5).

i, p, q, t, w. Mya salmonensis Clark [*Mya (Mya) salmonensis* Clark].

i, q. Paratype. UCMP 30396. UCMP loc. 3851. Clark (1932, pl. 17, fig. 4).

p, t, w. Holotype. UCMP 30397. UCMP loc. 3851. Clark (1932, pl. 17, fig. 3).

j, k. Macrocallista? rearensis Clark. Holotype. UCMP 30378. UCMP loc. 3854. Clark (1932, pl. 18, fig. 1).

n, o. Macoma cf. *M. middendorffii* Dall [*Macoma* cf. *M. incongrua* (von Martens)]. UCMP 12407. UCMP loc. 3850. Clark (1932, pl. 16, fig. 4).

r, s. Chione securis alaskensis Clark [*Securella alaskensis* (Clark)]. Holotype. UCMP 30406. UCMP loc. 3868. Clark (1932, pl. 18, figs. 2, 3).

u, v. Macoma cf. *secta* Conrad [*Macoma (Rexithaerus)* sp.]. UCMP 30387. UCMP loc. 3854. Clark (1932, pl. 16, fig. 2).

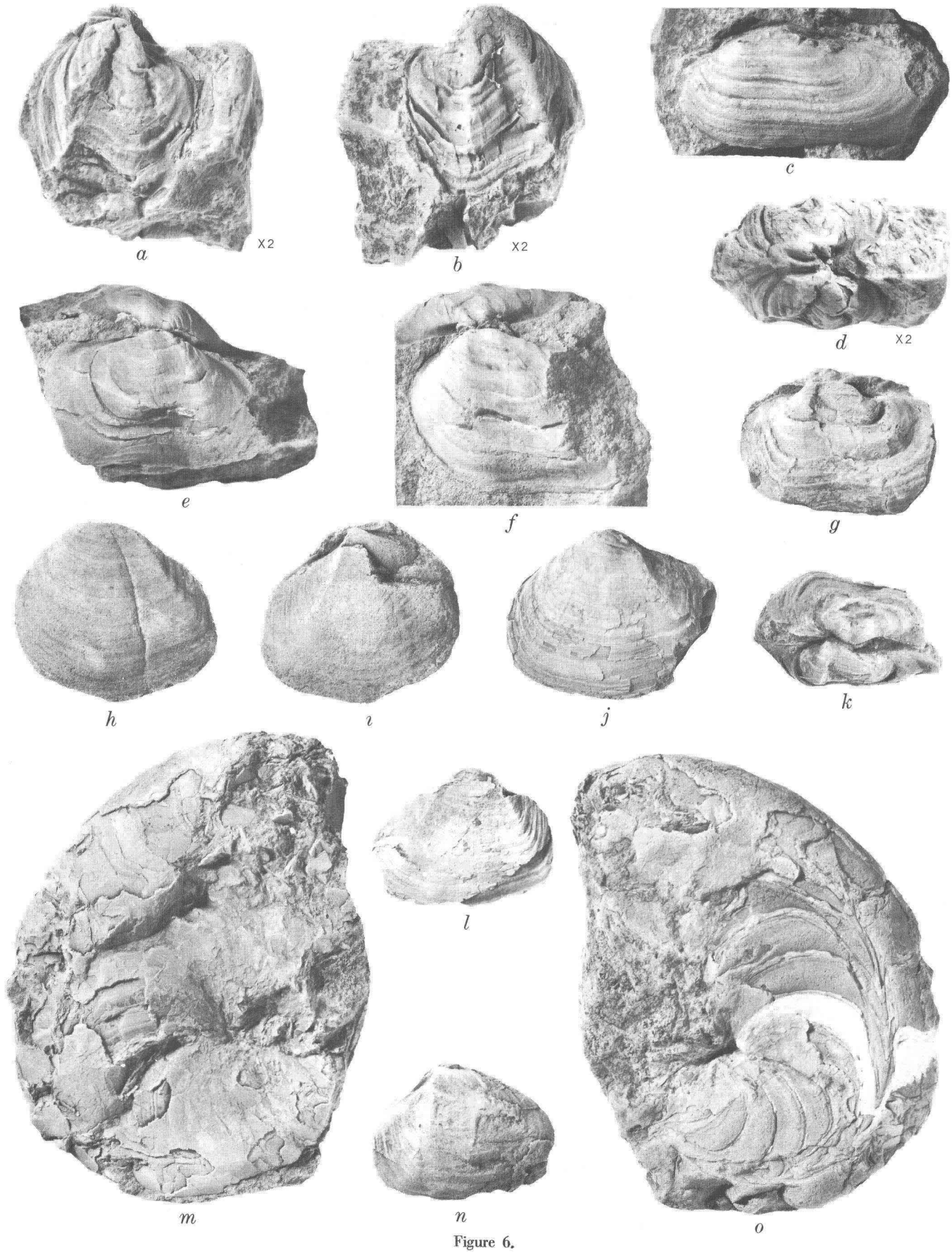

Figure 6.

Figure 6.—Molluscan fossils, from the Yakataga district, described by Clark (1932). All photographs natural size unless indicated otherwise.

a, b, d. Panomya n. sp.? Clark [*Panomya* cf. *P. arctica* (Lamarck)]. UCMP 30401. UCMP loc. 3858. Clark (1932, pl. 17, fig. 7).

c. Saxicava pholadis Linnaeus [?*Panomya* sp.]. UCMP 30395. UCMP loc. 3850. Clark (1932, pl. 18, fig. 9).

e, f, g, k. Panomya (Arctica) turgida Dall [*Panomya arctica* (Lamarck)].

e, f. UCMP 31347. UCMP loc. 3858. Clark (1932, pl. 17, fig. 9).

g, k. UCMP 30398. UCMP loc. 3864. Clark (1932, pl. 17, fig. 6).

h-j, l, n. Thracia schencki Tegland (1933) [*Thracia schencki* Clark].

h, i. UCMP 31342. UCMP loc. 3850. Clark (1932, pl. 15, fig. 3).

j. UCMP 31341. UCMP loc. 3854. Clark (1932, pl. 15, fig. 2).

l, n. UCMP 30377. UCMP loc. 3850. Clark (1932, pl. 15, fig. 5).

m, o. Aturia angustata (Conrad) *alaskensis* Schenck [*Aturia alaskensis* Schenck]. Holotype. UCMP 31362. UCMP loc. 3871. Clark (1932, pl. 16, figs. 5, 6).

THE ORDOVICIAN-SILURIAN BOUNDARY IN THE YORK MOUNTAINS, WESTERN SEWARD PENINSULA, ALASKA

