REPORT No. 53

Jurassic Microfaunas from Saskatchewan

by

J. H. WALL

1960

DEPARTMENT OF MINERAL RESOURCES

Petroleum and Natural Gas Branch

Geology Division

HON. J. H. BROCKELBANK
Minister

J. T. CAWLEY
Deputy Minister

PROVINCE OF SASKATCHEWAN

FOREWORD

The Department of Mineral Resources is pleased to publish this report which is based on a thesis submitted by the author to the University of Missouri for the degree Doctor of Philosophy. Dr. Wall is presently a geologist with the Research Council of Alberta and lecturer in micropaleontology at the University of Alberta.

The Department is of the opinion that this report adds much to what is already known about the Jurassic strata of Saskatchewan and hopes that the basic data presented in it will assist in the development of the petroleum resources of Saskatchewan.

A. J. WILLIAMS, *Director*,
Petroleum and Natural Gas Branch.

JURASSIC MICROFAUNAS FROM SASKATCHEWAN

ABSTRACT

Ninety-five species and varieties belonging to 39 genera of Foraminifera, and 33 species and varieties representing 15 genera of Ostracoda are figured and described from the Middle and Upper Jurassic sediments of Saskatchewan. Fourteen species of Foraminifera and three ostracode species are proposed as new.

The Jurassic stratigraphy of the western interior of the United States and Canada is summarized from published sources to provide background for viewing the Saskatchewan Jurassic sequence in its regional relationship. The Jurassic strata of Saskatchewan are discussed in some detail with the objective of coordinating the systems of nomenclature employed by different workers. The microfaunas of this sequence are listed and attention is directed toward species restricted to various stratigraphic levels. The Shaunavon formation of Saskatchewan is believed to be correlative with the Piper and Sawtooth formations of Montana which are Bathonian in age. The lower member of the Vanguard formation is equivalent to the Rierdon formation of Montana and the Stockade Beaver shale member of the Sundance formation in the Black Hills area which are Callovian in age. The middle and upper members of the Vanguard formation are collectively equated with the Swift formation of Montana and its correlative in the Black Hills, the Redwater shale member of the Sundance, which are Oxfordian in age.

Marine ostracodes seem to be the best group of microfossils for determination of biostratigraphic correlation in the Upper Jurassic of the western interior region. Foraminifera from the Saskatchewan Jurassic appear rather long-ranging with only a relatively small number of species restricted to any one stage. Charophytes and non-marine ostracodes are shown to be indicators of time planes when a sudden widespread change in environment rendered conditions favorable for their success.

The general aspect of the microfaunas implies shallow water deposition for the Shaunavon and Vanguard formations. The assemblages further seem to indicate that salinity varied from normal marine to weakly brackish (nearly fresh) levels but probably was nearly normal much of the time.

TABLE OF CONTENTS

Table of Contents—*Continued*

Table of Contents—*Continued*

Table of Contents—*Continued*

LIST OF ILLUSTRATIONS

List of Illustrations—*Continued*

CHAPTER I

INTRODUCTION

SCOPE OF PROJECT

Knowledge of the Jurassic in the province of Saskatchewan, Western Canada, is based on the subsurface studies as the system does not outcrop in the area. Intensive drilling for petroleum in the Canadian portion of the Williston Basin during the past decade has made available a number of excellent cored Jurassic sections in an area where previously little had been known about this system. These new sources of data have prompted attempts to correlate the Jurassic sequence in Saskatchewan with those encountered in outcrop to the south in the western interior region of the United States. Such efforts have been based largely on lithological studies with the work of Francis (1956, 1957) the most comprehensive, whereas this project follows the paleontological line of approach.

The initial objectives of this study were the identification, description, and determination of stratigraphic range of the common foraminiferal and ostracode species obtained from well cores in Saskatchewan. Attainment of these primary objectives provided the necessary background for broadening the scope of the project to encompass the important problem of time-rock correlation of the microfossil-bearing Saskatchewan sediments. This seems to have been solved in large measure through comparison of the Saskatchewan microfaunas with those found in various areas of the western interior region of the United States, which are calibrated with stages of the Jurassic in Europe by Imlay (1948) through the use of index ammonites. The conclusions of the present writer concerning the correlation of the Saskatchewan beds yielding microfaunal assemblages confirm those of Francis (1956, 1957) which were based on detailed lithological study.

The main purpose of interpretations offered regarding environment of the microfaunal assemblages has been to complement knowledge of sedimentational history as interpreted from lithological studies by various workers.

LOCATION AND PREPARATION OF SOURCE MATERIAL

The cored Jurassic sections were sampled in 13 wells, selected to give the best geographic distribution possible in the province of Saskatchewan up to the summer of 1954. (Figure 1 shows the location of the wells studied). Most of the available material is from the west-central and southwestern areas of the province, but several wells in the eastern sector provided samples at critical contacts. Unfortunately, coverage in the central area of the province is weak. Because of the danger of contamination from overlying beds, drilling samples were not used in this project.

From the 13 cored sections a total of 275 samples was obtained, all but 16 of which were prepared and examined for microfossils by the author.

The sampling method employed for those shale sections where core recovery is complete or nearly complete, was to chip small representative

pieces from the core over intervals of three feet. For limestones, only chips were selected which, on cursory examination, showed traces of microfossils.

In the preparation of the shale for washing, samples of 150 to 175 grams were placed in jars, covered with water and allowed to stand until

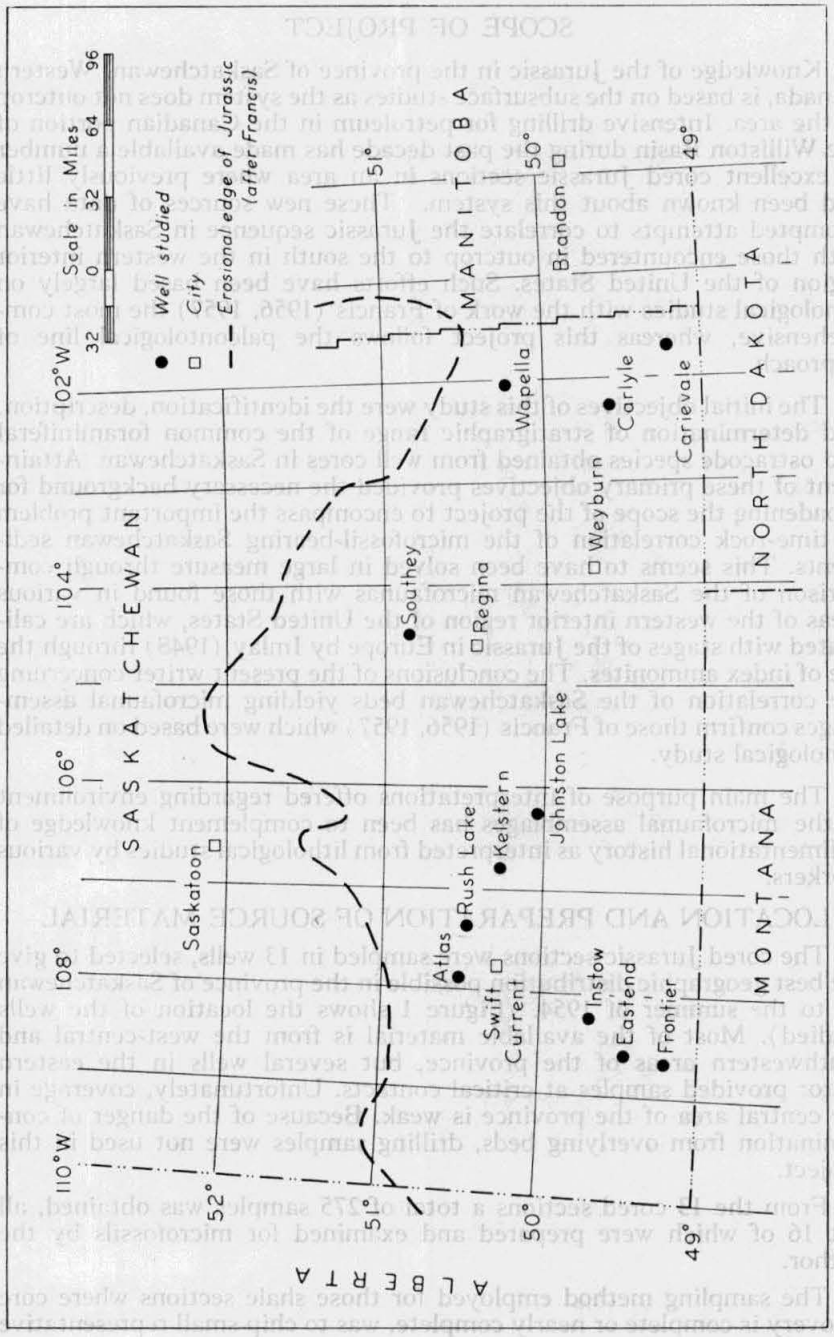

Figure 1.—Index map of southern Saskatchewan showing location of wells studied.

the soaking action could have an appreciable softening effect on the material. The shale samples were washed in a prospector's pan by the decantation method and the limestone chips were crushed with a mortar and pestle. The resulting residues were dried and sieved through various screen sizes for convenience in handling, and the microfossils were extracted using a stereoscopic microscope.

All figured specimens are catalogued and deposited in the University of Missouri Paleontological Collection at Columbia, Missouri. It is planned to deposit an additional set of specimens in the Paleontological Collections of the University of Alberta, Edmonton, Canada.

REVIEW OF PREVIOUS WORK

Lithologic-Stratigraphic

A summary review of the contributions by earlier workers to the study of Jurassic lithology and stratigraphy of Saskatchewan and adjoining areas of Western Canada and the interior plains region of the United States has been made by Francis (1956). The two major stratigraphic studies in Saskatchewan are those by Milner and Thomas (1954) and Francis (1956). In 1958, a number of smaller contributions on this subject were published in the Allan Memorial Volume of the American Association of Petroleum Geologists. This latter group of papers takes into account more recent information obtained from the many wells drilled since the appearance of the earlier major publications.

Milner and Thomas (1954) divided the Jurassic system into four formations, which in ascending order are the Watrous, Gravelbourg, Shaunavon and Vanguard. The oldest or Watrous formation consists chiefly of red beds and evaporites. The upper three formations consist mainly of limestones and calcareous shale and are largely of marine origin. Milner and Thomas suggested the equivalence of the Shaunavon formation to the Sawtooth of the Sweetgrass Arch area, but the great distances and lack of control made such a correlation of questionable value at that time. Milner and Blakslee (1958, p. 75) reaffirmed this suggested correlation by their statement, "the entire formation is equivalent to most of the Sawtooth formation in Montana." Milner and Thomas (1954) believed that the calcareous shale of the lower member, and the sand of the middle member of the Vanguard formation indicated approximate correlation with the Rierdon and Swift formations of Montana, respectively. This opinion of the correlation of the lower Vanguard with the Rierdon was reaffirmed by Milner and Blakslee (1958, p. 79), but they considered it unlikely that the middle member of the Vanguard is represented in the type section of either the Rierdon or Swift of the Sweetgrass arch.

Francis (1956) published a detailed report on the Jurassic rocks underlying Saskatchewan and adjacent areas of Manitoba, North Dakota and Montana, the purpose of which was to relate the sediments found in the subsurface of the Williston Basin area to type sections located in western Montana, Wyoming and South Dakota. He included the known Jurassic rocks of Saskatchewan in five formations which in ascending order are the Gypsum Spring, Piper, Rierdon, Swift and Morrison. A sequence of red silty shales of uncertain age underlying these formations was termed the "Jura-Triassic red beds." The detailed lithologic studies of Francis indicate that parts, and in some cases possibly all, of the strata to which he has applied American nomenclature are correlative with the formations in their type sections. In far eastern Saskatchewan, Francis reported the Swift, Rierdon and Piper formations could not be differentiated and, thus, the strata equivalent to them were assigned to the Sundance formation.

Klingspor (1958) has presented considerable recent information on Jurassic stratigraphy in the form of cross sections with accompanying discussions which extend eastward from the east flank of the Sweetgrass arch in Alberta across southern Saskatchewan and into western Manitoba. In his opinion the new data essentially confirm Milner's and Thomas' classification as the one most widely applicable in the Canadian portion of the Williston Basin, and, thus, he used their divisions with a few modifications.

Storey (1958) inferred that some of the generally accepted correlations of the Jurassic strata between the Williston Basin, the Black Hills and the Sweetgrass arch were erroneous. For example, he believed that the Sawtooth is not merely a facies of the Piper formation but is a discreet stratigraphic unit which is younger than the Piper or Gypsum Spring. He also held the opinion that the Stockdale Beaver member of the Lower Sundance is older than the type Swift and younger than the type Rierdon.

Paleontologic

Imlay (1945, 1948, 1953) has done most of the recent paleontological work, and through his ammonite studies he has been able to calibrate much of the western interior Jurassic with the classic European sections. The contributions of the earlier paleontological workers have been summarized by Imlay (1948) and Peterson (1954b).

In Saskatchewan, very little megafaunal information has been published. Frebold (1953, p. 1241) mentioned a marine fauna in a well at Avonlea. Crickmay, in Milner and Thomas (1954), reported on some pelecypods found in the formations proposed by these workers and discussed the correlation of the faunas.

Micropaleontologic

Loeblich and Tappan (1950a, p. 39) reviewed the scant literature that had been published on North American Jurassic Foraminifera prior to 1950. Subsequently, they have contributed most to our knowledge in this field with two important systematic papers, the first (1950a) on the Foraminifera of the type Redwater shale (Oxfordian) of South Dakota, and the second (1950b) on characteristic western interior Callovian species. Lalicker (1950) published on the Foraminifera of the Ellis group at its type locality in southwestern Montana and gave the known vertical ranges of the species described.

The first major ostracode study in the marine Jurassic of the western interior United States was done by Roberts (1934) in the form of an unpublished University of Missouri A.M. thesis on the fauna of the Sundance formation of central Wyoming. Swain and Peterson have been responsible for practically all the recent work done on the marine Jurassic ostracodes with their contributions of 1951 on the Redwater shale fauna of South Dakota, and of 1952 on the fauna of the upper part of the Sundance formation of South Dakota, Wyoming and southern Montana. Peterson (1954a) published a comprehensive report on the ostracodes of the "lower Sundance" and Rierdon formations of the western interior United States. A further important study in the same region by Peterson (1954b) deals with the stratigraphic and geographic distribution and paleoecology of various Upper Jurassic ostracode faunas.

In Saskatchewan, the first foraminiferal work was done by Wickenden (1933) who, after studying the faunas obtained from well cuttings, compared most of the forms with European Middle Jurassic species. Loranger (1955) made the only other significant contribution to the Jurassic micropaleontology of the province. She referred most of the

Foraminifera and Ostracoda encountered to species previously described by Loeblich and Tappan and Swain and Peterson, respectively. Loranger's study seems to have been based largely on drill cuttings and the correlations indicated are at some variance with those of the present author.

ACKNOWLEDGMENTS

The National Research Council of Canada provided financial assistance during the early stages of this study. The author received from this agency a summer supplementary grant for collecting material in Saskatchewan and a studentship for preliminary research at the University of Alberta, 1954 to 1955. The award of a Gregory graduate fellowship at the University of Missouri, 1956 to 1957, assisted the author in carrying out the more advanced stages of this project. The aid received from these sources is gratefully acknowledged.

A large number of individuals and organizations were most helpful during the course of this study in Canada and in the United States. Dr. R. L. Milner and Mr. G. E. Thomas formerly of the Tidewater Oil Company Operator, Regina, Saskatchewan, directed the author's attention in the summer of 1954 to much valuable source material their company had acquired in its exploratory operations and permitted sampling of this material. Mr. D. R. Francis of the Saskatchewan Government's Department of Mineral Resources pointed out additional cored sections and supplied certain stratigraphic data. Dr. C. R. Stelck of the Department of Geology, University of Alberta, furnished space in his office during the 1954 to 1955 academic year for preparatory work and offered continuous encouragement. Dr. J. D. Campbell, Paleobotanist, Research Council of Alberta, gave advice in the field of microscopic photography and allowed the use of photographic equipment in his laboratory.

Dr. R. E. Peck of the Department of Geology, University of Missouri, chief adviser to this study, read the original manuscript, made helpful suggestions, and gave much incentive to complete the project. Dr. A. G. Unklesbay of the same department offered helpful suggestions in the preparation of some of the illustrations. Dr. D. L. Frizzell of the Department of Geology, Missouri School of Mines and Metallurgy, edited the original manuscript and offered constructive criticism, particularly in matters pertaining to taxonomy. Dr. R. S. Campbell of the Department of Zoology, University of Missouri, also read the original manuscript.

Mr. P. C. Sylvester-Bradley, University of Sheffield and formerly visiting professor at the University of Kansas, and Dr. M. J. Copeland of the Geological Survey of Canada offered opinions on the identification of some of the ostracodes encountered in this study. Miss D. M. Loranger, Paleontologist, Imperial Oil Limited, Calgary, Alberta, made available for examination the specimens figured in her publication of 1955. Drs. G. A. Cooper and Ruth Todd of the United States National Museum extended the facilities of that organization for the examination of foraminiferal and ostracode type specimens deposited there.

The Department of Geology, University of Missouri, furnished facilities for research. The Research Council of Alberta supplied stenographic and drafting services for the preparation of this report.

CHAPTER II

JURASSIC SYSTEM IN THE WESTERN INTERIOR REGION, UNITED STATES AND CANADA

INTRODUCTORY STATEMENT

This chapter is an attempt to summarize from the publications of a number of workers the paleogeography and stratigraphy of this vast region. With the presentation of a broad regional picture, it is hoped that the reader will find it easier to visualize the general correlation of the Jurassic of Saskatchewan with that of distant areas. The local stratigraphy of Saskatchewan is discussed more completely in the succeeding chapter. The diverse systems of stratigraphic nomenclature used in the western interior region are shown on Figure 2.

PALEOGEOGRAPHY AND SEDIMENTATION

Physical features of the great interior seaway

Imlay (1949, p. 75 *et seq.*; 1957) has given an excellent account of the paleogeography, and the discussion to follow is extracted largely from his articles. The western interior Jurassic sea was bounded on the west by a long, narrow land mass, the Mesocordilleran geanticline, which extended from Mexico through the western United States into southern British Columbia. This interior sea was bounded on the south by a narrow land mass in southern New Mexico and separated from the Gulf sea to the southeast by uplifts in central Texas, southern Oklahoma and central Arkansas. The sea was bounded on the east in Minnesota and eastern South Dakota by a southwestern extension of the Canadian Shield and on the northeast in Manitoba by the western limb of the Canadian Shield proper.

The interior Jurassic seaway was divided into several subsidiary basins principally by two broad gentle uplifts—the Belt Island in north-central Montana and the Uncompahgre in west-central Colorado. Between the Belt Island uplift and the Canadian Shield lay the northwest-trending Williston Basin of eastern Montana, western North Dakota, southern Saskatchewan and southwestern Manitoba, in which a maximum thickness of nearly 1200 feet of Jurassic rocks has been encountered in the subsurface. South of the Belt Island uplift there was an eastward-trending basin in southern Montana and northern Wyoming, referred to as the Hardin seaway by Peterson (1954b), in which as much as 800 feet of sediments accumulated. The greatest amount of sedimentation occurred along the western margin of the interior seaway in the Twin Creek trough of authors in western Montana, eastern Idaho, far western Wyoming and central Utah. At least 10,000 feet of sediments were deposited along the western margin of the Wasatch Plateau in Utah (Spieker, 1946, p. 125) and about 7,500 feet in southeastern Idaho. These thick accumulations of sediments thin rapidly eastward, however, and undergo marked changes in facies within a distance of 30 miles or less.

During the Jurassic period there were four Arctic marine inundations of the western interior of North America, once during each of the Early and Middle Jurassic epochs and twice in the Late Jurassic (early Callovian and Early Oxfordian ages). According to Imlay (1949, p. 76), each transgression spread somewhat farther south than the one preceding but none connected with the Mexican or Pacific seas, except remotely through the Yukon or Alaska.

Lower Jurassic Deposits

The Early Jurassic sea in the western interior region occupied a narrow trough extending southward along the British Columbia-Alberta border toward Fernie in extreme southeastern British Columbia. The black shale (50-150 feet thick) of the lower member of the Fernie formation near Fernie, B.C., was laid down at this time (Warren, 1934, pp. 59-60).

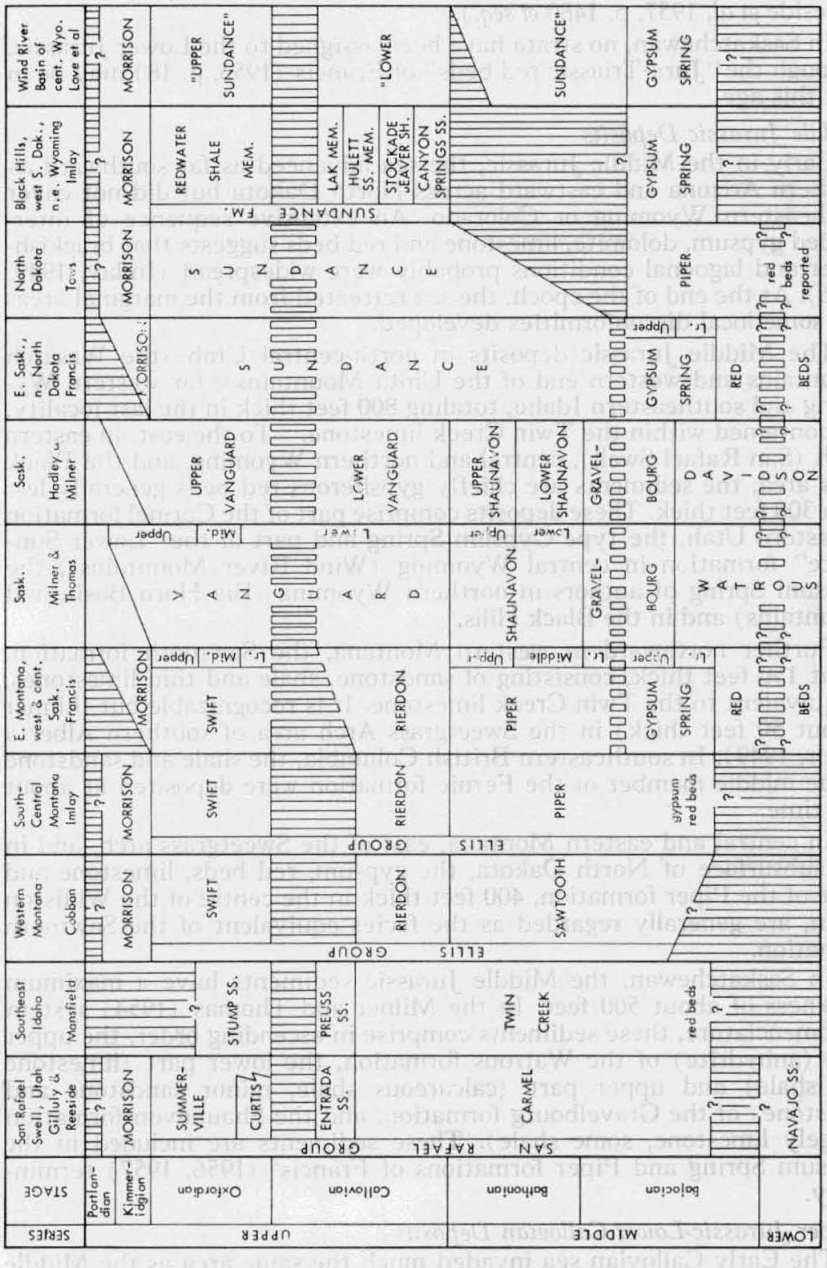

Figure 2.—Jurassic terminology in Saskatchewan and the western interior region. (Positions of unconformities and indicated correlations based on published reports by Imlay and Francis)

A distinctly different Lower Jurassic lithofacies is represented by the Navajo and Nugget sandstones of the area south of Montana. These sandstones, which attain a thickness of 2,000 feet or more, are generally considered to be mainly of eolian origin (Baker, Dane and Reeside, 1936, pp. 5-6, 44, 51-53). The age of these sandstones has not been settled. Recently, the Nugget has been assigned "somewhat arbitrarily" to the Triassic while the Navajo, which previously had been considered equivalent to the Nugget but is apparently younger, is retained in the Jurassic by the Triassic subcommittee of the Geological Society of America (Reeside *et al*, 1957, p. 1480 *et seq.*).

In Saskatchewan, no strata have been assigned to the Lower Jurassic, although the "Jura-Triassic red beds" of Francis (1956, p. 18) may be in part this age.

Middle Jurassic Deposits

Early in the Middle Jurassic, the sea advanced as far southward as northern Arizona and eastward across North Dakota but did not cover southeastern Wyoming or Colorado. An extensive sequence of interbedded gypsum, dolomite, limestone and red beds suggests that brackish-water and lagoonal conditions probably were widespread (Imlay, 1949, p. 76). At the end of the epoch, the sea retreated from the marginal areas and some local disconformities developed.

The Middle Jurassic deposits in north-central Utah (the Wasatch Mountains and western end of the Uinta Mountains), far western Wyoming and southeastern Idaho, totaling 800 feet thick in the last locality, are contained within the Twin Creek limestone. To the east, in eastern Utah (San Rafael Swell), central and northern Wyoming, and the Black Hills area, the sediments are chiefly gypsiferous red beds generally less than 300 feet thick. These deposits comprise part of the Carmel formation of eastern Utah, the type Gypsum Spring and part of the "Lower Sundance" formation in central Wyoming (Wind River Mountains), the Gypsum Spring of authors in northern Wyoming (Big Horn Basin and Mountains) and in the Black Hills.

Further northward in western Montana, the Sawtooth formation, about 150 feet thick, consisting of sandstone, shale and thin limestones, is equivalent to the Twin Creek limestone. It is recognizable but thinner (about 50 feet thick) in the Sweetgrass Arch area of southern Alberta (Weir, 1949). In southeastern British Columbia, the shale and sandstone of the middle member of the Fernie formation were deposited at about this time.

In central and eastern Montana, east of the Sweetgrass arch, and in the subsurface of North Dakota, the gypsum, red beds, limestone and shale of the Piper formation, 400 feet thick in the centre of the Williston Basin, are generally regarded as the facies equivalent of the Sawtooth formation.

In Saskatchewan, the Middle Jurassic sediments have a maximum thickness of about 500 feet. In the Milner and Thomas (1954) system of nomenclature, these sediments comprise in ascending order, the upper part (anhydrite) of the Watrous formation, the lower part (limestone and shale) and upper part (calcareous shale, minor sandstone and limestone) of the Gravelbourg formation, and the Shaunavon formation (largely limestone, some shale). These sediments are included in the Gypsum Spring and Piper formations of Francis' (1956, 1957) terminology.

Upper Jurassic-Lower Callovian Deposits

The Early Callovian sea invaded much the same area as the Middle Jurassic sea but inundated more of South Dakota and Wyoming. The

Lower Callovian sediments of the western interior consist mainly of normal marine sandstone, shale and limestone, but some lagoonal or brackish-water sediments accumulated in the southern end of the seaway.

In northern Utah (Wasatch and Uinta Mountains), this marine invasion is represented by a considerable thickness of gray shale and limestone in the upper part of the Twin Creek formation. To the north, a similar lithology is present in the upper Twin Creek of southwestern Wyoming and southeastern Idaho with 1800 feet of beds in the western part of this area. To the south, in central and southern Utah, the strata equivalent to the upper Twin Creek are the shale, sandstone, gypsum and thin limestone beds of the upper part of the Carmel formation. At the southern end of the seaway in the San Rafael Swell of east-central Utah, and in northeastern Arizona and northwestern New Mexico, a brackish-water or lagoonal facies is indicated by 100 feet or less of red sandstone and sandy shale of the Carmel formation.

Across central and eastern Wyoming, Montana and the Dakotas, the Lower Callovian deposits are mainly gray calcareous shale, with sandstone members characterizing the base and top of the sequence in central and eastern Wyoming and in the Black Hills area. In Wyoming these strata, up to about 350 feet thick, comprise the upper part of the "Lower Sundance" formation with the Canyon Springs and Hulett sandstone members at the base and top respectively, and with the Stockade Beaver shale member intercalated between them. The same sequence is present in the Black Hills area, where these members constitute the lower portion of the type Sundance formation.

The Rierdon formation of Montana, consisting mainly of calcareous shale with some limestone (Cobban, 1945), is correlative with the lower part of the Sundance. The Rierdon, 135 feet thick at its type locality in northwestern Montana, has been traced northward along the Sweetgrass arch into southern Alberta (Weir, 1949) and eastward into the subsurface of eastern Montana and North Dakota, attaining a thickness of about 250 feet in the centre of the Williston Basin. Brown shales from part of the upper member of the Fernie group in the British Columbia-Alberta border area were deposited in this Early Callovian sea (Frebold, 1953).

In Saskatchewan, these lower Callovian deposits are represented by the calcareous shale of the lower member of the three-member division of the Vanguard formation of Milner and Thomas (1954). Francis (1956) retained the name Rierdon for these beds.

Upper Jurassic- Upper Callovian Deposits

At the end of Early Callovian time, an uplift in central Montana apparently cut off the supply of normal marine Arctic water and continental conditions developed through a large area to the south. Simultaneously, a dead sea existed on the western side of the former seaway in Utah, southwestern Wyoming and adjoining southeastern Idaho, where a considerable thickness of red siltstone and sandstone containing bedded salt was deposited. Two different sedimentary facies occupy these areas but they intergrade within short distances. Because these sediments are not present in Saskatchewan, only brief mention of them seems warranted.

The southern facies occupying the Colorado Plateau area consists of the light-colored Entrada sandstone, which is generally less than 400 feet thick. The northern facies present in various parts of Utah is a thicker (up to 1200 feet thick), dark red, silty sandstone called Entrada and Preuss at different localities. The name Preuss is also applied to similar

sediments in north-central Utah, southwestern Wyoming and south eastern Idaho where bedded rock salt occurs in the sandstone (Mansfield 1927, p. 340; Spieker, 1946, pp. 124-125). To the northeast in the Black Hills area, a thin (25 to 100 feet thick) red bed unit, the Lak member of the Sundance formation, is correlative with the Preuss (Imlay, 1947). Upper Callovian beds were not deposited in Montana, and an unconformity developed between the Lower Callovian Rierdon and the Oxfordian Swift formations.

In North Dakota and Saskatchewan, however, such an unconformity does not seem to have developed as the Rierdon is overlain apparently conformably by the Swift, according to Francis (1956, p. 50; 1957, p. 387). Thus, the possibility is raised that the Upper Callovian substage may be represented in the upper portion of the Rierdon in this area, but recognition by microfaunal means of any time-rock unit smaller than stage is not as yet possible in this sequence.

Upper Jurassic-Oxfordian Deposits

The Early Oxfordian sea spread rapidly southward and eastward beyond the limits of the Early Callovian inundation. Oxfordian deposits of the western interior are normal marine over a large area north of northern Colorado and brackish-lagoonal to the south. The latter type of sediment occupies the same general area that is underlain by the Lower Callovian Entrada sandstone facies which covers northern Arizona, northern New Mexico, southeastern Utah, southwestern and eastern Colorado.

The brackish-lagoonal sediments have been subdivided into two facies occupying fairly distinct areas although merging laterally in places. The Summerville formation is probably the more conspicuous of these facies (Gilluly and Reeside, 1928, p. 78; Baker, Dane, and Reeside, 1936, pp. 8-9, 46) and extends from the San Rafael Swell of east-central Utah southeastward into southwestern Colorado and northeastern Arizona. It consists chiefly of red and white sandstone and maroon shale, but includes some gypsum locally. The formation is generally less than 400 feet thick.

The Summerville grades laterally in southwestern Colorado and adjoining parts of New Mexico and Arizona into the second facies, the Wanakah formation, which is thinner and more calcareous. This facies is characterized at its base by the Todilto limestone member which locally grades into thick gypsum beds. The upper part of the Wanakah is composed chiefly of sandstone, shale and marl and resembles the Summerville except it is lighter colored, more calcareous and coarser grained.

The normal marine facies of the Oxfordian extends as far south as southwestern Colorado and is represented here by the Curtis formation, which consists largely of glauconitic, greenish gray sandstone with some shale and gypsum. At its type area in the San Rafael Swell of east-central Utah, the Curtis is from 75 to 250 feet thick. The same terminology is applied to similar sediments in northeastern Utah and northwestern Colorado.

North of Utah and Colorado, the marine Oxfordian comprises two laterally intergrading facies, the sandstone of the Stump and Swift formations on the west, and the shale from the upper part of the Sundance formation on the east. The western or sandstone facies is known as the Stump formation in western Wyoming and southeastern Idaho, and attains a thickness of at least 600 feet. The same facies in Montana is represented by the Swift formation which is from 100 to 200 feet thick in the type area on the Sweetgrass arch. Both the Stump and Swift

consist dominantly of calcareous glauconitic sandstone, but there is a shale member at the base of the Swift.

The eastern or shale facies is present in the eastern half of Wyoming, the Black Hills area, and in the subsurface of eastern Montana and North Dakota. In Wyoming and the Black Hills, this facies is represented by the "Upper Sundance" formation and the Redwater shale member of the type Sundance, respectively. These sections are from 100 to 200 feet thick (Love, *et al*, 1945; Imlay, 1947) and composed largely of glauconitic shale with some sandstone at the base which tends to shale out in an easterly direction. In the subsurface of eastern Montana and North Dakota, the lower shale and upper sand members of the type Swift can be recognized with the shale predominant (Peterson, 1957, p. 411). A maximum thickness of over 400 feet is reported in the deeper part of the basin.

For Saskatchewan, as well as the American portion of the Williston Basin, Francis' opinion was at variance with Peterson's observation that the lower shale and upper sandstone members of the type Swift could be traced far into the subsurface. According to Francis (1956, p. 34) the Swift formation over the Williston Basin consists of three distinct units, a lower shale member which is absent in the western part of the basin, a middle sandstone zone and an upper shale member. Milner and Blakslee (1958) consider the upper member of the Vanguard formation, which is synonymous with Francis' upper shale member, as correlative with the Swift formation. They consider it unlikely, however, that the middle member of the Vanguard, which is synonymous with Francis' middle sandstone zone, is represented in the type section of either the Rierdon or Swift formations of the Sweetgrass arch. Francis (1956) reported a maximum thickness of nearly 500 feet for the Swift in southeastern Saskatchewan.

Upper Jurassic- Kimmeridgian and Portlandian Deposits

Near or at the close of Oxfordian time, the sea retreated into northern Alberta and continental deposition became widespread over the western interior during the remainder of the Jurassic (Imlay, 1949, p. 77). That marine sediments were deposited in the region after this time, however, is proven by Frebold's (1957, p. 4) description of an Upper Portlandian ammonite in the basal Kootenay sandstone of the Fernie district, British Columbia. This area, however, is on the outer fringe of the great interior region. The non-marine Morrison formation, consisting mainly of sandstone and shale, is present over nearly all of the western interior region. Its age is thought to be essentially Kimmeridgian with the higher beds possibly Portlandian (Imlay, 1952, p. 958).

In the Williston Basin, Francis (1956, p. 40) reported common thicknesses of 75 feet for the Morrison in the subsurface of eastern Montana and a maximum of 150 feet in central North Dakota. He believed the Morrison to be present in parts of extreme southern Saskatchewan but with thicknesses no greater than 25 feet. Loranger (1955, p. 44) also believed the "Morrison" (*sic*) to be present in southern Saskatchewan but omitted details with regard to occurrences of diagnostic microfossil species.

CHAPTER III

JURASSIC STRATA OF SASKATCHEWAN

INTRODUCTORY STATEMENT

In the preceding chapter, the general relationship of the Saskatchewan Jurassic sequence to those in other areas of the western interior region was discussed. The local Saskatchewan stratigraphy is next treated in some detail in an effort to coordinate the various systems of nomenclature employed by different workers prior to discussing the microfaunal associations in the succeeding chapter. Milner's and Thomas' (1954) classification of the Jurassic strata as revised by Milner and Blakslee (1958) is used as the basis for this chaper, and Francis' (1956, 1957) terminology is equated with it.

WATROUS FORMATION

The lowermost formation of post-Mississippian age in Saskatchewan, that is, the Watrous, consists of a basal red siltstone with some red shale and sandstone overlain by a bed of anhydrite (Milner and Blakslee, 1958, p. 71). This formation pinches out to the west and was not deposited in westernmost Saskatchewan nor in western Montana. Milner and Thomas (1954, p. 256) stated that the top of the formation is marked in most places by a prominent anhydrite bed. This bed corresponds with the lower evaporite unit of the Gypsum Spring formation of Francis (1956, p. 26).

No macrofossils have been reported from this formation and its age is uncertain. The basal silt is regarded as Triassic in age by some geologists according to Milner and Blakslee. The formation was not included in this study because of the unlikelihood of obtaining microfossils from these lithologies.

GRAVELBOURG FORMATION

The Gravelbourg formation is made up of a lower transitional group of sediments consisting of variegated shale and carbonates overlain by a marine, generally calcareous shale sequence. The formation is 90 feet thick at its type section in the Eastend well of southwestern Saskatchewan. A cherty zone at or near the top of the lower transitional group indicates an unconformity within the formation which is considered by some geologists to mark the top of the Gypsum Spring formation (Milner and Thomas, 1954, p. 257). Thus, the lower part of the Gravelbourg corresponds to the upper unit of the Gypsum Spring (Francis, 1956, p. 26). The upper part (calcareous shale) of the Gravelbourg corresponds to the lower unit of the Piper formation of Francis (1956, p. 28).

In eastern Saskatchewan, the upper Gravelbourg undergoes facies changes with considerable calcareous sandstone found interbedded with the shale. It is difficult to pick the upper boundary of the formation in this area because the overlying Shaunavon limestone also undergoes a somewhat similar facies change with sandstone and shale prominent (Milner and Thomas, 1954, p. 260).

SHAUNAVON FORMATION

This formation, which is 140 feet thick in the type section at the Eastend well in southwestern Saskatchewan, has been divided into lower and upper members by Milner and Thomas (1954, p. 260). The lower member is stated to be the best map unit in Saskatchewan, and consists of buff lithographic limestone which is generally sandy and oolitic at

the top. It corresponds to the middle unit of the Piper formation of Francis (1956, p. 30). The upper member consists of alternating thin, sandy, argillaceous limestone beds and calcareous, green and variegated shale (Milner and Thomas, 1954, p. 260). It corresponds to the upper unit of the Piper formation of Francis (1956, p. 30). In eastern Saskatchewan both members undergo facies change resulting in the development of much calcareous sand and variegated shale.

The green shale beds at the top of the formation are lithologically similar to the basal Vanguard strata and a sharp contact is difficult to draw. For this reason, according to Milner and Blakslee (1958, p. 75), some geologists prefer to regard the Upper Shaunavon as part of the Vanguard formation and hence as equivalent to the basal Rierdon.

The present writer is sympathetic toward considering the Upper Shaunavon as part of the Vanguard formation, but, with the exception of perhaps its upper 15 to 20 feet, would not endorse its correlation with the basal Rierdon in view of present knowledge. Only one of the ostracodes obtained from the Upper Shaunavon in this study, *Aparchitocythere elongata* Peterson, is a Rierdon species, whereas the bulk of the Rierdon ostracode fauna of Peterson (1954a) is identified herein from the Lower Vanguard.

Brief mention should be made here of the charophyte zone which occurs within the top 20 feet of the Shaunavon over a wide area in Saskatchewan and probably in correlative beds of adjoining areas as well. The zone is usually contained within about 5 feet of section and the charophytes are visible under low power microscopic examination in both the limestone and shale beds. If the zone were associated with some prominent and persistent lithological unit, and hence could be recognized by stratigraphers, it would be a logical point at which to draw the upper boundary of the Shaunavon formation. It is an extremely useful marker-bed and its probable ecological implications are discussed in a later chapter.

VANGUARD FORMATION

This formation has been divided by Milner and Thomas (1954, p. 263) into a lower calcareous shale member, a middle sand member and an upper essentially non-calcareous shale member. Drilling carried out since the formation and its three members were first established has accumulated sufficient new information to necessitate revision of this threefold division according to Milner and Blakslee (1958, p. 77). Revisions in the divisions of the Vanguard formation are shown on Figure 3. These workers stated that the middle sandstone of the Vanguard is now known to be present only in the south-central part of the province instead of over a much larger area of southern Saskatchewan as was indicated by earlier work. Similarly, Francis (1956, p. 34) stated that this sand unit was not developed in the province west of range 17-W3. Milner and Blakslee (*op. cit.*) reported that, "where this sandstone is absent the member either is represented by slightly calcareous shale and siltstone, or the upper Vanguard rests directly upon the lower Vanguard."

Milner and Blakslee lowered the base of the middle Vanguard to the top of the "high resistivity" (*sic*) calcareous shale found a short distance below the middle Vanguard sandstone comprising the original type section for the member in the Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, R. 6, W. 3rd Mer. They raised the top of the member to the base of the non-calcareous variegated shale found a short distance above the middle Vanguard sandstone in the same well. The type section

of the middle member of the Vanguard formation as redefined constitutes the interval in the Tidewater Kelstern Crown No. 1 well between 3,248 and 3,397 feet, whereas the former type section embraced the interval 3,284-3,384 feet. In summary, the redefined middle member is extended downwards to include the slightly calcareous shale below the main sand which was formerly included in the lower member, and is raised upward to include the slightly calcareous shale above the main sand which was formerly included in the upper member (Figure 3).