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Abstract.—Rocks of unquestionable Silurian age are rare on the Seward Peninsula. A biostratigraphic boundary between the Ordovician and the Silurian is recognized in a sequence of shelly fossil faunas near the top of a thick sequence of medium- to dark-gray dolomitic limestones. The rocks of Silurian age are light-brown fossiliferous limestones. Although the change from Ordovician to Silurian appears to be lithologically transitional, fossils suggest that rocks that contain a Middle Silurian fauna lie directly on rocks that contain a Late Ordovician fauna. The lithologic change to light-brown limestone is used to define a map unit of rocks of Silurian age; the gray limestones beneath this map unit are of Late Ordovician age except for a thin interval, not mappable lithologically, which also is of Silurian age.

Geologic mapping during 1966 in the York Mountains (fig. 1) resulted in recognition for the first time on the Seward Peninsula of a mappable boundary within a monotonous sequence of gray limestone which by fossils can be assigned to the Late Ordovician and to the Silurian (Sainsbury, 1969a). Many collections of fossils from this general area, which is structurally complex, were made in 1965 and 1966, and these indicated that most of the rocks range from Middle to Late Ordovician in age, but that upper light-brown limestone is of Silurian age (fig. 1). Fossils from the well-exposed transition were collected by Dutro and Churkin in July 1968 from 12 stratigraphic levels. This paper lists all the fauna collected prior to 1968, and it presents the stratigraphy and the sequence of fossils collected across the boundary. A geologic map of the area was published (Sainsbury, 1969a), but further large-scale mapping is recessed. Rocks of Silurian age have not been identified elsewhere. (See small-scale geologic map of the Teller 1:250,000 quadrangle, Sainsbury, 1970.) In view of current interest in the petroleum potential of northern Alaska, the intense structural complexity of the Seward Peninsula (Smith, 1910; Sainsbury, 1969a, b), and the paucity of Silurian rocks, the biostratigraphy at the locality herein described likely will be of some interest to petroleum geologists.

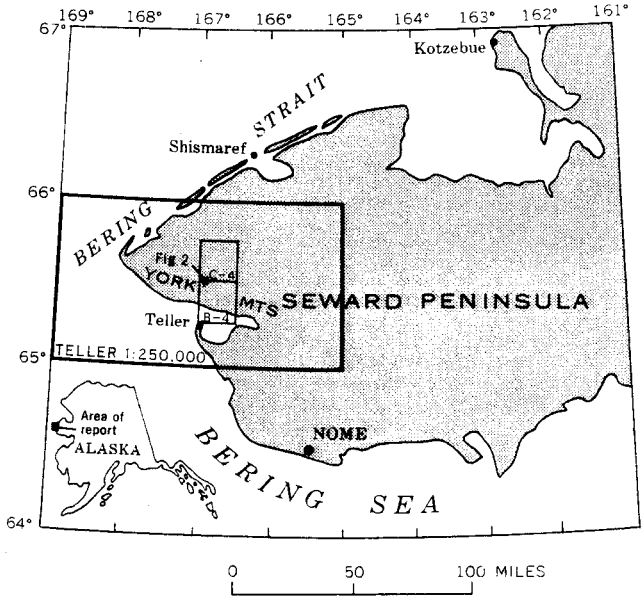

Figure 1.—Index map of the Seward Peninsula, showing areas of the Teller 1:250,000 quadrangle and the Teller B-4 and Teller C-4 quadrangles.

LOCATION

The rocks discussed herein crop out near the boundary of the Teller B-4 and C-4 quadrangles (fig. 2), at the east end of the main mass of the York Mountains. The contact between Ordovician and Silurian rocks is well exposed on a small hill 760 feet high between the Don River and its first large tributary which enters from the west at a point 9.3 miles by air from the mouth of the Don River. The mapped lithologic contact and the sites of critical fossil collections made by Sainsbury across the contact were marked in the field by rock cairns.