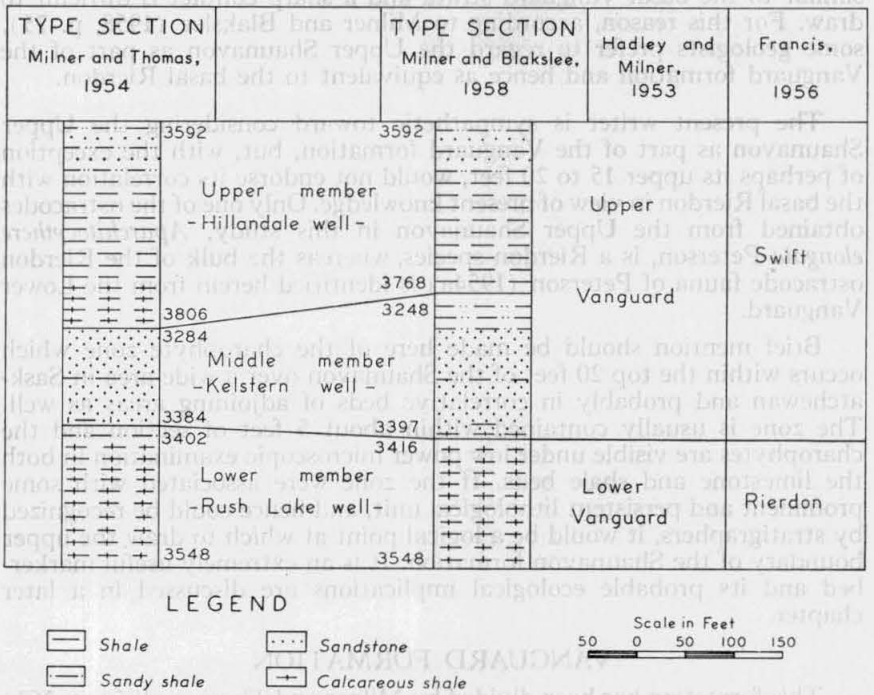

Figure 3.—Vanguard formation nomenclature.

As Milner and Blakslee pointed out, the redefinition of the middle Vanguard member necessitates redefinition of the type sections of the lower and upper members of the Vanguard. The type section of the lower member was originally designated as the interval 3,402-3,548 feet in the Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, R. 10, W. 3rd Mer. (Milner and Thomas, 1954, p. 263). Milner and Blakslee (1958, p. 79) have revised this to include only the interval 3,416-3,548 feet, thus shortening the member to exclude the slightly calcareous shale overlying the highly calcareous Rierdon equivalent, which has now been assigned to the middle member.

The present writer has examined the type section of the lower member of the Vanguard and would have placed the base of the member at about 3,562 feet, or 14 feet lower than the footage designated by Milner and Thomas. The reasons advanced for this opinion are, (1) the first limestone bed of any appreciable thickness (1-½ feet), which would seem to be the most logical place to draw the top of the Shaunavon formation, is observed at 3,562 feet and, (2) the microfauna from 3,548 to 3,562 feet does not differ from that present in the overlying beds of the lower shale member proper.

The type section of the upper member of the Vanguard was originally designated as the interval 3,592-3,806 feet in the Sohio-McCarty Coleman Hillendale No. 1 well in Lsd. 4, Sec. 11, Tp. 5, R. 20, W. 3rd Mer. (Milner and Thomas, 1954, p. 267). Milner and Blakslee (1958, p. 79) have revised this to include only the interval 3,592-3,768 feet, thus shortening the member to exclude the slightly calcareous shale overlying the main sand of the middle member, which has now been assigned to the middle member.

Francis (1956, p. 32) applied Montana nomenclature to these rocks with the Rierdon considered equivalent to the highly calcareous green shales of the lower member of the Vanguard in the revised sense of Milner and Blakslee. The top of the Rierdon equivalent is indicated by "a distinctive outward deflection of gamma ray and resistivity curves . . . . locally known as the Rierdon shoulder" (Francis, 1956, p. 31), which is regarded by stratigraphers as a very useful and consistent marker through much of the Williston Basin.

The Swift correlative of Francis embraces in ascending order, the slightly calcareous and slightly silty shale, the well sorted sands and the slightly calcareous shale of the middle member, and the greenish gray, non-calcareous, locally bentonitic shales of the upper member of the Vanguard formation. In far eastern Saskatchewan, where the Swift loses its identity, Francis (1956, p. 35) included strata equivalent to it in the Sundance formation.

Hadley and Milner (1953) employed a system of nomenclature for the Saskatchewan Jurassic which essentially is the same as that proposed by Milner and Thomas (1954). Hadley and Milner, however, used a two-fold division for the Vanguard formation—the "Lower Vanguard" and the "Upper Vanguard"—instead of the three-member division of Milner and Thomas.

The "Lower Vanguard" corresponds to the highly calcareous lower portion of the lower member of Milner and Thomas, which constitutes all of the lower member as revised by Milner and Blakslee (1958). The "Lower Vanguard" of Hadley and Milner is equivalent to the Rierdon formation of Francis' nomenclature.

The "Upper Vanguard" corresponds to what was formerly the upper portion of the lower member, the middle member and the upper member of Milner and Thomas. This sequence is now included in the middle and upper members as revised by Milner and Blakslee. The "Upper Vanguard" of Hadley and Milner is equivalent to the Swift formation of Francis' nomenclature.

CHAPTER IV

MICROFAUNAL CORRELATION OF THE SASKATCHEWAN JURASSIC

INTRODUCTORY STATEMENT

Much of the following information is recorded on charts 1 and 2 which summarize the distribution of Foraminifera and Ostracoda in the Jurassic of Saskatchewan and their occurrences in other areas of the western interior region. Microfaunal assemblages characteristic of smaller stratigraphic units than those discussed in this chapter, such as parts of members, are available for a few key wells (see Appendix).

WATROUS FORMATION

As mentioned previously in the text, this formation was omitted from this study because of the unlikelihood of obtaining microfossils from its characteristic red beds and evaporites.

GRAVELBOURG FORMATION

A sparse microfauna has been obtained to date from the few available Gravelbourg cores. In the Instow well of southwestern Saskatchewan, an ostracode-charophyte assemblage was observed in greenish gray, limey shale about 10 feet above the base of the formation. The ostracode present, *Darwinula leguminella* (Forbes), is a long-ranging species of little or no stratigraphic value. The Charophyta were not intensively studied but an undescribed species of *Obtusochara* is common.

A meagre assemblage of Foraminifera and Ostracoda was obtained from the uppermost six inches (between depths of 4,820 and 4,820.5 feet) of the formation in type section at the Eastend well. The composition of this fauna differs little, if any, from that of the microfaunal complex of the overlying lower member of the Shaunavon formation. The Foraminifera present are *Involutina francisi*, n. sp., *Eoguttulina* sp., and *Lenticulina* sp. The Ostracoda are identified as *Limnocythere climaxia* (Loranger) and *Protocythere* sp. cf. *P. quadricarinata* Swain and Peterson. In the underlying section at this well, poor assemblages of ostracodes with a few representatives of *Norcanolella* were noted. The foraminifer *Involutina* (formerly *Ammodiscus*) also occurs rarely in these beds.

In the eastern part of Saskatchewan, it is virtually impossible to differentiate the microfauna of the Gravelbourg from that of the greater portion of the overlying Shaunavon. Strata which seem correlative with the type Gravelbourg carry a meagre microfauna of *Involutina* and polymorphinid Foraminifera together with a few charophytes and rather featureless ostracodes.

Age and Correlation—Although there have been no truly diagnostic megafossils or microfossils reported from the main portion of the Gravelbourg, regional stratigraphers seem to have shown that the formation is correlative with parts of the Gypsum Spring and Piper formations, and lies within the Bajocian stage of the Middle Jurassic.

SHAUNAVON FORMATION

The following Foraminifera, many of which are figured on Plate 1, have been identified from the Shaunavon. One asterisk denotes a species restricted to this formation in Saskatchewan and two asterisks indicate a species occurring in the transitional beds between the upper Shaunavon

and basal Vanguard. The species of the latter group with the exception of *Involutina* sp. cf. *I. orbis* (Lalicker) and *Polymorphina* sp. all recur at higher levels in the Vanguard. Unmarked species are of limited stratigraphic value as they range through much of the Shaunavon and Vanguard formations:

Eoguttulina amygdalina Loeblich and Tappan
**Globigerina* ? sp.
***Glomospira gordialis* (Jones and Parker)
**Gümbelitria* sp.
Guttulina sp. A
**Involutina francisi*, n. sp.
***I.* sp. cf. *I. orbis* (Lalicker)
**I. southeyensis*, n. sp.
**I.* sp. cf. *I. southeyensis*, n. sp.
Nodosaria lirulata Loeblich and Tappan
Ophthalmidium saskatchewanensis, n. sp.
**Pealerina rhomboidalis*, n. sp.
***Polymorphina* sp.
***Reophax* sp. A
***R.* sp. B
Spirillina amphelicta Loeblich and Tappan
***Triplasia dahindensa* (Loranger)
***Trochammina instowensis*, n. sp.
**Trochammina* ? sp. A.

The following Ostracoda, which are illustrated on Plates 19 to 23 inclusive, have been identified from the Shaunavon formation. An asterisk denotes a species restricted to this formation in Saskatchewan:

**Aparchitocythere* sp. cf. *A. compressa* Peterson
**A. elongata* Peterson
Cythereis ? sp. C
Darwinula leguminella (Forbes)
**Limnocythere climaxia* (Loranger)
**L. pustulosa*, n. sp.
**Metacypris* sp. cf. *M. tenuimarginata* Bernard, Bizon and Oertli
Norcanolella parryi Loranger
**N.* sp. A
**Norcanolella* ? sp. B
**Paracypris* ? sp. A.

Limnocythere climaxia occurs as well in the topmost beds of the underlying Gravelbourg formation which are regarded paleontologically as part of the Shaunavon faunal complex. *Cythereis* ? sp. C was found only in eastern Saskatchewan at the contact of the Shaunavon and Vanguard formations. *Norcanolella parryi* is confined largely to the Shaunavon with a few specimens possibly occurring in the Gravelbourg.

The following Charophyta have been identified near the top of the Shaunavon formation:

Aclistochara rotunda Peck
Stellatochara sublaevis Peck
S. n. sp.

Age and Correlation—The foraminiferal fauna of the Shaunavon contributes little towards correlation of the formation. It is not a very prolific fauna and most of the components are either undescribed or are rather long-ranging. *Involutina* sp. cf. *I. orbis* (Lalicker) is, however, very close

to and probably identical with *Involutina* (formerly *Ammodiscus*) *orbis* from the Bathonian Sawtooth formation of Montana. The genus *Pealerina* (formerly *Ellisina*) seems peculiar to the Sawtooth and Shaunavon formations although the species described herein from the Shaunavon is quite distinct from Lalicker's species in the Sawtooth. With the exception of the two similarities mentioned above, however, there seems nothing in common between the foraminiferal faunas of the type Shaunavon of southwestern Saskatchewan and the Sawtooth of southwestern Montana.

Most of the diagnostic Shaunavon Ostracoda have not been reported from outside Saskatchewan, but this is rather to be expected as no faunas from pre-Rierdon sediments in other areas of the western interior region have been published. One of the previously described species occurring in the upper member of the Shaunavon, *Aparchitocythere elongata* Peterson is a "lower Sundance" (Rierdon correlative) species which seems to occupy a slightly lower stratigraphic position in Saskatchewan than in the Black Hills area. *Aparchitocythere* sp. cf. *A. compressa* Peterson, which is closely related to *A. compressa s.s.*, another "lower Sundance" species, occurs in association with *A. elongata* in the Upper Shaunavon. These observations tend to support the suggestion put forth by Peterson (1954b, p. 489) that the *Aparchitocythere compressa* fauna may have migrated from the north, which would account for its occurrence at a slightly higher stratigraphic level as far south as Wyoming. The species of *Metacypris* seems very closely related to *M. tenuimarginata* Bernard, Bizon and Oertli from the Bathonian of the Paris basin, France.

The previously described charophytes identified from the upper Shaunavon, *Aclistochara rotunda* Peck and *Stellatochara sublaevis* Peck, are known from the Bathonian Piper formation of central Montana (Peck, 1957, p. 10), with the latter species apparently restricted to the Piper.

The megafauna of the Shaunavon, identified by Crickmay and listed by Milner and Thomas (1954, p. 262), is inconclusive in determining age as some of the species have been reported from the Sawtooth and others from the Rierdon in Montana and other areas.

In summary, the microfaunal evidence is for the most part of little assistance in determining the age and correlation of the Shaunavon. The charophyte assemblage near the top of the formation does, however, suggest its equivalence with the Piper formation of central Montana. The broad stratigraphic studies of Francis (1956, pp. 28-30) and Milner and Thomas (1954, p. 262) lend strong support to this observation and, thus, the Shaunavon is herein considered correlative with the Piper and Sawtooth formations of Montana and to occupy the Bathonian stage of the Middle Jurassic.

VANGUARD FORMATION

Distribution Charts

On the distribution charts of the Foraminifera and Ostracoda and on the faunal plates of the writer's dissertation manuscript, the members of the Vanguard formation were further subdivided in an attempt to show any microfossils distinctive of smaller stratigraphic units. The lower member of the Vanguard formation as defined by Milner and Thomas (1954) was divided in west-central and southwestern Saskatchewan into basal, central and upper parts. The basal part included the bottom 30 feet of the member, the upper part where present, the top 20 to 40 feet, and the central part occupied the interval between them which ranged from 100 to about 170 feet.

The revision of the members of the Vanguard formation by Milner and Blakslee (1958) has necessitated minor changes in some of the terminology employed in the design of the original distribution charts and faunal plates. The upper part of the lower member has been reassigned to the middle member. The central part has been changed to the main part of the lower member. The basal part is retained as used originally to include the bottom 30 feet of the member. The main part includes the remainder of the member which varies considerably in thickness among the wells studied for this project. A maximum thickness of 175 feet was recorded for the main part of the lower member in the Tidewater Frontier Crown No. 1 well in southwestern Saskatchewan.

For this study, the upper member of the Vanguard has been divided in southwestern Saskatchewan into lower and upper parts characterized by calcareous and arenaceous Foraminifera, respectively. The upper part is 45 to 50 feet thick in both the Tidewater Instow Crown No. 1 and Tidewater Frontier Crown No. 1 wells of this area. The lower part shows no such consistency, however, as it is about 18 feet thick at Instow and approximately 100 feet at Frontier. This variation seems attributable to the presence of the middle sand member of the Vanguard at Instow and its absence at Frontier further west.

Faunal Lists

For convenience in showing regional correlation, the microfaunas of the Vanguard formation are discussed under two divisions, (1) the lower, which includes species occurring in the lower member of Milner and Blakslee or the Rierdon equivalent of Francis, and (2) the upper, which includes species occurring in the middle and upper members of Milner and Blakslee or the Swift correlative of Francis.

(1) Microfauna from lower member (Lower Vanguard) or Rierdon equivalent

The following Foraminifera, most of which are figured on Plates 2 to 7, have been identified from this lower division. The list comprises three-quarters of the species studied for the entire project. An asterisk denotes a species apparently restricted to these beds in Saskatchewan on the basis of the material examined. An (E) indicates a species which, in Saskatchewan, was not recorded in this study beyond the eastern border area. The names of formations or members, from which the restricted species have been reported in other areas of the western interior region, are included opposite the particular species involved:

Ammobaculites cobbani Loeblich and Tappan
A. venustus Loeblich and Tappan
A. sp. D
**Ammobaculoides* sp. cf. *A. phaulus* Loeblich and Tappan
**Ammomarginulina* sp. cf. *A. baryntica* Loeblich and Tappan
**Astacolus* sp. cf. *A. agalmatus* Loeblich and Tappan
A. ectypus Loeblich and Tappan
(E) **A. petalus* Loeblich and Tappan . . . Rierdon and Stockade Beaver
Citharina entypomatus Loeblich and Tappan
**C. latissima* Loeblich and Tappan . . . Rierdon and Stockade Beaver
**Citharinella compara* Loeblich and Tappan . . . Rierdon and Stockade Beaver
**C. latifolia* Loeblich and Tappan . . . Rierdon and Stockade Beaver

*C. *rhomboidea* Loeblich and Tappan . . . Redwater
Conorboides hofkeri (Bartenstein and Brand)
Dentalina ectadia Loeblich and Tappan
*D. *gracilistriata* Loeblich and Tappan var.
D. sp. cf. *D. liota* Loeblich and Tappan
D. sp. cf. *D. propinqua* Terquem
D. sp. A.
Eoguttulina amygdalina Loeblich and Tappan
Glomospira gordialis (Jones and Parker)
Guttulina stilla Lalicker
Guttulina sp. A
**Involutina cheradospira* (Loeblich and Tappan) . . . Rierdon
I. sp. cf. *I. orbis* (Lalicker)
Lenticulina audax Loeblich and Tappan
L. dilecta Loeblich and Tappan
**Lingulina hathra* Loeblich and Tappan . . . Rierdon and Stockade Beaver
L. tumida Loeblich and Tappan
L. micida Loeblich and Tappan
**L.* sp. B
**L.* sp. C
(E) **Marginulina* sp. cf. *M. scapha* Lalicker
**Marginulinopsis phragmites* Loeblich and Tappan . . . Rierdon and Stockade Beaver
**M. bandyi*, n. sp.
(E) **M. carievalensis*, n. sp.
(E) **M.* sp. B
* *Nodophthalmidium* sp.
Nodosaria balteata Loeblich and Tappan
N. lirulata Loeblich and Tappan
N. mecista Loeblich and Tappan
* *N. orthostoecha* Loeblich and Tappan . . . Rierdon
* *N. sphingothalama* Loeblich and Tappan . . . Rierdon
* *Nubeculinella* sp.
Ophthalmidium saskatchewanensis, n. sp.
**O.* sp. A
Polymorphina sp.
**Quinqueloculina* sp.
Reophax sp. A
R. sp. B
Spirillina amphelicta Loeblich and Tappan
Triplasia dahindensa (Loranger)
**Tristix nitidula* Loeblich and Tappan . . . Stockade Beaver
(E) **T. wapellensis*, n. sp.
**Trochammina rushlakensis*, n. sp.
**Turrispirillina* ? sp.
Vaginulina sp. cf. *V. cataulaca* Loeblich and Tappan
**V. inspissata* Loeblich and Tappan . . . Redwater
V. wickendeni, n. sp.
**Vaginulina* ? sp. A.
V. sp. B
**Vaginulinopsis* sp. cf. *V. enodis* Loeblich and Tappan
**V.* sp. cf. *V. epicharis* Loeblich and Tappan
**V. eritheles* Loeblich and Tappan . . . Rierdon and Stockade Beaver
**V. loeblichorum*, n. sp.
**V. loeblichorum*, var. A
**V. loeblichorum*, var. B

V. milneri, n. sp.
V. thomasi, n. sp.
**V.* sp. A
**V.* sp. B
V. sp. C
Verneuilinoides tryphera Loeblich and Tappan

The following Ostracoda, which are illustrated on Plates 24 to 26, have been identified from this lower faunal division. An asterisk denotes a species seemingly confined to this stratigraphic level based on present sample coverage:

**Bythocypris ambitruncata* Peterson . . . Rierdon
**Cythereis heteromorpha* Peterson . . . Rierdon
C. rushlakensis, n. sp.
C. rushlakensis var.
Cythereis ? sp. C
Cytherella paramuensteri Swain and Peterson
**Cytherelloidea recurvata* Peterson . . . Rierdon
Eucytherura reticulata Peterson
**Monoceratina incisa* Peterson . . . Rierdon
**M. pararossae* Peterson . . . Rierdon
**M. vulsa* (Jones and Sherborn)
Orthonotacythere dorsoconvexa Peterson
Paracypris projecta Peterson
**Procytheridea crassa* Peterson . . . Rierdon
P. exempla Peterson
**P. minuta* Peterson . . . Rierdon
**Progonocythere anoda* Peterson . . . Rierdon

Age and Correlation—Of the 38 foraminiferal forms apparently restricted to this lower faunal division, 19 are undescribed, six are compared with species from various formations, 11 are reported from the Rierdon formation or Stockade Beaver member of the Sundance, and two are known from the Redwater shale member (Swift correlative) of the Sundance but they are definitely rare. The evidence thus furnished by the foraminiferal fauna points to a Callovian age for the associated sediments and their correlation with the Rierdon formation of Montana and Stockade Beaver member of the Sundance formation in the Black Hills area.

Of the nine ostracodes restricted to this lower division in Saskatchewan, eight have been reported from the Rierdon of Montana. *Eucytherura reticulata* and *Orthonotacythere dorsoconvexa*, Rierdon species, are almost entirely restricted to this lower level in Saskatchewan and *Procytheridea exempla*, prominent Rierdon form, occurs abundantly in these beds. The ostracode assemblage indicates a Callovian age for the enclosing rocks and points very definitely to their equivalence with the Rierdon formation of Montana.

(2) Microfauna from the middle and upper members (Upper Vanguard) or Swift equivalent

The following Foraminifera, most of which are figured on Plates 14 to 18, have been identified from this upper division. An asterisk denotes a species which, on the basis of material available for study, is apparently restricted to these beds in Saskatchewan:

Ammobaculites cobbani Loeblich and Tappan
**A. imlayi* Loeblich and Tappan . . . Redwater

A. venustus Loeblich and Tappan
**A.* sp. A
A sp. D
**Ammomarginulina baryntica* Loeblich and Tappan . . . Redwater
**A.* sp. A
**A.* sp. cf. *A. cragini* Loeblich and Tappan
Astacolus ectypus Loeblich and Tappan
**Bulbobaculites* ? sp.
Citharina entypomatus Loeblich and Tappan
Conorboides hofkeri (Bartenstein and Brand)
Dentalina ectadia Loeblich and Tappan
**D.* sp. cf. *D. ejuncida* Loeblich and Tappan
D. sp. cf. *D. liota* Loeblich and Tappan
D. sp. cf. *D. propinqua* Terquem
Eoguttulina amygdalina Loeblich and Tappan
**Flabellammina instowensis,* n. sp.
Guttulina stilla Lalicker
** Haplophragmoides tryssa* Loeblich and Tappan . . . Redwater
** H.* sp. cf. *H. linki* Nauss
Lenticulina audax Loeblich and Tappan
L. dilecta Loeblich and Tappan
**L.* sp. A
Lingulina micida Loeblich and Tappan
L. tumida Loeblich and Tappan
**Massilina* sp. of Loeblich and Tappan . . . Redwater
**Miliammina* sp.
Nodosaria balteata Loeblich and Tappan
N. lirulata Loeblich and Tappan
N. mecista Loeblich and Tappan
** N.* sp. A
Spirillina amphelicta Loeblich and Tappan
Triplasia dahindensa (Loranger)
Trochammina instowensis, n. sp.
Vaginulina sp. cf. *V. cataulaca* Loeblich and Tappan
**V.* sp. cf. *V. compsa* Loeblich and Tappan
V. wickendeni, n. sp.
Vaginulinopsis milneri, n. sp.
V. thomasi, n. sp.
V. sp. C
Verneuilinoides tryphera Loeblich and Tappan

The following Ostracoda, most of which are illustrated on Plates 27 and 28, have been identified from this upper division. An asterisk denotes a species restricted to this stratigraphic level on the basis of available material.

**Cythereis robertsi,* n. sp.
C. rushlakensis, n. sp.
C. rushlakensis var.
Cytherella paramuensteri Swain and Peterson ?
Eucytherura reticulata Peterson
Orthonotacythere dorsoconvexa Peterson
Paracypris projecta Peterson
Procytheridea exempla Peterson
**P. radvillia* Loranger
**P.* sp. A
**Progonocythere crowcreekensis* Swain and Peterson . . . Swift
**P. hieroglyphica* Swain and Peterson . . . Swift
**P.* sp. A

Age and Correlation—Of the 15 Foraminifera apparently restricted to the upper faunal division, seven are undescribed forms, four are compared with species from various formations, and four species have been reported from the Redwater shale member (Swift correlative) of the Sundance formation of the Black Hills area. No exclusively Rierdon species are confined to this stratigraphic level. Although the evidence is not very strong, the foraminiferal content of these beds suggests an Oxfordian age, and their correlation with the Swift and its equivalents is indicated.

Of the six ostracodes restricted to this faunal division, two are exclusively Swift species, three have not been reported outside of Saskatchewan, and one (*Cythereis robertsi*, n. sp.) was described in an unpublished work by Roberts (1934) from undifferentiated Sundance in the Wind River basin of central Wyoming. The Rierdon species, *Eucytherura reticulata* and *Orthonotacythere dorsoconvexa*, are definitely rare in this upper division in Saskatchewan, the latter represented by only one specimen. The evidence supplied by the ostracodes is not particularly impressive, but like the Foraminifera it again suggests an Oxfordian age for the sediments, and indicates their equivalence with the Swift and its correlatives in various areas of the western interior region.

Comparison of Ostracoda with Sundance fauna of central Wyoming

An examination of Roberts (1934) unpublished work on the ostracodes from the Sundance formation in the Wind River basin of central Wyoming shows a considerable number of species in common with the Saskatchewan Vanguard assemblages. The following paired species are identical:

Vanguard of Saskatchewan	Sundance of Wind River basin (Roberts' manuscript names)
Cythereis robertsi, n. sp.	*C. antiprojecta*
C. rushlakensis, n. sp., var.	*C. projecta*
Cytherella paramuensteri S. and P.	*Cytherella sundancensis*
Cytherelloidea recurvata P.	*Cytherelloidea pulchra*
Monoceratina pararossae P.	*M. pentagona*
Orthonotacythere dorsoconvexa P.	Unnamed—Roberts, Pl. 1, figs. 13, 14
Paracypris projecta P.	*Paracypris? tenuis*
Procytheridea crassa P.	*Cythereis brevicula*
P. exempla P.	*Isocythere trilineata*
P. minuta P.	*Cythereis quadrilineata*
Progonocythere anoda P.	*Cythereis sundancensis*

As there was little or no stratigraphic control of Roberts' collections, the present writer is not able to delineate Rierdon and Swift equivalents in this area, but awareness of this faunal similarity may assist paleontologists in future work.

INDEX MICROFOSSILS

Foraminifera

Most Jurassic species of Foraminifera appear rather long-ranging and are unsuitable as indices for any interval shorter than a series. This generalization seems to hold for the western interior region, as many of the Callovian species range through the Oxfordian. Bielecka and Pozaryski (1956) report many of the Polish Jurassic species ranging through much of the period and even into the Lower Cretaceous. Without considerable further taxonomic and biostratigraphic research, it seems doubtful that Jurassic Foraminifera can be used with much accuracy for intercontinental correlation between North America and Europe. Some

of the North American species proposed as new by various authors may well be identical with European species, but specimen comparisons would be necessary to confirm such postulations.

Intercontinentally, the *Lenticulina dilecta* group of species seems characteristic of the Upper Jurassic series in North America and Europe. "*Cristellaria*" *sarthacensis* Schwager from the Oxfordian of Germany, "*Cristellaria*" *bruckmanni* Myatliuk from the Oxfordian of Russia and the Kimmeridgian of Poland, and *Lenticulina dilecta* L. and T. from the Callovian-Oxfordian of North America are very similar and may be conspecific.

In the western interior region, the following four common species seem diagnostic of Callovian strata and, in Saskatchewan, are restricted to the lower member of the Vanguard formation or the Rierdon equivalent:

Involutina cheradospira (L. and T.)
Lingulina hathra L. and T.
Marginulinopsis phragmites L. and T.
Vaginulinopsis eritheles L. and T.

It is difficult to compile a list of Oxfordian index Foraminifera for the western interior region because of the long-ranging nature of many of the species involved and because of spotty sample coverage in Saskatchewan. Although a considerable number of species attained their acmes in Oxfordian time, most of this group are found in Callovian strata as well, at least in Saskatchewan. *Ammobaculites imlayi* L. and T. seems confined to the Oxfordian stage in all areas studied, and although a rather featureless species, it is fairly common and serves as a suitable index. *Ammomarginulina baryntica* L. and T. also appears restricted to the Oxfordian stage, but it is rather rare and thus not a very satisfactory index. *Haplophragmoides* sp. cf. *H. linki* Nauss is a common species in Oxfordian strata (Swift equivalent or Upper Vanguard) of Saskatchewan, but as *H. linki s.s.* is found in Lower Cretaceous strata of Alberta, the form compared with it may reasonably be expected to recur at higher levels.

Ostracoda

The marine ostracodes are better than the Foraminifera for the purpost of effecting regional correlation in the Upper Jurassic of the western interior. Many of the species seem to have been relatively short-lived with the result that each stage has a rather distinctive fauna. Unfortunately, however, the ostracodes are not as common as the Foraminifera and this comparative paucity detracts considerably from their usefulness.

Callovian index fossils include:

Bythocypris ambitruncata P.
Cythereis heteromorpha P.
Cytherelloidea recurvata P.
Monoceratina incisa P.
M. pararossae P.
Procytheridea crassa P.
P. minuta P.

Oxfordian index fossils include:

Progonocythere crowcreekensis S. and P.
P. hieroglyphica S. and P.
Cythereis robertsi, n. sp. (for Saskatchewan).

The few similarities noticed to date getween Jurassic species in North America and Europe indicate difficulty in using this group for intercontinental correlation.

Charophyta

This group was not intensively studied in Saskatchewan except near the top of the Shaunavon formation where it occurs abundantly in association with fresh water ostracodes. The charophytes and ostracodes here constitute an ecological unit of widespread occurrence in western Canada and possibly in Montana and other areas. This ecological unit has a very short vertical and a wide lateral distribution, and, as its biotopes appear to have been synchronous everywhere, it provides an excellent time plane. The presence of one or more similar ecological units in older beds of the Jurassic of Saskatchewan seems indicated. Such units may become useful in detailed correlation studies.

LOCAL ZONATION BY MICROFOSSILS

Microfaunal zones for use in primarily local correlations were not formally established in this study because the author has been concerned more with the regional aspects of the faunas. In the preceding section, however, microfossils diagnostic of Callovian and Oxfordian strata in the province were listed and these may be used for broad determination of stratigraphic position within the Vanguard formation. Attempts at a detailed microfaunal zonation of the Saskatchewan Jurassic seemed unwarranted at the time of this study because of the limited amount of core coverage and the undesirability of basing determinations on bit cuttings obtained from a rapidly drilled section with the attendant high risk of contamination.

Notwithstanding these difficulties, Loranger (1955) proposed rather informally a number of zones which tend to be somewhat misleading either because they are found associated with stratigraphic levels besides those originally designated, or because the fossils denoted as characteristic occur commonly in contiguous zones. As an example of the first case, Zone B of Loranger, which is the faunal equivalent of the charophyte-ostracode assemblage from the upper Shaunavon, was considered by Loranger to be associated with the top of the Gravelbourg formation. In the second case, *Triplasia dahindensa* (Loranger) and *Conorboides hofkeri* (B. and B.), incorrectly identified as *Patellina crista* Lalicker, were thought by Loranger to be distinctive of Zones D and E, respectively, but these species occur with about the same frequency in both zones. The presence of *C. hofkeri* in the lower Vanguard was, however, later recognized by Loranger (Klingspor, 1958, p. 32). Some of this confusion may be attributed to the use of drill cuttings in Loranger's earlier work (1955), which would explain the apparent occurrences of some of these forms in beds below their true stratigraphic levels.

CHAPTER V

PALEOECOLOGY

INTRODUCTORY STATEMENT

Interpretations of the environments of Jurassic foraminiferal and ostracode species are necessarily speculative because none of these forms has lived to the Present. Ecological studies in Recent waters are concerned with the distribution of individual species and not genera or families. As reported in several recent publications in this field (Said, 1950, for example), the species of one genus may occupy a wide range of depth or temperature zones. Thus, interpretation of ecological conditions based on genera alone may lead to erroneous conclusions. In working out the paleoecology of entirely fossil faunas, we are, however, compelled to use the evidence available, which consists of the generic character of the assemblage and the morphological similarities of some extinct forms to Recent species.

GRAVELBOURG FORMATION

Theorization regarding the environments in which the various Saskatchewan Jurassic microfaunas lived is virtually confined to the Shaunavon and Vanguard suites. The red beds and evaporites of the Watrous formation were not included in this study and the Gravelbourg formation yielded few microfossils. The charophyte-ostracode assemblage observed in the Gravelbourg at the Instow well in southwestern Saskatchewan indicates the environment was probably not truly marine. Sporadic occurrences of *Involutina* (formerly *Ammodiscus*), polymorphinid Foraminifera, ostracodes including a few specimens of *Norcanolella*, and charophytes in Gravelbourg strata point to conditions other than normal marine. Through observation of various fossil associations, the author believes that all these organisms either thrived in waters of reduced salinity or could readily adapt to such an environment.

SHAUNAVON FORMATION

Lower Member

A rather meagre assemblage of Foraminifera was obtained from the few green shale beds intercalated with the buff lithographic limestone, the characteristic lithology of the Lower Shaunavon. *Eoguttulina, Nodosaria* and *Spirillina* occur in the shale beds and *Ophthalmidium* was observed in the limestone phase. An ostracode, *Aparchitocythere*, also occurs in the limestone beds. These Foraminifera are not particularly diagnostic of any segment of the marine environment, but evidence furnished by the megafossils and lithological character of the sediments indicates shallow depth. The pelecypod fauna reported by Crickmay in Milner and Thomas (1954, p. 262) includes the genera *Camptonectes, Corbula, Ostrea, Pinna* and *Protocardia* which point to a shallow marine environment. Concerning lithological evidence, Francis (1956, p. 49) stated, "the presence of oolites in this member indicates deposition in shallow waters, saturated with calcium carbonate and possessing considerable energy."

Upper Member

A complex paleoecological pattern is shown by the diverse assemblages of microfossils observed in this member. In general, the water appears to have been less saline than during the deposition of the lower member. The presence of *Ostrea* and *Gryphaea* in this member reported by Crickmay in Milner and Thomas (1954, p. 262) indicates shallow and somewhat brackish marine water. The fragmental limestones, varicolored shales,

and carbonaceous matter in this member are regarded by Francis (1956, p. 49) as evidence for the continuation of shallow waters during its deposition. The microfaunal assemblages are now discussed in some detail.

The lower part of the member carries a microfauna dominated by the ostracode *Aparchitocythere* (abundant) and polymorphinid Foraminifera. *Involutina* (formerly *Ammodiscus*) is abundant at this level in the west-central area. *Darwinula* and *Limnocythere* occur sporadically to commonly in the southwestern and west-central areas and *Norcanolella* is common to abundant in the west-central area. Although *Aparchitocythere* is not known from Recent waters, its association with Jurassic faunas elsewhere points to a normal or nearly normal marine habitat. The polymorphinid Foraminifera, although apparently typically normal marine forms in Recent oceans, are believed from their association with other organisms to have lived under conditions of subnormal salinity. *Darwinula* and *Limnocythere* occur today in virtually fresh to slightly brackish waters (Swain, 1955), but possibly fossil species had greater salinity tolerance. The ecological implication of *Norcanolella* is not clear but it probably preferred a salinity below that of normal marine water. Thus, from the foregoing interpretation of the microfaunal ecology, it seems likely that a shallow marine environment persisted in southwestern Saskatchewan during the deposition of the lower part of this member with waters becoming progressively less saline and probably shallower in a northeasterly direction. Essentially similar environmental conditions seem to have prevailed until near the end of the time involved in the deposition of this member.

A sudden and widespread change in environment is postulated for a short interval close to the end of the period in which this member was deposited. This hypothesis is based on the abundance of charophytes and ostracodes of a definite fresh water habitat near the top of the member. The ostracodes present are *Darwinula, Limnocythere, Metacypris* and *Paracypris*? The first three are typical Recent fresh water genera (Grekoff, 1956, p. 80) and there is good reason to believe that the species questionably referred to *Paracypris* also indicates fresh water as similar species have been found in the Purbeckian and other non-marine deposits.

As this charophyte-ostracode zone is contained within a maximum interval of 10 feet and generally probably does not include more than five feet, a short time span may be assumed for the existence of this biotope. In wells where the percentage of core recovery is low, the thinness of the zone is further attested by the paucity of the specimens obtained, especially if the few highly fossiliferous bands are lost. The ubiquity of this biofacies is shown by its occurrences in southwestern and eastern Saskatchewan, a distance of over 300 miles. It seems to be present farther east in Manitoba where Stott (1955, p. 31) reported charophyte oogonia and ostracodes in his Lower Melita unit which appears to be stratigraphically equivalent to the Upper Shaunavon. This biofacies may well extend into central Montana as identical species of Charophyta are present in the Piper limestone (Peck, 1957, p. 10). An investigation of the ostracode element of the Piper microfauna and more complete knowledge of stratigraphic position would be required, however, before assuming that the Piper and Shaunavon assemblages are part of the same biofacies.

It is difficult to account for the occurrence of this apparently nearly fresh water biotope in a succession of marine or brackish biotopes. Some widespread, sudden physical or chemical changes seem to have rendered conditions favorable for the "bloom" of the chara plant and the success of the fresh water ostracodes. The extensive occurrence of this assemblage,

the profusion and excellent preservation of the specimens appear to rule out the possibility that these organisms lived elsewhere and after death were transported to the sea by rivers. They may have originated in a fluviatile environment, but were able to expand their habitat to include the shallow sea because of optimum conditions there.

It is quite possible also that the water was more brackish than one would expect from the observance of such a normally fresh water assemblage of charophytes and ostracodes. Olsen (1944, p. 205) reported the upper salinity limit for brackish species of Charophyta living in the Baltic sea seems usually 18 parts per thousand or about half the ocean salinity of 35 parts per thousand. The ostracodes *Darwinula* and *Limnocythere*, normally associated with a fresh water environment, also live in the upper part of San Antonia Bay, Texas (Swain, 1955), where chlorinity ranges from one to 16 parts per thousand (open gulf or normal marine chlorinity is 20 parts per thousand). Definite knowledge of the salinity tolerance of living *Metacypris* is lacking, but some fossil species may have lived in brackish water (Hoare, 1953).

A sparse foraminiferal fauna is associated with this charophyte-ostracode assemblage over much of Saskatchewan. Except in the Eastend and Frontier wells, where it is absent, the foraminifer *Involutina* (formerly *Ammodiscus*) occurs commonly at this level in other western Saskatchewan wells examined, and is present also in some eastern Saskatchewan wells. In two of the west-central area wells, a weak assemblage of pelagic Foraminifera (*Globigerina* and *Gümbelitria*) was observed at this level. In Recent oceans, such pelagic forms are characteristic of the outer bathyal and abyssal zones, but are known to be transported into much shallower waters (Todd and Bronniman, 1957, p. 40). As many individuals of this assemblage are worn and appear to have been reworked, it is theorized that they were washed into the area and probably rolled along the bottom of this shallow depositional basin near its shoreline. A similar near shore occurrence of *Globigerina* is indicated by Weynschenk (1950, p. 9) who reported this genus in littoral mudstones of the Lower Jurassic of the Tirol.

As mentioned previously, conditions favorable to the existence of the charophyte and non-marine ostracode biota were short lived. A return to a more brackish environment is shown by the dominantly arenaceous foraminiferal fauna occurring in the topmost beds of the Shaunavon, that is, in the transitional green shale beds between the Shaunavon and Vanguard formations. This fauna includes representatives of *Glomospira*, *Involutina*, *Reophax*, *Triplasia*, *Trochammina* and *Polymorphina*. *Involutina*, *Reophax* and *Trochammina* are known from Recent shallow waters and the Polymorphinidae have a wide depth range. *Triplasia* is unknown in Recent waters, but by faunal association, is deduced to have lived in shallow waters of past seas. Recent species of *Trochammina* and *Reophax* are well developed in very shallow, brackish water in ponds and lagoons adjacent to the Atlantic coast of the New York-New England area (Ronai, 1955; Said, 1953).

VANGUARD FORMATION

Environmental aspects of the Vanguard microfossil assemblages are discussed under the same two-fold division employed for showing the regional correlation of the faunas, that is, (1) the Lower Vanguard or Rierdon equivalent (Callovian) and (2) the Upper Vanguard or Swift equivalent (Oxfordian).

(1) *Lower Vanguard or Rierdon equivalent*

The general nature of the microfossils in sediments equated with the Rierdon points to a middle or inner neritic, normal or nearly normal

marine environment of deposition. Calcareous Foraminifera, the Lagenidae in particular, dominate the microfauna. Although members of this family have a wide bathymetric range in Recent oceans, they do occur commonly in shallow waters of the neritic zone in some areas (Norton, 1930) and it is reasonable to expect similar occurrences in past oceans (Khan, 1950, p. 176; Weynschenk, 1950, p. 26). Attached ophthalmidiids, which are common to abundant at and near the base of this section, would seem indicative of shallow water especially as the substratum is typically *Ostrea*. Parker (1948, p. 227) reported attached forms at a depth of 12 metres off Cape Cod Light, Massachusetts.

The arenaceous fauna is definitely overshadowed quantitatively and qualitatively by the calcareous element. It consists chiefly of a large species of *Involutina* (formerly *Ammodiscus*) (abundant), *Ammobaculites* (common), and fine to medium-grained individuals of *Triplasia* (sporadic). *Trochammina* is not a conspicuous component of the arenaceous suite. This relatively weak arenaceous fauna in itself would seem to indicate that salinity was at normal marine level. Recent contributions of foraminiferal ecologists (Phleger, 1954, for example) suggest that faunas dominated by arenaceous elements are characteristically brackish in habitat.