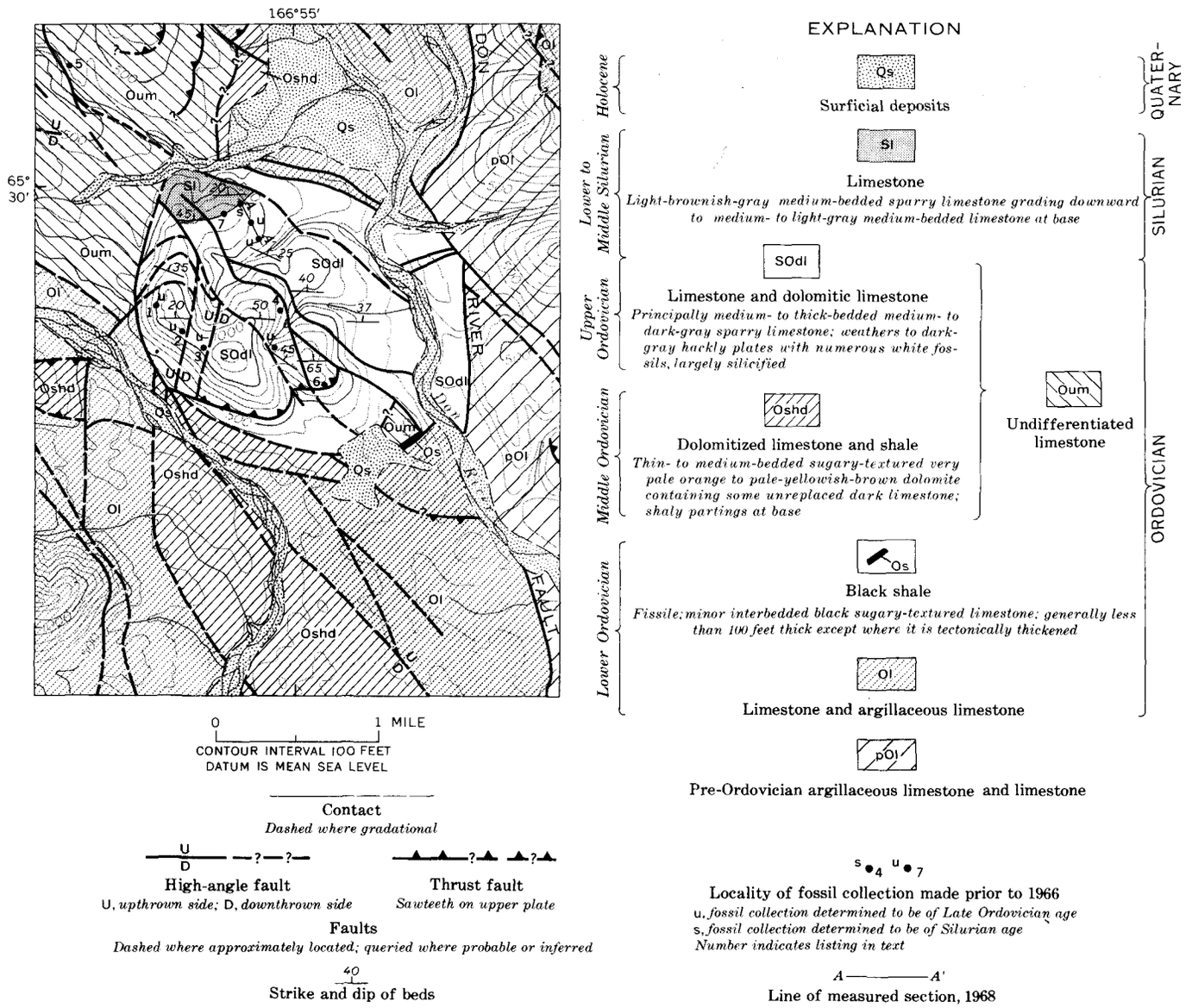

Figure 2.—Geologic map of the Don River area, showing fossil localities. Modified from Sainsbury (1969a). Base from U.S. Geological Survey Teller B-4 and Teller C-4 quadrangles, 1950; contour interval 100 feet.

GENERAL GEOLOGY

The general geology, stratigraphy, and structure of the York Mountains (just west of the area of fig. 2) were discussed in detail by Sainsbury (1969b). The geologic structure is dominated by thrust tectonics, inasmuch as rocks of the entire Seward Peninsula lie within the Collier thrust belt (Sainsbury, 1969c) and rocks of Precambrian and Paleozoic age are intimately intermixed in imbricate thrust sheets.

The geology of the immediate area of interest is shown in figure 2. Fossils of Late Ordovician age collected from this general area by earlier workers were summarized by Steidtmann and Cathcart (1922). As the locations of these old collections are not accurately known, only those collections made by the writers are discussed herein.

The Upper Ordovician and Silurian rocks crop out continuously over an area of about 4 square miles; they are bounded on all sides by faults, and are faulted within themselves. The Upper Ordovician rocks are mostly medium- to thick-bedded dark-gray limestone, finely crystalline, and with great numbers of fossils, many of which are silicified and weather into relief. The dark color and silicified fossils are diagnostic, and have allowed immediate recognition of equivalent rocks exposed in small windows in thrust sheets at other localities in the Teller 1:250,000 quadrangle. Dark chert occurs sporadically in the carbonates, commonly as nodules and small lentils a few inches in length, but discrete chert beds are lacking. Above thrust faults, and along normal faults cutting thrust plates, the dark limestones are extensively dolomitized; this dolomite is light tan to reddish tan. At the outer margins of the

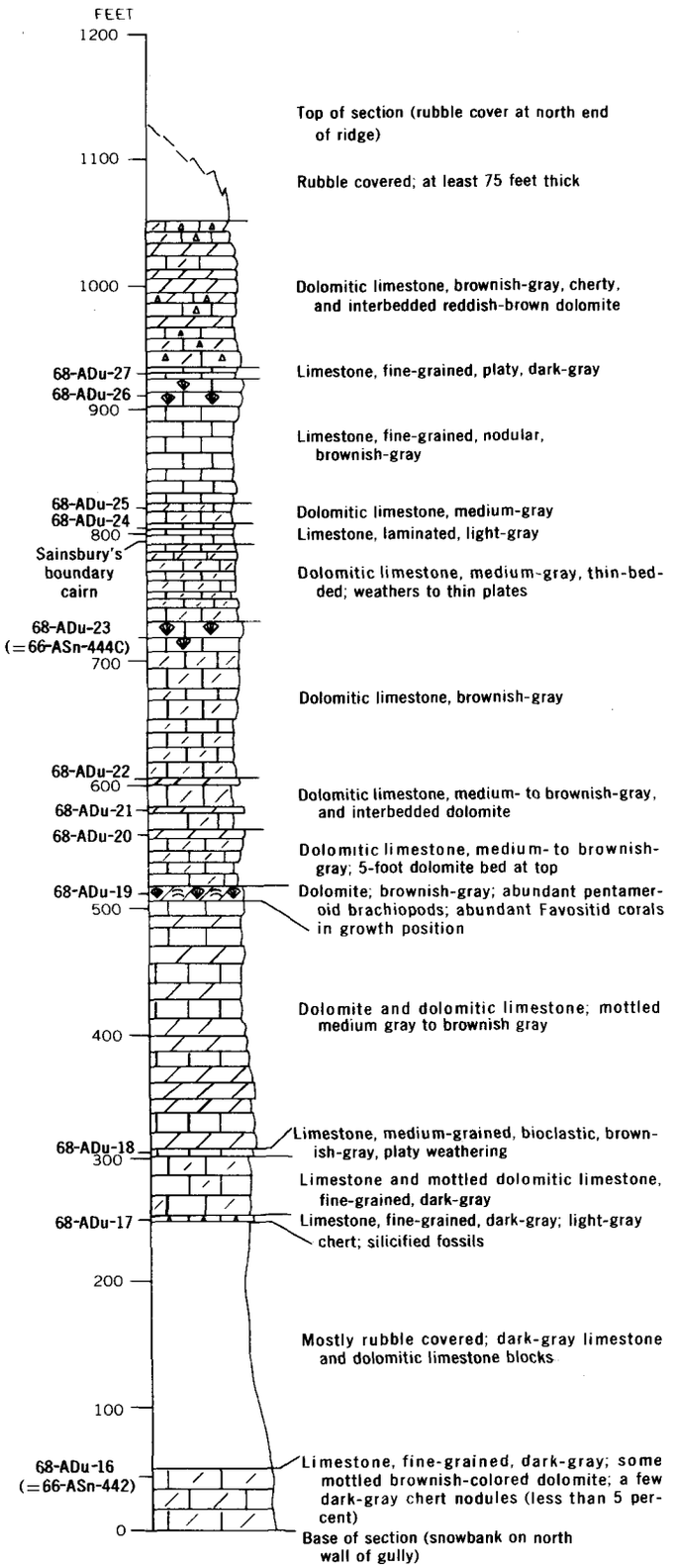

Figure 3.—Measured section of Ordovician and Silurian rocks. Hill 760, about 1 mile west of Don River; 65° 29′50″N., 166°56′W.; Teller B-4 quadrangle, Seward Peninsula, Alaska. 68–ADu–27, fossil collection number. Line of section shown on figure 2.

dolomitization, irregular mottling is characteristic; near faults, the limestone is completely replaced. Most of the dolomite exposed in the rocks discussed herein is considered by Sainsbury to be of tectonic origin, similar to that described by Spörli (1968) in the Helvetic nappes of central Switzerland.

Near the base of the Silurian rocks, the limestone changes abruptly upward from dark gray to light brownish gray, but dark-gray limestone reappears interbedded with light-brown limestone below the main lithologic change to light-brownish-gray limestone. The mappable lithologic change to light-brown limestone lies within the Silurian, and there is no evidence of an unconformity. In fact, the repetition of dark-gray and light-brown limestones suggests a transition indicative of rather continuous deposition, but fossils indicate a time hiatus.

A section was measured and systematically collected along a line trending southeast from the top of the hill at 760 feet down to an altitude of 500 feet (section A–A′, fig. 2). The measured section of beds is shown in figure 3.