Most of the ostracode genera are either unknown in present seas or are referred with some reservation to Recent genera. *Cytherella* and *Cytherelloidea*, which were observed sporadically in these beds, are reported living between depths of 100 to 200 metres in the neritic zone (Grekoff, 1956, p. 80). *Bythocypris* and *Paracypris* also live in the neritic zone and it is believed that seemingly congeneric forms buried in the Rierdon sediments occupied similar habitats in the past. *Procytheridea*, the dominant ostracode in this fauna, is only known in the fossil state, but is closely related to *Cytheridea* and its subgenera which prefer shallow marine water, possibly of diminished salinity (Grekoff, 1956, p. 45).

In the southwestern area of Saskatchewan, the water in which the Rierdon sediments accumulated seems to have been somewhat deeper than in the west-central and eastern areas of the province. This observation is based, however, on incomplete sample coverage from two wells. The absence of attached Foraminifera, the virtual disappearance of arenaceous forms, reduced foraminiferal populations in general, and weak showing of ostracodes point to a deeper water environment in the middle or outer neritic zone with little, if any, reduction in normal salinity. This hypothesis seems substantiated by regional stratigraphic studies of various workers which show the centre of the depositional basin in adjacent northern Montana.

(2) *Upper Vanguard or Swift equivalent*

The microfaunal assemblages obtained from the middle and upper members of the Vanguard formation reflect a shallowing of the seas and development of brackish conditions over most of the province. Both features become progressively more evident as this interval of sedimentation drew to a close. The southwestern area, again, was nearest the centre of the depositional basin. Changes in biofacies become rather pronounced in sediments deposited in the Kelstern-Rush Lake (west-central) area near the shoreline of the Oxfordian sea.

Southwestern area—The foraminiferal fauna of the Frontier well is probably a neritic assemblage. It consists chiefly of lagenids (dominant), *Conorboides* (common), and *Eoguttulina* (sporadic). Arenaceous forms are of minor importance except in the upper portion of the Swift section

where the calcareous elements disappear. Ostracodes are rare throughout this section.

The arenaceous fauna is much better developed in the Instow well, 37 miles to the northeast, in shale beds above the middle sand member of the Vanguard. The middle sand member is absent at Frontier and that part of the province west of Range 17, W. 3, (Francis, 1956, p. 34). The calcareous fauna, on the other hand, is not as well developed at Instow where a shallowing trend is already indicated with increase in sand content of the section.

The arenaceous fauna at Instow consists of *Ammobaculites, Ammomarginulina, Bulbobaculites?, Flabellammina, Haplophragmoides, Miliammina, Proteonina, Triplasia, Trochammina* and *Verneuilinoides. Trochammina* is the dominant genus but *Ammobaculites, Ammomarginulina, Haplophragmoides* and *Verneuilinoides* are all important constituents of the fauna. A shallow, slightly to moderately brackish water environment is implied by such a faunal suite. Species of *Ammobaculites, Miliammina, Proteonina* and *Trochammina* are characteristic of lagoons and ponds along the Atlantic coastline where the salinity is much below that of normal marine water (Ronai, 1955; Said, 1953). The dwarfing of species of *Bulbobaculites?, Miliammina, Trochammina* and *Verneuilinoides* is perhaps suggestive of an oxygen deficiency and resulting unaerated bottom (Said, 1953). Virtually all the individuals of *Bulbobaculites?, Haplophragmoides, Miliammina, Trochammina* and *Verneuilinoides* are pyritized. Similar conditions have been reported in Cretaceous foraminiferal faunas by Stelck and Wall (1955, p. 28) and Bolin (1956, p. 284), and are thought to indicate rather toxic conditions such as might be encountered in a lagoonal environment with restricted circulation.

West-central area—The microfauna of the Kelstern well shows the change in biofacies taking place as the edge of the basin is approached. In the basal beds of the middle member of the Vanguard as revised by Milner and Blakslee (1958), lagenids are dominant and *Eoguttulina* is common. An arenaceous fauna consisting of *Ammobaculites*, coarse-grained *Ammomarginulina* and coarse-grained *Triplasia* is rather weak at Kelstern but is much better developed to the north at Rush Lake. No calcareous Foraminifera were observed above the level of this mixed calcareous-arenaceous suite, which is possibly explained by the water becoming much shallower and less saline. The thick (100 feet) sand unit of the middle member at Kelstern is interrupted by a thin shale tongue carrying coarse-grained *Triplasia* (abundant) and *Trochammina* (common), which are probably lagoonal in habitat. An arenaceous fauna, consisting chiefly of *Ammobaculites, Trochammina* and *Verneuilinoides,* is present in the shale at the top of the middle member of the Vanguard indicating that a shallow, brackish-water environment prevailed when these beds were deposited. From an assessment of the microfauna in the upper member of the Vanguard at Instow, it may be assumed that a similar brackish-water environment persisted in the west-central area until the onset of fresh water or continental deposition represented in the overlying "Blairmore" formation.

CHAPTER VI

SYSTEMATIC MICROPALEONTOLOGY

INTRODUCTION TO TAXONOMY

This chapter is devoted to the description, areal and stratigraphic distribution, and relationships of 95 species and varieties of Foraminifera and 33 species and varieties of Ostracoda obtained from the Jurassic rocks of Saskatchewan. The data on areal and stratigraphic distribution, and relative abundance of the various species described are summarized on charts 1 and 2 for the Foraminifera and Ostracoda, respectively.

Of the 95 species and varieties of Foraminifera, 37 are identical with described species, 14 are compared with described species, 14 are proposed as new, and 30 are left as *nomina aperta*. Of the 33 species and varieties of Ostracoda, 21 are identical with described species, two are compared with described species, three are proposed as new, and seven are left as *nomina aperta*.

A considerable number of forms were not named because of their rarity, small size, lack of distinguishing features or difficulty in appraising variability. Some of these forms are, however, useful stratigraphically and have been included largely for this reason. Letter designations have been used for these unnamed forms where more than one has been assigned to the same genus. The letter designations refer to the same species in both the writer's dissertation and in this publication. Some of the species designated by letter in the dissertation have been assigned to previously described species or proposed as new in this publication. All such cases involving any reassignment of species upon transfer from the dissertation to this publication are recorded under the remarks in the descriptions of the species.

Considerable information on the composition of the microfaunal suites has been offered in previous discussions of their stratigraphic and ecological significance. The few additional data presented here are concerned only with some taxonomic aspects of the faunas.

The Foraminifera are described in a sequence following Glaessner's (1947) scheme of classification which is outlined in the table of contents. The foraminiferal fauna is dominated by the Family Lagenidae with 51 species and varieties belonging to 12 genera. Such prominence of lagenids seems characteristic of Jurassic microfaunas in other parts of the world. The Lituolidae are the second most prominent family with 14 species belonging to six genera. The Tolypamminidae are represented by six species belonging to two genera; the Polymorphinidae by five species belonging to four genera; the Ophthalmidiidae by four species belonging to three genera. Nine other foraminiferal families are represented by a total of only 15 species.

Considerable difficulty was experienced in assignment of forms to those lagenid genera which are gradational with one another. The *Lenticulina-Astacolus-Planularia* lineage is an example of such an intergradational series. The policy followed in this study has been to leave species in the lagenid genera to which they have been assigned by the original authors, even though the present author believes that in some cases they would be more properly placed in other genera. Reassignment of published names would, however, only add to the confusion already surrounding the status of some of these genera.

Cifelli (1960) has drawn attention to the difficult problems of taxonomy generated by the wide variation within lagenid populations. In

this respect, the present author acknowledges that recognition of some of the lagenid genera encountered in this study may well be based on characters of significance only for species differentiation. A thorough taxonomic revision of this family is needed but it is too formidable a task to be undertaken in any form except as a strictly systematic study.

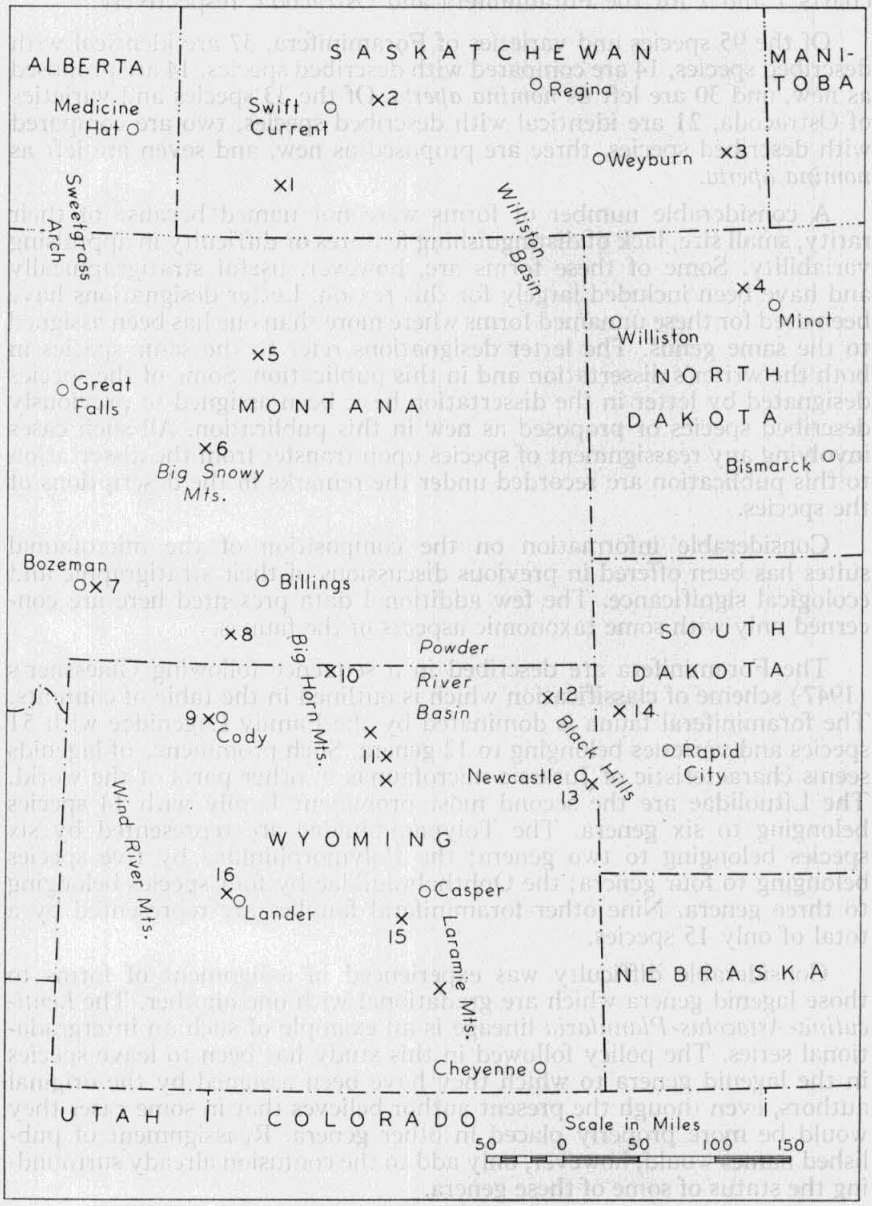

Figure 4.—Index map of western interior region showing microfossil localities of various authors. Numbers refer to list of localities on following pages.

The Ostracoda are dominated by the Family Cytheridae with 27 species belonging to 10 genera. The Cytherellidae are represented by two species belonging to two genera. The remaining three families, Cypridae, Bairdiidae and Darwinulidae are represented by a total of only four species.

MICROFOSSIL LOCALITIES OF WESTERN INTERIOR REGION

A list of the localities in the western interior region from which Jurassic microfossils have been obtained by various workers is given in the following section. References are made to these localities in the discussion of the stratigraphic distribution of the species herein described. The approximate positions of the microfaunal localities are shown on the accompanying index map (Figure 4).

1.—Saskatchewan, southwestern area, central point of group of wells. Type area of Gravelbourg and Shaunavon formations; sections of Vanguard formation.

2.—Saskatchewan, west-central area, central point of group of wells. Type area of lower and middle members of Vanguard formation; sections of Upper Shaunavon.

3.—Saskatchewan, eastern area, central point of group of wells. Sections of Lower Vanguard and Upper Shaunavon.

4.—North Dakota, Ward County, J. H. Kline well no. 1, 3½ miles southeast of Carpio. Sundance formation. Locality 7 of Loeblich and Tappan, 1950b, p. 6.

5.—Montana, Little Rocky Mountains, Phillips County. Rierdon and Swift formations. Locality XX of Peterson, 1954a, p. 158.

6.—Montana, Big Snowy Mountains, Fergus County. Piper (type section), Rierdon and Swift formations. Localities Js-XVII and Js-XVIII of Peterson, 1954a, p. 158; locality 2 of Loeblich and Tappan, 1950b, p. 6; locality D-294 of Peck, 1957, p. 10.

7.—Montana, Gallatin County, 7 miles southeast of Bozeman. Type section of Ellis group (Sawtooth, Rierdon and Swift formations). Collecting locality of Lalicker, 1950, p. 5.

8.—Montana, Pryor Mountains, Carbon County. Ellis group (Piper, Rierdon and Swift formations). Locality Js-XVI of Peterson, 1954a, p. 156; locality 1 of Loeblich and Tappan, 1954b, p. 6.

9.—Wyoming, Park County, 2 miles west of Cody. "Lower" and "Upper Sundance" formations. Locality Js-X of Peterson, 1954a, p. 158; locality 5 of Loeblich and Tappan, 1950b, p. 6.

10.—Wyoming, Big Horn Mountains, Sheridan County. Stockade Beaver shale member, Hulett sandstone member and Redwater shale member of the Sundance formation. Locality Js-XV of Peterson, 1954a, p. 156; locality 4 of Loeblich and Tappan, 1950b, p. 6.

11.—Wyoming, western margin of Powder River basin, Johnson County. Sundance formation. Localities Js-I, Js-II and Js-III of Peterson, 1954a, p. 158.

12.—Wyoming, Black Hills, Crook County. Stockade Beaver shale member of Sundance formation. Locality Js-IX of Peterson, 1954a, p. 158.

13.—Wyoming, Black Hills, Weston County, 5 miles northeast of Newcastle. Type locality of the Stockade Beaver shale and Lak members of the Sundance formation. Locality Js-XIII of Peterson, 1954a, p. 156; locality 3 of Loeblich and Tappan, 1950b, p. 6.

14.—South Dakota, Black Hills, Lawrence and Butte Counties. Sections of Sundance formation including the type locality of the Redwater shale member. Localities Js-XI and Js-XII of Peterson, 1954a, p. 156; collecting locality of Loeblich and Tappan, 1950a, p. 40.

15.—Wyoming, Laramie Mountains, Albany and Natrona Counties. Central point of several sections of Sundance formation. Localities Js-VI and Js-VIII of Peterson, 1954a, p. 158.

16.—Wyoming, Wind River Mountains, vicinity of Lander. Sundance formation. Collecting localities of Roberts, 1934.

SYSTEMATIC DESCRIPTIONS

Phylum PROTOZOA
Class SARCODINA
Order FORAMINIFERA
Superfamily ASTRORHIZIDEA
Family TOLYPAMMINIDAE
Subfamily INVOLUTININAE
Genus INVOLUTINA Terquem, 1862

INVOLUTINA CHERADOSPIRA (Loeblich and Tappan)

Plate 2, figures 1-3

Ammodiscus cheradospirus Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, p. 6, pl. 1, figs. 1-2b.

Ammodiscus cheradospirus Loeblich and Tappan. Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 45, pl. 10, figs. 15, 16.

Test large, flat, planispiral, composed of proloculum and long undivided tube increasing rather rapidly in diameter during its six coils around proloculum in mature specimens; central portion of test gently depressed in most specimens; spiral suture distinct, flush, thickened progressively outward from proloculum; wall arenaceous with considerable fine cementing material failing, however, to coat the exterior resulting in a pustulose irregular surface; aperture formed by the open end of the tube; color light brown.

Greatest diameter of hypotype (figs. 1, 2), a microspheric individual, 1.07 mm.; least diameter, 0.87 mm.; thickness, 0.14 mm.; diameter of proloculum, 0.02 mm.

Greatest diameter of hypotype (fig. 3), a megalospheric individual, 0.90 mm.; least diameter, 0.67 mm.; thickness, 0.09 mm.; diameter of proloculum, 0.07 mm.

Mean maximum diameter of 12 microspheric specimens from Kelstern well, 1.20 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-53-2 and F-53-3.

Stratigraphic distribution: *Involutina cheradospira* is confined largely to the basal beds of the Vanguard formation. It occurs commonly in the Kelstern and Rush Lake wells of west-central Saskatchewan and sporadically in the Wapella oil field in the eastern part of the province.

Loeblich and Tappan reported this species as common near the base of the Rierdon formation in south-central Montana. It seems to be a good index fossil for Callovian strata in the western interior region.

Remarks: The present author (1958) assumed erroneously that he had found a new species and called this form *Ammodiscus* n. sp. 1. He was misled to some extent by the description given by the authors of this species, in which they described the spiral suture as depressed, whereas it appears flush and thickened to the present author. The average size of the Saskatchewan specimens seems larger than that of the suite from the type locality.

Loeblich and Tappan (1954) proposed suppressing the name *Ammodiscus* because the type species is calcareous and belongs to *Spirillina*. They advocated the assignment of species previously considered as *Ammodiscus* to *Involutina*, which is an agglutinated form and completely undivided internally. It is to be regretted that a most appropriate name, which has been in use for 100 years to embrace these arenaceous discoidal forms, should be replaced by a name that is quite inappropriate for the sake of strict compliance with the rules of nomenclature.

INVOLUTINA FRANCISI Wall, n. sp.

Plate 1, figures 1, 2

Test small, discoidal to very thin, planispiral, composed of proloculum and long undivided tube making four or five coils around proloculum and gradually increasing in diameter during early turns but rapidly widening in ultimate coil; coiling typically regular but final coil may overlap preceding; central area of test gently depressed on both sides in most specimens; spiral suture generally quite distinct, depressed; wall very finely arenaceous with much cement giving a nearly hyaline appearance, insoluble in acid; aperture formed by the open end of the tube.

Greatest diameter of holotype, 0.22 mm.; least diameter, 0.21 mm.; thickness, 0.05 mm. Mean maximum diameter of 57 specimens from type locality, 0.27 mm.

Type locality: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3601 and 3607 feet, in green shale of the upper member of the Shaunavon formation, 0 to 6 feet above the base.

Holotype: Univ. of Missouri No. F-53-1.

Stratigraphic distribution: This species ranges from the upper part of the Gravelbourg formation through most of the Shaunavon formation. This species occurs commonly in the basal beds of the Upper Shaunavon in the Rush Lake and Kelstern wells of west-central Saskatchewan and sporadically in the same strata at the Instow well in the southwestern area. It is questionably present in equivalent strata of the Wapella area in eastern Saskatchewan.

Remarks: This new species was assumed by the author (1958) to have been identical with *Ammodiscus orbis* Lalicker from the Middle Jurassic Sawtooth formation of the type Ellis in southwestern Montana. An examination of the holotype of *A. orbis*, however, shows it to be con-

siderably larger with more turns around the proloculum. Furthermore, in *A. orbis*, the tube very gradually increases in diameter during its turns around the proloculum, whereas there is a rapid increase in diameter in the outer whorl of *Involutina francisi*, n. sp.

The species is named for Mr. David R. Francis, Chief Geologist, Petroleum and Natural Gas Branch, Saskatchewan Department of Mineral Resources, Regina.

INVOLUTINA sp. cf. I. ORBIS (Lalicker)

Plate 1, figures 3-6

?*Ammodiscus orbis* Lalicker, 1950, Univ. of Kansas Paleontological Contrib., Protozoa, Article 2, p. 11, pl. 1, fig. 2.

Test small, generally pyritized, thinly discoidal, planispiral, consisting of fairly prominent proloculum and long undivided tube increasing very gradually in diameter during its six coils around proloculum with little or no overlapping; proloculum raised slightly above plane of first and possibly second coils; central area of test occupied by gentle saucer-shaped concavity on both sides; spiral suture distinct, depressed; wall finely arenaceous with much cement, smooth; aperture formed by the open end of the tube.

Maximum diameter of specimen (figs. 3, 4), a presumed microspheric individual, 0.24 mm.; least diameter, 0.21 mm.; thickness, 0.04 mm.; diameter of proloculum (estimated), 0.017 mm.

Maximum diameter of specimen (figs. 5, 6), a presumed megalospheric individual, 0.22 mm.; least diameter, 0.20 mm.; thickness, 0.05 mm.; diameter of proloculum, 0.025 mm.

Locality of figured specimens: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 15, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3566 and 3572 feet, in green shale of the upper member of the Shaunavon formation, 18 to 24 feet below the top.

Figured specimens: Univ. of Missouri Nos. F-53-7 and F-53-8.

Stratigraphic distribution: This species occurs commonly in the uppermost Shaunavon beds at the Rush Lake well in west-central Saskatchewan. It occurs sporadically in the basal Vanguard beds at the Frontier and Instow wells in the southwestern area.

Remarks: The present author (1958) referred to this species as *Ammodiscus* sp. A. It resembles *A. orbis* Lalicker closely in having a tube which makes the same number of turns and increases in diameter at the same rate. Although the Saskatchewan specimens are about one-third smaller, they probably are referable to Lalicker's species from the Middle Jurassic Sawtooth formation of southwestern Montana.

INVOLUTINA SOUTHEYENSIS Wall, n. sp.

Plate 1, figures 9-12

Test small to medium-sized, discoidal, planispiral, composed of tiny indistinct proloculum and long essentially undivided tube making six or seven coils around proloculum and increasing gradually in diameter during early whorls but widening perceptibly in later whorls, especially in final whorl; constrictions in final whorl of some specimens indicating incipient chamber development; coiling regular but ultimate coil overlapping penultimate; central area of test rather prominently depressed

on both sides; spiral suture indistinct, rendered visible by wetting, slightly depressed; wall finely arenaceous with a considerable amount of cement, smooth; aperture formed by the open end of the tube; color grayish-white to brownish-white.

Greatest diameter of holotype (figs. 9, 10), 0.35 mm.; least diameter, 0.32 mm.; thickness, 0.07 mm.

Greatest diameter of paratype (figs. 11, 12) 0.37 mm.; least diameter, 0.34 mm.; thickness 0.10 mm.

Average maximum diameter of 25 specimens from type locality, 0.33 mm.

Type locality: Tidewater Southey Crown No. 1 well in Lsd. 4, Sec. 29, Tp. 22, Rge. 18, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2179 and 2182 feet, in gray shale from near the base of the equivalent of the Shaunavon formation.

Types: Holotype, No. F-53-4; paratype, No. F-53-5, Univ. of Missouri.

Stratigraphic distribution: This species occurs commonly at the type locality and in the Imperial Tidewater Wapella No. 4-3 well between depths of 2348 and 2352 feet. Both occurrences are from beds of an age equivalent to the Shaunavon formation of western Saskatchewan which is correlative with the upper two-thirds of the Piper of Montana (Francis, 1956, p. 30).

Remarks: This new species was designated *Ammodiscus* n. sp. 2 by the author (1958). The indistinct spiral suture of *I. southeyensis*, n. sp., serves to distinguish it from other Jurassic species described from the western interior region.

The species is named from its occurrence in the Tidewater Southey Crown No. 1 well, the type locality of the species.

INVOLUTINA sp. cf. I. SOUTHEYENSIS

Plate 1, figures 13, 14

Test medium-sized, flattened, thin, planispiral, composed of indistinct proloculum and long undivided tube making four or five coils around proloculum and increasing gradually in diameter during early turns but sharply widening in ultimate coil; coiling irregular in some specimens with occasional overlapping of previous coils by the tube, more noticeable in final whorl; area of proloculum typically marked by depression; spiral suture indistinct, depressed; wall finely arenaceous with much cement, smooth; aperture formed by the open end of the tube; color white.

Greatest diameter of figured specimen, 0.45 mm.; least diameter 0.42 mm.; thickness, 0.05 mm.

Locality of figured specimen: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4545 and 4546 feet, in green shale of the upper member of the Shaunavon formation, 10 to 11 feet below the top.

Figured specimen: Univ. of Missouri No. F-53-6.

Stratigraphic distribution: This species occurs commonly in the uppermost beds of the upper member of the Shaunavon formation in the Instow, Kelstern and Johnston Lake wells of western Saskatchewan.

Remarks: This form is much thinner and the tube makes fewer turns around the proloculum than in *I. southeyensis s.s.*, but otherwise the forms are similar and are probably identical. The thinness of the figured specimen may merely reflect the flattening during fossilization of certain individuals of *I. southeyensis*.

Genus GLOMOSPIRA Rzehak, 1888

GLOMOSPIRA GORDIALIS (Jones and Parker)

Plate 1, Figures 7, 8

Trochammina squamata var. *gordialis* Jones and Parker, 1860, Geol. Soc. London, Quart. Jour., vol. 16, p. 304.

Glomospira gordialis (Jones and Parker). Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, pp. 18-19, pl. 1, fig. 38, 39?, 40? (synonymy in part).

Glomospira gordialis (Jones and Parker). Cushman, 1948, Foraminifera, p. 96, key pl. 4, fig. 5 (after Haeusler).

Test small, composed of proloculum and long undivided tube which irregularly overlaps its earlier coils as it winds about in several planes; suture distinct, depressed; wall finely arenaceous with much cement; aperture at the open end of the tube.

Greatest diameter of hypotype, 0.29 mm.; thickness 0.10 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3566 and 3572 feet, in green shale of the upper member of the Shaunavon formation, 18 to 24 feet below the top.

Hypotype: Univ. of Missouri No. F-53-9.

Stratigraphic distribution: This species ranges from the upper member of the Shaunavon formation through the lower member of the Vanguard formation in southwestern and west-central Saskatchewan.

Remarks: If the species discussed here is actually the same as Jones and Parker's from the Recent (no figure was given by these authors), then it is obviously a very long-ranging species of little stratigraphic value. It is of interest to note that Cushman (1948) reproduced a figure of the species after Haeusler from the Jurassic of Switzerland.

Superfamily LITUOLIDEA

Family REOPHACIDAE

Genus REOPHAX Montfort, 1808

REOPHAX sp. A

Plate 8, figures 10, 11

Test small to medium, top-shaped, initial portion slightly curved; test consists of four to five chambers, the first three to four small, low, increasing rather rapidly in width, and the final chamber much larger, inflated, elongate, with a prominent, extended, curved neck giving distal region the appearance of an acorn; sutures fairly distinct, depressed, transverse to slightly oblique, sinuous; wall fine to medium-grained arenaceous, moderate amount of cement, fairly smooth, tests partially pyritized; aperture simple, at the end of the pronounced neck.

Length of specimen (fig. 10), 0.40 mm.; greatest width, 0.21 mm.

Length of specimen (fig. 11), 0.60 mm.; greatest width, 0.22 mm.

Locality of figured specimens: Tidewater Atlas Crown No. 2 well in Lsd. 13, Sec. 11, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3316.5 and 3321 feet, in green shale of the lower member of the Vanguard formation, 8.5 to 13 feet below the top.

Figured specimens: Univ. of Missouri Nos. F-53-10 and F-53-11.

Stratigraphic distribution: This species is best developed at the locality of the figured specimens, but some occurrences were noted in the uppermost beds of the Shaunavon and in the lower Vanguard formation at Rush Lake. Both wells are in the west-central area of Saskatchewan.

Remarks: This species appears very similar to *Reophax eckernex* Vieaux from the Lower Cretaceous Washita group of Texas. *Reophax* sp. A is considerably smaller, but otherwise no major differences are apparent.

REOPHAX sp. B
Plate 1, figures 18, 19

Test medium size, outline varying considerably, most specimens rather flattened, initial portion slightly curved; test consists of four to five chambers, the first three to four usually indistinct, small, low, increasing rather rapidly in width, and the final chamber much larger, elongate, with a prominent neck; sutures indistinct, depressed, nearly straight; wall rather coarsely arenaceous, grains to about 0.75 mm. in diameter, not much cement, surface rough as many of the grains protrude; aperture simple, at the end of the neck.

Length of specimen (fig. 18), 0.57 mm.; greatest width, 0.30 mm.

Length of specimen (fig. 19), 0.77 mm.; greatest width, 0.37 mm.

Locality of figured specimens: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3566 and 3572 feet, in green shale of the upper member of the Shaunavon formation, 18 to 24 feet below the top.

Figured specimens: Univ. of Missouri Nos. F-53-12 and F-53-13.

Stratigraphic distribution: This species is best developed at the locality of the figured specimens, in the transitional beds between the Shaunavon and Vanguard formations. There are a few specimens in the overlying Vanguard of this and probably other wells in the western area of Saskatchewan.

Remarks: This rather characterless species may represent collapsed tests of *Reophax* sp. A, although it is more coarsely arenaceous than the latter.

Family LITUOLIDAE
Subfamily HAPLOPHRAGMOIDINAE Maync, 1952
Genus HAPLOPHRAGMOIDES Cushman, 1910
HAPLOPHRAGMOIDES sp. cf. H. LINKI Nauss
Plate 17, figures 4, 5

? *Haplophragmoides linki* Nauss, 1947, Jour. Paleontology, vol. 21, no. 4, p. 339, pl. 49, figs. 7a-b.

Test medium size, not noticeably compressed, planispiral, partly evolute with portions of earlier whorls and sometimes the proloculum exposed, shallow umbilicus developed, periphery rounded; chambers

distinct, about eight in ultimate whorl, of nearly equal size; sutures distinct, thickened, flush, radial; wall generally finely arenaceous with considerable cement, smooth; aperture a low arched opening at the base of the terminal face.

Maximum diameter of figured specimen, 0.36 mm.; minimum diameter, 0.32 mm.; greatest thickness, 0.16 mm. Average maximum diameter of 25 specimens from locality of figured specimen, 0.38 mm.

Locality of figured specimen: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4239 and 4243 feet, in green shale of the upper member of the Vanguard formation, 5 to 9 feet below the top.

Figured specimen: Univ. of Missouri No. F-53-15.

Stratigraphic distribution: This species seems confined to the upper member of the Vanguard formation in the Instow and Frontier wells of southwestern Saskatchewan, and has been recorded from the middle member in the Kelstern well of the west-central area. It occurs commonly in the uppermost beds of the upper member of the Vanguard in the Instow well.

Remarks: The present author (1958) referred to this species as *Haplophragmoides* sp. A. This species is closely related to *H. linki* Nauss from the basal part of the Lloydminster shale of east-central Alberta which is of late Lower Cretaceous (Albian) age. The Saskatchewan specimens are more evolute and have flush instead of the depressed sutures of the holotype.

HAPLOPHRAGMOIDES TRYSSA Loeblich and Tappan

Plate 14, figures 18, 19

Haplophragmoides tryssa Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 41, pl. 11, figs. 2a-b.

Test small, subglobose, planispiral, involute or nearly so, umbilicus shallow, periphery rounded; chambers increasing rather rapidly in size in earlier portion of test but the last three of nearly equal size, about five and one-half chambers in ultimate whorl; sutures distinct, depressed, radial; wall finely arenaceous with considerable cement, smooth; aperture a low arched opening at the base of the terminal face.

Greatest diameter of hypotype, 0.30 mm.; least diameter, 0.25 mm.; maximum thickness, 0.16 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3438 and 3447 feet, in green shale from the type section of the lower member of the Vanguard formation, 22 to 31 feet below the top.

Hypotype: Univ. of Missouri No. F-53-14.

Stratigraphic distribution: This species was positively recognized at only the level and locality of the hypotype where it is rare. Some small representatives of this species probably occur in the upper member of the Vanguard formation at the Frontier well in the southwestern area. The species is illustrated with the fauna occurring in the middle and upper members of the Vanguard or the Swift equivalent.

Remarks: A comparison of the Saskatchewan specimens with the types of the species from the Oxfordian Redwater shale of South Dakota

shows that they are very likely identical. The only apparent difference is the existence of an additional chamber in the Saskatchewan specimens.

Subfamily LITUOLINAE Brady (*partim*), *emendatio* Maync, 1952

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES COBBANI Loeblich and Tappan

Plate 8, figures 1-4; Plate 14, figures 3-6

Ammobaculites cobbani Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 41-42, pl. 11, figs. 9a-13.

Test small to medium-sized, early portion comprising from one-fourth to two-fifths length, compressed, planispiral, somewhat trochoid in some specimens as exhibited by hypotype (pl. 8, figs. 1-4), slightly to moderately umbilicate; later portion straight to curved, uniserial, cylindrical; about eight chambers exposed in the coiled portion (only five on the involute side of trochoid specimens), enlarging fairly rapidly, three to four chambers in uniserial portion, increasing very gradually in length and width as added, somewhat inflated; sutures in coiled portion indistinct to distinct, depressed, nearly straight, sutures in uniserial portion distinct, depressed, transverse; wall arenaceous, of various grain sizes up to about 0.04 mm., moderate amount of cement, exterior surface somewhat rough to fairly smooth; aperture terminal, a fairly prominent circular to elliptical opening.

Length of hypotype (pl. 8, figs. 1-4), 0.75 mm.; diameter of coiled portion, 0.22 mm.; length of ultimate chamber, 0.19 mm.; width of ultimate chamber, 0.27 mm.; maximum thickness, 0.25 mm.

Length of hypotype (pl. 14, figs. 3-5), 0.52 mm.; diameter of coiled portion, 0.27 mm.; length of ultimate chamber, 0.15 mm.; width of ultimate chamber, 0.20 mm.; maximum thickness, 0.17 mm.

Length of hypotype (pl. 14, fig. 6), 0.47 mm.; other measurements identical with above hypotype.

Locality of hypotype (pl. 8, figs. 1-4): Tidewater Atlas Crown No. 2 well in Lsd. 13, Sec. 11, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3319 and 3321 feet, in green shale of the lower member of the Vanguard formation, 94 to 96 feet above the base.

Locality of hypotypes (pl. 14, figs. 3-6): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3389 and 3396 feet, in green shale from the basal beds of the middle member of the Vanguard formation, 1 to 8 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-53-16, F-53-20, F-54-1.

Stratigraphic distribution: This species occurs sporadically in the lower member of the Vanguard formation of the Atlas and Kelstern wells in west-central Saskatchewan. It was also observed in the basal beds of the middle member of the Vanguard at Kelstern and Rush Lake, and in the upper member of the Vanguard at Instow in the southwestern area.

Remarks: The present author (1958) referred to the hypotype (pl. 8, figs. 1-4) as *Ammobaculites* sp. cf. *A. cobbani* and the hypotypes (pl. 14, figs. 3-6) as *Ammobaculites* sp. B. A comparison of the Saskatchewan specimens with the types of the species from the Oxfordian Redwater

shale of South Dakota shows that they are identical. It was at first thought that because the Saskatchewan specimens have cylindrical as compared with the flattened uniserial portions of the illustrated types, they might not be the same species. The present author, however, observed several unfigured paratypes with nearly cylindrical uniserial portions. In any event, this feature is probably dependent on the fossilization process and of little, if any, taxonomic importance.

AMMOBACULITES IMLAYI Loeblich and Tappan

Plate 14, figures 1, 2

Ammobaculites imlayi Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 42, pl. 11, figs. 17a-b.

Test small, strongly compressed; early portion close-coiled comprising one-quarter length with five or six indistinct chambers exposed; later portion straight or nearly straight, of three or four uniserial, approximately equal chambers; sutures faint, depressed, nearly transverse in uncoiled portion; wall arenaceous with grains averaging about 0.025 mm., but with a sporadic grain up to 0.075 mm., not much cement, surface rather rough; aperture terminal, elliptical.

Length of hypotype, 0.50 mm.; diameter of coiled portion, 0.20 mm.; length of ultimate chamber, 0.15 mm.; width of ultimate chamber, 0.17 mm.; maximum thickness, 0.10 mm. Average length of eight specimens from hypotype locality, 0.51 mm.; average maximum diameter of coil, 0.19 mm.; average maximum thickness, 0.09 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3414 and 3416 feet, in green shale from the basal beds of the middle member of the Vanguard formation, 0 to 2 feet above the base.

Hypotype: Univ. of Missouri No. F-54-2.

Stratigraphic distribution: This species has been recognized in the Rush Lake and Kelstern wells of west-central Saskatchewan where it occurs sporadically in the basal beds of the middle member of the Vanguard formation.

Remarks: The present author (1958) designated this species as *Ammobaculites* sp. C and commented on its similarity to *A. imlayi* from the Redwater shale of South Dakota. A comparison of the Saskatchewan specimens with the types has shown them to be unquestionably identical.

AMMOBACULITES VENUSTUS Loeblich and Tappan

Plate 8, figures 8, 9; Plate 17, figures 6, 7.

Ammobaculites venustus Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 42, pl. 11, figs. 7, 8a-b.

Test small, compressed, flattened-ovate in section; early portion slightly umbilicate, planispiral, evolute, consisting of proloculum and seven to eight chambers increasing rather rapidly in size; later portion rectilinear, of four uniserial chambers nearly equal or increasing slightly in size; sutures distinct, depressed, nearly straight in coiled portion, oblique and slightly sinuous in uncoiled portion; wall finely arenaceous with considerable cement, smooth; aperture terminal, appearing as an elliptical slit.

Length of hypotype (Pl. 8, figs. 8, 9), 0.40 mm.; greatest diameter of coiled portion, 0.15 mm.; thickness, 0.06 mm.

Length of hypotype (Pl. 17, figs. 6, 7), 0.47 mm.; greatest diameter of coiled portion, 0.15 mm.; thickness 0.07 mm.

Locality of hypotype (Pl. 8, figs. 8, 9): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Locality of hypotype (Pl. 17, figs. 6, 7): Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4247 and 4252 feet, in green shale of the upper member of the Vanguard formation, 13 to 18 feet below the top.

Hypotypes: Univ. of Missouri Nos. F-53-17 and F-53-18.

Stratigraphic distribution: This species ranges through the Vanguard formation in Saskatchewan and is present in the fine portions (mesh size 100 openings or more per inch) of most core samples examined. It is perhaps more common in the upper shale member.

Loeblich and Tappan proposed the species on the basis of material from the type Redwater shale (Oxfordian) in the Black Hills area.

AMMOBACULITES sp. A

Plate 17, figures 1-3

Test medium size, not compressed, umbilicate, consisting only of a rather closely coiled early portion, the coil slightly off-centre and appearing trochoid; periphery rounded, peripheral margin lobulate; chambers subglobular, gradually enlarging, seven exposed; sutures fairly distinct, depressed, straight; wall medium to coarse-grained arenaceous, grains up to 0.08 mm. in diameter but averaging less than half this size, moderate amount of cement, exterior somewhat rough; aperture terminal, an oval opening on a short collar.

Maximum diameter of figured specimen, 0.75 mm.; minimum diameter, 0.47 mm.; thickness, 0.30 mm. Average maximum diameter of two additional specimens from locality of figured specimen, 0.55 mm.

Locality of figured specimen: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4257 and 4262 feet, in green shale of the upper member of the Vanguard formation, 23 to 28 feet below the top.

Figured specimen: Univ. of Missouri No. F-53-19.

Stratigraphic distribution: This uncommon and rather characterless species seems to be confined to the upper member of the Vanguard formation.

Remarks: The author (1958) believed this species to be similar to *A. cobbani* Loeblich and Tappan from the Oxfordian Redwater shale of South Dakota, but a comparison has shown the Saskatchewan specimens to be much larger with inflated chambers, and the two species were found to be quite dissimilar.

AMMOBACULITES sp. D

Plate 8, figures 6, 7

Test fairly small, cylindrical, preserved as a partially pyritized replacement; early portion comprising only about one-seventh length,

tightly and somewhat irregularly coiled, of about five rather rapidly enlarging chambers; later portion uniserial, of four chambers increasing gradually in length but maintaining near constant width; sutures fairly distinct, depressed, transverse in uncoiled portion; wall rather finely arenaceous with considerable cement, fairly smooth; aperture terminal, elliptical, generally produced on short collar.

Length of figured specimen, 0.50 mm.; diameter of coiled portion, 0.11 mm.; length of ultimate chamber, 0.19 mm.; width of ultimate chamber, 0.12 mm. Average length of eight specimens from locality of figured specimen, 0.45 mm.; average diameter of coil, 0.12 mm.

Locality of figured specimen: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3288 and 3292 feet, in green shale of the lower member of the Vanguard formation, 73 to 77 feet above the base.

Figured specimen: Univ. of Missouri No. F-54-3.

Stratigraphic distribution: *Ammobaculites* sp. D. apparently ranges through the Vanguard formation in western Saskatchewan. Specimens from the lower member were identified in the Atlas, Kelstern, Rush Lake and Frontier wells, and representatives were recorded from the Instow well in the upper member. A larger and more coarsely arenaceous form, possibly a variety of this species, is present in the top of the middle member of the Vanguard at Kelstern.

Remarks: The author (1958) thought this species to be similar to *A. imlayi* Loeblich and Tappan from the Redwater shale of South Dakota, but a comparison has since shown that the cylindrical test and elongate chambers of *Ammobaculites* sp. D serve to distinguish it readily. This species is left unnamed for the present, but is probably sufficiently distinct to warrant proposing as a new species.

Genus AMMOMARGINULINA Wiesner, 1931

AMMOMARGINULINA BARYNTICA Loeblich and Tappan

Plate 18, figures 1, 2

Ammomarginulina baryntica Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 41, pl. 11, figs. 3-6.

Test large, compressed, early portion close-coiled, of six to eight gradually enlarging chambers; later portion curved, uniserial, of three to four broad low equi-sized chambers; sutures indistinct, slightly curved backwards in the coiled portion and early part of the uniserial portion, oblique and not recurved near distal end; sutures depressed at the margins of the test resulting in somewhat lobulate periphery; wall medium-grained arenaceous with considerable cement, fairly smooth; aperture terminal, an elliptical opening.

Greatest length of hypotype, 1.57 mm.; greatest width of coiled portion, 0.95 mm.; width of ultimate chamber, 0.90 mm.; length of ultimate chamber, 0.40 mm.; greatest thickness, 0.25 mm.

Locality of hypotype: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4257 and 4262 feet, in green shale of the upper member of the Vanguard formation, 23 to 28 feet below the top.

Hypotype: Univ. of Missouri No. F-54-4.

Stratigraphic distribution: In Saskatchewan, this species was observed rarely in the upper member of the Vanguard formation at Instow and in the top beds of the middle member of the Vanguard at Kelstern.

Loeblich and Tappan proposed the species on the basis of material from the type Redwater shale (Oxfordian) of the Black Hills area, South Dakota.

AMMOMARGINULINA sp. cf. A. BARYNTICA Loeblich and Tappan

Plate 8, figure 12

?*Ammomarginulina baryntica* Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 41, pl. 11, figs. 3-6.

Test monstrous, compressed; early portion coiled, rather involute, with about ten gradually enlarging chambers exposed in final whorl, small umbilicus developed; later portion elongate, uniserial, tapering slightly proximally, of nine or ten low broad chambers, nearly equi-sized except higher and narrower ultimate chamber; sutures indistinct, nearly straight in coiled portion, sutures depressed, transverse to slightly arched in uncoiled portion, their positions emphasized by crushing of the chambers; wall rather finely arenaceous, moderate amount of cement, fairly smooth, siliceous-appearing; aperture terminal, an elliptical opening; color brown.

Length of figured specimen, 2.82 mm.; maximum diameter of coiled portion, 0.95 mm.; maximum thickness, 0.27 mm.

Locality of figured specimen: Tidewater Atlas Crown No. 2 well in Lsd. 13, Sec. 11, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3325 and 3329 feet, in green shale of the lower member of the Vanguard formation, 86 to 90 feet above the base.

Figured specimen: Univ. of Missouri No. F-54-8.

Stratigraphic distribution: This species was identified only in the lower member of the Vanguard formation in the Atlas wells of west-central Saskatchewan where it is rare.

Remarks: The present author (1958) referred to this species as *Ammomarginulina* sp. C. This one very large individual (the figured specimen) probably is teratological. Three or four closely related although considerably smaller individuals were found in the same strata. This latter group of specimens probably is identical with an unfigured paratype of *A. baryntica* which consists of a coiled portion only.

AMMOMARGINULINA sp. cf. A. CRAGINI Loeblich and Tappan

Plate 18, figures 5, 6

?*Ammomarginulina cragini* Loeblich and Tappan, 1950c, Univ. of Kansas Paleontological Contrib., Protozoa, Article 3, p. 6, pl. 1, figs. 4a-6.

Test medium-sized, compressed; early portion coiled, constituting about one-half length, planispiral, evolute, consisting of proloculum and two whorls; later portion uncoiled, curved, tapering slightly distally, uniserial; about six small chambers in initial whorl of coiled portion, five to six gradually enlarging chambers in final whorl of coiled portion; three to four nearly equi-sized chambers in uncoiled portion, ultimate chamber generally broken; sutures fairly distinct, partly thickened, curved backwards in the coiled portion, oblique and slightly recurved in uncoiled portion, depressed, particularly at margins of test giving periphery somewhat lobulate appearance; wall medium-grained arenaceous with considerable cement, smooth; aperture terminal, an elliptical slit.

Maximum length of figured specimen, 0.75 mm.; greatest diameter of coiled portion, 0.37 mm.; thickness, 0.11 mm.

Locality of figured specimen: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4247 and 4252 feet, in green shale of the upper member of the Vanguard formation, 13 to 18 feet below the top.

Figured specimen: Univ. of Missouri No. F-54-7.

Stratigraphic distribution: This species was not recognized beyond its rather rare occurrence in the upper member of the Vanguard formation at the locality of the figured specimen.

Remarks: The figured specimen was compared with the holotype of *A. cragini* from the Lower Cretaceous Kiowa shale of Kansas and the two were found to be very nearly, if not entirely similar. The Saskatchewan specimens have a more developed uncoiled portion with an additional chamber, but this character probably represents only intraspecific variation.

AMMOMARGINULINA sp. A

Plate 18, figures 3, 4, 7-9

Test medium size, compressed, consisting of a coiled portion only; test evolute with proloculum exposed, followed by one and one-half whorls of small low rectangular chambers and ultimate whorl of six much larger chambers; sutures rather indistinct, somewhat thickened, straight save ultimate one which is curved, sutures flush except at margins where they are depressed and impart a rather lobulate appearance to the periphery; wall medium-grained arenaceous with sporadic pyrite crystals, considerable amount of cement, fairly smooth; aperture an elongated opening on the truncated terminal face.

Maximum diameter of specimen (figs. 3, 4), 0.62 mm.; minimum diameter, 0.50 mm.; maximum thickness, 0.14 mm.

Maximum diameter of specimen (figs. 7-9), 0.87 mm.; minimum diameter, 0.62 mm.; maximum thickness 0.17 mm.

Locality of figured specimens: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4247 and 4252 feet, in green shale of the upper member of the Vanguard formation, 13 to 18 feet below the top.

Figured specimens: Univ. of Missouri Nos. F-54-5 and F-54-6.

Stratigraphic distribution: This species occurs characteristically in the upper member of the Vanguard formation in the Instow well of southwestern Saskatchewan. More coarsely arenaceous individuals, which may not be identical with this species, were found in the basal beds of the middle member of the Vanguard in the Rush Lake well.

Remarks: This species seems closely related to *Ammomarginulina baryntica* Loeblich and Tappan and possibly represents an early phylogenetic stage in the ancestry of the latter species.

Genus BULBOBACULITES Maync, 1952

BULBOBACULITES? sp.

Plate 17, figure 10

Test minute, early portion in a trochoid spire of four whorls constituting about one-sixth length, generally quite regularly coiled, partly con-

camerate; later portion rectilinear, cylindrical in cross section, of 10 to 12 low wide equal-sized chambers; sutures distinct, slightly depressed, transverse in later portion; wall finely arenaceous with considerable cement, smooth, largely pyritized; aperture terminal, a simple round opening.

Length of figured specimen, 0.22 mm.; maximum width, 0.06 mm. Average length of five specimens at locality of figured specimen, from an interval of four to five feet above and below level of figured specimen, 0.20 mm.; average maximum width, 0.055 mm.

Locality of figured specimen: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4239 and 4243 feet, in green shale of the upper member of the Vanguard formation, 5 to 9 feet below the top.

Figured specimen: Univ. of Missouri No. F-54-9.

Stratigraphic distribution: This species apparently is restricted to the upper portion of the upper member of the Vanguard formation judging from its occurrences in the Instow well.

Remarks: This species is questionably referred to *Bulbobaculites* because of uncertainty regarding the character of the early portion of the test. In some specimens there is no evidence of division into chambers in the early portion, which would suggest possible closer affinity to *Turritellella* Rhumbler. The species was included in the study because of its apparent restriction to the upper portion of the upper Vanguard. It is not common but a few specimens can be found in the fine portions (mesh size 100 openings or more per inch) of most core samples.

Genus FLABELLAMMINA Cushman, 1928

FLABELLAMMINA INSTOWENSIS Wall, n.sp.

Plate 17, figures 18-20

Test large, compressed, wide, early portion planispiral, partly evolute with proloculum and portion of penultimate whorl exposed, shallow umbilicus developed, its position emphasized by thickened ridge along trace of the spiral suture; later portion uncoiling, uniserial, nearly straight and about the same width as the coil, with peripheral margins somewhat lobulate; chambers indistinct, numerous, 10 to 12 in final whorl of the coil, three to four sickle to chevron-shaped, excavated chambers in later portion; sutures indistinct, seemingly radial in coil, arched in later portion, their positions marked by thickened ridges along traces of the intercameral walls; wall medium-grained arenaceous with moderate amount of cement, somewhat rough; aperture terminal, an elliptical slit at the end of a short wide neck.

Length of holotype, 1.40 mm.; diameter of coiled portion, 0.67 mm.; greatest width of uncoiled portion, 0.80 mm.; thickness, 0.20 mm. Average length of five adult specimens at type locality from a level 10 feet above holotype, 1.19 mm.; mean maximum width, 0.73 mm.

Type locality: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4257 and 4262 feet, in green shale of the upper member of the Vanguard formation, 23 to 28 feet below the top.

Holotype: Univ. of Missouri. No. F-54-10.

Stratigraphic distribution: This species occurs characteristically in the upper part of the upper member of the Vanguard formation in the

Instow well in southwestern Saskatchewan. A few specimens were observed in the middle member of the Vanguard in the Kelstern and Rush Lake wells in west-central Saskatchewan.

Remarks: This new species lacks close similarity to any previously published. The striking features are its well-developed coil, and arched sutures marked by ridges in the uniserial portion.

The species is named from its occurrence in the Tidewater Instow Crown No. 1 well, the type locality of the species.

Genus TRIPLASIA Reuss, 1854

TRIPLASIA DAHINDENSA (Loranger)

Plate 2, figures 4-8; Plate 15, figures 1-6

Frankeina? sp. Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, pp. 158-159, pl. 1, fig. 2.

Frankeina commutata Loeblich and Tappan (in part), 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, pp. 6-7 (synonymic entry only).

Frankeina dahindensa Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, pp. 46-47, pl. 10, figs. 1, 2.

Test large, rather robust; early portion coiled rather tightly with six chambers in final whorl; later portion uncoiling, uniserial, slightly curved, of four nearly equi-sized, rounded-triangular chambers; sides of test strongly excavated in coiled portion, moderately so in uncoiled portion, test appearing as a blunted triangle in ventral peripheral view with margin of coil prominently truncate and that of uniserial portion broadly rounded; sutures generally indistinct except along peripheral margins where they are more readily visible and are depressed, sutures straight in coil, slightly oblique in uniserial portion, also slightly depressed in central area of the latter; wall arenaceous, highly variable in grain size, amount of cement and character of surface; aperture terminal, a round opening.

Maximum diameter of hypotype (Pl. 2, figs. 4, 5), a juvenile individual, 0.60 mm.; minimum diameter, 0.49 mm.

Length of hypotype (Pl. 2, figs. 6-8), an adult individual, 1.21 mm.; greatest diameter of coiled portion, 0.65 mm.; greatest width of uniserial portion, 0.55 mm.

Length of hypotype (Pl. 15, figs. 1-3), an adult individual, 1.47 mm.; greatest diameter of coiled portion, 0.90 mm.; greatest width of uniserial portion, 0.75 mm.

Length of hypotype (Pl. 15, figs. 4-6), a juvenile individual, 0.87 mm.; greatest width, 0.67 mm.

Locality of hypotype (Pl. 2, figs. 4, 5): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Locality of hypotypes (Pl. 15, figs. 1-6): as above, between depths of 3325 and 3329 feet, in green shale from the type section of the middle member of the Vanguard formation, 68 to 72 feet above the base.

Locality of hypotype (Pl. 2, figs. 6-8): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3548 and 3556 feet, in green shale from the base of the type section of the lower member of the Vanguard formation.

Hypotypes: Univ. of Missouri Nos. F-54-11, F-54-12, F-54-13, F-54-14.

Stratigraphic distribution: This species seems to range through all of the Vanguard formation in western Saskatchewan, and was found in the lower Vanguard of the eastern area.

Remarks: Possibly two separate species are presently included under this name: (1), the coarsely arenaceous specimens as illustrated by the hypotypes (Pl. 15, figs. 1-6) and (2), the fine to medium-grained arenaceous specimens as illustrated by the hypotypes (Pl. 2, figs. 4-8). The coarse-grained individuals probably occupied a shallower or more brackish environment as indicated by their occurrence in the transitional beds between the Shaunavon and Vanguard formations of the Rush Lake well, in the basal beds of the middle member of the Vanguard at Rush Lake and Kelstern, in the shale tongue in the main sand unit of the middle member of the Vanguard at Kelstern, and in the upper Vanguard at Instow. On the other hand, the more finely arenaceous individuals probably lived in deeper, although still relatively shallow water, as evidenced by their occurrences in the basal and main portions of the lower member of the Vanguard at Kelstern, Rush Lake, and in the Wapella area.

Remarks: The present author, after examining many paratypes of *Frankeina commutata* Loeblich and Tappan (1950b, pp. 6-7, pl. 1, figs. 3-4) from the Rierdon formation of south-central Montana and adjoining areas of Wyoming, believes that it probably is identical with this species of Loranger. It is true, as Loranger pointed out, that the coiled portion of the holotype of *F. commutata* is compressed and planispiral, but a few of the paratypes of *F. commutata* have incipiently trihedral coiled portions and thus are virtually indistinguishable from *T. dahindensa*.

The generic name *Frankeina* Cushman and Alexander has been suppressed as a synonym of *Triplasia* by Loeblich and Tappan (1952).

Family TEXTULARIIDAE
Genus AMMOBACULOIDES Plummer, 1932
AMMOBACULOIDES sp. cf. A. PHAULUS Loeblich and Tappan
Plate 8, figure 5

?*Ammobaculoides phaulus* Loeblich and Tappan, 1950c, Univ. of Kansas Paleontological Contrib., Protozoa, Article 3, p. 8, pl. 1, figs. 18a-20.

Test minute, strongly compressed, preserved as a pyritized replacement; early portion planispirally coiled, of six to seven chambers; later portion rectilinear, of seven chambers in alternating biserial pattern; sutures distinct, slightly depressed, radial in coiled portion, forming a zigzag median line between the two series of chambers in biserial portion; wall presumably finely arenaceous; aperture terminal, character obscure.

Length of figured specimen, 0.22 mm.; diameter of coiled portion, 0.09 mm.; thickness, 0.04 mm. Average length of four specimens from locality of figured specimen, 0.21 mm.; average diameter of coiled portion, 0.07 mm.

Locality of figured specimen: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4412.5 and 4415 feet, in green shale of the lower member of the Vanguard formation, 80 to 82.5 feet above the base.

Figured specimen: Univ. of Missouri No. F-54-15.

Stratigraphic distribution: This tiny species has not been positively recognized beyond its rare occurrence in the lower member of the Vanguard formation in the Frontier well.

Remarks: The figured specimen was compared with a paratype of *A. phaulus* (*op. cit.*, fig. 19) from the Lower Cretaceous Kiowa shale of Kansas and the two were found to be nearly identical. The Kansas species, however, has a greater tendency to become uniserial.

Family TROCHAMMINIDAE
Subfamily TROCHAMMININAE
Genus TROCHAMMINA Parker and Jones, 1859
TROCHAMMINA INSTOWENSIS Wall, n.sp.
Plate 17, figures 13-17

Test small, periphery rounded, peripheral margin slightly to moderately lobulate; test trochoid, with a low spire, of three whorls with about eight chambers in each of the primary and penultimate whorls and six in final whorl, ventral side prominently umbilicate; chambers gradually enlarging in size from tiny proloculum, inflated ventrally in final whorl, all chambers visible from dorsal side, only those of ultimate whorl visible ventrally; sutures distinct, depressed, only slightly curved; wall finely arenaceous with much cement, smooth, partially pyritized; aperture obscure, thought to be a notch on the ventral side at the base of the terminal chamber.

Greatest diameter of holotype (figs. 13-16), 0.22 mm.; least diameter, 0.20 mm.; greatest thickness, 0.10 mm.

Greatest diameter of paratype (fig. 17), 0.32 mm.; least diameter, 0.25 mm.; greatest thickness, 0.12 mm.

Average maximum diameter of 20 specimens from level and locality of holotype, 0.21 mm.

Average maximum diameter of 30 specimens from level and locality of paratype, 0.245 mm.

Locality of holotype: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4234 and 4239 feet, in green shale of the upper member of the Vanguard formation, 0 to 5 feet below the top.

Locality of paratype: As above, between depths of 4247 and 4252 feet, 13 to 18 feet below the top.

Types: Holotype, No. F-54-17; paratype, No. F-54-18, Univ. of Missouri.

Stratigraphic distribution: This species ranges from the top beds of the Shaunavon formation into the upper member of the Vanguard formation. It seems to be most characteristic of the upper member of the Vanguard, and is probably the commonest species in this member at the Instow well. This species is fairly common in the two available samples from the uppermost and central beds of the middle member of the Vanguard in the Kelstern well. It is sparse in the basal beds of the middle member of the Vanguard at Kelstern and Rush Lake. It is rather rare in the lower member of the Vanguard in southwestern and west-central Saskatchewan, and quite rare at this level in the eastern area of the province, where a few specimens were found at Wapella and Carievale. The only locality to yield specimens from the uppermost Shaunavon

(actually, transitional beds to the basal Vanguard) is the Rush Lake well, where the species is abundant.

Remarks: The author (1958) referred to this species as *Trochammina* n. sp. 2. This new species is quite similar to *Trochammina gatesensis* Stelck and Wall from the Albian (Lower Cretaceous) Fort St. John group of British Columbia, but has a deeper, more conspicuous umbilicus and a more lobulate peripheral margin.

The species is named from its occurrence in the Tidewater Instow Crown No. 1 well, the type locality of the species.

TROCHAMMINA RUSHLAKENSIS Wall, n. sp.
Plate 8, figures 13-17

Test very small, periphery rounded, peripheral margin lobulate; test trochoid, moderate spire developed, of three whorls with about five chambers in each of the primary and penultimate whorls and closer to four in final whorl, ventral side with prominent umbilicus; chambers gradually enlarging in size from proloculum, inflated and subglobular in final whorl, all chambers visible from dorsal side, only those of ultimate whorl visible ventrally; sutures distinct, depressed, radial; wall finely arenaceous with much cement, smooth, partially pyritized; aperture a broadly arched opening on the ventral side in the middle of the base of the terminal chamber, quite distinct in most specimens.

Greatest diameter of holotype, 0.25 mm.; least diameter, 0.22 mm.; greatest thickness, 0.15 mm. Average maximum diameter of 10 specimens from level and locality of holotype, 0.25 mm.; average maximum thickness, 0.125 mm.

Type locality: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3508 and 3516 feet, in green shale from the type section of the lower member of the Vanguard formation, 32 to 40 feet above the base.

Holotype: Univ. of Missouri No. F-54-16.

Stratigraphic distribution: This species occurs sporadically in the Rush Lake and Atlas wells of west-central Saskatchewan in the lower member of the Vanguard formation.

Remarks: The author (1958) referred to this species as *Trochammina* n. sp. 1. It is similar to *T. wetteri* Stelck and Wall from the Cenomanian (early Late Cretaceous) portion of the Kaskapau formation of the Peace River area of Alberta, but is considerably smaller and has only four chambers in its final whorl as compared with typically five in *T. wetteri*.

TROCHAMMINA? sp. A
Plate 1, figures 15-17

Test medium size, compressed, periphery subacute, peripheral margin rather lobulate; test trochoid with very low spire, whorls indistinct, apparently about three with five chambers in final whorl, the last chamber somewhat larger and seemingly attenuated in a manner indicative of incipient uncoiling; chambers indistinct, all difficultly visible on dorsal side, only those of ultimate whorl visible ventrally; sutures very faint dorsally, sutures indistinct but visible ventrally, straight; wall finely arenaceous with much cement, smooth; aperture apparently a large

arched opening occupying much of the peripheral face of the terminal chamber, parallel to the plane of coiling.

Greatest diameter of figured specimen, 0.57 mm.; least diameter, 0.37 mm.; approximate height, 0.17 mm. Average maximum diameter of 13 specimens at the level and locality of figured specimen, 0.42 mm. (Because of distortion, this measurement probably is inaccurate).

Locality of figured specimen: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4510 and 4514 feet, in green shale of the upper member of the Shaunavon formation, 15 to 19 feet below the top.

Figured specimen: Univ. of Missouri No. F-54-19.

Stratigraphic distribution: This species was encountered only at the level and locality of the figured specimen.

Remarks: Most individuals of this species are considerably distorted in fossilization, and for this reason the character of the aperture as described may be more apparent than real. This species does not appear similar to any published species of *Trochammina*.

Family VERNEUILINIDAE
Subfamily VERNEUILININAE
Genus VERNEUILINOIDES Loeblich and Tappan, 1949
VERNEUILINOIDES TRYPHERA Loeblich and Tappan
Plate 17, figures 8, 9

Verneuilinoides tryphera Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 42-43, pl. 11, figs. 16a-b.

Test minute, tapering, triangular in cross section with the angles rounded; test triserial, with typically six convolutions of three chambers each; chambers subglobular, increasing rather rapidly in size; sutures distinct, depressed; wall finely arenaceous with considerable cement, smooth; aperture a rather prominent notch at the base of the ultimate chamber.

Length of hypotype (fig. 8), 0.19 mm.; greatest width, 0.07 mm.

Length of hypotype (fig. 9), 0.15 mm.; greatest width, 0.07 mm.

Locality of hypotypes: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4243 and 4247 feet, in green shale of the upper member of the Vanguard formation, 9 to 13 feet below the top.

Hypotypes: Univ. of Missouri Nos. F-54-20 and F-55-1.

Stratigraphic distribution: This species ranges through the Vanguard formation in western Saskatchewan, but is characteristic of the upper member, where it is common in the fine portions (mesh size 100 openings or more per inch) of core samples. This species is rather sparse in the middle member and definitely rare in the lower member of the Vanguard.

Loeblich and Tappan proposed this species on the basis of material from the type Redwater shale (Oxfordian) of South Dakota. These authors reported it as well in the "Upper Sundance" of Wyoming.

Superfamily MILIOLIDEA
Family MILIOLIDAE
Genus QUINQUELOCULINA d'Orbigny, 1826
QUINQUELOCULINA sp.
Plate 3, Figures 3-5

Test small, subelliptical; chambers quinqueloculine, four visible on one side of test, three on opposite side; side with three chambers visible flattened, periphery rather sharp; sutures indistinct, slightly if at all depressed; wall calcareous, imperforate, flesh-colored; aperture simple, the open end of the final chamber which is extended as a neck.

Length of figured specimen, 0.21 mm.; greatest width, 0.10 mm.; maximum thickness, 0.06 mm.

Locality of figured specimen: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Figured specimen: Univ. of Missouri No. F-55-2.

Stratigraphic distribution: This species is restricted to the lower member of the Vanguard formation and was positively recognized in only the Kelstern and Johnston Lake wells of west-central Saskatchewan, where a total of about 10 specimens were found.

Remarks: Terquem and Berthelin (1875) have described several small species of *Quinqueloculina* from the Lias of France which may be rather closely related to this species.

Genus MASSILINA Schlumberger, 1893
MASSILINA sp.
Plate 16, figures 11, 12

Massilina sp. Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 43, pl. 11, figs. 15a-b.

Test small, elongate-rectangular in outline, periphery rounded; early portion quinqueloculine, later chambers a half-coil in length added alternately on opposite sides of test, six chambers exposed on each side; sutures distinct, depressed; wall presumably calcareous originally, preserved as a pyritized replacement; aperture at the end of the final chamber.

Length of figured specimen, 0.25 mm.; greatest width, 0.10 mm.; maximum thickness, 0.06 mm.

Locality of figured specimen: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4197 and 4207 feet, in green shale of the upper member of the Vanguard formation, 54 to 64 feet below the top.

Figured specimen: Univ. of Missouri No. F-55-3.

Stratigraphic distribution: This species has not been observed in Saskatchewan beyond the locality and level of the figured specimen, where only three individuals were found.

Remarks: The present author has compared the Saskatchewan specimens with the one illustrated by Loeblich and Tappan from the Oxfordian Redwater shale of South Dakota, and believes that they belong to the

same species although there are one to two additional chambers in the Saskatchewan specimen.

Genus MILIAMMINA Heron-Allen and Earland, 1930

MILIAMMINA sp.

Plate 17, figures 11, 12

Test minute, subelliptical in outline; chambers tubular, in quinqueloculine arrangement, four visible on one side of test, three on the other; sutures distinct, depressed; wall presumably arenaceous, preserved as a pyritized replacement; aperture simple, the open end of the final chamber.

Length of figured specimen, 0.11 mm.; greatest width, 0.07 mm.; approximate thickness, 0.05 mm.

Locality of figured specimen: Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4243 and 4247 feet, in green shale of the upper member of the Vanguard formation, 9 to 13 feet below the top.

Figured specimen: Univ. of Missouri No. F-55-4.

Stratigraphic distribution: This tiny species was found in only the upper member of the Vanguard formation in the Instow and Frontier wells of southwestern Saskatchewan, where it is rather rare in core samples.

Family OPHTHALMIDIIDAE

Genus NODOPHTHALMIDIUM Macfayden, 1939

NODOPHTHALMIDIUM sp.

Plate 3, figure 13

Test attached, large, elongate, composed of proloculum succeeded by two tube-like chambers, each one-half coil in length, followed by a curved, later straightening, uniserial series of chambers, seven in figured specimen; chambers flask-shaped, inflated at their bases and narrowed toward the apertural ends, increasing gradually in size; wall calcareous, porcellaneous, imperforate; aperture terminal, simple, the open end of the final chamber.

Estimated length of figured specimen, 2.07 mm.; diameter of coiled portion, 0.16 mm.; greatest width of uniserial portion, 0.24 mm.

Locality of figured specimen: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3538 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 7 feet above the base.

Figured specimen: Univ. of Missouri No. F-55-5.

Stratigraphic distribution: This species is known with certainty from only the basal Vanguard beds in the Kelstern well, but it may also be present in the lower Vanguard at Rush Lake. Both localities are in west-central Saskatchewan.

Remarks: The chamber arrangement in the early portion of this species is somewhat obscure, but it seems to conform to the diagnosis of *Nodophthalmidium* given by Macfayden (1939, p. 167). Normally, only fragments of this species are encountered in the samples with the figured specimen representing the only complete individual found.

Genus NUBECULINELLA Cushman, 1929

NUBECULINELLA sp.

Plate 3, figures 1, 2

Test attached, initial chamber tubular, occupying about three-quarters of a whorl, followed by an irregular series of inflated chambers; earlier chambers generally flask-shaped, last three or four stomach-shaped, the the latter tending to wind in different planes; wall calcareous, porcellaneous, imperforate; aperture terminal, simple, the rather large open end of the final chamber.

Estimated length of specimen (fig. 1) if chambers in straight line, 1.42 mm.; maximum width (approximate), 0.14 mm.

Estimated length of specimen (fig. 2), 0.61 mm.

Locality of figured specimens: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3538 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 7 feet above the base.

Figured specimens: Univ. of Missouri Nos. F-55-6 and F-55-7.

Stratigraphic distribution: This species is known with certainty from only the basal beds of the Vanguard formation at the locality of the figured specimens in west-central Saskatchewan. Closely related specimens, however, were found in the lower Vanguard of the Johnston Lake well in the same general area.

Remarks: A perusal of the sparse and confusing literature of this genus and related attached ophthalmidiids revealed a slight similarity of this species to *Nubecularia depressa* Chapman from the Lower Cretaceous Gault of England.

It is apparent that species of these attached genera exhibit much variation in shape occasioned by their diverse windings over the objects of attachment. Assignment of specific names for this material could well be deferred until a much better array of specimens is available.

Genus OPHTHALMIDIUM Kübler and Zwingli, 1870, *emendatio* Wood and Barnard, 1946

OPHTHALMIDIUM SASKATCHEWANENSIS Wall, n. sp.

Plate 3, figures 9-12

Test rather small, planispiral, compressed; test consists of spherical proloculum, a second chamber occupying one to two whorls, followed by three whorls of two overlapping chambers apiece, with final whorl of three chambers; whorls gradually increasing in diameter outward from proloculum, separated from each other by a ribbon of cream-colored, shelly material; wall calcareous, imperforate, colorless and translucent; aperture terminal, the open end of the final chamber, simple.

Maximum diameter of holotype (figs. 9, 10), 0.32 mm.; minimum diameter, 0.27 mm.; greatest thickness, 0.04 mm.

Maximum diameter of paratype (figs. 11, 12), 0.32 mm.; minimum diameter, 0.27 mm.; greatest thickness, 0.05 mm.

Type locality: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3548 and 3556 feet, in green shale from the base of the type section of the lower member of the Vanguard formation.

Types: Holotype, No. F-55-8; paratype, No. F-55-9, Univ. of Missouri.

Stratigraphic distribution: This species is known from two levels: (1), the basal green shale beds of the Vanguard formation from its occurrences at Rush Lake and Kelstern in west-central Saskatchewan and (2), the buff lithographic limestone of the lower member of the Shaunavon formation from its occurrences at Frontier, Instow and Eastend in southwestern Saskatchewan. It was not recognized in the intervening upper member of the Shaunavon.

Remarks: The author (1958) referred to this species as *Ophthalmidium* n. sp. 1. This new species with its extended cornuspirine stage is suggestive of the genus *Hauerinella* Schubert and is rather similar to the Recent *Hauerina inconstans* Brady, the species designated as the type species of *Hauerinella* by Schubert. The Saskatchewan species lacks the peripheral wing of the Recent species and its later chambers are not as strongly overlapping.

The author has inferred from the study of Wood and Barnard (1946) that the characters displayed by Schubert's *Hauerinella* come within the range of variation of *Ophthalmidium* and the former would thus become a synonym of the latter.

O. saskatchewanensis, n. sp., differs mainly from *O. rotula* Lalicker (1950) from the Middle Jurassic Sawtooth formation of southwestern Montana in the circular outline of the test compared with the distinctly ovate shape of *O. rotula*.

This new species is named from its occurrence in the province of Saskatchewan.

OPHTHALMIDIUM sp. A

Plate 3, figures 6-8

Test small, planispiral, elliptical in outline; test consists of spherical proloculum, a second chamber occupying about one coil, succeeded by four tubular chambers, each one-half coil in length; diameters of the later chambers increasing as added, especially near their terminals; whorls seemingly separated from each other by a thin shelly plate, sutures depressed; wall calcareous, imperforate, colorless and translucent but partially pyritized in many specimens; aperture simple, the open end of the final chamber.

Length of figured specimen, 0.26 mm.; greatest width, 0.11 mm.; maximum thickness, 0.05 mm.

Locality of figured specimen: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3538 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 7 ft above the base.

Figured specimen: Univ. of Missouri No. F-55-10.

Stratigraphic distribution: This species is fairly common in the basal Vanguard beds from the Kelstern well of west-central Saskatchewan, where at least 15 specimens were found.

Remarks: This small species seems rather closely related to a number of European Jurassic species, including *Ophthalmidium okenii* Kübler and Zwingli from the Bathonian of Germany. It is left as a *nomen apertum* for the present because its small size and only fair preservation render any specific assignment very difficult.

Superfamily LAGENIDEA
Family LAGENIDAE
Genus LENTICULINA Lamarck, 1804
LENTICULINA AUDAX Loeblich and Tappan
Plate 9, figure 17; Plate 16, figures 1-4

Lenticulina audax Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 43-44, pl. 11, figs. 18a-21b.

Test large, lenticular, planispiral and involute; test usually prominently biumbonate, umbos clear, part of penultimate whorl and proloculum typically visible; periphery subacute, peripheral margin keeled; chambers numerous, gradually enlarging, maximum of 12 in final whorl of adult specimens; sutures distinct, slightly thickened, flush, gently curved, more noticeably curved backwards at the peripheral margin; wall calcareous, hyaline, finely perforate; aperture an oval opening on the terminal face just below the outer point of the last chamber, radiate.

Greatest diameter of hypotype (Pl. 9, fig. 17), 0.57 mm.; least diameter, 0.42 mm.; greatest thickness, 0.27 mm.

Greatest diameter of hypotype (Pl. 16, figs. 1, 2), 0.77 mm.; least diameter, 0.55 mm.; greatest thickness, 0.27 mm.

Greatest diameter of hypotype (Pl. 16, fig. 3), 0.92 mm.; least diameter, 0.76 mm.; greatest thickness, 0.36 mm.

Greatest diameter of hypotype (Pl. 16, fig. 4), 0.40 mm.; least diameter, 0.35 mm.; greatest thickness, 0.20 mm.

Locality of hypotype (Pl. 9, fig. 17): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Locality of hypotypes (Pl. 16, figs. 1-4): Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4192 and 4197 feet, in green shale of the upper member of the Vanguard formation, 49 to 54 feet below the top.

Hypotypes: Univ. of Missouri Nos. F-55-11, F-55-12, F-55-13, F-55-14.

Stratigraphic distribution: This commonly-occurring species ranges from the base of the Vanguard formation into the lower portion of the upper member of that formation in Saskatchewan. It is the most common of the lower Vanguard species and was observed in every well section examined.

Loeblich and Tappan described the species from the type Redwater shale (Oxfordian) of South Dakota.

Remarks: The authors of the species have commented on its similarity to several European species including "*Cristellaria*" *mamillaris* Terquem from the Bajocian (Middle Jurassic) of France. The present author has observed a striking resemblance of *L. audax* to "*Cristellaria*" *magna* Myatliuk (1939, p. 52 (Russian), p. 71 (English), pl. 3, figs. 32, 34) from the Upper Jurassic, Lower Volga series of the Saratov District, U.S.S.R.

This species, as interpreted in the present study, may include two or more units of specific or varietal rank. A careful study of the range of

variation exhibited by this form would be needed to delimit the boundaries of any taxonomic units one might wish to recognize.

LENTICULINA DILECTA Loeblich and Tappan
Plate 9, figure 5; Plate 16, figures 13-16

Lenticulina helios (Terquem). Sandidge, 1933, Amer. Midland Nat., vol. 14, no. 2, p. 178, pl. 1, figs. 1, 2 (not *Cristellaria helios* T.).

Lenticulina sarthacensis (Schwager). Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, pp. 160-161, pl. 1, figs. 9a-11b (not *Cristellaria sarthacensis* S.).

Lenticulina dilecta Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, pp. 7-8, pl. 1, figs. 5a-8.

Lenticulina dilecta Loeblich and Tappan. Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 47, pl. 9, figs. 9, 10; pl. 10, figs. 9, 10, 23, 24; pl. 11, figs. 11, 12.

Test medium size, lenticular, close-coiled but not completely involute with portion of penultimate whorl and proloculum typically exposed; later portion of test uncoiled in some specimens (such as hypotype, pl. 16, fig. 14); periphery angular, peripheral margin with a thin keel, ventral face conspicuously truncate; chambers numerous, slightly increasing in size, 9 to 11 in the final whorl; sutures distinct, curved, prominently raised, limbate, their inner ends coalescing to form a ring around the umbilicus, and in well-developed specimens (such as hypotype, pl. 16, figs. 15, 16) their outer ends uniting to form a ridge along the dorsal margin paralleling the keel; wall calcareous, hyaline, finely perforate; aperture on the terminal face just below the outer point of the last chamber, circular, faintly crenulated at the margins.

Greatest diameter or length of hypotype (Pl. 9, fig. 5), 0.77 mm.; least diameter, 0.42 mm.; greatest thickness, 0.25 mm.

Greatest diameter of hypotype (Pl. 16, fig. 13), 0.51 mm.; least diameter, 0.36 mm.; greatest thickness, 0.20 mm.

Greatest diameter or length of hypotype (Pl. 16, fig. 14), 0.82 mm.; least diameter, 0.42 mm.; greatest thickness, 0.25 mm.

Greatest diameter of hypotype (Pl. 16, figs. 15, 16), 1.10 mm.; least diameter, 0.77 mm.; greatest thickness, 0.30 mm.

Locality of hypotype (Pl. 9, fig. 5): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Locality of hypotypes (Pl. 16, figs. 13-16): Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4192 and 4197 feet, in green shale of the upper member of the Vanguard formation, 49 to 54 feet below the top.

Hypotypes: Univ. of Missouri Nos. F-55-15, F-55-16, F-55-17, F-55-18.

Stratigraphic distribution: This commonly-occurring species ranges through the lower member of the Vanguard formation into the lower portion of the upper member. It has a wide lateral distribution in Saskatchewan as it was identified in nearly every well section examined, and ranks second to *L. audax* Loeblich and Tappan in frequency of occurrence in the lower Vanguard.

Loeblich and Tappan report this species from the Rierdon formation of extreme south-central Montana and northwestern Wyoming, and from the Sundance formation of a well in north-central North Dakota.

Remarks: This species seems very closely related to "*Cristellaria*" *sarthacensis* Schwager from the Oxfordian of Germany and differs only in being less closely coiled. Wickenden apparently had a similar opinion as he referred this species directly to *C. sarthacensis*.

"*Cristellaria*" *bruckmanni* Myatliuk (1939, p. 59 (Russian), p. 73 (English), pl. 4, fig. 49) from the Oxfordian of the U.S.S.R. strongly resembles uncoiled specimens of *L. dilecta*.

LENTICULINA sp. A
Plate 16, figures 9, 10

Test rather small, close-coiled, involute, periphery narrowly rounded; chambers gradually enlarging, maximum of about seven present, later chambers moderately inflated; sutures distinct, curved, thickened, flush to slightly raised; wall calcareous, finely perforate; aperture radiate, at the peripheral angle.

Greatest diameter of figured specimen, 0.37 mm.; least diameter, 0.25 mm.; maximum thickness, 0.15 mm. Average maximum diameter of six specimens from level and locality of figured specimen, 0.30 mm.; average maximum thickness, 0.14 mm.

Locality of figured specimen: Tidewater Instow Crown No. 1 well, in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4289 and 4294 feet, in green shale of the upper member of the Vanguard formation, 6 to 11 feet above the base.

Figured specimen: Univ. of Missouri No. F-55-19.

Stratigraphic distribution: This species was not definitely recognized outside of the basal beds of the upper Vanguard at the Instow well in southwestern Saskatchewan.

Remarks: This species is somewhat like "*Cristellaria*" *stellaris* Terquem from the Bathonian of France but has more prominent thickened sutures.

Genus ASTACOLUS Montfort, 1808

ASTACOLUS sp. cf. A. AGALMATUS Loeblich and Tappan
Plate 5, figures 4-6

?*Astacolus agalmatus* Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 44-45, pl. 12, figs. 5a-7.

Test medium to large-sized, compressed, auriculate in outline, periphery subacute, dorsal margin with narrow keel; early portion coiled, slightly biumbonate, later portion uncoiled with chambers reaching back toward coil; chambers numerous, maximum of 16, low and elongate; sutures distinct, somewhat thickened, flush, gently curved backwards near the dorsal margin; wall calcareous, finely perforate; aperture at the peripheral angle, radiate.

Length of specimen (figs. 4, 5), 0.73 mm.; greatest width, 0.37 mm.; greatest thickness, 0.17 mm.

Length of specimen (fig. 6), 1.10 mm.; greatest width, 0.47 mm.

Locality of figured specimens: Tidewater Wapella Crown No. 16-33 well in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2232 and 2237 feet, in green shale of the lower member of the Vanguard formation, 6 to 11 feet above the base.

Figured specimens: Univ. of Missouri Nos. F-55-20 and F-56-1.

Stratigraphic distribution: This species is fairly prominent in the basal beds of the lower Vanguard formation in the Wapella area of eastern Saskatchewan. A few occurrences were recorded from the lower member of the Vanguard in the Rush Lake and Atlas wells of west-central Saskatchewan.

Remarks: The present author (1958) believed this species to be identical with *A. agalmatus* from the type Redwater shale of South Dakota. An examination of the types of *A. agalmatus*, however, has shown it to be wider and much thicker in the coiled portion than the Saskatchewan species.

ASTACOLUS ECTYPUS Loeblich and Tappan
Plate 9, figures 1-4

Lenticulina sculpta (Terquem and Berthelin). Sandidge, 1933, Amer. Midland Nat., vol. 14, no. 2, pp. 179-180, pl. 1, fig. 10 (not *Cristellaria sculpta* T. & B.).

?*Lenticulina sarthacensis* (Schwager) (in part). Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, pp. 160-161, pl. 1, figs. 10a-b (not figs. 9 and 11) (not *Cristellaria sarthacensis* S.).

Astacolus ectypus Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, p. 8, pl. 1, figs. 14-18b.

Test variable in size and outline, early portion close-coiled, later portion uncoiling with chambers extending back toward coil; presumed microspheric individuals show a more enrolled, broader test, whereas presumed megalospheric individuals are more uncoiled, elongate and narrower; periphery acute keeled, ventral face conspicuously truncate; chambers, maximum of 12, sharply inflated just anterior to the sutures, with ridges arising from inflated areas and running nearly parallel to sutures but sometimes curving toward aperture in central portion of test; sutures distinct, deeply depressed, curved; wall calcareous, hyaline, finely perforate; aperture at the peripheral angle, radiate.

Length of hypotype (figs. 1, 2), a megalospheric individual, 0.74 mm.; greatest diameter of coil, 0.32 mm.; greatest width above coil, 0.32 mm.; maximum thickness, 0.25 mm.

Length of hypotype (fig. 3), a microspheric individual, 0.47 mm.; greatest width, 0.27 mm.; maximum thickness, 0.15 mm.