FOSSILS AND AGE

The initial collection that yielded Silurian fossils was made in 1965 about 25 feet stratigraphically above the base of the light-brown Silurian limestone, where a stromatoporoidal zone is well developed (locality 4 on fig. 2). Over a thickness of some 4 feet, dark-brown stromatoporoids constitute some 35–50 percent of the rock, making a good stratigraphic marker. Other fossils are so numerous that the rock is virtually a biohermal limestone. Specimens of the types most numerous in the stromatoporoidal limestone were collected, and these are reported in the following list (W. A. Oliver, Jr., written commun., 1966-67) along with fauna of other collections made nearby. Corals were identified by W. A. Oliver, Jr., gastropods by E. L. Yochelson, pelecypods by John Pojeta, Jr., and trilobites by R. J. Ross, Jr.

Locality 4 (fig. 2) 65–ASn–79 (USGS 7593–SD)
Laminar stromatoporoid.
Massive stromatoporoid.
Alveolites sp.
Favosites sp.
Hexisma? sp.
Multisolenia sp. cf. *M. tortuosa* Fritz.
Parastriatopora sp.
Rugose corals (including *Cystiphyllum* sp.).
Age: Middle Silurian (W. A. Oliver, Jr.).

Locality 3 (fig. 2) 66–ASn–444C (USGS 7731–SD)
Halysites? sp.
Multisolenia sp.
Syringopora sp.
Cystiphyllum? sp.
Cyathophylloid coral, indeterminate.
Age: Certainly Silurian (W. A. Oliver, Jr.).

Locality 1 (fig. 2) 65–ASn–PG 4 (USGS 5513–CO)
Labechiid stromatoporoid.
Catenipora sp. cf. *C. robusta* (Wilson).
C. sp. a (cf. *C. jacovickii* of Duncan).

C. sp. b.
Favistina sp.
Cf. *Nyctopora* sp. a.
Age: Late Ordovician (W. A. Oliver, Jr.).

Locality 2 (fig. 2) 65–ASn–78 A (USGS 5446–CO)
Loxoplocus (Donaldiella) sp.
Straparollina sp.
Helicotoma "* * * it is a peculiar one. If not *Helicotoma* it is probably a new genus."
Age: "This fauna gives a superficial resemblance to later Middle Ordovician * * *." (E. L. Yochelson).

Locality 3 (fig. 2) 65–ASn–78 (USGS 5516–CO)
Massive stromatoporoid.
Calapoecia sp.
Catenipora sp. cf. *C. robusta* (Wilson).
C. sp. a?
Propora sp.
Horn coral, indeterminate.
Age: Late Ordovician (W. A. Oliver, Jr.).

Locality 4 (fig. 2) 65–ASn–64 (USGS 5515–CO)
Labechiid stromatoporoid.
Auloporoid? coral.
Catenipora sp. cf. *C. robusta* (Wilson).
C. sp. a (cf. *C. jacovickii* of Duncan).
Cf. *Nyctopora* sp. a.
Age: Late Ordovician (W. A. Oliver, Jr.).

Locality 5 (fig. 2) 65–ASn–85 (USGS 5517–CO)
Receptaculitid.
Labyrinthites? sp.
Reuschia sp.
Age: Late Ordovician (W. A. Oliver, Jr.).

Locality 6 (fig. 2) 65–ASn–278 (USGS 5518–CO)
Cystostroma sp.
Labechia sp.
Reuschia sp.
Age: Late Ordovician (W. A. Oliver, Jr.).

Locality 7 (fig. 2) 65–ASn–79 (USGS 7593–SD)
Laminar stromatoporoid.
Massive stromatoporoid.
Alveolites sp.
Favosites sp.
Hexisma? sp.
Multisolenia sp. cf. *M. tortuosa* Fritz.
Parastriatopora sp.
Rugose corals (not determined but includes *Cystiphyllum* sp.).
Age: Middle Silurian (W. A. Oliver, Jr.).

Fossil collections from the Don River area along the measured section (fig. 3) made by Dutro and Churkin in 1968 were studied as follows: corals and stromatoporoids by W. A. Oliver, Jr.; pelecypods by John Pojeta, Jr.; gastropods by E. L. Yochelson; ostracodes by J. M. Berdan; trilobites by R. J. Ross, Jr.; conodonts by John Huddle; and brachiopods by A. J. Boucot and J. T. Dutro, Jr. Collections are listed beginning with those at the top of the measured section.