Length of hypotype (fig. 4), a microspheric? individual, 0.60 mm.; greatest width, 0.32 mm.; maximum thickness, 0.17 mm.

Locality of hyptypes: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-56-2, F-56-3, F-56-4.

Stratigraphic distribution: This species is diagnostic of the lower member of the Vanguard formation throughout Saskatchewan and is sporadic to fairly common in most well sections. In the Instow and Frontier wells of southwestern Saskatchewan, *A. ectypus* was recorded from the lower part of the upper member of the Vanguard formation.

Loeblich and Tappan report this species from the Rierdon formation of south-central Montana and northwestern Wyoming, the Stockade Beaver shale member of the Sundance formation in north-central Wyoming, and in the Sundance formation from a well in north-central North Dakota.

Remarks: The distinction between microspheric and megalospheric individuals is not readily discernible in the Saskatchewan suites. Unlike the type material, the presumed broader microspheric specimens generally do not have a significantly greater number of chambers than the elongate, uncoiled megalospheric specimens.

The present author doubts the correctness of placing part of Wickenden's *Lenticulina sarthacensis* (Schwager), *i.e.*, Wickenden's figs. 10a-b, in this species as done by Loeblich and Tappan, because the figure probably represents an uncoiled individual of *Lenticulina dilecta* Loeblich and Tappan (1950b, pp. 7-8, pl. 1, figs. 5-8). Such specimens have been observed in the faunal suites.

The similarity of *Astacolus ectypus* to *"Cristellaria" sarthacensis* Schwager from the Oxford group of the German Upper Jurassic has been noted by Loeblich and Tappan.

ASTACOLUS PETALUS Loeblich and Tappan

Plate 6, figures 14-16

Astacolus petalus Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, pp. 8-9, pl. 1, figs. 19-21b.

Test rather large, auriculate, strongly compressed; early portion coiled, small, later portion uncoiling with chambers extending back toward coil; periphery acute, ventral face subtruncate; chambers numerous, maximum of 12, maintaining approximately same height but increasing rapidly in width, the later chambers four to five times as wide as high; sutures rather faint to fairly distinct, very slightly depressed, gently curved; wall calcareous, probably finely perforate but character obscured in fossilization; aperture at the peripheral angle, radiate.

Length of hypotype, 0.95 mm.; greatest width, 0.47 mm.; greatest thickness, 0.12 mm.

Locality of hypotype: Tidewater Wapella Crown No. 16-33 well in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2232 and 2237 feet, in green shale of the lower member of the Vanguard formation, 6 to 11 feet above the base.

Hypotype: Univ. of Missouri No. F-56-5.

Stratigraphic distribution: This species in Saskatchewan has been observed in only the basal beds of the Vanguard formation in the Wapella area on the eastern border and seems quite rare as only two specimens were recognized.

Loeblich and Tappan report this species from the Rierdon formation of south-central Montana and northwestern Wyoming, and from the Stockade Beaver shale member of the Sundance formation in north-central Wyoming.

Remarks: There are one to two additional chambers in the Saskatchewan specimens and the chambers are slightly lower than in the holotype. An examination of the type material shows considerable variation from the holotype, however, and the present author believes the Saskatchewan specimens to fall within this range of variation.

The strong compression of this species together with its reduced coiled portion suggests closer affinity with the genus *Planularia* Defrance than with *Astacolus*.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA sp. cf. M. SCAPHA Lalicker

Plate 5, figures 8-10

?*Marginulina scapha* Lalicker, 1950, Univ. of Kansas Paleontological Contrib., Protozoa, Article 2, pp. 12-13, pl. 1, figs. 7a-b.

Test elongate, arcuate, somewhat compressed, early portion close-coiled, small, of five chambers; later portion uncoiling, of six chambers gradually increasing in height, slightly inflated, inflation more pronounced in final chamber; sutures fairly distinct, somewhat thickened, flush and gently curved in the coil, raised and recurved near the dorsal peripheral margin in the earlier part of the uncoiled portion, final two sutures depressed and nearly straight, oblique; wall calcareous, hyaline, finely but distinctly perforate; aperture radiate, produced at the outer peripheral angle.

Length of figured specimen, 1.05 mm.; greatest width, 0.25 mm.; maximum thickness, 0.17 mm.

Locality of figured specimen: Tidewater Wapella Crown No. 16-33 well in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2232 and 2237 feet, in green shale of the lower member of the Vanguard formation, 6 to 11 feet above the base.

Figured specimen: Univ. of Missouri No. F-56-6.

Stratigraphic distribution: The figured specimen marks the only occurrence of this species in Saskatchewan.

Remarks: The present author has compared the figured specimen with the holotype of *M. scapha* Lalicker from the Bathonian Sawtooth formation of Montana and believes them to be very close, although the final chamber in the Saskatchewan specimen is more inflated. The poor preservation of the holotype, however, renders any comparison with it somewhat uncertain.

Genus MARGINULINOPSIS Silvestri, 1904

MARGINULINOPSIS BANDYI Wall, n. sp.

Plate 10, figures 11-15

Test large, robust, elongate; earliest portion curved, close-coiled, with a few peripheral spines, later portion straight, uncoiling, uniserial, ovoid to nearly circular in cross section, periphery broadly rounded; earliest chambers of coil very small, subsequent chambers gradually increasing in size, rather low and broad, about twice as wide as high toward distal end, maximum of eight chambers in coiled portion and about six in straight portion; sutures distinct, curved in coil and earlier part of uncoiled portion, last three almost straight, slightly oblique; sutures, excepting those in first half of coil, prominently thickened but flush with surface and not raised; wall calcareous, finely perforate; aperture radiate, circular, on a slight neck near the outer peripheral angle.

Length of holotype (figs. 11-13), 1.17 mm.; greatest diameter of coil, 0.34 mm.; greatest width of uniserial portion, 0.40 mm.; maximum thickness, 0.27 mm.

Length of paratype (figs. 14, 15), 1.07 mm.; greatest diameter of coil, 0.25 mm.; greatest width of uniserial portion, 0.31 mm.; maximum thickness, 0.27 mm.

Locality of holotype: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4436 and 4439 feet, in green shale of the lower member of the Vanguard formation, 56 to 59 feet above the base.

Locality of paratype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Types: Holotype, No. F-56-9; paratype, No. F-56-10, Univ. of Missouri.

Stratigraphic distribution: This distinctive species seems restricted to the lower member of the Vanguard formation, and although rather rare, it has a widespread distribution in Saskatchewan. It was found in the Frontier and Rush Lake wells of southwestern and west-central Saskatchewan, and in the Wapella and Carlyle wells in the eastern area of the province.

Remarks: The author (1958) referred to this species as *Marginulinopsis* n. sp. 1. There is some similarity between this species and *Marginulina formosa* Myatliuk (1939, p. 62 (Russian), p. 74 (English) pl. 4, fig. 54) from the Upper Jurassic Lower Volga series of the U.S.S.R., but the Russian species is smaller, has a less well-developed coil, and its sutures are described as raised compared with the flush sutures in the new species.

The species is named for Dr. Orville L. Bandy, Department of Geology, University of Southern California, Los Angeles, California.

MARGINULINOPSIS CARIEVALENSIS Wall, n. sp.

Plate 5, figures 1-3

Marginulina sp.? Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, p. 163, pl. 1, figs. 12a, b.

Vaginulinopsis eritheles Loeblich and Tappan (in part), 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, pp. 9-10 (synonymic entry only).

Test of moderate size, robust, elongate; early portion cristellarian in character, close-coiled and moderately biumbonate, six to seven chambers in final whorl rather rapidly enlarging; later portion uncoiling, uniserial, nearly straight to moderately arcuate, of three to four chambers becoming progressively more inflated toward distal end with cross section changing from ovoid to circular; sutures generally indistinct, curved and flush in the coil, later sutures oblique and rather deeply depressed; wall calcareous, perforate but character of perforations obscured; aperture round, radiate, on a slight neck near the outer peripheral margin.

Length of holotype, 0.80 mm.; greatest diameter of coil, 0.34 mm.; greatest width of uniserial portion, 0.26 mm.; maximum thickness, 0.25 mm. Average length of five specimens from type locality, 0.74 mm.; average maximum diameter of coil, 0.34 mm.; average maximum width of uniserial portion, 0.27 mm.

Type locality: Socony-Western Prairie-Imperial Carievale No. 1 well in Lsd. 16, Sec. 4, Tp. 3, Rge. 32, W. 1st Meridian, Saskatchewan, Canada,

between depths of 3178 and 3187 feet, in green shale of the lower member of the Vanguard formation, 10 to 19 feet above the base.

Holotype: Univ. of Missouri No. F-56-11.

Stratigraphic distribution: This species appears restricted to the basal section of the lower member of the Vanguard in Saskatchewan. Its distribution seems limited to the eastern area of the province, as it was found in only the Carievale and Wapella wells.

Remarks: The present author (1958) referred to this species as *Marginulinopsis* sp. A. It is identical with *Marginulina* ? sp. of Wickenden. This species, however, is not the same as *V. eritheles* Loeblich and Tappan (1950b, pp. 9-10, pl. 1, figs. 9a-13) which has a widespread occurrence in correlative beds in the western interior region. The chambers in the uncoiled portion of *M. carievalensis*, n. sp., are ovoid to circular in cross section compared with the trihedral shape of the later chambers in *V. eritheles*. A paratype of *V. eritheles* (*op. cit.*, fig. 10) does have ovoid, *Nodosaria*-like chambers in its uncoiled portion but these are much more elongate than the chambers in *M. carievalensis*, n. sp.

Although Loeblich and Tappan (1950b) referred *Marginulina* sp. ? of Wickenden (1933) to *Vaginulinopsis eritheles*, it is the present author's opinion that Wickenden's species with its cylindrical uncoiled portion would be more properly assigned to the genus *Marginulinopsis*. This genus was proposed by Silvestri to include those forms with an early cristellarian and a later marginuline or cylindrical stage, whereas *Vaginulinopsis* was at the same time proposed by Silvestri to embrace those forms with an early cristellarian and a later vaginuline or compressed stage (Thalmann, 1937, pp. 346-351).

This species is named from its occurrence in the Socony-Western Prairie-Imperial Carievale No. 1 well, the type locality of the species.

MARGINULINOPSIS PHRAGMITES Loeblich and Tappan
Plate 9, figures 6-8

Marginulina cf. *lacunata* (Terquem). Sandidge, 1933, Amer. Midland Nat., vol. 14, no. 2, p. 180, pl. 1, figs. 6-8.

Marginulina cf. *lacunata* (Terquem and Berthelin). Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, p. 162, pl. 1, fig. 13 (not *Cristellaria lacunata* T. & B.).

Marginulina cf. *sparsa* (Terquem and Berthelin). Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, p. 161, pl. 1, fig. 14 (not *Cristellaria sparsa* T. & B.).

Marginulinopsis phragmites Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, p. 9, pl. 1, figs. 22-23b, text fig. 1.

Marginulinopsis phragmites Loeblich and Tappan. Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 48, pl. 9, figs. 7, 8.

Test rather robust, elongate, early portion close-coiled, later portion uncoiling, uniserial, nearly straight to moderately curved, oval in cross section; chambers indistinct, four or five in coil, as many as six rather low and wide chambers in uncoiled portion; sutures indistinct, somewhat thickened, curved in coil and part of uncoiled portion, later sutures nearly straight, oblique and depressed; wall calcareous, hyaline, rather finely perforate; surface ornamented with from 11 to 14 (typically 12) strongly elevated longitudinal costae running uninterruptedly across the sutures, and covering all of test except part of the truncate apertural face; the costae tend to unite over the coiled region giving a contour line nose effect to the pattern and an occasional costa may branch over the later portion of the test; aperture round, radiate, on a short neck near the outer peripheral margin.

Length of hypotype (fig. 6), 0.75 mm.; greatest diameter of coil, 0.22 mm.; greatest width of uniserial portion, 0.25 mm.; maximum thickness, 0.19 mm.

Length of hypotype (figs. 7, 8), 0.72 mm.; greatest diameter of coil, 0.25 mm.; greatest width of uniserial portion, 0.29 mm.; maximum thickness, 0.21 mm.

Locality of hypotypes: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-56-7 and F-56-8.

Stratigraphic distribution: This species is restricted to the lower member of the Vanguard formation in Saskatchewan, where it occurs commonly in most of the wells examined and is known from all areas of the province included in this study.

Loeblich and Tappan report this characteristic Callovian species from the Rierdon formation of south-central Montana and northwestern Wyoming, the Stockade Beaver shale member of the Sundance formation in north-central Wyoming, and from the Sundance of a well in north-central North Dakota.

Remarks: As Loeblich and Tappan have pointed out, there is some similarity of this species to "*Cristellaria*" *lacunata* Terquem and Berthelin and "*Cristellaria*" *sparsa* Terquem and Berthelin from the Lower Jurassic of France, but *M. phragmites* may be readily distinguished on the basis of size and number of ribs.

MARGINULINOPSIS sp. B

Plate 5, figure 7

Test monstrous, robust, elongate; early portion coiled, small relative to overall size, of about seven chambers gradually increasing in size; later portion uncoiling, nearly straight, ovoid to nearly circular in cross section, up to nine chambers, first five low and wide and increasing very gradually in size, last four much expanded, of approximately equal size and nearly as high as wide; sutures indistinct, curved in coil, slightly oblique in later portion, somewhat thickened and flush in later part of coil and earlier portion of uncoiled section, depressed and apparently not thickened between last four chambers; wall calcareous, recrystallized in part obscuring original character; aperture radiate, on a neck-like prolongation of the final chamber.

Length of figured specimen, 1.90 mm.; greatest diameter of coil, 0.27 mm.; greatest width of uncoiled portion, 0.37 mm.; thickness, 0.34 mm.

Locality of figured specimen: Socony-Western Prairie-Imperial Carievale No. 1 well in Lsd. 16, Sec. 4, Tp. 3, Rge. 32, W. 1st Meridian, Saskatchewan, Canada, between depths of 3178 and 3187 feet, in green shale of the lower member of the Vanguard formation, 10 to 19 feet above the base.

Figured specimen: Univ. of Missouri No. F-56-12.

Stratigraphic distribution: This species was recognized at only the level and locality of the figured specimen, *i.e.*, in the basal Vanguard of the Carievale well in southeastern Saskatchewan, where it is rare with only three specimens found.

Remarks: A search of the literature revealed nothing similar to this very large species, which may represent an aberrant development of *Marginulinopsis carievalensis*, n. sp., from the same stratigraphic level.

Genus VAGINULINOPSIS Silvestri, 1904

VAGINULINOPSIS sp. cf. V. ENODIS Loeblich and Tappan

Plate 4, figures 11-13

?*Vaginulinopsis enodis* Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 46-47, pl. 12, figs. 11a-16b.

Test rather small, compressed; early portion close-coiled, of three to four gradually enlarging chambers; later portion uncoiling with four to five rather low and wide chambers, increasing very slightly in height, inflated centrally, inflation pronounced in final chamber; periphery narrowly rounded, dorsal margin slightly convex, ventral margin slightly concave, ventral face semitruncate; sutures distinct, slightly raised and limbate in coil, depressed in later portion, slightly curved backwards on the dorsal peripheral margin; wall calcareous, hyaline, finely perforate; aperture radiate, at outer peripheral angle on a short neck.

Length of figured specimen, 0.50 mm.; greatest diameter of coil, 0.22 mm.; greatest width of uncoiled portion, 0.22 mm.; maximum thickness, 0.12 mm.

Locality of figured specimen: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Figured specimen: Univ. of Missouri No. F-56-13.

Stratigraphic distribution: This species was obtained from only the basal beds of the Vanguard formation at the above locality with about 10 specimens observed.

Remarks: This species is closely related to *V. enodis* Loeblich and Tappan from the Redwater shale of South Dakota, the similarity to the figured paratypes (figs. 14 and 16 of the original publication) being quite evident. The uncoiled portions in the Saskatchewan specimens, however, are considerably less inflated than in these paratypes.

VAGINULINOPSIS EPICHARIS Loeblich and Tappan

Plate 11, figures 9, 10

Vaginulinopsis epicharis Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 47, pl. 12, figs. 21-23b.

Test moderate size, elongate, strongly compressed, periphery subacute, ventral face narrow and truncate; early portion close-coiled, provided with a keel becoming vestigial on merging with the dorsal and ventral margins, composed of four gradually enlarging chambers occupying about one-sixth length of test; later portion uncoiling, of six chambers maintaining about the same height but increasing steadily in width so that distal region tends to flare out moderately; sutures distinct, curved and flush in the coil, in the uncoiled portion depressed, somewhat thickened, reaching back toward coil on the ventral margin and gently recurved near the dorsal margin; wall calcareous, finely perforate, largely pyritized; aperture radiate, at outer peripheral angle.

Length of hypotype, 0.70 mm.; greatest diameter of coil, 0.15 mm.; greatest width of uncoiled portion, 0.27 mm.; maximum thickness, 0.12 mm.

Locality of hypotype: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4410 and 4412.5 feet, in green shale of the lower member of the Vanguard formation, 82.5 to 85 feet above the base.

Hypotype: Univ. of Missouri No. F-56-14.

Stratigraphic distribution: This species seems rare in Saskatchewan, with only one additional specimen obtained from the basal Vanguard at the Frontier well.

Remarks: The Saskatchewan hypotype flares out more toward the distal region than the holotype but this probably represents only individual variation. The unfigured specimen is closer to the Redwater shale (Oxfordian) species in that it does not flare distally, but its preservation rendered it unsuitable for illustration.

VAGINULINOPSIS ERITHELES Loeblich and Tappan
Plate 10, figures 1-5

Vaginulinopsis eritheles Loeblich and Tappan (in part), 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, pp. 9-10, pl. 1, figs. 9a-13 (exclusive of synonymy).

Test medium to fairly large, rather robust, elongate; early portion close-coiled and cristellarian in character with a clear umbonal boss through which a portion of penultimate whorl and proloculum are sometimes visible, peripheral margin of coil keeled; later portion uncoiling and slightly to moderately curved, periphery narrowly rounded; chambers numerous, eight or nine in final whorl of coiled portion, gradually enlarging, followed by two to four uncoiled chambers inflated near the ventral margin and compressed toward the dorsal margin, thus appearing subtriangular in cross section, final chamber quite variable in outline; sutures in coiled portion distinct to obscure depending on preservation of individual specimen, generally thickened, flush, curved; sutures in uncoiled portion distinct, depressed, oblique, nearly straight; wall calcareous, finely perforate; aperture circular, radiate, at the peripheral angle which is somewhat produced.

Length of hypotype (figs. 1-3), 0.92 mm.; greatest width of coil, 0.45 mm.; greatest width of uniserial portion, 0.39 mm.; greatest thickness, 0.32 mm.

Length of hypotype (figs. 4, 5), 0.90 mm.; greatest width of coil, 0.32 mm.; greatest width of uniserial portion, 0.30 mm.; greatest thickness, 0.26 mm.

Locality of hypotype (figs. 1-3): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Locality of hypotype (figs. 4, 5): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3288 and 3292 feet, in green shale of the lower member of the Vanguard formation, 73 to 77 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-56-15 and F-56-16.

Stratigraphic distribution: This species seems restricted to the lower member of the Vanguard formation in Saskatchewan and has a wide lateral distribution, as it is present in nearly every well examined.

Loeblich and Tappan report this characteristic Callovian species from the Rierdon formation of south-central Montana and northwestern Wyoming, the Stockade Beaver shale member of the Sundance formation in north-central Wyoming, and from the Sundance formation of a well in north-central North Dakota.

Remarks: A microspheric-megalospheric relationship probably exists in the Saskatchewan populations with the wider, thicker hypotype (figs. 1-3) being the microspheric form and the narrower hypotype (figs. 4, 5) the megalospheric. This species seems to have evolved from *Lenticulina audax* Loeblich and Tappan (1950a, pp. 43-44, pl. 11, figs. 18-21) which uncoiled to give rise to this species. The coiled portion of *V. eritheles* is identical with *L. audax*.

It appears that Leoblich and Tappan regard *Marginulina* sp.? of Wickenden (1933, p. 163, pl. 1, fig. 12) as identical with this species, but the present author believes its cylindrical uncoiled portion would justify its assignment to *Marginulinopsis*. It is thus, in this publication, included under *Marginulinopsis carievalensis*, n. sp.

The present author has noticed a similarity of *V. eritheles* to *Cristellaria russiensis* Myatliuk (1939, p. 58 (Russian), p. 73 (English), pl. 4, figs. 44-46) from the Upper Jurassic (Kimmeridgian) of the Saratov District, U.S.S.R. The Russian species has lower chambers but there seems little doubt of the close relationship between the two species.

VAGINULINOPSIS LOEBLICHORUM Wall, n. sp.

Plate 11, figures 1-5

Test fairly large, slightly compressed but rather robust, typically auriculate, but variable in outline; early portion close-coiled, of five to six chambers; later portion uncoiling, of four low broad chambers extending back toward coil; periphey angular, dorsal margin convex, ventral margin nearly straight, ventral face truncate; sutures distinct, curved, later sutures becoming nearly straight and oblique, although still recurved near dorsal margin; earliest two or three sutures not thickened, flush, subsequent sutures bordered distally by prominent thick ridges, the sutures themselves apparently depressed; wall calcareous, rather finely perforate; aperture at outer peripheral angle, radiate.

Length of holotype (figs. 1-3), 0.72 mm.; greatest diameter of coil, 0.32 mm.; greatest width of uncoiled portion, 0.37 mm.; maximum thickness, 0.20 mm.

Length of paratype (figs. 4, 5), 0.70 mm.; greatest diameter of coil, 0.30 mm.; greatest width of uncoiled portion, 0.37 mm.; maximum thickness, 0.25 mm.

Type locality: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Types: Holotype, No. F-56-17; paratype, No. F-56-18, Univ. of Missouri.

Stratigraphic distribution: *Vaginulinopsis loeblichorum*, n. sp., is a characteristic species of the lower member of the Vanguard formation and is widespread in its occurrence, as it was found in all wells studied except Instow.

Remarks: The present author (1958) referred to this species as *Vaginulinopsis* n. sp. 1. This species probably represents the central unit from which a number of similar species found in the Vanguard formation originated. For example, the two varieties discussed next, *Vaginulinopsis thomasi*, n. sp., and *Vaginulinopsis* sp. A seem directly related to this species.

This new species is somewhat like *Marginulina rica* Lalicker (1950, p. 14, pl. 2, figs. 2a-b) from the Bathonian Sawtooth formation of Montana. Lalicker's species, however, is more arcuate, has a longer coil in proportion to the total length of the test, and its sutures are not bordered by raised ridges as they are in this new species.

This species is named for Dr. Alfred R. Loeblich, Jr., California Research Corporation, La Habra, California, and Dr. Helen Tappan Loeblich, United States Geological Survey and University of California at Los Angeles.

VAGINULINOPSIS LOEBLICHORUM variety A

Plate 11, figures 6-8

Test rather large, compressed, wide, auriculate in outline; early portion curved, close-coiled, of six to seven chambers; later portion uncoiling, of four to five low broad chambers extending back toward coil; periphery angular, dorsal margin convex, incipiently keeled, ventral margin slightly concave, ventral face truncate; sutures distinct, curved with later sutures more nearly straight, oblique, although still recurved near dorsal margin; earliest three or four sutures not thickened, flush, subsequent sutures bordered distally by prominent thick ridges, the sutures themselves apparently depressed; wall calcareous, rather finely perforate; aperture at outer peripheral angle, radiate.

Length of figured specimen, 0.82 mm.; maximum width, 0.47 mm.; greatest thickness, 0.17 mm.

Locality of figured specimen: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Figured specimen: Univ. of Missouri No. F-56-19.

Stratigraphic distribution: *Vaginulinopsis loeblichorum* variety A is rather rare and occurs in association with *V. loeblichorum*, n. sp., in the lower member of the Vanguard formation in the Rush Lake well. Two specimens, probably referable to this variety, were obtained from the Atlas No. 1 and Carievale wells in equivalent strata.

Remarks: This form probably is merely a wide variety of *V. loeblichorum* although the difference in shape might be considered ample justification by some paleontologists for the proposal of a new species.

VAGINULINOPSIS LOEBLICHORUM variety B

Plate 11, figures 11-13

Test fairly large, elongate, compressed; early portion rather close-coiled, of seven chambers; later portion uncoiling, of five chambers

reaching back toward coil, maintaining about the same height but width decreasing toward distal end causing test to taper and giving ventral margin an indented effect; dorsal margin strongly convex, ventral margin nearly straight, periphery angular, ventral face truncate; sutures distinct, curved, final two nearly straight, oblique, earliest sutures not thickened, flush, later sutures bordered distally by prominent ridges with the sutures themselves apparently depressed; wall calcareous, rather finely perforate; aperture at outer peripheral angle, radiate.

Length of figured specimen, 0.77 mm.; maximum width, 0.36 mm.; greatest thickness, 0.20 mm.

Locality of figured specimen: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Figured specimen: Univ. of Missouri No. F-56-20.

Stratigraphic distribution: This variety is rather rare and occurs in association with *V. loeblichorum*, n. sp., in the lower member of the Vanguard formation in the Rush Lake well. A single specimen was found in the Atlas No. 1 well at the same level.

Remarks: This variety differs from the typical in its pronounced distal taper and more strongly convex dorsal margin.

VAGINULINOPSIS MILNERI Wall, n. sp.

Plate 4, figures 24-26

Test moderate size, somewhat compressed, rather narrow, elongate, nearly straight, periphery angular, ventral face incipiently truncate; early portion small, close-coiled, but partly evolute with about one and one-half whorls visible, of eight rather rapidly enlarging chambers; later portion uncoiling, subovoid in cross section with maximum of five chambers reaching back toward coil, rather low and wide but gradually increasing in height, somewhat inflated centrally, inflation more pronounced in ultimate chamber; sutures distinct, curved in coil, slightly curved near dorsal margin in uncoiled portion; earliest two or three sutures not thickened, flush, subsequent sutures, except final one or two, bordered distally by prominent ridges, the sutures themselves depressed; wall calcareous, hyaline, finely perforate; aperture radiate, at outer peripheral angle, on a short neck, which is directed outward.

Length of holotype, 0.72 mm.; greatest width, 0.22 mm.; maximum thickness, 0.15 mm. Type material ranges in length from 0.47 mm. to 0.72 mm., and in width from 0.17 mm. to 0.22 mm.

Type locality: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3538 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 7 feet above the base.

Holotype: Univ. of Missouri No. F-57-1.

Stratigraphic distribution: This species occurs rather commonly in the basal beds of the lower Vanguard at the Kelstern well in west-central Saskatchewan. Isolated occurrences of only one specimen were recorded in the lower Vanguard at the Atlas No. 1 and Frontier wells.

Remarks: The author (1958) referred to this species as *Vaginulinopsis* n. sp. 2. This new species is somewhat like *Marginulina ridica* Lalicker (1950, p. 12, pl. 1, fig. 6) from the Bathonian Sawtooth formation of Montana but is less elongate and has sutures bordered by ridges. The holotype of *M. ridica* is poorly preserved and it is difficult to ascertain the character of the sutures, but apparently these are plain.

Vaginulinopsis milneri, n. sp., seems fairly closely related to *V. cf. enodis* Loeblich and Tappan of this report, and possibly represents adult individuals of the latter species.

The species is named for Dr. R. L. Milner, former geologist, Tidewater Associated Oil Company-Operator, Regina, Saskatchewan.

VAGINULINOPSIS THOMASI Wall, n. sp.

Plate 4, figures 21-23; Plate 16, figures 6-8

Test medium size, somewhat compressed, narrow, elongate, arcuate; early portion close-coiled, small, involute, of four chambers; later portion uncoiling, of four to six chambers reaching back toward coil, increasing gradually in height, not inflated, subovoid in cross section; periphery angular, dorsal margin moderately convex, ventral margin concave, ventral face subtruncate; sutures distinct, flush and nearly radial in coil, later sutures limbate, bordered distally by prominent ridges, gently curved near the dorsal margin but becoming progressively more nearly straight, oblique between final chambers; wall calcareous, finely perforate; aperture radiate, at outer peripheral angle which is slightly produced.

Length of holotype (Pl. 16, figs. 6-8), 0.50 mm.; greatest width, 0.19 mm.; maximum thickness, 0.12 mm.

Length of paratype (Pl. 4, figs. 21-23), 0.66 mm.; greatest width, 0.20 mm.; maximum thickness, 0.15 mm.

Locality of holotype: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4197 and 4207 feet, in green shale of the upper member of the Vanguard formation, 54 to 64 feet below the top.

Locality of paratype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3548 and 3556 feet, in green shale from the base of the type section of the lower member of the Vanguard formation.

Types: Holotype, No. F-57-2; paratype, No. F-57-3, Univ. of Missouri.

Stratigraphic distribution: This species occurs in both the lower and upper members of the Vanguard formation. It is not very common but has a fairly wide geographic distribution in Saskatchewan, as it was found in the Rush Lake, Kelstern and Wapella wells in the lower member of the Vanguard. The holotype locality of Frontier yielded at least eight representatives of this species from the upper Vanguard.

Remarks: The author (1958) referred to this species as *Vaginulinopsis* n. sp. 3. This species seems closely related to *V. loeblichorum*, n. sp., but is much narrower and thinner. It is also rather similar to *Vaginulinopsis* sp. A but is narrower and more arcuate.

V. thomasi, n. sp., shows a fairly close relationship to "*Cristellaria*" *multangulosa* Schwager from the lower Oxfordian of Germany but the latter species is smaller and probably does not have limbate sutures. Schwager (1865) emphasized the overlapping of the chambers along the

dorsal periphery in his description and this feature is present in the Saskatchewan species. Such a character is, however, rather commonplace in these forms and not of much help in differentiation.

V. thomasi, n. sp., seems very closely related to a species from Callovian and Oxfordian beds in Russia referred to "*Cristellaria*" *erucaeformis* Wisniowski by Myatliuk (1939, pl. 4, figs. 47a-b). Myatliuk's figured specimen, however, seems to differ considerably from the type figure of the species (Wisniowski, 1890, pl. 9, fig. 23).

The species is named for Mr. G. E. Thomas, former geologist, Tidewater Associated Oil Company-Operator, Regina, Saskatchewan.

VAGINULINOPSIS sp. A

Plate 12, figures 1-3

Test fairly large, strongly compressed, elongate; early portion close-coiled, of five chambers; later portion uncoiling, of six low wide chambers; periphery acute, ventral face truncate, dorsal margin slightly convex, ventral margin nearly straight; sutures distinct, prominently thickened, raised, sutures curved in early portion, oblique in later portion; wall calcareous, hyaline, finely perforate; aperture radiate, at outer peripheral angle which is somewhat attenuated.

Length of figured specimen, 1.00 mm.; maximum width, 0.37 mm.; greatest thickness, 0.14 mm.

Locality of figured specimen: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3279 and 3284 feet, in green shale of the lower member of the Vanguard formation, 81 to 86 feet above the base or 2 to 7 feet below the top.

Figured specimen: Univ. of Missouri No. F-57-4.

Stratigraphic distribution: This is a rare species recorded from only the Atlas wells of west-central Saskatchewan in the lower member of the Vanguard formation.

Remarks: This species is similar to *Vaginulinopsis* sp. B but is much more compressed and has an attenuated outer peripheral angle.

VAGINULINOPSIS sp. B

Plate 12, figures 4-6

Test moderately large, compressed, elongate; early portion close-coiled, of five chambers; later portion uncoiling, of six low wide chambers, about four times as wide as high reaching back toward coil; periphery angular, dorsal margin slightly convex, ventral margin slightly concave; sutures distinct, earliest two or three flush, subsequent sutures prominently thickened and raised, sutures gently curved in coiled portion, nearly straight, oblique in uncoiled portion but recurved slightly along dorsal margin; wall calcareous, probably medium perforate although character of perforations obscure; aperture radiate, at outer peripheral angle which is slightly produced.

Length of figured specimen, 0.99 mm.; greatest diameter of coil, 0.30 mm.; greatest width of uncoiled portion, 0.35 mm.; maximum thickness, 0.20 mm.

Locality of figured specimen: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan,

Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Figured specimen: Univ. of Missouri No. F-57-5.

Stratigraphic distribution: This species occurs rarely in the lower member of the Vanguard formation of western Saskatchewan, and is recorded from the Rush Lake, Atlas and Frontier wells.

Remarks: This species is closely related to *V. loeblichorum*, n. sp., but is much more elongate. It is also similar to *Vaginulinopsis* sp. A but is much less compressed.

VAGINULINOPSIS sp. C
Plate 12, figures 7-9

Marginulina cf. *candonensis* (d'Orbigny). Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, p. 162, pl. 2, figs. 1a-b (not *Cristellaria cadomensis* d'Orbigny, 1850).

Test medium-sized, strongly compressed, thin; early portion close-coiled, six chambers in ultimate whorl; later portion uncoiling, of five rather low and elongate chambers extending back toward coil; periphery acute, dorsal margin convex, ventral margin slightly concave, ventral face subtruncate; sutures rather indistinct, rendered visible by wetting, slightly thickened, flush in coil and depressed in uncoiled portion, sutures curved in coil, oblique and gently recurved near dorsal margin in later portion; wall calcareous, hyaline, finely perforate; aperture at outer peripheral angle, radiate.

Length of figured specimen, 0.67 mm.; maximum width, 0.30 mm.; greatest thickness, 0.15 mm.

Locality of figured specimen: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Figured specimen: Univ. of Missouri No. F-57-6.

Stratigraphic distribution: This species occurs sporadically in the lower member of the Vanguard formation at the Atlas, Rush Lake and Frontier wells in western Saskatchewan.

Remarks: This species is rather closely related to *Astacolus agalmatus* Loeblich and Tappan (1950a, pp. 44-45, pl. 12, figs. 5-7) but is more compressed, has a less evolute coil, and a less prominently curved dorsal margin with the later chambers not extending as strongly back toward the coil.

This species is not identical with "*Cristellaria*" *cadomensis* d'Orbigny which has elevated sutures.

Genus DENTALINA d'Orbigny, 1826

DENTALINA ECTADIA Loeblich and Tappan
Plate 4, figure 2; Plate 14, figure 7

Dentalina ectadia Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 47-48, pl. 13, figs. 3-5.

Test fairly large, slender, elongate, arcuate, oval in cross section; chambers increasing gradually in size from the rounded base, seven to

eight in mature specimens, ultimate chamber about twice as long as penultimate one and drawn out into a blunt point; chambers slightly inflated centrally and constricted at the sutures; sutures distinct, depressed, oblique; wall calcareous, finely perforate; aperture radiate, produced on short neck.

Length of hypotype (Pl. 4, fig. 2), 0.87 mm.; greatest width, 0.17 mm.

Length of hypotype (Pl. 14, fig. 7), 1.00 mm.; greatest width, 0.20 mm.

Locality of hypotype (Pl. 4, fig. 2): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Locality of hypotype (Pl. 14, fig. 7): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3430 and 3438 feet, in green shale from the type section of the lower member of the Vanguard formation, 14 to 22 feet below the top.

Hypotypes: Univ. of Missouri Nos. F-57-7 and F-57-8.

Stratigraphic distribution: This species is more prevalent in the lower member of the Vanguard formation and has a rather wide distribution in Saskatchewan, as it was found in both the eastern and west-central areas. *D. ectadia* seems to range into the upper member of the Vanguard formation, as a few poorly preserved specimens were encountered in the basal portion of that member in the Instow well of southwestern Saskatchewan.

Loeblich and Tappan proposed the species on the basis of material from the type Redwater shale (Oxfordian) of South Dakota.

Remarks: The authors of this species have commented on its similarity to *D. funiculus* Schwager and *D. oppeli* Schwager from the lower Oxfordian of Germany.

DENTALINA sp. cf. D. EJUNCIDA Leoblich and Tappan

Plate 14, figure 16

?*Dentalina ejuncida* Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 48, pl. 13, figs. 9-11.

Test small, elongate, slender, oval in cross section, nearly straight, base rounded; chambers of nearly equal size, maximum of five observed, slightly inflated centrally; sutures distinct, depressed, slightly oblique; wall calcareous, finely perforate, largely pyritized; aperture terminal, radiate, slightly produced.

Length of figured specimen, 0.45 mm.; greatest width, 0.10 mm.

Locality of figured specimen: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3430 and 3438 feet, in green shale from the type section of the lower member of the Vanguard formation, 14 to 22 feet below the top.

Figured specimen: Univ. of Missouri No. F-57-9.

Stratigraphic distribution: This species is rare in the Vanguard formation of west-central Saskatchewan, as only a few specimens were obtained from the upper beds of the lower member in the Rush Lake well and from

the basal beds of the middle member in the Kelstern well. It is also rare in the middle member of the Vanguard at the Instow well in southwestern Saskatchewan.

Remarks: A comparison of this species with the types of *D. ejuncida* from the Redwater shale of South Dakota shows that they are quite close. The chambers are somewhat longer in the Saskatchewan specimens as there are five compared with seven in the holotype of *D. ejuncida*, although the length of the test is about the same. The Saskatchewan specimens have a considerably larger proloculum than *D. ejuncida*.

This species may be closer to *D. bullaefera* Wisniowski from the Callovian of Poland than to *D. ejuncida*. The sutures in the Polish species seem more oblique than in the Saskatchewan species, but otherwise no differences are apparent.

DENTALINA GRACILISTRIATA Loeblich and Tappan variety
Plate 4, figure 5

Test large, robust, elongate, slightly arcuate, circular in cross section, base rounded; chambers, maximum of nine observed, inflated centrally, increasing gradually in diameter but rather rapidly in length so that the final chambers are one and one-half times or more as long as wide; sutures distinct, depressed, nearly straight; wall calcareous, hyaline, finely perforate, surface ornamented by 20 or more fine longitudinal costae running uninterruptedly across the sutures over the entire length of test; aperture terminal, round, at the end of a beak-like projection of the final chamber.

Length of figured specimen, 1.52 mm.; greatest width, 0.22 mm.

Locality of figured specimen: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Figured specimen: Univ. of Missouri No. F-57-10.

Stratigraphic distribution: This variety is rare in the lower Vanguard formation of west-central Saskatchewan with only two specimens found at the above locality and one at the Atlas No. 2 well.

Remarks: This variety differs from the typical *D. gracilistriata* Loeblich and Tappan (1950b, p. 10, pl. 1, figs. 24a-b) from the Stockade Beaver member of the Sundance formation of north-central Wyoming in being about twice as long and more robust, and in having coarser costae and a more pronounced apertural projection. The differences are probably of sufficient magnitude to warrant the proposal of a new species, but with only three specimens available, such action seems hardly justified.

DENTALINA sp. cf. D. LIOTA Loeblich and Tappan
Plate 13, figure 13; Plate 16, figure 5

?*Dentalina liota* Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 48, pl. 14, figs. 13-14.

Test medium size, fairly robust, slightly arcuate, oval in cross section, base sharply pointed; chambers in early portion of test indistinct, later ones increasing gradually in length, apparently five or six chambers

present; sutures indistinct, oblique, slightly depressed; wall calcareous, finely perforate, nearly always replaced by pyrite; aperture terminal, radiate.

Length of specimen (Pl. 13, fig. 13), 0.57 mm.; greatest width, 0.13 mm.

Length of specimen (Pl. 16, fig. 5), 0.70 mm.; greatest width, 0.17 mm.

Locality of specimen (Pl. 13, fig. 13): Tidewater Atlas Crown No. 2 well in Lsd. 13, Sec. 11, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3344 and 3347 feet, in green shale of the lower member of the Vanguard formation, 68 to 71 feet above the base.

Locality of specimen (Pl. 16, fig. 5): Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4284 and 4289 feet, in green shale of the upper member of the Vanguard formation, 11 to 16 feet above the base.

Figured specimens: Univ. of Missouri Nos. F-57-13 and F-57-14.

Stratigraphic distribution: In western Saskatchewan, this species ranges from the lower member into the basal portion of the upper member of the Vanguard formation as demonstrated by the occurrences of the figured specimens. This species was obtained from the lower member of the Vanguard in the Rush Lake and Wapella 16-33 wells. It is not a common species.

Remarks: Because of the poor preservation of these figured specimens and the types of *D. liota* from the Oxfordian Redwater shale of South Dakota, it is difficult to ascertain whether they are identical. The Saskatchewan specimen (pl. 16, fig. 5) seems very close to the paratype (USNM 104974) of *D. liota*, illustrated as figure 14 of plate 14 in the original publication.

DENTALINA sp. cf. D. PROPINQUA Terquem

Plate 14, figure 17

?*Dentalina propinqua* Terquem, 1870, Acad. Imp. Metz., Mem., Metz, France, vol. 51 (ser. 2, vol. 18) (1869-1870), p. 365, pl. 28, figs. 1, 2.

?*Dentalina propinqua* Terquem. Sandidge, 1933, Amer. Midland Nat., vol. 14, no. 2, p. 181, pl. 1, fig. 16.

Test rather small, elongate, slender, cylindrical in cross section, slightly to moderately arcuate, base rounded; chambers increasing very slightly in height except final one which is about twice as long as preceding one, maximum of eight observed; sutures distinct, slightly depressed, nearly transverse; wall calcareous, finely perforate, largely pyritized; aperture terminal, radiate, slightly produced.

Length of figured specimen, 0.52 mm.; greatest width, 0.10 mm.

Locality of figured specimen: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3430 and 3438 feet, in green shale from the type section of the lower member of the Vanguard formation, 14 to 22 feet below the top.

Figured specimen: Univ. of Missouri No. F-57-15.

Stratigraphic distribution: This is a rare and rather featureless species isolated with certainty only from the Rush Lake well in the lower member of the Vanguard, although it may well be present in other sections.

Remarks: Terquem described *D. propinqua s.s.* from the Bajocian (Middle Jurassic) of France, and Sandidge figured apparently the same species from the Sundance of south-central Montana.

Although the Saskatchewan specimens are perhaps closer to *D. propinqua* than to any other European species, there is also a striking similarity to *D. corniformis* Haeusler from the Malm of Argovian (Oxfordian) age of Switzerland.

Genus NODOSARIA Lamarck, 1812

NODOSARIA BALTEATA Loeblich and Tappan

Plate 4, figures 7-9

Nodosaria balteata Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 49, pl. 13, figs. 6-8.

Test small, rectilinear, elongate, base rather acuminate; chambers, six to seven present, earlier chambers increasing quite rapidly in diameter, later chambers increasing only slightly in width, their heights irregular but chambers generally considerably higher than wide in distal region; sutures transverse, slightly depressed, varying from distinct to indistinct; wall calcareous, hyaline, finely perforate; surface ornamented by about 15 fine longitudinal costae; aperture terminal, a circular opening, possibly radiate.

Length of hypotype (figs. 7, 8), 0.34 mm.; greatest width, 0.08 mm.

Length of hypotype (fig. 9), 0.27 mm.; greatest width, 0.07 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-57-16 and F-57-17.

Stratigraphic distribution: This species was observed chiefly in the lower member but is present as well in the upper member of the Vanguard formation of Saskatchewan. Although not very common, it has a wide lateral distribution in the lower Vanguard of the province.

Loeblich and Tappan proposed the species on the basis of material from the type Redwater shale (Oxfordian) of South Dakota.

Remarks: Loeblich and Tappan have discussed the similarity of this species to several European Jurassic species including *Nodosaria opalini* Bartenstein from the Dogger (Middle Jurassic) of northwest Germany, which seems particularly closely related to *N. balteata.*

NODOSARIA LIRULATA Loeblich and Tappan

Plate 4, figures 3, 4

Nodosaria cf. *corallina* Gümbel. Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, pp. 165-166, pl. 2, fig. 11.

Nodosaria lirulata Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 49, pl. 13, figs. 12-14.

Nodosaria lirulata Loeblich and Tappan. Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 48, pl. 9, figs. 17, 18.

Test small to medium-sized, elongate, rectilinear, strongly constricted at the sutures; chambers subglobular, usually three or less found as test tends to fracture at the constrictions; sutures distinct, depressed, trans-

verse; wall calcareous, hyaline, finely perforate; surface ornamented by a maximum of about 15 fairly coarse longitudinal costae; aperture terminal, a round, simple opening.

Length of hypotype (fig. 3), 0.52 mm.; greatest width, 0.24 mm.

Length of hypotype (fig. 4), 0.51 mm.; greatest width, 0.20 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-57-18 and F-57-19.

Stratigraphic distribution: In Saskatchewan, this common species ranges from the base of the Shaunavon formation into the lower portion of the upper member of the Vanguard formation. It is widely distributed, as specimens were encountered in every well examined.

Loeblich and Tappan described the species from the Oxfordian Redwater shale of South Dakota. Its occurrences in Saskatchewan indicate a time span embracing the Callovian and Bathonian stages of the Jurassic as well.

Remarks: The authors of this species and Wickenden have commented on its similarity to *Nodosaria corallina* Gümbel from the lower Oxfordian of Germany.

N. lirulata is quite similar to *N. orthostoecha* Loeblich and Tappan, also included in this study, but the former has larger and more inflated chambers, with two chambers of *N. lirulata* corresponding to about three of *N. orthostoecha*.

NODOSARIA MECISTA Loeblich and Tappan

Plate 13, figures 16-18

Nodosaria mecista Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 49-50, pl. 13, figs. 17, 20-22.

Test medium size, elongate, tapering, with considerable variation in outline; chambers gradually increasing in size from rounded proloculum, slightly inflated centrally, maximum of at least seven observed, ultimate chamber in many specimens subpyriform; sutures distinct, transverse, depressed; wall calcareous, finely perforate, nearly always pyritized; aperture terminal, radiate.

Length of hypotype (fig. 16), 0.50 mm.; greatest width, 0.14 mm.

Length of hypotype (fig. 17), 0.29 mm.; greatest width, 0.14 mm.

Length of hypotype (fig. 18), 0.45 mm.+; greatest width, 0.11 mm.

Locality of hypotypes: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4410 and 4412.5 feet, in green shale of the lower member of the Vanguard formation, 82.5 to 85 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-57-20, F-58-1, F-58-2.

Stratigraphic distribution: This species seems more common in the lower member of the Vanguard formation in west-central and southwestern Saskatchewan, and was found in the Rush Lake, Kelstern and Frontier wells. Rare possible occurrences were noted at Wapella and Carlyle in eastern Saskatchewan.

Remarks: The Saskatchewan representatives of this species exhibit considerable variation, but it is no greater than that shown by the type material from the Oxfordian Redwater shale of South Dakota. The shorter, more globular hypotype (fig. 17) of this publication and the paratype (fig. 17) of the original publication represent the same phase of this variation.

Loeblich and Tappan have discussed the relationship of this species to several European Jurassic species of which *Nodosaria waageni* Schwager from the Dogger of Germany seems the closest.

The specimen which Loranger (1955, p. 48, pl. 9, figs. 19,20) assigned to this species is curved and more robust. It probably is referable to *Dentalina ectadia* Loeblich and Tappan.

NODOSARIA ORTHOSTOECHA Loeblich and Tappan

Plate 13, figure 19

? *Nodosaria* cf. *corallina* Gümbel. Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, pp. 165-166, pl. 2, fig. 11.

Nodosaria orthostoecha Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, p. 11, pl. 1, figs. 33a-b.

Test medium-sized, elongate, rectilinear; chambers somewhat inflated, of nearly equal size and dimensions, slightly broader than high in some specimens, six chambers observed; sutures distinct, transverse, moderately constricted; wall calcareous, finely perforate; surface ornamented by about 13 straight longitudinal costae; aperture terminal, circular, radiate, on a slight neck.

Length of hypotype, 0.75 mm.; greatest width, 0.16 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Hypotype: Univ. of Missouri No. F-58-3.

Stratigraphic distribution: This species was positively identified from only the lower member of the Vanguard formation in the Rush Lake well of west-central Saskatchewan. It may be present in other wells, but because of its similarity to *N. lirulata* Loeblich and Tappan, it may not have always been isolated from suites of the latter common species.

Loeblich and Tappan report this species from the Rierdon formation of central and south-central Montana and northwestern Wyoming.

Remarks: Leoblich and Tappan include in this species the specimen which Wickenden had compared with *N. corallina* Gümbel, but in the present author's opinion, Wickenden's specimen should be assigned to *N. lirulata* Loeblich and Tappan. The similarity of *N. orthostoecha* to *N. lirulata* has been discussed in this report under the latter species.

NODOSARIA SPHINGOTHALAMA Loeblich and Tappan

Plate 4, figure 10

Nodosaria sphingothalama Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, pp. 11-12, pl. 1, figs. 34a-b.

Test large, robust, elongate, rectilinear; chambers inflated, subglobular, only three in most complete specimen; sutures distinct, trans-

verse, strongly constricted; wall calcareous, hyaline, finely perforate, surface ornamented by about 22 fairly strong, straight, longitudinal costae; aperture terminal, radiate, on a prominent neck.

Length of hypotype, 1.27 mm.; greatest width, 0.45 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3548 and 3556 feet, in green shale from the base of the type section of the lower member of the Vanguard formation.

Hypotype: Univ. of Missouri No. F-58-4.

Stratigraphic distribution: This species seems rare in the lower Vanguard of Saskatchewan with only a few chambers observed in the Atlas No. 1 well in addition to the hypotype. Both occurrences are in the west-central area.

Leoblich and Tappan report this species from the Rierdon formation of central and extreme south-central Montana.

Remarks: The Saskatchewan hypotype is somewhat more robust than the holotype, but there is no doubt of its belonging to this species.

Loeblich and Tappan have commented on the similarity of this species to part of *Nodosaria fontinensis* Terquem from the Bajocian of France. Some of the specimens of *N. variabilis* Terquem and Berthelin from the Lower Jurassic of France appear rather closely related to this species as well.

NODOSARIA sp. A

Plate 14, figure 24

Test fairly large, robust, cigar-shaped, base rounded, apertural end broadly rounded; chambers rather low and broad, increasing gradually in height, seven in number, final chamber subpyriform; sutures transverse, flush to slightly depressed in distal region, rendered indistinct by the ornamentation but visible after wetting; wall calcareous, character of perforations obscure; surface ornamented by numerous, evenly-spaced, rather fine, longitudinal costae, running uninterruptedly the entire length of test; aperture terminal, central, radiate.

Length of figured specimen, 0.89 mm.; greatest width, 0.24 mm.

Locality of figured specimen: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3430 and 3438 feet, in green shale from the type section of the lower member of the Vanguard formation, 14 to 22 feet below the top.

Figured specimen: Univ. of Missouri No. F-58-5.

Stratigraphic distribution: This species was encountered at only the locality and level of the figured specimen, where two specimens were found. It is illustrated with the fauna occurring in the middle and upper members of the Vanguard or the Swift equivalent.

Remarks: This species is fairly closely related to *Nodosaria linea* Lalicker (1950, p. 15, pl. 2, fig. 8) from the Bathonian Sawtooth formation of Montana, but is a much more robust species. The holotype of *N. linea* is poorly preserved, and it is difficult to make a satisfactory comparison of most features.

Genus LINGULINA d'Orbigny, 1826
LINGULINA HATHRA Loeblich and Tappan
Plate 13, figures 1-5

Frondicularia cf. *franconica* Gümbel. Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, p. 164, pl. 2, fig. 5.

Frondicularia lingulaeformis Wickenden, 1933 (not of Schwager, 1865), Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, pp. 164-165, pl. 2, figs. 4, 10.

Lingulina hathra Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, p. 12, pl. 1, figs. 29a-30.

Test medium to large-sized, compressed, sides rounded, extremely variable in outline, ranging from wide, palmate, strongly tapering individuals such as hypotype (figs. 1, 2) to narrow, elongate individuals with sides more nearly parallel such as hypotype (fig. 3) with numerous gradations between these shapes; test consists of rounded proloculum followed by an average of five equitant chambers increasing gradually in size, generally rather low and broad; sutures distinct, flush to slightly depressed, moderately arched, in some specimens slightly constricted; wall calcareous, hyaline, finely perforate, surface ornamented by numerous very fine longitudinal striations tending to converge toward middle of test at the apertural ends of the chambers; aperture terminal, circular, radiate, slightly produced.

Length of hypotype (figs. 1, 2), 1.02 mm.; greatest width, 0.40 mm.; greatest thickness, 0.17 mm.

Length of hypotype (fig. 3), 0.84 mm.; greatest width, 0.30 mm.; greatest thickness, 0.18 mm.

Length of hypotype (fig. 4), 0.57 mm.; greatest width, 0.28 mm.; greatest thickness, 0.10 mm.

Length of hypotype (fig. 5), 0.75 mm.; greatest width, 0.31 mm.; greatest thickness, 0.10 mm.

Locality of hypotypes (figs. 1-3): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Locality of hypotypes (figs. 4, 5): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-58-6, F-58-7, F-58-8, F-58-9.

Stratigraphic distribution: This species appears restricted in Saskatchewan to the lower member of the Vanguard formation. It is widely distributed and has been observed in every area where core coverage was available. It is by far the most common of the various species of *Lingulina* identified in the region.

Loeblich and Tappan report the species from the Rierdon formation of south-central Montana, the Stockade Beaver shale member of the Sundance formation in north-central Wyoming, and the Sundance formation of a well in north-central North Dakota.

Remarks: Loeblich and Tappan have already commented on the similarity of this species to *Frondicularia franconica* Gümbel and *Frondicularia lingulaeformis* Schwager from the lower Oxfordian of Germany.

LINGULINA MICIDA Loeblich and Tappan
Plate 13, figures 7, 8

Lingulina micida Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 51, pl. 13, figs. 29a-30b.

Test elongate, slightly arcuate, compressed, oval in cross section, margins subrounded; test tapers slightly proximally; chambers uniserial, average of seven, first three low and broad, last four increasing proportionately in height; sutures distinct, depressed, weakly arched centrally; wall calcareous, finely perforate, nearly always pyritized; aperture terminal, fissurine.

Length of hypotype, 0.56 mm.; greatest width, 0.11 mm.; approximate thickness, 0.07 mm.

Locality of hypotype: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Hypotype: Univ. of Missouri No. F-58-11.

Stratigraphic distribution: This species is rare in the Vanguard formation of Saskatchewan. It was encountered in the lower member in the Rush Lake, Kelstern and Atlas wells of the west-central area, and ranges into the middle member at Rush Lake and Kelstern. It was also found in the lower member at the Wapella No. 4-3 well in eastern Saskatchewan.

Loeblich and Tappan proposed the species on the basis of material from the type Redwater shale (Oxfordian) of South Dakota.

Remarks: The present author (1958) referred to this species as *Lingulina* sp. A and commented on its similarity to *L. micida*. Subsequently, a comparison has shown that, although the chambers in the Saskatchewan specimens possibly are slightly higher than in the holotype, these specimens should be referred to *L. micida*.

LINGULINA TUMIDA Loeblich and Tappan
Plate 14, figures 14, 15

Lingulina tumida Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 51, pl. 13, figs. 27a-b.

Test small, elongate, only slightly compressed and rather robust; chambers uniserial, eight present, first four gradually increasing in height and width, last four of nearly equal size so that sides of test are approximately parallel, later chambers about twice as wide as high; sutures distinct, depressed, roughly transverse but somewhat sinuous; wall presumably calcareous, preserved as a pyritized replacement; aperture terminal, an elongate fissure.

Length of hypotype, 0.40 mm.; greatest width, 0.12 mm.

Locality of hypotype: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3384 and 3389 feet, in green shale from the type section of the middle member of the Vanguard formation, 8 to 13 feet above the base.

Hypotype: Univ. of Missouri No. F-58-10.

Stratigraphic distribution: This species is rare in the Vanguard formation of west-central Saskatchewan, with only one specimen identified from the lower member in the Atlas No. 2 well besides the hypotype.

Loeblich and Tappan proposed this species on the basis of material from the type Redwater shale (Oxfordian) of South Dakota.

Remarks: Loeblich and Tappan have discussed the similarity of this species to several European Jurassic species including *Lingulina ovalis* Schwager from the lower Oxfordian of Germany, which, in the opinion of the present author, seems the most closely related.

LINGULINA sp. B
Plate 4, figures 14-17

Test rather small, elongate, strongly compressed, margins subacute, test tapers proximally, more abruptly in presumed megalospheric form; test consists of rounded proloculum followed by six equitant chambers in probable megalospheric form (figs. 16, 17) and as many as eight in microspheric form (figs. 14, 15); chambers low and broad, increasing very slightly in height and gradually in diameter; sutures distinct, slightly depressed, strongly arched; wall calcareous, hyaline, finely perforate, ornamented by numerous very fine, barely visible, discontinuous, longitudinal striations; aperture terminal, fissurine.

Length of specimen (figs. 14, 15), a microspheric individual, 0.54 mm.; greatest width, 0.14 mm.; approximate thickness, 0.04 mm.

Length of specimen (figs. 16, 17), a probable megalospheric individual, 0.42 mm.; greatest width, 0.17 mm.; approximate thickness, 0.05 mm.

Locality of figured specimens: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3548 and 3559 feet, in green shale from the base of the type section of the lower member of the Vanguard formation.

Figured specimens: Univ. of Missouri Nos. F-58-12 and F-58-13.

Stratigraphic distribution: This species appears confined to the lower member of the Vanguard formation in Saskatchewan. It is rare with only a few specimens identified from the Rush Lake, Frontier and Atlas No. 1 wells of western Saskatchewan.

Remarks: *Lingulina* sp. B. may come within the range of variation of *Frondicularia oölithica* Terquem from the Bajocian of France, although it is questionable whether they are conspecific.

LINGULINA sp. C
Plate 13, figures 9-12

Test medium size, compressed, margins subacute, test tapers proximally, more noticeable in the elongate, presumed microspheric form (figs. 9-11); test consists of rounded proloculum followed by as many as eight equitant chambers in the microspheric form and six in the megalospheric form; chambers low and broad, increasing very slightly in height but more rapidly in width so that the test tends to flare out gradually, ultimate chamber rounded at apertural end appearing cupola-shaped; sutures not too distinct, visible on wetting, broadly arched, slightly depressed, slightly constricted in later part of test; wall calcareous, hyaline, finely perforate, surface ornamented by numerous, very fine, barely visible, disconnected longitudinal striations; aperture terminal, fissurine.

Length of specimen (figs. 9-11), a microspheric individual, 0.72 mm.; greatest width, 0.30 mm.; approximate thickness, 0.09 mm.

Length of specimen (fig. 12), a probable megalospheric individual, 0.60 mm.; greatest width, 0.30 mm.; approximate thickness, 0.11 mm.

Locality of figured specimens: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Figured specimens: Univ. of Missouri Nos. F-58-14 and F-58-15.

Stratigraphic distribution: This species is rare in the lower member of the Vanguard formation and was positively identified in only the west-central Saskatchewan area from the Atlas and Rush Lake wells.

Remarks: The microspheric form of *Lingulina* sp. C is somewhat similar to *Frondicularia subtilis* Wisniowski from the upper Callovian of Poland, but the latter seems to lack the slight sutural constrictions between the later chambers and the faint striations of the Saskatchewan species.

Genus TRISTIX Macfayden, 1941

TRISTIX NITIDULA Loeblich and Tappan

Plate 6, figures 1-3

Dentalinopsis oölithica? (Terquem). Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, p. 167, pl. 2, figs. 6a-b (not *Tritaxia oölithica* T.).

Tristix nitidula Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, p. 13, pl. 1, figs. 37a-b.

Test medium size, elongate, narrow, tapering slightly toward the base, triangular in cross section with the sides slightly reëntrant, angles rounded; chambers uniserial, five to six present, increasing only slightly in height from the rounded proloculum; sutures rather indistinct, rendered more easily visible upon wetting, slightly depressed, moderately arched in the center of the sides, curving downward over the angles; wall calcareous, hyaline, finely perforate; aperture a terminal, round, radiate opening.

Length of hypotype (figs. 1, 2), 0.77 mm.; greatest breadth, 0.20 mm.

Length of hypotype (fig. 3), 0.72 mm.; greatest breadth, 0.22 mm.

Locality of hypotypes: Socony-Western Prairie-Imperial Carievale No. 1 well in Lsd. 16, Sec. 4, Tp. 3, Rge. 32, W. 1st Meridian, Saskatchewan, Canada, between depths of 3161 and 3169 feet, in gray shale of the lower member of the Vanguard formation, 28 to 36 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-58-16 and F-58-17.

Stratigraphic distribution: This species is confined to the lower member of the Vanguard formation in Saskatchewan, and seems restricted largely to the eastern part of the province. It was observed in small numbers from one of the Wapella wells, the Carlyle and Carievale wells. One occurrence was noted in the Rush Lake well of west-central Saskatchewan.

The type locality of this Callovian species is in the Stockade Beaver shale member of the Sundance formation in north-central Wyoming.

Remarks: The present author (1958) inferred that the Saskatchewan specimens apparently have more strongly arched sutures than the holotype, but a comparison has since shown the sutures to be arched about the same amount.

TRISTIX WAPELLENSIS Wall, n. sp.

Plate 6, figures 4-6

Test medium to large-sized, elongate, sides tapering rather strongly towards the base from a point one-third to two-fifths of the distance from the broadly rounded initial end; test triangular in cross section, the sides moderately excavated, and the angles rather sharp; chambers uniserial, average of about six, increasing rather rapidly in width over the initial third of the test, thereafter maintaining nearly the same size; sutures distinct, depressed, moderately arched in the center of the sides, curving downward over the angles; wall calcareous, finely perforate; aperture a terminal, round, radiate opening.

Length of holotype (figs. 4, 5), 0.65 mm.; greatest breadth, 0.41 mm.

Length of paratype (fig. 6), 0.87 mm.; greatest breadth, 0.36 mm.

Type locality: Tidewater Wapella Crown No. 16-33 well in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2232 and 2237 feet, in green shale of the lower member of the Vanguard formation, 6 to 11 feet above the base.

Types: Holotype No. F-58-18; paratype, No. F-58-19, Univ. of Missouri.

Stratigraphic distribution: This species in Saskatchewan is known from only the lower member of the Vanguard formation in the eastern area of the province, and was found at Carievale in addition to the type locality. It is rather rare with eight specimens obtained from the type locality.

Remarks: The author (1958) referred this species to *T. reesidei* Loeblich and Tappan (1950a, p. 53-54, pl. 14, figs. 1-5) from the Redwater shale of South Dakota. A comparison has since shown, however, that this new Saskatchewan species is much more robust and its angles are much less sharp than those of *T. reesidei*. *T. wapellensis*, n. sp., probably is more closely related to *T. alcima* Loeblich and Tappan (1950a, p. 52-53, pl. 14, figs. 6a-b), also from the Redwater shale, but the angles of the Saskatchewan species are not as sharp and its sutures are more strongly arched. *T. wapellensis*, n. sp., tends to be more robust as well.

A megalospheric-microspheric relationship may be exhibited by the types of this new species, with the stubby holotype representing the megalospheric form, and the elongate paratype the microspheric form. This is uncertain, however, because of the small population available for study and of breakage in the initial portions of the two or three elongate individuals present.

The species is named from its occurrence in the Wapella oil field of eastern Saskatchewan, the type locality of the species.

Genus VAGINULINA d'Orbigny, 1826

VAGINULINA sp. cf. V. CATAULACA Loeblich and Tappan

Plate 11, figures 14, 15

?*Vaginulina cataulaca* Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 54-55, pl. 14, figs. 22-23b.

Test medium size, strongly compressed, flattened, early portion coiled, small, of four to five chambers; later portion uncoiling with the chambers reaching back toward coil, seven in number, low and broad, increasing very gradually in size; periphery angular, dorsal margin slightly convex,

ventral margin nearly straight, ventral face narrow and truncate; sutures fairly distinct, curved in the coil, becoming progressively less curved and nearly straight, oblique toward distal end of test, sutures limbate, bordered by thin raised strips, with the actual sutures depressed between later chambers; wall calcareous, hyaline, finely perforate, surface ornamented by numerous fine striae running slightly oblique to the long axis of test and not continuous, becoming disconnected at the sutures in some specimens; aperture radiate, at outer peripheral angle.

Length of figured specimen, 0.72 mm.; greatest diameter of coil, 0.16 mm.; greatest width of uncoiled portion, 0.27 mm.; maximum thickness, 0.07 mm.

Locality of figured specimen: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Figured specimen: Univ. of Missouri No. F-58-20.

Stratigraphic distribution: This species is rare in the lower member of the Vanguard formation at the two Atlas wells in west-central Saskatchewan. It is more common in the basal beds of the middle member of the Vanguard at Kelstern, also in the west-central area.

Remarks: This species is closely related to *V. cataulaca* from the Oxfordian Redwater shale of South Dakota, but is definitely larger and has a more developed coil.

VAGINULINA sp. cf. V. COMPSA Loeblich and Tappan

Plate 14, figures 22, 23

?*Vaginulina compsa* Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 55, pl. 14, figs. 15-19b.

Test medium to fairly large size, elongate, much compressed; early portion coiled, small, of three to four chambers gradually increasing in size; later portion uncoiling with peripheral margins straight, of six to seven low wide chambers maintaining about the same size; periphery angular, ventral face truncate; sutures distinct, curved in coil, oblique and slightly curved near the dorsal peripheral margin in uncoiled part, flush with the surface, sutures somewhat thickened in uncoiled portion; wall calcareous, finely perforate; aperture radiate, at the peripheral angle.

Length of figured specimen, 0.77 mm.; greatest width, 0.25 mm.; maximum thickness, 0.14 mm.

Locality of figured specimen: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3384 and 3389 feet, in green shale of the middle member of the Vanguard formation, 8 to 13 feet above the base.

Figured specimen: Univ. of Missouri No. F-59-1.

Stratigraphic distribution: In Saskatchewan, this species was found only at the Kelstern well of the west-central area, where it is rare in the basal beds of the middle member of the Vanguard.

Remarks: The present author (1958) referred this species to *V. compsa* from the Oxfordian Redwater shale of South Dakota. A comparison has since shown that, although the relationship between the two is undoubtedly close, the Saskatchewan species is considerably wider and thicker, and probably is not the same.

VAGINULINA INSPISSATA Loeblich and Tappan
Plate 6, figures 10-12

Vaginulina inspissata Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, pp. 55-56, pl. 14, figs. 24-25b.

Test medium size, elongate, moderately compressed, early portion coiled, small, of three to four chambers; later portion uncoiling, of six chambers increasing slightly in size except narrowing ultimate one, chambers inflated centrally; periphery subacute, dorsal margin slightly convex and rather angular, ventral margin nearly straight and rounded, slightly lobulate; sutures distinct, depressed, curved in coil, oblique in uncoiled portion and nearly straight with evidence of recurving only along dorsal margin; wall calcareous, finely perforate, largely pyritized; aperture radiate, at the peripheral angle.

Length of hypotype, 0.56 mm.; greatest width, 0.15 mm.; maximum thickness, 0.10 mm.

Locality of hypotype: Tidewater Wapella Crown No. 16-33 well in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2232 and 2237 feet, in green shale of the lower member of the Vanguard formation, 6 to 11 feet above the base.

Hypotype: Univ. of Missouri No. F-59-2.

Stratigraphic distribution: This species is rare in the lower member of the Vanguard formation in Saskatchewan with occurrences of one specimen in each of the Rush Lake and Atlas wells of the west-central area, and with two specimens recorded in the Wapella area on the eastern border.

Remarks: The Saskatchewan hypotype is narrower and thinner than the holotype from the Oxfordian Redwater shale of South Dakota, but as it is larger than most of the unfigured paratypes (USNM 105041), it falls within the size range of the type material.

VAGINULINA WICKENDENI Wall, n. sp.
Plate 10, figures 6-10

Test medium size, elongate, nearly straight, considerably compressed, periphery subacute, ventral face moderately truncate; early portion close-coiled, small, of three chambers; later portion uncoiling, with about six rather low and broad chambers increasing very little in size, final three or four inflated just distal to the sutures; sutures indistinct, difficultly visible upon wetting, flush in coil to depressed in uncoiled portion, oblique and only slightly recurved along dorsal margin; wall calcareous, surface covered with innumerable fine pits aligned in some areas to give a reticulate appearance; aperture radiate, at outer peripheral angle.

Length of holotype (figs. 8-10), 0.77 mm.; greatest width, 0.25 mm.; maximum thickness, 0.15 mm.

Length of paratype (figs. 6, 7), 0.54 mm.; greatest width, 0.20 mm.; maximum thickness, 0.12 mm.

Type locality: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4431 and 4433 feet, in green shale of the lower member of the Vanguard formation, 62 to 64 feet above the base.

Types: Holotype, No. F-59-3; paratype, No. F-59-4, Univ. of Missouri.

Stratigraphic distribution: This species is rather rare in the Vanguard formation of western Saskatchewan. Some specimens were recorded in the lower member at Frontier and Rush Lake, and in the basal beds of the middle member at Kelstern.

Remarks: This new species is rendered distinct by its peculiar pitted wall, and the author could find no similar, previously published species. It was designated *Vaginulina* n. sp. 1 by the author (1958).

The species is named for Dr. R. T. D. Wickenden, geologist-in-charge, Geological Survey of Canada, district office, Calgary, Alberta.

VAGINULINA ? sp. A

Plate 6, figures 7-9

Test medium size, elongate, much compressed; early portion attenuated in a vestigial coil with three to four chambers; later portion uncoiling, with as many as nine low wide chambers increasing very gradually in height and width, extending back toward coil; periphery subacute, dorsal margin gently convex, ventral margin slightly concave, ventral face semitruncate to truncate; sutures distinct, flush, strongly oblique, recurved along dorsal margin; wall calcareous, finely perforate; aperture radiate, at outer peripheral angle.

Length of figured specimen, 0.65 mm.; greatest breadth of coil, 0.15 mm.; greatest width of uncoiled portion, 0.27 mm.; maximum thickness, 0.10 mm.

Locality of figured specimen: Tidewater Wapella Crown No. 16-33 well in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2232 and 2237 feet, in green shale of the lower member of the Vanguard formation, 6 to 11 feet above the base.

Figured specimen: Univ. of Missouri No. F-59-5.

Stratigraphic distribution: Four or five representatives of this species were found at the level and locality of the figured specimen. A very few occurrences of closely related, although probably not identical, specimens were recorded in the Kelstern and Rush Lake wells from the basal beds of the middle member of the Vanguard formation.

Remarks: This much compressed species with its later chambers extending strongly back toward the coil may be more appropriately included under *Astacolus*, but is retained at present in *Vaginulina* because of its nearly vestigial coil.

Vaginulina ? sp. A is rather similar to "*Cristellaria*" *anceps* Terquem from the Bathonian of France, but in the latter species more of the later chambers actually reach back to the coil.

VAGINULINA sp. B

Plate 4, figure 1; Plate 13, figure 6

Test medium to fairly large size, elongate, compressed, subcylindrical in cross section; early portion of test slightly curved in presumed microspheric form (Pl. 13, fig. 6), with a tiny planispiral coil of up to eight chambers followed by a straight uncoiled portion of about 10 chambers increasing gradually in size; test nearly straight in presumed megalospheric form (Pl. 4, fig. 1), consisting of prominent initial chamber followed by five gradually enlarging chambers; sutures distinct, oblique, flush except last two or three which are depressed; wall calcareous, hyaline, finely perforate; aperture terminal, radiate.

Length of figured specimen (Pl. 4, fig. 1), 0.66 mm.; greatest width, 0.17 mm.

Length of figured specimen (Pl. 13, fig. 6), 0.87 mm.; greatest width, 0.16 mm.

Locality of figured specimen (Pl. 4, fig. 1): Tidewater Kelstern Crown No. 1 well is Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Locality of figured specimen (Pl. 13, fig. 6): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3288 and 3292 feet, in green shale of the lower member of the Vanguard formation, 73 to 77 feet above the base.

Figured specimens: Univ. of Missouri Nos. F-57-11 and F-57-12.

Stratigraphic distribution: *Vaginulina* sp. B occurs characteristically in the lower member of the Vanguard formation in west-central Saskatchewan with the best suites obtained from the Atlas wells. These suites are composed of nearly all presumed microspheric individuals. This species is rather rare in the same member in the Kelstern well, where most of the specimens appear to be megalospheric individuals. This species may be present in the lower portion of the upper member of the Vanguard formation at the Instow well in southwestern Saskatchewan, where a few questionable juvenile representatives of the megalospheric form were recorded.

Remarks: The author (1958) referred both of the figured specimens to *Dentalina leptosyna* Loeblich and Tappan (1950a, p. 48, pl. 13, fig. 2) from the Oxfordian Redwater shale of South Dakota. Further work, however, has shown this assignment to be erroneous. The presence of a coil in the early portion of the Atlas specimens, which was overlooked in the original study, necessitates removal of this species from *Dentalina*. Further investigation also showed that this species is less robust or more compressed than *D. leptosyna* and lacks the sharp apertural projection of the latter species.

Genus CITHARINA d'Orbigny, 1839

CITHARINA ENTYPOMATUS Loeblich and Tappan

Plate 7, figures 1-4

?*Vaginulina lepida* (Schwager). Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, p. 163, pl. 1, figs. 15, 16 (not *Cristellaria lepida* S.).

Citharina entypomatus Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 57, pl. 15, figs. 1-12.

Test large, compressed, elongate-subtriangular in outline, sides slightly convex to nearly straight, periphery angular; chambers maintaining about the same height as added but increasing gradually in width so that later chambers are low and elongate, test of nine or ten chambers on the average but as many as 14 observed; sutures fairly distinct, slightly depressed between earlier chambers to more conspicuously depressed in later portion, oblique, very slightly curved near dorsal margin; wall calcareous, finely perforate, surface ornamented with low fine longitudinal costae, about 12 in mature specimens, running from near base of test uninterruptedly across sutures over the distal margin to near median point of ventral face; aperture radiate, on a neck-like extension of the peripheral angle.

Length of hypotype (figs. 1, 2), 1.37 mm.; greatest width, 0.40 mm.; greatest thickness, 0.15 mm.

Length of hypotype (fig. 3), 0.55 mm.; greatest width, 0.22 mm.; greatest thickness, 0.12 mm.

Length of hypotype (fig. 4), 1.15 mm.; greatest width, 0.35 mm.; greatest thickness, 0.12 mm.

Locality of hypotypes (figs. 1-3): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 12 feet above the base.

Locality of hypotype (fig. 4): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-59-6, F-59-7, F-59-8.

Stratigraphic distribution: This species has a wide distribution in the lower member of the Vanguard formation across Saskatchewan, and although not very common, a few specimens were identified from nearly every well section studied. It is also present in the basal beds of the middle member of the Vanguard at Kelstern in the west-central area.

Loeblich and Tappan proposed the species on the basis of material from the type Redwater shale (Oxfordian) of South Dakota.

Remarks: The authors of this species have commented on its similarity to several of Terquem's species from the *Systeme Oölithique*, Bathonian, of France.

The specimens referred to *Vaginulina lepida* (Schwager) by Wickenden probably should be included in *C. entypomatus*.

CITHARINA LATISSIMA Loeblich and Tappan
Plate 7, figures 5-8

Citharina latissima Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, p. 14, pl. 1, figs. 40a-b, text figs. 2a-h.

Test large, wide, compressed, subtriangular in outline but basal margin may vary considerably; periphery angular, ventral face truncate; chambers numerous, about 11 in mature specimens, low and wide, increasing slightly in height but rapidly in width; sutures distinct, thickened internally, slightly depressed, curving gently from basal margin to much higher positions on dorsal margin; wall calcareous, hyaline, very finely perforate, ornamented in some specimens by a variable number of very fine longitudinal costae interrupted at the sutures; aperture radiate, on a short neck-like extension of the dorsal peripheral angle.

Length of hypotype (figs. 5, 6), 1.76 mm.; greatest width, 0.62 mm.; greatest thickness, 0.11 mm.

Length of hypotype (fig. 8), 0.97 mm.; greatest width, 0.32 mm.; greatest thickness, 0.09 mm.

Length of hypotype (fig. 7), 1.50 mm.; greatest width, 0.50 mm.; greatest thickness, 0.12 mm.

Locality of hypotypes (figs. 5, 6, 8): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan,

Canada, between depths of 3533 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 12 feet above the base.

Locality of hypotype (fig. 7): Tidewater Wapella Crown No. 16-33 well in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2217 and 2222 feet, in green shale of the lower member of the Vanguard formation, 21 to 26 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-59-9, F-59-10, F-59-11.

Stratigraphic distribution: This species is confined to the lower member of the Vanguard formation in Saskatchewan, and has a widespread distribution with a few specimens encountered in most of the wells examined.

Loeblich and Tappan report the species from the Rierdon formation of south-central Montana and northwestern Wyoming, and from the Stockdale Beaver shale member of the Sundance formation in north-central Wyoming.

Remarks: The authors of this species have noted its similairty to *Marginulina condita* Terquem from the *Systeme Oölithique*, Bathonian, of France.

Because of the large and delicate tests, the Saskatchewan specimens are subject to considerable breakage.

Genus CITHARINELLA Marie, 1938

CITHARINELLA COMPARA Loeblich and Tappan

Plate 12, figure 10

Citharinella compara Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, pp. 14-15, pl. 1, figs. 36a-b, text figs. 3a-d.

Test elongate, palmate, compressed, increasing gradually in size; early portion citharine, of three to four chambers; later portion frondicularian, of six to seven low broad equitant chambers; sutures distinct, slightly depressed, oblique in citharine portion, highly arched in frondicularian portion; wall calcareous, finely perforate, ornamented by numerous very fine, nearly invisible, longitudinal striations; aperture terminal, radiate, on an incipient neck, which ordinarily does not survive fossilization; positions of earlier apertures indicated by collars at junctions of sutural limbs.

Length of hypotype, 1.00 mm.; greatest width, 0.42 mm.; greatest thickness, 0.10 mm.

Locality of hypotype: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3288 and 3292 feet, in green shale of the lower member of the Vanguard formation, 73 to 77 feet above the base.

Hypotype: Univ. of Missouri No. F-59-12.

Stratigraphic distribution: This species is rather rare in the lower member of the Vanguard formation. In addition to the hypotype occurrence in west-central Saskatchewan, a few specimens were found in the Tidewater Wapella Crown No. 16-33 well in the eastern border area.

Loeblich and Tappan report the species from the Rierdon formation of central and south-central Montana and northwestern Wyoming, the Stockade Beaver shale member of the Sundance formation in north-central Wyoming, and the Sundance formation of a well in north-central North Dakota.

Remarks: The similarity of this species to *Flabellina jurensis* Franke from the Lower Jurassic of Germany has been noted by Loeblich and Tappan.

CITHARINELLA LATIFOLIA Loeblich and Tappan

Plate 4, figure 6; Plate 12, figures 11-13; Plate 14, figures 20-21

Flabellina muralis Wickenden, 1933 (not of Terquem, 1870), Roy. Soc. Canada, Trans., ser. 3, sec. IV, vol. 27, p. 165, pl. 2, fig. 3.

Citharinella latifolia Loeblich and Tappan, 1950b, Wash. Acad. Sci., Jour., vol. 40, no. 1, p. 15, pl. 1, figs. 35a-b, text figs. 4a-c.

Test medium to fairly large size, palmate, compressed, periphery truncate; early portion citharine, of three to four chambers; later portion frondicularian, of from four to six low broad equitant chambers increasing gradually in width as added; sutures distinct, slightly depressed, highly arched centrally; wall calcareous, hyaline, finely perforate, surface traversed longitudinally by numerous fine and discontinuous to moderately coarse and continuous costae; aperture terminal, radiate, slightly produced in some specimens, on a pronounced neck in others.

Length of hypotype (Pl. 4, fig. 6), 0.95 mm.; greatest width, 0.45 mm.; greatest thickness, 0.11 mm.

Length of hypotype (Pl. 12, fig. 11), 0.87 mm.; greatest width, 0.40 mm.; greatest thickness, 0.07 mm.

Length of hypotype (Pl. 12, figs. 12, 13), 0.97 mm.; greatest width, 0.42 mm.; greatest thickness, 0.06 mm.

Length of hypotype (Pl. 14, figs. 20, 21), 1.00 mm.; greatest width, 0.50 mm.; greatest thickness, 0.11 mm.

Locality of hypotype (Pl. 4, fig. 6): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3538 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 7 feet above the base.

Locality of hypotypes (Pl. 12, figs. 11-13): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3288 and 3292 feet, in green shale of the lower member of the Vanguard formation, 73 to 77 feet above the base.

Locality of hypotype (Pl. 14, figs. 20, 21): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3421 and 3429 feet, in green shale from the type section of the lower member of the Vanguard formation, 5 to 13 feet below the top.

Hypotypes: Univ. of Missouri Nos. F-59-13, F-59-14, F-59-15, F-59-16.

Stratigraphic distribution: This species is rare in the lower member of the Vanguard formation in west-central Saskatchewan with few occurrences recorded other than the hypotypes. The Rush Lake hypotype (Pl. 14, figs. 20, 21) is from near the top of the lower member of the Vanguard and is illustrated with the fauna occurring in the middle and upper members of the Vanguard or the Swift equivalent.

Loeblich and Tappan report this species from the Rierdon formation of central and south-central Montana and from the Stockade Beaver shale member of the Sundance formation in north-central Wyoming.

Remarks: The present author (1958) referred the Kelstern and Rush Lake hypotypes to this species, but merely compared the Atlas hypotypes with it. An examination of the type material has shown, however, that the authors of this species have included specimens with a considerable diversity of shape and ornamentation, and that the Atlas specimens definitely belong here. The Rush Lake hypotype seems also correctly referred, but the assignment of the Kelstern specimen is somewhat doubtful. Considerable breakage and unsatisfactory preservation render identification of some of this material rather uncertain.

In the opinion of the present author, the specimen which Wickenden referred to *Flabellina muralis* Terquem from the Bajocian of France belongs to *C. latifolia*. The French species has a smaller citharine portion and lacks the apertural neck of the specimens figured by Wickenden, Loeblich and Tappan, and the present author.

CITHARINELLA RHOMBOIDEA Loeblich and Tappan
Plate 6, figure 13

Citharinella rhomboidea Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 58, pl. 16, figs. 1-3b.

Test medium size, flattened, rhomb-shaped; early portion citharine, of three chambers; later portion frondicularian, of four to five low broad chevron-shaped chambers, increasing in width; sutures distinct, depressed, oblique in citharine portion, highly arched upward in frondicularian portion; wall calcareous, very finely perforate, smooth; aperture terminal, radiate, on a slight neck; positions of earlier apertures indicated by collars at junctions of sutural limbs.

Length of hypotype, 0.95 mm.; greatest width, 0.54 mm.; greatest thickness, 0.07 mm.

Locality of hypotype: Tidewater Wapella Crown No. 16-33 well, in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2232 and 2237 feet, in green shale of the lower member of the Vanguard formation, 6 to 11 feet above the base.

Hypotype: Univ. of Missouri No. F-59-17.