68–ADu–27 (USGS 8345-SD)
Auloporoid corals, indeterminate.
Bryozoan?, indeterminate.
Atrypa sp.
Rhynchonelloid brachiopods, undetermined.

68–ADu–26 (USGS 8344–SD)
Horn corals, indeterminate
Favosites spp.

68–ADu–25 (USGS 8343–SD) = 65–ASn–79 (USGS 7593–SD)
Massive stromatoporoid, indeterminate.
Favosites sp.
Heliolites sp.
Alveolites sp.

68–ADu–24 (USGS 8342–SD)
Small horn corals, perhaps *Tabularia* sp. (identification by J. T. Dutro, Jr.).

68–ADu–23 (USGS 8341–SD) = 66–ASn–444C (USGS 7731–SD)
Massive stromatoporoid, undetermined.
Cystiphyllid coral, indeterminate.
Alveolites? sp.
Favosites spp.

68–ADu–22 (USGS 8340–SD)
Thamnopora? sp.
Halysites? sp.
Favosites sp.

68–ADu-21 (USGS 8339–SD)
Rugose horn coral indeterminate.
Halysites? sp.
Favosites sp.

68–ADu–20 (USGS 8338–SD)
Halysites? sp.
Favosites sp.
Pentamerus? sp.

68–ADu–19 (USGS 8337–SD)
Favosites spp.
Pentamerus sp.
Conchidium? sp.

68–ADu–18 (USGS D2036–CO)
Ostracodes (J. M. Berdan).
Aparchitella? sp.
Schmidtella sp., large.
Krausella sp., large.
Leperditellid, indeterminate.
Eurychilinid, indeterminate.
Smooth ostracodes, indeterminate.
Trilobites (R. J. Ross, Jr.).
Remipyga sp.
Monorakos n. sp.
Conodonts (John Huddle).
Panderodus sp.
Drepanodus suberectus (Branson and Mehl).
Brachiopods, indeterminate fragments.

68–ADu–17 (USGS 6747–CO).
Catenipora cf. *C. gracilis*
Horn corals, indeterminate.
Brachiopods, indeterminate.
Maclurites cf. *M. manitobensis* (Whiteaves).
Macluritacean operculum fragment.

68–ADu–16 (USGS 6746–CO) = 66–ASn–442 (USGS 6026–CO)
Catenipora spp. (two species).
Bighornia sp.
Favistina sp.
Tollina sp.
Maclurites cf. M. *manitobensis* (Whiteaves).
?Murchisonia (Hormotoma) sp. indeterminate.

On the basis of North American biostratigraphic assignments, the Silurian-Ordovician boundary falls somewhere between collections 68–ADu–18 and 19 (fig. 3). According to both J. M. Berdan and R. J. Ross, Jr. (written commun., 1969), the arthropods in 68–ADu–18 are of Ordovician (probably Late Ordovician) age. John Huddle stated (written commun., 1969) that the conodonts are of Middle or Late Ordovician age. The lowest pentamerids were collected 200 feet higher in the section; according to A. J. Boucot (written commun., 1969), these are either late Wenlockian (late Middle Silurian) or Ludlovian (Late Silurian) equivalents. There is no apparent unconformity in the sequence, and the alternation of lithologies suggests continuous deposition.

A few comments, based upon relations observed west of the Don River area (Sainsbury, 1969b), are pertinent to the age assignments discussed in the preceding paragraph. In that area a well-defined time-stratigraphic unit occurs at the Early Ordovician-Middle Ordovician time boundary; this unit is a thin black shale that has yielded numerous and diagnostic trilobites and graptolites of late Early Ordovician age (Ross, 1965, and written commun. in Sainsbury, 1969a). Above the shale, the Middle Ordovician rocks consist of medium- to thin-bedded dark-gray limestones with shaly partings, and, higher up, dark limestone with discoid bits of gray chert. (See Sainsbury, 1969b, p. 28–30 for a more detailed description.) These rocks are extensively dolomitized near thrust faults; they also weather to distinctly dusky brown slopes unlike any other limestone in this region, and they are fossiliferous. Because of their position immediately above the only shale so far recognized in the Ordovician, they are likely not misplaced, and their age of early Middle Ordovician is well established. Fossil collection USGS 5517–CO (fig. 2, loc. 5; p. C55, this report) is from these rocks; yet it is determined on the basis of corals to be of Late Ordovician age. Unfortunately, coral faunas have not been collected elsewhere near the shale, and comparative faunas are not available, but it seems possible that Ordovician coral faunas in this part of North America may appear to be younger than they actually are, relative to graptolites.