Stratigraphic distribution: This species is rather rare in the lower member of the Vanguard formation but its areal distribution is quite wide in Saskatchewan. In addition to the hypotype occurrence from Wapella and the identification of this species in the Atlas No. 2 well, it probably is present in the Rush Lake and Carievale wells, where identification is questionable because of breakage.

The species was described by Loeblich and Tappan from the Oxfordian Redwater shale of South Dakota.

Family POLYMORPHINIDAE
Genus EOGUTTULINA Cushman and Ozawa, 1930
EOGUTTULINA AMYGDALINA Loeblich and Tappan
Plate 14, figures 8-13

Eoguttulina amygdalina Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 59, pl. 15, figs. 16a-b.

Test small to medium-sized, acuminate; chambers narrow and elongate, somewhat inflated, added in a spiral series, each chamber farther removed from the base; sutures distinct, depressed; wall calcareous, finely perforate, nearly always pyritized; aperture terminal, radiate.

Length of hypotype (figs. 8, 9), 0.35 mm.; greatest width, 0.15 mm.; maximum thickness, 0.09 mm.

Length of hypotype (figs. 10, 11), 0.45 mm.; greatest width, 0.16 mm.

Length of hypotype (figs. 12, 13), 0.55 mm.; greatest width, 0.20 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3384 and 3396 feet, in green shale of the middle member of the Vanguard formation, 1 to 13 feet above the base.

Hypotypes: Univ. of Missouri No. F-59-18, F-59-19, F-59-20.

Stratigraphic distribution: This species is known to range in southwestern Saskatchewan from the top beds of the Gravelbourg formation into the basal portion of the upper member of the Vanguard formation. In other areas of the province, *E. amygdalina* was found in the lower member of the Vanguard.

Loeblich and Tappan described this species from the Oxfordian Redwater shale of South Dakota.

Remarks: The present author (1958) referred only the hypotype (figs. 8, 9) to this species and proposed a new species, *Eoguttulina* n. sp. 1, with the hypotypes (figs. 10-13) as holotype and paratype. An examination of the paratypes of *E. amygdalina* has shown, however, that the proposal of a new species is unnecessary. The hypotypes (figs. 10-13) are about one-third larger than the paratypes of *E. amygdalina*, but as the shape of the test and chamber arrangement are the same, it seems that all of these Saskatchewan suites are properly assigned to this species.

Genus GUTTULINA d'Orbigny, 1839

GUTTULINA STILLA Lalicker

Plate 13, figures 14, 15

Guttulina stilla Lalicker, 1950, Univ. of Kansas Paleontological Contrib., Protozoa, Article 2, p. 20, pl. 4, figs. 8a-b.

Tests rather small, globular, base rounded, apertural end bluntly pointed; chambers arranged in a quinqueloculine manner, each successive chamber farther removed from the base, all visible in basal view, six in number, initial three small, final three much enlarged and inflated; sutures distinct, depressed; wall calcareous, finely perforate; aperture terminal, radiate.

Length of hypotype, 0.36 mm.; maximum width, 0.29 mm.; thickness, 0.22 mm. Average length of 14 specimens from hypotype locality, 0.30 mm.; mean maximum width, 0.22 mm.; average thickness, 0.18 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Hypotype: Univ. of Missouri No. F-60-1.

Stratigraphic distribution: In Saskatchewan, this species occurs characteristically in the lower member of the Vanguard formation, and has been found in the west-central and eastern areas of the province. It is fairly common in this member at Rush Lake and less common at other localities. Some possibly reworked representatives of this species were recorded in the middle member of the Vanguard in the southwestern area.

The type level and locality of *G. stilla* is the Bathonian Sawtooth formation near Bozeman, southwestern Montana. The type level is stratigraphically lower than the Saskatchewan occurrence.

Remarks: The identification of these Saskatchewan specimens as *G. stilla* is somewhat uncertain, and it is possible that they should be assigned to *G. pera* Lalicker, also from the Sawtooth formation. The present author has examined the types of both species, but because of their poor preservation, could not determine the difference in chamber arrangement between the two species. The last chamber in the Saskatchewan specimens is bluntly pointed as it is in *G. stilla*. Population measurements of the Saskatchewan material showed the mean dimensions to be very close to the measurements given for the holotype of *G. stilla*, but an examination of the holotype showed it, in fact, to be considerably smaller and less inflated than the Saskatchewan specimens. The Saskatchewan hypotype is actually close to *G. pera* in size.

GUTTULINA sp. A

Plate 1, figures 29-32

Test rather small, compressed, base broadly rounded, apertural end tapering to blunt point; chambers in a quinqueloculine series, each successive chamber farther removed from the base; about six chambers present, earliest two very small and indistinct, last two much enlarged and considerably inflated compared with the intermediate chambers; chamber arrangement in side view generally such that four chambers are visible on one side and three on opposite side; sutures fairly distinct, moderately depressed; wall calcareous, hyaline, finely perforate; aperture terminal, radiate.

Length of figured specimen, 0.31 mm.; maximum width, 0.20 mm.; thickness, 0.11 mm.

Average length of 12 specimens from locality of figured specimen, 0.30 mm.; average maximum width, 0.18 mm.; average thickness, 0.11 mm.

Locality of figured specimen: Tidewater Eastend Crown No. 1 well in Lsd. 15, Sec. 11, Tp. 6, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4733 and 4734 feet, in a siltstone bed from the upper member of the type section of the Shaunavon formation, 7 to 8 feet above the base.

Figured specimen: Univ. of Missouri No. F-60-4.

Stratigraphic distribution: This species ranges through the upper member of the Shaunavon formation into the basal beds of the lower member of the Vanguard in western Saskatchewan, and was found in the Eastend, Instow and Rush Lake wells. It is abundant at the Eastend locality. This species probably is present in the Gravelbourg formation (Piper of Francis, 1956) of the Southey well in central Saskatchewan.

Remarks: The author (1958) referred to this species as *Paleopolymorphina* sp. A. It does not, however, belong to that genus. This species appears similar in chamber arrangement to the one referred to *G. stilla* Lalicker in this report, but is much less robust as it lacks the strongly inflated chambers of the latter.

Genus POLYMORPHINA d'Orbigny, 1826

POLYMORPHINA sp.

Plate 1, figures 33, 34

Test medium size, compressed, elongate, subacuminate; chambers in an irregular biserial arrangement, six to seven visible, each chamber farther removed from the base and increasing rather rapidly in length as added; sutures distinct, depressed; wall presumably calcareous originally, tests preserved as pyritized replacements; aperture terminal, radiate.

Length of specimen (fig. 33), 0.49 mm.; greatest width, 0.25 mm.; maximum thickness, 0.14 mm.

Length of specimen (fig. 34), 0.52 mm.; greatest width, 0.22 mm.; maximum thickness, 0.12 mm.

Locality of figured specimens: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18 Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3566 and 3572 feet, in green shale of the upper member of the Shaunavon formation, 18 to 24 feet below the top.

Figured specimens: Univ. of Missouri Nos. F-60-2 and F-60-3.

Stratigraphic distribution: This species ranges through the upper member of the Shaunavon formation into the basal beds of the lower Vanguard in western Saskatchewan. The species was recorded in the Rush Lake, Kelstern, Instow and Eastend wells.

Remarks: The author (1958) referred to this species as *Paleopolymorphina* sp. cf. *P. elacatoides* Loeblich and Tappan from the Oxfordian Redwater shale of South Dakota, but a comparison has since shown that it is entirely different from *P. elacatoides*. The Saskatchewan species is compressed with a chamber arrangement approaching that of *Polymorphina*, whereas *P. elacatoides* is a robust, oval-shaped species with the earliest chambers spiral.

Genus PEALERINA Lalicker, 1951

PEALERINA RHOMBOIDALIS Wall, n. sp.

Plate 1, figures 25-28

Test small, rhomboidal in outline, widest centrally, compressed, both ends broadly rounded, test slightly curved in cross section; chambers somewhat inflated, earliest chambers arranged in a guttuline pattern at an angle (maximum of 30° and usually much less) to the plane of test, later chambers narrow and elongate, added in an uneven biserial manner with the pairs not quite in the same plane, three to four pairs present; sutures distinct, depressed, very slightly curved; wall calcareous, hyaline, finely perforate; aperture terminal, radiate, rather wide.

Length of holotype (figs. 25-27), 0.38 mm.; greatest width, 0.25 mm.; maximum thickness, 0.11 mm.

Length of paratype (fig. 28), 0.37 mm.; greatest width, 0.25 mm.; maximum thickness, 0.11 mm.

Average length of 20 individuals from type locality, 0.33 mm.; average maximum width, 0.22 mm.

Type locality: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3585 and 3588 feet, in green, red and yellow shale of the upper member of the Shaunavon formation, 13 to 16 feet above the base.

Types: Holotype, No. F-60-5; paratype, No. F-60-6, Univ. of Missouri.

Stratigraphic distribution: This species was recorded from only the level and locality of the types where, however, it is common.

Remarks: This new species differs considerably from the type species of *Pealerina*, i.e., *Ellisina spatula* Lalicker (1950, p. 19, pl. 4, fig. 3; text fig. 5) from the Bathonian Sawtooth formation of the Ellis group in southwestern Montana, in being rhomboidal rather than spatuloid in outline, and in lacking the extremely elongated final chamber of *P. spatula*.

Superfamily ROTALIIDEA
Family SPIRILLINIDAE
Subfamily SPIRILLININAE
Genus SPIRILLINA Ehrenberg, 1843
SPIRILLINA AMPHELICTA Loeblich and Tappan
Plate 5, figures 11-14

Spirillina amphelicta Loeblich and Tappan, 1950a, Jour. Paleontology, vol. 24, no. 1, p. 60, pl. 16, fig. 11.

Test small, planispiral, compressed, consisting of spherical proloculum followed by a long undivided tube making about four coils around proloculum, increasing gradually in diameter during its early coils but widening rather rapidly between penultimate and ultimate convolutions; spiral suture rather indistinct except in pyritized specimens, slightly depressed; wall calcareous, hyaline, apparently finely perforate; aperture simple, formed by the open end of the tube.

Greatest diameter of hypotype (figs. 11-13), 0.20 mm.; least diameter, 0.17 mm.; approximate thickness, 0.04 mm.

Greatest diameter of hypotype (fig. 14), 0.15 mm.; least diameter, 0.14 mm.; approximate thickness, 0.04 mm.

Locality of hypotypes: Socony-Western Prairie-Imperial Carievale No. 1 well in Lsd. 16, Sec. 4, Tp. 3, Rge. 32, W. 1st Meridian, Saskatchewan, Canada, between depths of 3178 and 3187 feet, in green shale of the lower member of the Vanguard formation, 10 to 19 feet above the base.

Hypotypes: Univ. of Missouri Nos. F-60-7 and F-60-8.

Stratigraphic distribution: This species occurs characteristically in the lower member of the Vanguard formation and is distributed throughout Saskatchewan, although it seems more common in the eastern area. One suite was encountered in the lower member of the Shaunavon formation in the Eastend well of the southwestern area.

The species was proposed by Loeblich and Tappan on the basis of material from the type Redwater shale (Oxfordian) of South Dakota.

Genus TURRISPIRILLINA Cushman, 1927
TURRISPIRILLINA? sp.
Plate 4, figures 18-20

Test very small, consisting of a proloculum and a long, essentially undivided tube slightly increasing in diameter during its five coils around proloculum and forming a low conical spire; ventral side (opposite to spire) concave with the whorls tending involute; the coiling not entirely regular with slight overlapping or possible concameration occurring in the

later convolutions; spiral suture distinct, depressed; wall presumably calcareous and hyaline originally, fossilized as a pyritic mold; aperture simple, at the open end of the tube.

Greatest diameter of figured specimen, 0.15 mm.; greatest thickness (approximate), 0.04 mm.

Locality of figured specimen: Tidewater Johnston Lake Crown No. 1 well in Lsd. 9, Sec. 20, Tp. 12, Rge. 2, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3861 and 3866 feet, in green shale of the lower member of the Vanguard formation, 14 to 19 feet above the base.

Figured specimen: Univ. of Missouri No. F-60-9.

Stratigraphic distribution: This species was identified at only the locality and level of the figured specimen where about 10 representatives were obtained, but at other localities it may not have been differentiated from poorly preserved specimens of *Spirillina amphelicta* Loeblich and Tappan.

Remarks: This species differs from *Turrispirillina spirella* Loeblich and Tappan (1950b, p. 16, pl. 1, fig. 41) from the Rierdon formation of Montana in having more whorls and becoming involute ventrally, the latter characteristic pointing in the direction of the Jurassic genus *Conicospirillina* Cushman.

Family GLOBIGERINIDAE
Subfamily GLOBIGERININAE
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA? sp.
Plate 1, figures 20-22

Test small, rotaloid, moderate spire developed, ventral side flattened, weakly if at all umbilicate; periphery narrowly rounded, peripheral margin somewhat lobulate; chambers indistinct, partly inflated, about four and one-half in final whorl, much increased in size; sutures indistinct, depressed, straight or nearly so; wall calcareous, rather finely perforate, flesh-colored; aperture not definitely observed, probably a small opening into the umbilicus.

Greatest diameter of figured specimen, 0.20 mm.; least diameter, 0.17 mm.; maximum thickness, 0.10 mm.

Locality of figured specimen: Tidewater Johnston Lake Crown No. 1 well in Lsd. 9, Sec. 20, Tp. 12, Rge. 2, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3883 and 3898 feet, in green shale of the upper member of the Shaunavon formation, 3 to 18 feet below the top.

Figured specimen: Univ. of Missouri No. F-60-10.

Stratigraphic distribution: This species was positively identified from only the level and locality of the figured specimen, but a few specimens probably referable to this species occur at the same level in the top of the Shaunavon at the Kelstern well. Both localities are in west-central Saskatchewan. Some of the specimens are worn indicating possible reworking or perhaps a washing in to shore.

Remarks: Because of the inadequacy of the material, no name is assigned this species. It does not seem at all similar to *Globigerina*? sp. of Wickenden (1933, p. 168, pl. 2, fig. 16) from the Jurassic of a well in southeastern Alberta, as the latter species has more globular chambers, distinct sutures and a prominent aperture.

Family GÜMBELINIDAE
Genus GÜMBELITRIA Cushman, 1933
GÜMBELITRIA sp.
Plate 1, figures 23, 24

Test small, tapering, rounded trihedral in cross section; test triserial with four or five whorls of three chambers each; chambers enlarging rapidly, inflated, becoming globular in final whorl; sutures indistinct, depressed; wall calcareous, rather finely perforate, flesh-colored; aperture a rather highly arched opening at the inner margin of the last chamber.

Length of specimen (fig. 23), 0.25 mm.; greatest width, 0.15 mm.

Length of specimen (fig. 24), 0.17 mm.; greatest width, 0.15 mm.

Locality of figured specimens: Tidewater Johnston Lake Crown No. 1 well in Lsd. 9, Sec. 20, Tp. 12, Rge. 2, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3883 and 3898 feet, in green shale of the upper member of the Shaunavon formation, 3 to 18 feet below the top.

Figured specimens: Univ. of Missouri Nos. F-60-11 and F-60-12.

Stratigraphic distribution: This small species was positively identified from only the level and locality of the figured specimens in west-central Saskatchewan, where it occurs in association with *Globigerina*? sp., *Involutina* sp. cf. *I. southeyensis*, n. sp., and an ostracode, *Paracypris*? sp. A. The appearance of many of the specimens of *Gümbelitria* sp. and of *Globigerina*? sp. as well suggests the possibility of their having been reworked or perhaps washed in to shore. A few specimens obtained from the Instow and Kelstern wells, at the same stratigraphic level as the figured specimens, are probably referable to this species, but the preservation is too poor to permit positive identification.

Remarks: This species differs from *Gümbelitria cretacea* Cushman in having a less sharply tapering test with less inflated chambers.

Family CONORBOIDIDAE Hofker, 1952
Genus CONORBOIDES Hofker, 1952
CONORBOIDES HOFKERI (Bartenstein and Brand)
Plate 9, figures 9-16

Eponides cf. *semiornata* (Schwager). Wickenden, 1933, Roy. Soc. Canada, Trans., ser. 3, sec. IV., vol. 27, pp. 167-168, pl. 2, figs. 15a-c (not *Rotalia semiornata* S.).

Conorbis hofkeri Bartenstein and Brand, 1951, Senckenb. Naturf. Ges., Abh., no. 485, p. 325, figs. 320 a-c.

Patellina crista Loranger, 1955 (not of Lalicker, 1950), Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 46, pl. 11, figs. 1, 2.

Test small, trochoid, dorsal side moderately convex, ventral side weakly convex to concave, periphery subacute, peripheral margin somewhat lobulate in some specimens; test consists of spherical proloculum followed by two or three whorls of five to six chambers apiece; chambers gradually enlarging in size, all visible dorsally, only those of final whorl visible ventrally embracing to umbilicus; sutures distinct, arcuate, thickened and slightly raised in unaltered specimens but depressed and incised in the pyritic internal molds; wall calcareous, hyaline, finely perforate, completely or partially pyritized in most individuals; aperture ventral, multiple, consisting of loop-shaped openings running axially from the bases of sutures on to the chamber faces.

Greatest diameter of hypotype (figs. 9-12), 0.50 mm.; least diameter, 0.42 mm.; greatest thickness, 0.15 mm.

Greatest diameter of hypotype (figs. 13-15), 0.32 mm.; least diameter, 0.30 mm.; greatest thickness, 0.17 mm.

Greatest diameter of hypotype (fig. 16), 0.20 mm.; least diameter, 0.17 mm.; greatest thickness, 0.07 mm.

Average maximum diameter of 17 adult individuals from hypotype locality, 0.37 mm.

Locality of hypotypes: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3458 and 3466 feet, in green shale from the type section of the lower member of the Vanguard formation, 42 to 50 feet below the top.

Hypotypes: Univ. of Missouri Nos. F-60-13, F-60-14, F-60-15.

Stratigraphic distribution: This species ranges through the Vanguard formation of Saskatchewan. Loranger (1955, p. 43) stated it was characteristic of the upper Vanguard in the deeper part of the basin, and the present author is aware of its common occurrence in this member at the Frontier well of the southwestern area. The results of the present study show that *C. hofkeri* is also a common and distinctive component of the microfauna of the lower Vanguard throughout the province.

Remarks: Although the indicated mean diameter of the Saskatchewan specimens is somewhat less than the diameter of the holotype, they seem referable to this species. The type locality of this species is in northwest Germany in beds of Valanginian age, Lower Cretaceous. From these widespread occurrences, one may assume the species occupies a time span embracing the Upper Jurassic and lowest Cretaceous.

Phylum ARTHROPODA
Class CRUSTACEA
Order OSTRACODA Latreille, 1802
Suborder PLATYCOPA Sars, 1866
Family CYTHERELLIDAE Sars, 1866
Genus CYTHERELLA Jones, 1849

CYTHERELLA PARAMUENSTERI Swain and Peterson

Plate 24, figures 8, 9

Cytherella paramuensteri Swain and Peterson, 1952, U.S. Geol. Surv. Prof. Paper 243-A, p. 9, pl. 1, figs. 1-7.

Cytherella paramuensteri Swain and Peterson. Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, pp. 159-160, pl. 17, figs. 5-8.

Shell subquadrate in lateral view; greatest height near anterior end; dorsal margin nearly straight, about two-thirds of shell length; ventral margin slightly concave medially, subparallel to dorsum; anterior margin broadly and evenly rounded; posterior margin not as evenly rounded, subtruncate.

Right valve larger than left, extending beyond the other around entire periphery, overlap more conspicuous along dorsal and ventral margins. Shell compressed, tapering gradually toward anterior end in dorsal view; greatest thickness near posterior end.

Anterior extremity compressed and bearing low marginal rim. General surface of valves smooth except for the occasional, faint, small pit; a larger, ovoid but not too well-defined pit, the external expression of the muscle scar, lies in the dorsomedian area just dorsad to midheight.

Margin of right valve grooved for reception of edge of left; character of groove rendered obscure through poor preservation.

Muscle scar, as viewed from the exteriors of two free valves probably belonging to this species, consists of an arcuate row of five spots in dorsomedian area.

Length of hypotype, 0.59 mm.; height, 0.32 mm.; maximum thickness, 0.20 mm.

Locality of hypotype: Imperial Tidewater Carlyle Crown No. 1 well in Lsd. 16, Sec. 23, Tp. 7, Rge. 3, W. 2nd Meridian, Saskatchewan, Canada, at a depth of 3194 feet, in green shale of the lower member of the Vanguard formation, about 25 feet above the base.

Hypotype: Univ. of Missouri No. 0-1210-1.

Stratigraphic distribution: This species occurs sporadically in the lower portion of the Vanguard formation in eastern Saskatchewan, and was identified in the Wapella, Carlyle and Carievale wells. Two free valves, probably assignable to this species, were found in the basal beds of the middle member of the Vanguard at Kelstern in west-central Saskatchewan. One valve was questionably identified from the basal Vanguard at Frontier in the southwest. Loranger (1955) reported the species from the Lower Shaunavon formation (J2B) in the Imperial Lawson No. 1 well in southwestern Saskatchewan, but an examination of the specimen figured by that author indicates an *Aparchitocythere*, closely related to *A. compressa* Peterson.

Peterson (1954a, p. 160) reported this species as relatively common to abundant in both the "lower" and "upper Sundance" formations along the western and southern margins of the Powder River Basin in northeastern Wyoming, and in the Rierdon and Swift formations of extreme south-central and central Montana.

Roberts (1934, p. 19, pl. 1, figs. 18, 19) described and illustrated this species as *Cytherella sundancensis* (*ms.* name) from the Sundance formation in the Lander area of west-central Wyoming, where it was reported common in some samples.

Remarks: The Saskatchewan specimens are smaller and less robust than the figured types of this species, but in the collection of unfigured paratypes from Red Gulch, Sheridan County, Wyoming, there are several individuals which are the same size or are smaller than the Saskatchewan specimens.

Genus CYTHERELLOIDEA Alexander, 1929

CYTHERELLOIDEA RECURVATA Peterson

Plate 24, figures 10-13

Cytherelloidea recurvata Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, pp. 160, 161, 163, pl. 17, figs. 1-4; text fig. 2g.

Cytherelloidea recurvata Peterson. Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 49, pl. 8, figs. 9-10.

Shell subrectangular in lateral view; greatest height in anterior third; dorsal margin nearly straight, slightly arched; ventral margin broadly

sinuate medially and subparallel to dorsum; anterior margin broadly and uniformly rounded; posterior margin more narrowly rounded, subtruncate.

Right valve larger than left, extending beyond the other around entire periphery, overlap more conspicuous along dorsal and ventral margins. Shell compressed, particularly in anterior portion; greatest thickness across posterior end.

Anterior extremity compressed and bearing a narrow, rounded rim. General surface of valves pitted. A sharp, narrow ridge extends along ventrum, continues around anterior and posterior margins, the anterior arm curving backward along the dorsal margin and terminating slightly posterad of the anterodorsal angle, while the posterior arm curves inward or turns forward about one-fourth height from dorsum, extending forward and slightly downward to terminate just behind midlength. A large, roughly circular pit, apparently the external expression of the muscle scar, is present in the central portion of each valve, dorsad to which, an elongate, rounded node extends obliquely posteriorly to the dorsal margin. A second, elongate, rounded node, approximately parallel to the first and anterad to it, located about one-third from anterior end, develops into a low ridge which swings forward at midheight and loses its identity posterad of the anterior marginal ridge.

Margin of right valve grooved around entire periphery to receive edge of left valve with the groove deeper along the dorsal margin and upper half of posterior margin, also fairly prominent along the ventrum.

Muscle scar consists of a median prominent circular elevation upon which there is a cluster of five or six smaller raised spots.

Length of hypotype (figs. 10-12), a carapace, 0.85 mm.; height, 0.47 mm.; maximum thickness, 0.32 mm.

Length of hypotype (fig. 13), a valve, 0.75 mm.; height, 0.40 mm.

Locality of hypotype (carapace): Tidewater Wapella Crown No. 16-33 well in Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian, Saskatchewan, Canada, between depths of 2232 and 2237 feet, in green shale of the lower member of the Vanguard formation, 6 to 11 feet above the base.

Locality of hypotype (valve): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3288 and 3292 feet, in green shale of the lower member of the Vanguard formation, 73 to 77 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1210-2 and 0-1210-3.

Stratigraphic distribution: This species has a widespread distribution in Saskatchewan in the lower member of the Vanguard formation, and has been found in most of the wells examined.

Loranger's (1955) reported occurrence from the Lower Shaunavon formation in the Norcanols Radville No. 1 well of south-central Saskatchewan may well have resulted from the hole cavings in the overlying Vanguard shale.

Peterson (1954a, p. 161) reported the species as rare to abundant in the Rierdon formation of central and south-central Montana and extreme north-central Wyoming.

Roberts (1934, pp. 20-21, pl. 2, figs. 20, 21) described and illustrated this species as *Cytherelloidea pulchra* (*ms.* name) from the Sundance formation in the Lander area of west-central Wyoming.

Remarks: The Saskatchewan hypotype is larger than any of the types of *C. recurvata*, but its outline, ornamentation and other characters match those of the types perfectly.

Suborder PODOCOPA Sars, 1865
Family BAIRDIIDAE Sars, 1887
Genus BYTHOCYPRIS Brady, 1880
BYTHOCYPRIS AMBITRUNCATA Peterson
Plate 24, figures 1-7

Bythocypris ambitruncata Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, p. 163, pl. 18, figs. 23, 24.

Bythocypris ambitruncata Peterson, Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 49, pl. 10, figs. 21, 22.

Shell ovate-subreniform in lateral view; greatest height medial; dorsal margin strongly arched, subtruncate posterad and anterad of greatest height; ventral margin nearly straight; anterior margin rather broadly and evenly rounded; posterior margin less broadly rounded, extending below and truncate above.

Left valve larger than right, extending beyond it around entire periphery, the overlap more prominent along dorsal and ventral margins. Valves moderately convex, terminal margins slightly to moderately compressed, greatest thickness median. Surface of valves smooth to faintly pitted.

Hingement apparently simple, no suitably preserved left, *i.e.*, larger, valve found. Line of concrescence and inner margin rather widely separated around the anterior and posterior margins, seemingly more nearly coincident along ventral margin. Muscle scar, as seen through exterior of one valve, seems to consist of a median cluster of three spots with two smaller posterior spots.

Length of hypotype (figs. 1-3), a carapace, 0.72 mm.; height, 0.37 mm.; maximum thickness, 0.25 mm.

Length of hypotype (figs. 4-6), a carapace, 0.62 mm.; height, 0.34 mm.; maximum thickness, 0.25 mm.

Length of hypotype (fig. 7), a valve, 0.65 mm.; height, 0.30 mm.

Locality of hypotypes: Socony-Western Prairie-Imperial Carievale No. 1 well in Lsd. 16, Sec. 4, Tp. 3, Rge. 32, W. 1st Meridian, Saskatchewan, Canada, between depths of 3178 and 3187 feet, in green shale of the lower member of the Vanguard formation, 10 to 19 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1210-4, 0-1210-5, 0-1210-6.

Stratigraphic distribution: In the present study, this species was encountered sporadically to commonly in the lower Vanguard of the Wapella No. 16-33 and Carievale wells in eastern Saskatchewan. Loranger (1955) reported it from the same level in the Norcanols Radville well of south-central Saskatchewan.

Peterson (1954a, p. 163) originally described the species from the Rierdon formation of extreme south-central Montana, where it was reported as rare.

Roberts (1934, pp. 21-22, pl. 1, figs. 15, 16) described a closely related species under the *ms.* name, *Bythocypris semicircularis*, from the Sundance formation of the Lander area of west-central Wyoming, where it was reported as rare to abundant in various outcrop samples.

Remarks: The present author (1958) merely compared these Saskatchewan specimens with *B. ambitruncata*, but a subsequent study of the types has shown that the Saskatchewan material is definitely referable to this species. The valve overlap in the Saskatchewan hypotypes seems more pronounced than that shown on the type figure by Peterson, but this condition is more apparent than real because of the superior preservation of the Saskatchewan suite.

Family CYPRIDAE Baird, 1845
Genus PARACYPRIS Sars, 1865
PARACYPRIS PROJECTA Peterson
Plate 26, figure 22; Plate 27, figures 20, 21

Paracypris projecta Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, pp. 163-164, pl. 17, figs. 14, 15.

Paracypris acuminatus Loranger, 1955 (not of Roth, 1933), Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 49, pl. 11, figs. 13, 14.

Shell elongate-sublanceolate in side view; greatest height medial or slightly forward of this point, greatest length below midheight; dorsal margin strongly arched, subtruncate behind and in front of point of greatest height; ventral margin gently sinuous; anterior margin broadly rounded, slightly extended below; posterior margin acuminate, rather strongly extended below midheight.

Left valve the larger, extending beyond the right around entire periphery with overlap more conspicuous midventrally. Convexity of valves rather weak, greatest thickness slightly anterior to median line, compression more pronounced posteriorly. Surface of valves smooth, shell wall pyritized or partly recrystallized in many specimens.

No free valves found. Hingement presumed simple. Information on internal features wanting.

Length of hypotype (Pl. 26, fig. 22), 0.72 mm.; height, 0.30 mm.; maximum thickness, 0.22 mm.

Length of hypotype (Pl. 27, figs. 20, 21), 0.52 mm.; height, 0.22 mm.; maximum thickness, 0.17 mm.

Locality of hypotype (Pl. 26, fig. 22): Tidewater Johnston Lake Crown No. 1 well in Lsd. 9, Sec. 20, Tp. 12, Rge. 2, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3800 and 3805 feet, in green shale of the lower member of the Vanguard formation, 75 to 80 feet above the base.

Locality of hypotype (Pl. 27, figs. 20, 21): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3389 and 3396, in green shale of the middle member of the Vanguard formation, 1 to 8 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1210-7 and 0-1210-8.

Stratigraphic distribution: In Saskatchewan, this species ranges through the lower member into the basal beds of the middle member of the Vanguard formation. A few specimens are present in most samples and it may be common.

Peterson (1954a, pp. 163-164) reported this species as relatively common to abundant in the Rierdon formation of south-central Montana and in the "lower Sundance" formation of north-central Wyoming.

Roberts (1934, pp. 22-23, pl. 1, figs. 17,20) described this species as *Paracypris* (?) *tenuis* (*ms.* name) from the Sundance formation in the Lander area of west-central Wyoming, where it was reported as rare to abundant in various outcrop samples.

Remarks: The elongate hypotype (pl. 26, fig. 22) has been compared with the holotype and found to match it perfectly. Most of the Saskatchewan representatives of this species, exemplified by the hypotype (pl. 27, figs. 20, 21), are considerably smaller than the holotype but possess the same relative dimensions. In some of the smaller specimens, the right valve seems to overlap the left, in which event these individuals may belong in the genus *Macrocypris* Brady.

P. projecta is distinguished from *Paracypris*? sp. A in the underlying Shaunavon formation by being much lower, that is having considerably less height in proportion to its length, and also by its more acuminate posterior margin.

PARACYPRIS? sp. A

Plate 22, figures 16-18

Shell sublanceolate in side view; greatest height about one-third from the anterior or rounded end, greatest length slightly below midheight; dorsal margin moderately convex, subtruncate behind and in front of point of greatest height; ventral margin nearly straight with typically only a faint, broad sinuosity developed; anterior margin broadly rounded, subtruncate above; posterior margin bluntly acuminate, extended below; cardinal angles broadly obtuse, poorly defined.

Left valve slightly larger than right, extending beyond it around entire periphery. Convexity of valves weak, greatest thickness median, compression more pronounced posteriorly. Surface of valves almost smooth, faintly and minutely pitted, shell wall partly recrystallized in many specimens.

Hingement simple. Inner lamellae rather narrow; line of concrescence and inner margin slightly separated except around anterior end where separation is more marked. Muscle scar not observed.

Length of specimen (figs. 17, 18), a carapace, 0.77 mm.; height, 0.40 mm.; maximum thickness, 0.27 mm.

Length of specimen (fig. 16), a valve, 0.82 mm.; height, 0.37 mm.

Average length of 18 non-crushed adult individuals from Eastend well, between depths of 4697 and 4701 feet, 0.82 mm.; height, 0.40 mm.; thickness, 0.25 mm.

Locality of specimen (carapace): Tidewater Eastend Crown No. 1 well in Lsd. 15, Sec. 11, Tp. 6, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4699 and 4701 feet, in greenish-gray calcareous shale from the upper member of the type section of the Shaunavon formation, 19 to 21 feet below the top.

Locality of specimen (valve): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3550 and 3555 feet, in green shale of the upper member of the Shaunavon formation, 5 to 10 feet below the top.

Figured specimens: Univ. of Missouri Nos. 0-1210-9 and 0-1210-10.

Stratigraphic distribution: This species is rather rare to common in the upper member of the Shaunavon formation of Saskatchewan, and was found in most wells studied with a distribution covering much of the province.

Remarks: This species is similar in outline, length-height ratio, and valve overlap to *Eucypris*? sp. of Martin (1940, p. 356, pl. 8, figs. 117-118) from the Purbeckian beds of northern Germany. Martin's species seems to have considerably greater convexity of the valves, however, and the two species probably are not identical although the relationship seems quite close.

This species also shows much in common with *Paracypris acuminatus* Roth (1933, p. 404, pl. 48, figs. 5a-c) from the Morrison formation of South Dakota, the outline and dimensions being similar, but in the latter species the right valve is reported as overlapping the left along the hinge line, the reverse of the situation prevailing in the Saskatchewan material.

Family DARWINULIDAE Brady and Norman, 1889
Genus DARWINULA Brady and Norman, 1889
DARWINULA LEGUMINELLA (Forbes)
Plate 23, figures 11-13

Cypris leguminella Forbes, 1855 in Lyell's Manual of Elementary Geology, 5th edition, p. 294, fig. 334c.

Cypridea leguminella H. Woodward, 1877, Cat. British Fossil Crustacea, p. 89.

Darwinula leguminella Jones, 1885, Geol. Soc. London, Quart. Jour., vol. 41, p. 346, pl. 8, figs. 30-31.

Darwinula leguminella Jones, 1886, Geol. Mag., decade 3, vol. 3, p. 147, pl. 4, figs. 4 a-c.

Darwinula leguminella Jones, 1888, Geol. Mag., decade 3, vol. 5, p. 538.

Paracypris simplus Roth, 1933, Jour. Paleontology, vol. 7, no. 4, pp. 403-404, pl. 48, figs. 3 a-d.

Darwinula leguminella Martin, 1940, Senckenbergiana, vol. 32, pp. 317-318, pl. 4, figs. 58-61.

Candona radvillia Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 50, pl. 9, figs. 5, 6.

Darwinula cf. *leguminella* Bernard, Bizon and Oertli, 1957, Geol. Soc. France, Bull., ser. 6, vol. 6, no. 6, p. 757, pl. 21, figs. 8-11.

Shell elongate-reniform or bean-shaped in side view. Dorsal margin gently arched, ventral margin straight except for sinuosity developed near posterior or more acuminate end. Anterior margin broadly rounded, slightly extended above; posterior margin narrowly rounded, extending below midheight. Greatest height median to anterad of center.

Right valve much larger than left enclosing the other around entire periphery. Valves moderately convex, greatest thickness about one-third of the distance from anterior or higher end; convexity decreases rapidly in posterior region to a rather sharp terminus. Surface typically smooth, rarely with a faint, indefinite ornamentation pattern; shell material partly recrystallized in many specimens.

Hinge simple, consisting of a shallow groove in the dorsal edge of the left valve into which the lower part of the dorsal edge of the right valve fits, the rim of the right valve, however, overlapping the left. Radial canals appear to be present in the posterior or more acuminate end and possibly elsewhere. Muscle scar at midheight, slightly posterior to center, a distinctive rosette of 10 to 12 elongate-rectangular and triangular spots, the latter situated at the base of the pattern.

Length of hypotype (fig. 11), 0.86 mm.; height, 0.40 mm.; maximum thickness, 0.25 mm.

Length of hypotype (figs. 12, 13), 0.92 mm.; height, 0.42 mm.; maximum thickness, 0.36 mm.

Locality of hypotypes: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3580 and 3600 feet, in green shale of the upper member of the Shaunavon formation, 7 to 27 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1210-11 and 0-1210-12.

Stratigraphic distribution: This species is common to abundant in the upper member of the Shaunavon formation of Saskatchewan, and has a wide distribution in the province, as some specimens were recorded from every well in which there was core sample coverage of this level. The species is present also in pre-Shaunavon beds in the Instow well and ranges apparently through all of the pre-Vanguard Jurassic section in the province.

Remarks: A comparison of the Saskatchewan specimens with the illustrations and descriptions of Martin and Jones indicates identification with *D. leguminella* (Forbes) from the Purbeck-Wealden beds of western Europe. *Paracypris simplus* Roth (1933, pp. 403-404, pl. 48, figs. 3a-d) from the Morrison formation of the Black Hills, South Dakota appears identical with this species. Loranger's establishment of a new species, *Candona radvillia*, for the Saskatchewan representatives seems unnecessary. In any event, the species probably should not have been referred to *Candona* Baird because the muscle scar in the latter has fewer spots (Triebel, 1949), and *Candona* seems to have typically a subquadrate outline rather than the elongate-ovate design of *Darwinula*.

The present author has oriented this species differently from both Martin and Loranger who regarded the more acuminate and lower end as anterior, and consequently the left valve as larger than the right. In this study, the more rounded, higher end is considered the anterior, the lower and more acuminate end the posterior, and the right valve as overlapping the left. This orientation scheme was employed to avoid confusion with similar genera encountered in this project, and *Paracypris* is also regarded as acuminate posteriorly following the treatment of Peterson (1954a).

This species is apparently a long-ranging one of little stratigraphic use and is a characteristic component of many fresh to brackish water microfaunas. It is significant to note, however, that Bernard, Bizon and Oertli (1957) have reported this species or one very closely related from the Bathonian beds of the Paris Basin in an assumed lagoonal-lacustrine environment.

Family CYTHERIDAE Baird, 1850
Genus APARCHITOCYTHERE Swain and Peterson, 1952
APARCHITOCYTHERE sp. cf. A. COMPRESSA Peterson
Plate 19, figures 1-13, 18-20

?*Aparchitocythere compressa* Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, p. 168, pl. 18, figs. 10-14, text figs. 2c, d.

Shell subovate to subquadrate in side view; greatest height at antero-cardinal angle. Dimorphism prominently developed with males shorter and less quadrate than females. Hinge margin nearly straight, about

three-fifths of shell length in females, slightly less in males, ventral margin sinuous and subparallel to dorsum in females, slightly convex and converging rather strongly toward posterior with respect to dorsum in males. Anterior margin broadly rounded, slightly extended below, truncate above in males, subtruncate above in females; posterior margin more narrowly rounded in both dimorphs, extending slightly above median in females.

Left valve larger than right, overlapping and extending slightly beyond the other except along hinge, where right valve overlaps and extends beyond the left rather prominently. Valves rather strongly convex; greatest thickness just postmedian.

Anterior end strongly compressed and bearing a prominent marginal rim; posterior end much less compressed with marginal rim obscured or wanting. Surface of valves weakly and finely pitted.

Hingement details obtained from presumed juvenile specimens. Hinge of left valve consists of terminal, elongate sockets connected by the valve edge in which the positions of the sockets are reflected by incisions or reëntrants as viewed dorsally. Hinge of right valve consists of terminal, elongate teeth formed of the extended valve edge, and an interterminal narrow groove, ventral to the dorsal rim of the valve, into which the edge of the left valve fits.

Inner lamellae of moderate width, sloping gradually but not too steeply toward interior. Line of concrescence and inner margin nearly coincide. Normal canals readily visible on valve surfaces, fairly closely spaced. Radial canals distinct in the inner lamellae of many specimens, not branching, distributed such that there are normally about 15 in the anterior end. Muscle scar consists of a median subvertical row of three or four small spots and two smaller spots anterad.

Length of specimen (figs. 1, 2), an adult male carapace, 0.65 mm.; height, 0.42 mm.; maximum thickness, 0.34 mm.

Length of specimen (figs. 3, 4), an adult female carapace, 0.70 mm.; height, 0.40 mm.; maximum thickness, 0.32 mm.

Length of specimen (fig. 5), an adult female carapace, 0.69 mm.; height, 0.41 mm.; thickness, 0.31 mm.

Length of specimen (fig. 18), a carapace, 0.67 mm.; height, 0.39 mm.; maximum thickness, 0.32 mm.

Length of specimen (figs. 19, 20), a carapace, 0.61 mm.; height, 0.35 mm.; maximum thickness, 0.32 mm.

Length of specimen (figs. 6, 7). a juvenile male carapace, 0.47 mm.; height, 0.30 mm.; maximum thickness, 0.22 mm.

Length of specimen (figs. 8, 9), a juvenile female carapace, 0.52 mm.; height, 0.31 mm.; maximum thickness, 0.21 mm.

Length of specimen (fig. 10), a male left valve, 0.44 mm.; height, 0.27 mm.

Length of specimen (fig. 11), a male right valve, 0.45 mm.; height, 0.27 mm.

Length of specimen (fig. 12), a female left valve, 0.52 mm.; height, 0.29 mm.

Length of specimen (fig. 13), a female right valve, 0.50 mm.; height, 0.30 mm.

Locality of specimens (figs. 1-5), adult carapaces, Tidewater Eastend Crown No. 1 well in Lsd. 15, Sec. 11, Tp. 6, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4733 and 4734 feet, in a siltstone bed from the upper member of the type section of the Shaunavon formation, 7 to 8 feet above the base.