Three other collections were made several hundred yards south of the measured section, but are in areas separated by faults. These three collections listed below appear to correlate at about the level of 68–ADu–16 in the measured section. Their locations are not shown on figure 2.

68–ADu–28 (USGS 6748–CO)
Catenipora cf. *C. gracilis.*
Prisochiton sp.
"*Liospira*" aff. "*L.*" *mundula* Ulrich.
Trochonemella cf. *T. montrealensis* Okulitch.
Loxoplocus (Lophospira) cf. *L. (L.) burginensis* (Ulrich and Scofield).
Daidia cerithoides (Salter).
?Helicotoma n. sp.
Trochonema (Trochonema) n. sp.
Straparella circe Billings.
"*Straparella*" cf. "*S.*" *eurydice* Billings.
Murchisonia (Hormotoma) sp. indeterminate.
Gastropod, undetermined.
Cephalopods, undetermined.

68–ADu–29 (USGS 6749–CO)
Favistina sp.
Catenipora cf. *C. gracilis.*
Calenipora sp.
Calapoecia sp.

68–ADu–30 (USGS 6750–CO)
Horn coral, undetermined.
Tabulate coral, undetermined.
Bryozoan, undetermined.
?Hebertella sp.
"*Liospira*" aff. "L." *mundula* Ulrich.
Liospira cf. *L. progne* (Billings).
Trochonemella cf. *T. montrealensis* Okulitch.
Daidia cerithoides (Salter).
Loxoplocus (Lophospira) sp. indeterminate.
Trochonema (Trochonema) n. sp.
?Murchisonia (Hormotoma) sp. indeterminate.
Straparella cf. *S. circe* Billings.
Gastropod, undetermined (2 kinds).
Ctenodont pelecypod fragment, indeterminate.
Curved flattened tube of unknown origin.

Concerning the age of 6749–CO, W. A. Oliver, Jr. (written commun., 1969), stated, "these corals, and those of collections 16 and 17 of the measured section, are of Late Ordovician age, probably representatives of the Bighorn-Red River coral fauna that seems to be so widespread in the Canadian and Arctic provinces."

Although the gastropod faunas come from beds slightly higher in the sequence, Yochelson was inclined to consider them as late Middle Ordovician correlatives. This difference of opinion may be more semantic than real.

The Ordovician age of D2036–CO seems to be well documented. R. J. Ross, Jr. (written commun., 1969), in discussing the two trilobites, stated: "One genus, *Remipyga*, is previously reported from Baffin Island and is like what the Russians identify as *Ceraurinus. Monorakos* is a Siberian Late Ordovician genus. The trilobites favor a Late Ordovician age for this collection."

In summing up a discussion of the ostracodes in D2036–CO, J. M. Berdan (written commun., 1969) stated: "Although the possibility of an Early Silurian age cannot be eliminated, the general aspect of the assemblage suggests an Ordovician age."

John Huddle considered the presence of *Drepanodus suberectus* as a clear indication of Middle or Late Ordovician age.

In summary, the Ordovician beds appear to be general correlatives of the Upper Ordovician Red River Formation of the Williston basin area and thus in terms of the standard

American sequence would be equivalent to beds high in the Trenton Limestone (Middle Ordovician) or Eden Stage (Upper Ordovician). A later Ordovician age for the ostracode-trilobite assemblage of D2036–CO is yet to be precisely determined. The oldest Silurian fossils seem, on the basis of the ages of corals, to be no older than Wenlockian, whereas the remainder of the Silurian sequence apparently would fall into the Late Silurian; the absence of Early Silurian, however, is not considered to be clearly established.

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