Locality of specimens (figs. 18-20), carapaces, Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4613 and 4622 feet, in buff, dense limestone of the lower member of the Shaunavon formation, 18 to 27 feet below the top.

Locality of specimens (figs. 6-9), juvenile carapaces, Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3582 and 3585 feet, in green, yellow and reddish-brown shale of the upper member of the Shaunavon formation, 16 to 19 feet above the base.

Locality of specimens (figs. 10-13), valves, as above, between depths of 3594 and 3597 feet, in green shale of the upper member of the Shaunavon formation, 4 to 7 feet above the base.

Figured specimens: Univ. of Missouri Nos. 0-1210-14, 0-1210-15, 0-1210-16, 0-1210-17, 0-1210-18, 0-1210-19, 0-1210-20, 0-1211-1, 0-1211-2, 0-1211-5, 0-1211-6.

Stratigraphic distribution: This species is common to abundant in the Upper Shaunavon of southwestern and west-central Saskatchewan, and was found in every well where core coverage was available. It also occurs sporadically to fairly commonly through a 20-foot interval in buff limestone of the Lower Shaunavon in the Instow well of the southwestern area. It may well occur at this level in other wells, but only casual samples were prepared for microfaunal examination at these localities.

Remarks: The present author (1958) assigned all of these specimens except the pair from Instow well (figs. 18-20) to *A. compressa* Peterson from the "lower Sundance" of northeastern Wyoming. A comparison of the Saskatchewan specimens with the types of *A. compressa* has shown, however, that the former are not as strongly compressed in the anterior end and lack the very prominent anterior marginal rims of the types. Similarly, at the posterior extremity, there is much more compression in the type material.

The specimens (figs. 18-20) from the lower member of the Shaunavon in the Instow well were designated *Camptocythere*? sp. by the present author (1958). These differ from the rest of the illustrated suite by having more compressed terminals and somewhat inflated ventral areas, and appear externally almost identical with the holotype (a male) of *A. compressa*. This suite from the Instow well seems to fall into a different taxonomic unit than the rest of the figured specimens, and perhaps should be assigned directly to *A. compressa*.

APARCHITOCYTHERE ELONGATA Peterson

Plate 19, figures 14-17

Aparchitocythere elongata Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, pp. 168-169, pl. 18, figs. 15-18.

Shell small, elongate-subrectangular in outline, greatest height near anterior end. Hinge margin straight, about three-fourths of shell length; ventral margin slightly sinuous, subparallel to dorsum. Anterior margin

broadly rounded, slightly extended below; posterior margin similarly rounded, extended above midheight. Cardinal angles obtuse, the anterior better defined.

Valves appear to be nearly equal in size, the left probably slightly larger, but right valve overlaps left along the hinge. Convexity of valves slight to moderate; greatest thickness slightly behind middle.

Anterior extremity compressed, bearing a narrow, rounded marginal rim; posterior end gently compressed. Surface ornamented in a weak, discontinuous ridge and reticulation pattern, the ridges tending to become longitudinally aligned near ventral border. In some specimens, a faint, subvertical sulcus lies anterad of the median line.

Hinge of right valve, as viewed in one poorly preserved specimen, probably consists of terminal, elongate teeth, formed of the valve edge, and an interterminal narrow groove, the latter more readily visible. No left valves found. Inner lamellae rather broad; radial canals spaced such that there are about 15 around the anterior end. Muscle scar not observed.

Length of hypotype (figs. 14, 15), 0.45 mm.; height, 0.22 mm.; maximum thickness, 0.19 mm.

Length of hypotype (figs. 16, 17), 0.47 mm.; height, 0.22 mm.; maximum thickness, 0.17 mm.

Average length of 27 specimens from hypotype locality, 0.44 mm.; height, 0.22 mm.; thickness, 0.17 mm.

Locality of hypotypes: Tidewater Eastend Crown No. 1 well in Lsd. 15, Sec. 11, Tp. 6, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4733 and 4734, in a siltstone bed from the upper member of the type section of the Shaunavon formation, 7 to 8 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1211-3 and 0-1211-4.

Stratigraphic distribution: This species occurs commonly in the Upper Shaunavon of southwestern and west-central Saskatchewan and was recorded from all wells studied in these areas.

Peterson (1954a, p. 169) reported *A. elongata* as relatively common in the "lower Sundance" formation along the western and southern margins of the Powder River Basin in northeastern Wyoming, and in the Black Hills of extreme northeastern Wyoming.

Remarks: A comparison has been made between the Saskatchewan specimens and the type material, and it is believed that the former should be referred to this species. The anterior and posterior extremities are slightly more compressed in the types, and as a result, the marginal rims are more pronounced in the type material than in the Saskatchewan suite.

Dimorphism probably is developed in the Saskatchewan material with the presumed males slightly shorter and their ventra converging more strongly posteriorly with respect to dorsa than in the more elongate and more nearly rectangular females.

Genus CYTHEREIS Jones, 1849

CYTHEREIS HETEROMORPHA Peterson

Plate 26, figures 1-3

Cythereis heteromorpha Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, pp. 174-175, pl. 19, figs. 20-24; text fig. 2b.

Shell small, subquadrate in outline; greatest height near anterior end, greatest length median; dorsal margin straight, about four-fifths of shell length; cardinal angles obtuse, fairly well defined; ventral margin nearly straight, converging posteriorly toward dorsum; anterior end broadly rounded; posterior end bluntly acuminate, extended medially.

Valves seem equal. Convexity weak, greatest thickness in posterior half.

Anterior extremity compressed, with a narrow marginal rim, the lower half of which is spinose. Posterior end compressed, bearing a faint marginal rim. A low, rounded node lies near anterodorsal angle and passes downward into a well-defined but discontinuous ridge. A similar node lies just anterad of the posterocardinal angle and also passes downward into a well-defined ridge. Posteroventral margin of each valve is occupied by an incipiently alate, rather blunt protuberance. Ornamentation is irregular, consisting of scattered short ridges with faint reticulations in the intervening areas.

Hinge of left valve consists of terminal sockets, which open ventrally into valve interior, and a long, faintly crenulate interterminal bar, the valve edge. Hinge of right valve consists of an anterior, small, rounded tooth, and a posterior, more elongate, faintly incised dental unit connected by the weakly crenulate, grooved valve edge.

Inner lamellae fairly wide, sloping rather steeply toward valve interior. Line of concrescence and inner margin seem nearly coincident. Muscle scar located just forward of midlength, consists of a nearly vertical row of four or five spots.

Length of hypotype (figs. 1, 2), a carapace, 0.35 mm.; height, 0.20 mm.; maximum thickness, 0.17 mm.

Length of hypotype (fig. 3), a valve, 0.32 mm.; height, 0.17 mm.

Locality of hypotype (carapace): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Locality of hypotype (valve): Tidewater Atlas Crown No. 2 well in Lsd. 13, Sec. 11, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3325 and 3329 feet, in green shale of the lower member of the Vanguard formation, 86 to 90 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1211-7 and 0-1211-8.

Stratigraphic distribution: Although this species occurs rather rarely in the lower member of the Vanguard formation in Saskatchewan, it is widely distributed through the province. It was encountered in the Frontier well of the southwest; the Kelstern, Rush Lake and Atlas wells of the west-central area; and in the Wapella and Carlyle wells of the eastern area.

Peterson (1954a, p. 175) reported this species as relatively common to abundant in the Rierdon formation, south-central Montana, and in the

"lower Sundance" formation in north-central Wyoming. Further north, in the Big Snowy Mountains area of central Montana, Peterson reported the species as rare, a condition which seems to extend still further north in Saskatchewan.

CYTHEREIS ROBERTSI Wall, n. sp.

Plate 27, figures 1-8

Procytheridea minuta Loranger, 1955 (not of Peterson, 1954), Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 53, pl. 11, figs. 5, 6.

Shell elongate-subovate in lateral view; greatest height near anterior end; dorsal margin slightly convex, about two-thirds of shell length; cardinal angles broadly obtuse; ventral margin slightly convex, converging rather strongly toward posterior with respect to dorsum; anterior margin broadly rounded; posterior margin bluntly acuminate, extended medially.

Valves subequal, the left slightly overlapping the right except along the hinge margin where the right overlaps the left. Valves moderately convex, greatest thickness slightly posterad of the median line.

Anterior extremity rather strongly compressed and bearing low marginal rim; median extension of posterior end compressed to form a short but fairly sharp caudal process. General surface ornamented in a rather fine reticulate pattern. Two long, low horizontal ridges, a median and a ventral, traverse much of the shell length and sometimes unite at either or both ends—the median ridge is more prominent while the ventral ridge tends to merge with the edge of the valve below. The ventral surface of the valves is somewhat bevelled and here the reticulations pass into longitudinal ridges. At the anterocardinal angle of each valve lies a small, poorly defined, node-like swelling which passes downward into a short, oblique, anteriorly-directed ridge.

Hinge of left valve consists of terminal sockets, which open ventrally into valve interior, and the long, faintly crenulate, valve edge. Hinge of right valve consists of terminal, small, elliptical, weakly incised dental units connected by an apparently faintly crenulate groove into which the edge of the left valve slides.

Inner lamellae of moderate width, sloping fairly steeply toward valve interior. Line of concrescence and inner margin coincide. The presence of radial pore canals is indicated around the anterior border. Muscle scar located just anterad of midlength consists of a subvertical row of four rectangular spots and two additional anterior spots.

Length of holotype (figs. 1, 2), a carapace, 0.42 mm.; height, 0.25 mm.; maximum thickness, 0.21 mm.

Length of paratype (figs. 3, 4), a carapace, 0.47 mm.; height, 0.24 mm.; maximum thickness, 0.20 mm.

Length of paratype (figs. 5, 7), a left valve, 0.40 mm.; height, 0.24 mm.

Length of paratype (figs. 6, 8), a right valve, 0.39 mm.; height, 0.22 mm.

Average length of 14 specimens from type locality, 0.43 mm.; height, 0.24 mm.; thickness, 0.20 mm.

Type locality: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths

of 3389 and 3396 feet, in green shale of the middle member of the Vanguard formation, 1 to 8 feet above the base.

Types: Holotype, No. 0-1211-9; paratypes, Nos. 0-1211-10, 0-1211-11, 0-1211-12, Univ. of Missouri.

Stratigraphic distribution: This species is rather common in the basal beds of the middle member of the Vanguard formation in the Kelstern well of west-central Saskatchewan but rare in other localities, with one specimen found at about the same level in the Rush Lake well. Two valves were recorded in the lower portion of the upper member of the Vanguard from the Instow well of southwestern Saskatchewan.

Roberts (1934, pp. 35-37, pl. 1, figs. 7, 10) described and figured this species as *Cythereis antiprojecta* (*ms.* name) from the Sundance formation in the Lander area of west-central Wyoming.

Remarks: The present author (1958) referred to this species as *Cythereis* n. sp. 1. The hingement of this species is not as well developed as in Cretaceous and Cenozoic species of *Cythereis*, but as the general hinge structure, outline of the carapace and valve overlap suggest this genus, the new species is assigned to it.

The species is named for Mr. John F. Roberts, author of an unpublished work on the Sundance ostracodes.

CYTHEREIS RUSHLAKENSIS Wall, n. sp.
Plate 27, figures 9-12

Shell subquadrate in lateral view; greatest height near anterior end; dorsal margin nearly straight, about four-fifths of shell length; cardinal angles obtuse; ventral margin nearly straight and subparallel to but slightly convergent with dorsum toward posterior; anterior margin broadly rounded; posterior margin narrowly rounded, extended medially.

Valves subequal, the left slightly overlapping the right except along the hinge margin where the right overlaps the left. Valves moderately convex, greatest thickness at about midlength.

Anterior extremity compressed and bearing low marginal rim; median extension of posterior end compressed to form a short caudal process; ventral surface of carapace bevelled. Two long, sharp horizontal ridges, a median and a ventral, traverse most of the shell length and converge or unite at the anterior end. A third lateral ridge, nearly parallel and ventrad to the principal ventral ridge, traverses the anterior two-thirds of the ventral surface. At the anterocardinal angle of each valve lies a small, poorly defined, node-like swelling which passes downward into a short, oblique, anteriorly-directed ridge. The remainder of the shell surface is essentially unornamented, although some specimens are faintly pitted in part.

Hinge of right valve consists of terminal, small, elliptical, weakly incised dental units connected by an apparently faintly crenulate groove into which the edge of the left valve slides. No left valves found, but hingement assumed to consist of terminal sockets and the valve edge as in *C. robertsi*, n. sp.

Inner lamellae of moderate width, sloping fairly steeply toward valve interior. Line of concrescence and inner margin coincide. Muscle scar not clearly seen, but probably is the same as that observed in *C. robertsi*, n. sp., *i.e.*, a subvertical row of four rectangular spots and two additional anterior spots.

Length of holotype (figs. 9, 10), 0.42 mm.; height, 0.22 mm.; maximum thickness, 0.22 mm.

Length of paratype (figs. 11, 12), 0.45 mm.; height, 0.24 mm.; maximum thickness, 0.20 mm.

Type locality: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3438 and 3447 feet, in green shale from the type section of the lower member of the Vanguard formation, 22 to 31 feet below the top.

Types: Holotype, No. 0-1211-14; paratype, No. 0-1211-15, Univ. of Missouri.

Stratigraphic distribution: *Cythereis rushlakensis*, n. sp., occurs rather commonly in the upper beds of the lower member of the Vanguard formation at the Rush Lake well in west-central Saskatchewan. It seems quite rare elsewhere in the lower member of the Vanguard, with one valve obtained from the basal Vanguard at Rush Lake, and one carapace observed in the basal Vanguard at Carievale in southeastern Saskatchewan. Because of the chief occurrence of this species near the top of the lower member of the Vanguard, it is illustrated with the fauna occurring in the middle and upper members of the Vanguard or the Swift equivalent.

Remarks: The author (1958) referred to this form as *Cythereis* n. sp. 1, variety A. It seems, however, to differ sufficiently in external characters from *C. robertsi*, n. sp., to warrant proposing as a new species. *C. rushlakensis* is distinguished by its sharper principal longitudinal ridges and by the possession of an additional lateral ridge traversing the anterior part of the ventral surface. Between the ridges, the surface of *C. rushlakensis* is essentially unornamented compared with the prominent reticulation pattern of *C. robertsi*.

The species is named from its occurrence in the Tidewater Rush Lake Crown No. 1 well, the type locality of the species.

CYTHEREIS RUSHLAKENSIS variety

Plate 27, figures 13, 14

Shell subquadrate in lateral view; greatest height near anterior end; dorsal margin nearly straight, about four-fifths of shell length; cardinal angles obtuse; ventral margin nearly straight converging posteriorly with respect to dorsum; anterior margin narrowly rounded, extended below, subtruncate above; posterior end bluntly acuminate, extended medially, somewhat indented above and below.

Valves subequal, the left slightly overlapping the right, the overlap more pronounced along the hinge margin where the dorsal rim of the left valve is projected as a knife-edged ridge. Valves moderately convex, the greatest thickness at about midlength.

Anterior extremity compressed and bearing low marginal rim; median extension of posterior end compressed to form a rather sharp caudal process; ventral surface of carapace flat. Surface of each valve is ornamented with two prominent, elevated, horizontal ridges, one of which runs along the median axis while the other runs close and nearly parallel to the ventral border; a third, shorter, horizontal ridge traverses the ventral surface of each valve but is visible in lateral view; a rather prominent vertical ridge originates at the anterodorsal angle, extends downward and slightly forward for about one-fourth of the height of the shell,

and then bifurcates—one branch is directed downward and forward nearly reaching the anterior margin at midheight, and the other branch is directed downward and slightly posteriorly uniting with the prominent horizontal median ridge. The remainder of the shell surface is randomly ornamented with disconnected short ridges and scattered weak reticulations.

No free valves recovered, thus no information available on hingement and internal features.

Length of figured specimen, 0.65 mm.; height, 0.34 mm.; maximum thickness, 0.28 mm.

Locality of figured specimen: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3438 and 3447 feet, in green shale from the type section of the lower member of the Vanguard formation, 22 to 31 feet below the top.

Figured specimen: Univ. of Missouri No. 0-1211-16.

Stratigraphic distribution: This form is rare in the lower member of the Vanguard formation with occurrences of one specimen at the Rush Lake and Atlas No. 1 wells in west-central Saskatchewan, and with a few specimens obtained from one of the Wapella wells in eastern Saskatchewan.

Roberts (1934, pp. 34-35, pl. 1, figs. 11, 12) described and figured this form as *Cythereis projecta* (*ms.* name) from the Sundance formation of the Lander area of west-central Wyoming.

Remarks: The author (1958) referred to this form as *Cythereis* n. sp. 1, variety B. It seems, however, to be sufficiently distinct from *C. robertsi*, n. sp., to remove it entirely from that category. On the other hand, its relationship to *C. rushlakensis*, n. sp., appears close. It differs from the typical species in its larger size, conspicuous caudal extension, and in the projection of the dorsal rim of the left valve so that it overlaps the right along the hinge margin.

CYTHEREIS? sp. C

Plate 21, figures 10, 11

Shell subquadrate in lateral view; greatest height at anterodorsal angle, greatest length median; hinge margin nearly straight, about three-fourths of shell length; cardinal angles obtuse, the posterior less so and better defined; ventral margin slightly convex, converging only slightly with dorsum posteriorly; anterior margin broadly and uniformly rounded; posterior margin more narrowly rounded subtruncate.

Valves nearly equal in size, although there is some indication the left overlaps the right slightly along the cardinal slopes and the ventrum while the reverse may hold along the hinge margin. Entire shell compressed, greatest thickness median although carapace is of nearly uniform breadth.

Anterior and posterior extremities compressed bearing very faint marginal rims. General surface of valves weakly reticulate. A narrow, rather sharp ridge extends along ventrum, continues around anterior and posterior margins and then curves inward along the dorsal margin, the extension of the anterior marginal arc terminating at about the anterodorsal angle, while the similar posterior extension runs forward to about midpoint on the hinge margin; a broad, shallow depression lies

between the dorsal terminals of this incurved ridge in which a rather poorly defined, dorsoventrally elongated node is typically present.

Hinge of right valve, as based upon examination of a few poorly preserved specimens, consists of terminal, small, elliptical, faintly incised dental units, and the connecting weakly crenulate valve edge in which no groove was detected.

Length of specimen (fig. 10), 0.67 mm.; height, 0.35 mm.; maximum thickness, 0.21 mm.

Length of specimen (fig. 11), 0.66 mm.; height, 0.35 mm.; maximum thickness, 0.24 mm.

Locality of figured specimens: Socony-Western Prairie-Imperial Carievale No. 1 well in Lsd. 16, Sec. 4, Tp. 3, Rge. 32, W. 1st Meridian, Saskatchewan, Canada, between depths of 3195 and 3200 feet, in green shale at the contact of the Shaunavon and Vanguard formations.

Figured specimens: Univ. of Missouri Nos. 0-1211-17 and 0-1211-18.

Stratigraphic distribution: This species was recognized only in eastern Saskatchewan at the contact of the Shaunavon and Vanguard formations, with most of the specimens (10) obtained from the Carievale well. Two representatives were found in the Tidewater Wapella No. 16-33 well, also at the Shaunavon-Vanguard contact.

Remarks: This species is referred very questionably to *Cythereis* as it lacks the typical hingement of that genus. The surface ornamentation and outline of the carapace are strongly suggestive of *Cytherelloidea*, but the possession of actual dental units precludes assignment to the latter. A new genus probably is represented by this species.

Genus EUCYTHERURA Müller, 1894

EUCYTHERURA RETICULATA Peterson

Plate 26, figures 4-9

Eucytherura reticulata Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, p. 169, pl. 18, fig. 19; text figs. 2h, i, j.

Shell small, subrhomboidal in lateral view; greatest height anterior; hinge margin gently arched, about four-fifths of shell length; ventral margin nearly straight, converging posteriorly toward dorsum; cardinal angles fairly well defined; anterior end extended below, truncate above; posterior end bluntly acuminate, extended just above middle.

Valves seem nearly equal in size, although the right may slightly overlap the left along the hinge margin, which is furrowed as seen in dorsal view. Valves compressed in anterior half; maximum thickness about one-third from posterior end.

Anterior extremity compressed, bearing a faint marginal rim, ventral half spinose; posterior end compressed to form a short caudate extension. A shallow vertical sulcus lies slightly anterad of the median line in each valve. Posteroventral areas of valves swollen into near-alate expansions which slightly overhang the ventral margin. General surface of valves finely reticulate. There are three, fine, lateral ridges in most specimens, two of which run near and parallel with the dorsal and ventral margins, with a third along the central axis running from the central posterior through the central area. An incipient node seems to be developed at the anterocardinal angle in each valve.

Hinge of right valve consists of small, terminal, crenulate dental units connected by a weakly crenulate groove in the valve edge into which the bevelled surface of the left valve apparently slides. Hinge of left valve consists of small, terminal sockets connected by the weakly crenulate arched bar, which is the inner side of the bevelled dorsal surface of the valve. Internal features obscure, inner lamellae seem fairly wide; no muscle scar observed.

Length of hypotype (figs. 8, 9), a carapace, 0.32 mm.; height, 0.17 mm.; maximum thickness, 0.14 mm.

Length of hypotype (figs. 6, 7), a carapace, 0.35 mm.; height, 0.17 mm.; maximum thickness, 0.17 mm.

Length of hypotype (fig. 4), a left valve, 0.35 mm.; height, 0.17 mm.

Length of hypotype (fig. 5), a right valve, 0.32 mm.; height, 0.17 mm.

Locality of hypotype (carapace, figs. 8, 9): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3538 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 7 feet above the base.

Locality of hypotypes (others): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3288 and 3292 feet, in green shale of the lower member of the Vanguard formation, 73 to 77 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1211-19, 0-1211-20, 0-1212-1, 0-1212-2.

Stratigraphic distribution: This species occurs rather rarely in the lower member of the Vanguard formation in Saskatchewan. Specimens were identified from the Kelstern and Atlas wells of the west-central area and from Wapella on the eastern border of the province.

Peterson (1954a, p. 169) described this species from the lowermost Sundance beds along the Big Horn Mountains, north-central Wyoming, where it was reported as rare.

Remarks: The assignment of these Saskatchewan specimens to this species is questionable. The species was established on the basis of a very few, rather poorly preserved specimens, and it was not possible to make a satisfactory comparison. The Saskatchewan specimens appear, however, to be closely related if not identical with this species.

Genus LIMNOCYTHERE G. S. Brady, 1866

LIMNOCYTHERE CLIMAXIA (Loranger)

Plate 22, figures 1-12

Monaceratina climaxia Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 50, pl. 8, figs. 11, 12 (generic name misspelled).

Prognocythere radvillia Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 52, pl. 8, figs. 13, 14 (generic name misspelled).

Monaceratina sundancensis Loranger, 1955 (not of Swain and Peterson, 1951), Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 51, pl. 9, figs. 3, 4.

Shell subquadrate in lateral view, highest at the anterocardinal angle. Dimorphism apparently developed with the presumed females more elongate and appearing incipiently trilobate in dorsal view. Hinge margin straight, about two-thirds of shell length; ventral margin moderately sinuous and subparallel to dorsum in females, slightly sinuous and con-

verging more rapidly toward posterior with respect to dorsum in males. Anterior margin broadly and quite evenly rounded; posterior margin more narrowly rounded, extended above midheight. Cardinal angles obtuse but fairly well defined.

Left valve slightly larger than the right extending beyond it along the free margins. Valves moderately convex, greatest thickness about median in females, slightly postmedian in males.

Anterior extremity strongly compressed and bearing rather prominent marginal rim; posterior extremity much less compressed, the marginal rim not as strong. General surface finely reticulate. A prominent vertical sulcus, located slightly anterad to midlength in males, proportionately more forward in females, occupies the dorsal half of each valve; a rather conspicuous node is situated just forward of this sulcus and slightly ventrad to the dorsal margin. A second, less well-defined vertical sulcus, located about one-third from posterior end, occupies the ventral half of each valve in females and imparts to them a trilobate appearance in dorsal view. The central ventral area is slightly swollen in both dimorphs, more pronounced in males, however, where the swellings take on the appearance of blunted alate projections; in some specimens, more commonly in males, a nodose projection emanates from the posterocentral area of each valve slightly above midheight, and being aligned with the ventral alate projection just mentioned, gives a double wing appearance in dorsal view.

Hinge of left valve consists of terminal elliptical sockets in recesses overhung by gentle up-archings of the dorsal margin, and the interconnecting flange projection slightly ventrad to the dorsal rim of the valve. Hinge of right valve consists of terminal, elongate dental units formed of the valve edge and an interterminal groove which accommodates the projecting flange of the left valve in a rabbet type of hingement. (In dorsal view a narrow furrow is visible between the valve edges). Inner lamellae broad; line of concrescence and inner margin coincide. Normal canals fairly common; radial canals not too closely spaced, about 12 around anterior end, not branching. Muscle scar at midheight, slightly anterad of the median line at the base of the anterior vertical sulcus, an arcuate row of four spots with an additional two anterior spots.

Length of hypotype (figs. 1, 2), a male carapace, 0.62 mm.; height, 0.37 mm.; maximum thickness, 0.27 mm.

Length of hypotype (figs. 3, 4), a male carapace, 0.60 mm.; height, 0.32 mm.; maximum thickness, 0.26 mm.

Length of hypotype (figs. 5, 6), a female carapace, 0.67 mm.; height, 0.37 mm.; maximum thickness, 0.27 mm.

Length of hypotype (figs. 7, 8), a female carapace, 0.66 mm.; height, 0.34 mm.; maximum thickness, 0.25 mm.

Length of hypotype (figs. 9, 10), a female left valve, 0.65 mm.; height, 0.35 mm.

Length of hypotype (figs. 11, 12), a female right valve, 0.64 mm.; height, 0.32 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3588 and 3601 feet, in green shale of the upper member of the Shaunavon formation, 0 to 13 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1212-3, 0-1212-4, 0-1212-5, 0-1212-6, 0-1212-7, 0-1212-8.

Stratigraphic distribution: This species is common in the upper member of the Shaunavon formation of southwestern and west-central Saskatchewan, and was recorded from all wells examined in these areas. It is present in the top of the Gravelbourg formation at Eastend in the southwest area.

Remarks: The occurrence of this species in the Bathonian Shaunavon formation would appear to mark the lowest recorded level of the genus. *Limnocythere fragilis* Martin (1940, pp. 348-350, pl. 7, figs. 105-109; pl. 9, fig. 152) from the Wealden beds of northern Germany was hithertofore apparently the earliest recorded representative of the genus. In this regard, the Saskatchewan representatives, named *Monaceratina climaxia* and *Prognocythere radvillia* by Loranger, may be identical with *L. fragilis* of Martin inasmuch as there are quite a number of similarities between them. For the present, however, in view of the lack of information on the hingement in Martin's species, and some apparent differences in external features between the two forms, it seems advisable to allow *L. climaxia* (Loranger) to stand.

In the present author's opinion, the specimens selected by Loranger as holotypes for *Monaceratina climaxia* and *Prognocythere radvillia* probably are male and female dimorphs, respectively, of the same species. Inasmuch as the former appears first in the manuscript, the name "*climaxia*" would have priority over "*radvillia*". Further, it is thought that the form referred to *Monoceratina sundancensis* Swain and Peterson by Loranger is a molt of *Limnocythere climaxia*. The present author has a suite of like specimens from the top of the Shaunavon formation in the Kelstern well, and considers them as belonging to this species.

LIMNOCYTHERE PUSTULOSA Wall, n. sp.

Plate 22, figures 13-15

Shell subquadrate in lateral view, highest at the anterocardinal angle. Dimorphism apparently developed with the presumed females more elongate and appearing incipiently trilobate in dorsal view. Hinge margin straight, about two-thirds of shell length; ventral margin moderately sinuous and subparallel to dorsum in females, slightly sinuous and converging more rapidly toward posterior with respect to dorsum in males. Anterior margin broadly and quite evenly rounded; posterior margin more narrowly rounded, extended above midheight. Cardinal angles obtuse but fairly well defined.

Left valve slightly larger than the right extending beyond it along the free margins. Valves moderately convex, greatest thickness about median in females, slightly postmedian in males.

Anterior extremity strongly compressed and bearing rather prominent marginal rim with tubercles; posterior extremity much less compressed, the marginal rim not as strong. General surface covered with pustules, which tend to be more prominent in the shorter specimens or presumed males. A prominent vertical sulcus, located slightly anterad to midlength in males, proportionately more forward in females, occupies the dorsal half of each valve; a rather conspicuous node is situated just forward of this sulcus and slightly ventrad to the dorsal margin. A second, less well-defined vertical sulcus, located about one-third from posterior end, occupies the ventral half of each valve in females and imparts to them a

trilobate appearance in dorsal view. The central ventral area is slightly swollen in both dimorphs, more pronounced in males, however, where the swellings take on the appearance of blunted alate projections; in some specimens more commonly in males, a nodose projection emanates from the posterocentral area of each valve slightly above midheight, and being aligned with the ventral alate projection just mentioned, gives a double wing appearance in dorsal view.

No free valves found, but hingement and other internal features probably are identical with those of *L. climaxia* (Loranger).

Length of holotype (figs. 13, 14), a male carapace, 0.64 mm.; height, 0.37 mm.; maximum thickness, 0.30 mm.

Length of paratype (fig. 15), a female carapace, 0.72 mm.; height, 0.32 mm.; maximum thickness, 0.27 mm.

Type locality: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4541 and 4548 feet, in green shale of the upper member of the Shaunavon formation, 2 to 9 feet above the base.

Types: Holotype, No. 0-1212-9; paratype, No. 0-1212-10, Univ. of Missouri.

Stratigraphic distribution: About 18 specimens were obtained from the type locality. Isolated occurrences of generally one specimen were recorded from the same level at Eastend, Instow and Rush Lake in western Saskatchewan.

Remarks: The author (1958) referred to this form as *L. climaxia* (Loranger) variety, but it seems to be sufficiently different from *L. climaxia* to warrant proposing as a new species. It is true that *L. climaxia* and *L. pustulosa*, n. sp., have the same shell outline, sulci, nodose and alate projections, but *L. pustulosa* is readily distinguished by its pustulose surface and tuberculate anterior marginal rim. Nearly all of the specimens of *L. pustulosa* have been pyritized.

Genus METACYPRIS Brady and Robertson, 1870

METACYPRIS sp. cf. M. TENUIMARGINATA Bernard, Bizon and Oertli

Plate 23, figures 1-10

?*Metacypris tenuimarginata* Bernard, Bizon and Oertli, 1957, Geol. Soc. France, Bull., ser. 6, vol. 6, no. 6, pp. 765-766, pl. 23, figs. 15-24 (1956).

Shell subrectangular in lateral view. Dimorphism prominently developed, the female strongly tumid in posterior region. Greatest height at the anterocardinal angle in females, at this point or center of dorsal margin in males; greatest length slightly below midheight in both dimorphs. Dorsal margin in males slightly convex, about three-fifths of shell length, in females nearly straight, less than half of shell length. Ventral margin slightly convex in both sexes, subparallel to dorsum. Anterocardinal angle well defined in females, less so in males; posterocardinal angle broadly obtuse and poorly defined in females, better defined in males. Anterior margin broadly rounded, extended below midheight, truncate above, more conspicuously so in females; posterior margin more narrowly rounded, extended below midheight, truncate above in males, subtruncate in females.

Valves appear nearly equal in size, left valve seems to extend slightly beyond the right along dorsal slopes. Convexity of valves pronounced in

posterior region of females, with greatest thickness about one-fourth from posterior end; convexity of valves only moderate in males, greatest thickness median.

Anterior extremity rather strongly compressed, the valves bearing narrow, marginal rims. In females, a wide, gentle, oblique depression occupies the dorsal half of each valve in the area slightly anterior to mid-length. Ventral surface bevelled. Surface ornamentation weak, an indefinite pattern of small pits, reticulations, with rather prominent horizontal lines in the ventral area.

Hinge structure not clearly observed, apparently simple. Muscle scar slightly anterior and ventrad to midpoint of shell, a subvertical row of four rectangular spots.

Length of specimen (figs. 1, 2), an adult female, 0.95 mm.; height, 0.57 mm.; maximum thickness, 0.54 mm.

Length of specimen (figs. 3, 4), an adult male, 0.85 mm.; height, 0.53 mm.; maximum thickness, 0.42 mm.

Length of specimen (figs. 5, 6), a juvenile female, 0.52 mm.; height, 0.32 mm.; maximum thickness, 0.34 mm.

Length of specimen (figs. 7, 8), a juvenile male, 0.57 mm.; height, 0.36 mm.; maximum thickness, 0.31 mm.

Length of specimen (figs. 9, 10), an adult female, 0.96 mm.; height, 0.54 mm.; maximum thickness, 0.57 mm.

Locality of specimen (figs. 9, 10): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3572 and 3580 feet, in green shale of the upper member of the Shaunavon formation, 24 to 32 feet below the top.

Locality of figured specimens (others): Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4500 and 4503 feet, in green shale of the upper member of the Shaunavon formation, 5 to 8 feet below the top.

Figured specimens: Univ. of Missouri Nos. 0-1212-11, 0-1212-12, 0-1212-13, 0-1212-14, 0-1212-15.

Stratigraphic distribution: This species occurs sporadically to commonly in the upper member of the Shaunavon formation and is widely distributed in the province of Saskatchewan. It has been observed in the Frontier and Eastend wells of the southwestern area, the Rush Lake and Johnston Lake wells of the west-central area, and the Wapella and Carlyle wells of the eastern area.

Remarks: The Saskatchewan female specimens seem very close to *M. tenuimarginata* from the upper Bathonian of the Paris Basin, but their maximum widths are nearer the posterior ends than in the type where the greatest thickness is slightly postmedian. The ornamentation pattern, although similarly reticulate in both the Saskatchewan and type material, is much weaker in the former. An exception to this generalization was noted in the Carlyle well, however, where a few red valves were found which showed the same strong reticulate pattern of the types.

Genus MONOCERATINA Roth, 1928

MONOCERATINA INCISA Peterson

Plate 26, figures 14, 15

Monoceratina incisa Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, pp. 164-165, pl. 17, figs. 16, 17.

Shell small, sublanceolate in lateral view; greatest height near anterior end; hinge margin straight, about three-fourths of shell length; antero-

cardinal angle obtuse, fairly well defined; posterocardinal angle generally poorly defined because of caudation but rather well defined in hypotype; ventral margin slightly convex, converging abruptly toward dorsum in posterior third; anterior margin broadly rounded, slightly extended below; posterior end acuminate, strongly extended above midheight.

Valves seem nearly equal in size, the right, however, overlapping the left slightly along dorsal margin. Valves only weakly convex; greatest thickness just behind middle.

Extremities compressed and bearing faint marginal rims; posterior compression extends along ventral margin for about one-third of shell length. Surface of valves is strongly and sharply sculptured. A deep vertical sulcus occupies the anteromedian portion of each valve, bounded anteriorly by a sharp, arcuate ridge and posteriorly by a short, lateral, knife-edge ridge just dorsad of midheight, and a prominent spinose projection near the posteroventral angle. A narrow, sharp ridge extends along the dorsal margin of each valve and curves abruptly downward about one-fifth from posterior end. The general valve surface is finely reticulate between the ridges.

No free valves found, thus no information available on hingement and internal features.

Length of hypotype, 0.30 mm.; height, 0.16 mm.; maximum thickness, 0.14 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3548 and 3556 feet, in green shale from the base of the type section of the lower member of the Vanguard formation.

Hypotype: Univ. of Missouri No. 0-1212-16.

Stratigraphic distribution: In Saskatchewan, this species seems confined to the lower portion of the lower member of the Vanguard formation as indicated by its rather rare occurrences in the Kelstern, Rush Lake and Johnston Lake wells of the west-central area.

Peterson (1954a, p. 165) reported the species as rare in the Rierdon formation of extreme south-central (Carbon County) Montana and in the "lower Sundance" formation of north-central Wyoming.

MONOCERATINA PARAROSSAE Peterson

Plate 26, figures 16-19

Monoceratina pararossae Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, p. 165, pl. 17, figs. 21-24.

Shell elongate-pentagonal in lateral view; greatest height at the anterodorsal angle; hinge margin straight, about two-thirds of shell length; cardinal angles well defined, the posterior more obtuse than the anterior; ventral margin nearly straight and parallel to dorsum. Anterior margin broadly rounded, slightly extended below and truncate above midheight; posterior end extended medially to form a prominent, compressed, sharp caudal process.

Valves nearly equal in size although left overlaps the right slightly along the cardinal slopes and very slightly along the ventrum. Convexity of valves low, greatest along ventrum; maximum width about one-third from posterior end.

Posterior third and posteroventral region of shell strongly compressed; anteriorly, only the extremity is compressed, bearing a low marginal rim. General surface of valves finely pitted. A distinct dorsocentral vertical sulcus divides each valve into two subequal lobes; a fairly deep, obliquely elongate sulcus lies near and parallel to the dorsal two-thirds of the anterior margin. Dorsal border of each valve raised slightly, forming a spindle-shaped groove in the hinge margin as seen in dorsal view. A narrow, horizontal ridge situated in the posterior half of shell between midheight and the dorsal margin runs nearly parallel to the latter and merges into apex of the caudal extension. In some specimens, a similar but less well-defined ridge rises from the swollen posteroventral border and converges toward the dorsal ridge mentioned above.

Hinge of left valve, as seen in a thin, probable molt specimen, shows only the weakly crenulate valve edge. Hinge of right valve similar, consisting of the crenulate valve edge. No other internal features observed.

Length of hypotype (figs. 16, 17), 0.55 mm.; height, 0.24 mm.; maximum thickness (estimated), 0.18 mm.

Length of hypotype (figs. 18, 19), 0.67 mm.; height, 0.27 mm.; maximum thickness, 0.24 mm.

Locality of hypotypes: Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3292 and 3300 feet, in green shale of the lower member of the Vanguard formation, 65 to 73 feet above the base.

Hypotype (figs. 16, 17): Univ. of Missouri No. 0-1212-17.

Hypotype (figs. 18, 19): Lost after photography.

Stratigraphic distribution: In Saskatchewan, this species seems confined to the lower member of the Vanguard formation and occurs sporadically in the Kelstern and Atlas wells of the west-central area.

Peterson (1954a, p. 165) reported this species as common to abundant in the Rierdon formation of central and extreme south-central Montana and of extreme north-central Wyoming, and in the "lower Sundance" formation of the Cody area of northwestern Wyoming.

Roberts (1934, pp. 42-43, pl. 2, figs. 1, 2) described this species as *Monoceratina pentagona* (*ms.* name) from the Sundance formation of the Lander area of west-central Wyoming, where it was reported as rare in various outcrop samples.

MONOCERATINA VULSA (Jones and Sherborn)

Plate 26, figures 20, 21

Cytheridea vulsa Jones and Sherborn, 1888, Bath Nat. Hist. and Antiq. Field Club, Proc., vol. 6, p. 263, pl 2, figs. 4a-b.

Monoceratina vulsa (Jones and Sherborn). Triebel and Bartenstein, 1938, Senckenbergiana, vol. 20, pp. 516-517, pl. 3, figs. 17-18b.

Shell sublanceolate in lateral view; greatest height at the anterodorsal angle; hinge margin straight, about two-thirds of shell length; anterocardinal angle slightly obtuse, well-defined, posterocardinal angle poorly defined because of caudation; ventral margin straight and parallel to dorsum. Anterior margin broadly rounded, slightly extended below and truncate above midheight; posterior end acuminate, extended above midheight to form a prominent, compressed, sharp caudal process.

Valves appear equal in size with hinge line depressed slightly below dorsal border. Convexity of valves moderate, greatest thickness about one-third from posterior end.

Anterior extremity compressed and bearing a prominent marginal rim; posterior fourth of shell strongly compressed; central ventral areas of valves somewhat swollen giving slightly alate appearance to shell. General surface of valves pitted. A distinct, median, vertical sulcus traverses the dorsal two-thirds of each valve dividing the shell into two subequal lobes.

No free valves available, thus information on hingement and internal features wanting.

Length of hypotype, 0.62 mm.; height, 0.26 mm.; maximum thickness, 0.28 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3548 and 3556 feet, in green shale from the base of the type section of the lower member of the Vanguard formation.

Hypotype: Univ. of Missouri No. 0-1212-18.

Stratigraphic distribution: In Saskatchewan, this species seems confined to the lower member of the Vanguard formation and occurs rarely in the Kelstern and Rush Lake wells of the west-central area.

Remarks: The Saskatchewan specimens are thicker and probably more acuminate posteriorly than the German representatives of the species, which in turn were reported to differ slightly from the English type material. According to Triebel and Bartenstein, the species in Europe appears to be limited to the higher Dogger of northwest Germany and England.

Genus NORCANOLELLA Loranger, 1955

Inasmuch as the original author offered few details on the hinge structure and gave a confusing picture of the overlap relationship of the valves, it seems advisable to make a revised generic diagnosis.

Shell subovate to subquadrate; hinge margin straight to prominently arched; ventral margin slightly convex to slightly sinuous; terminal margins broadly rounded, the posterior less than the anterior. Right valve larger than left, but left overlaps right along hinge. Valves moderately convex, strongly compressed at anterior extremity bearing prominent marginal rims. Alate extension in central ventral area of each valve, with posterior sweep, typically with sharp terminus. Surface of valves weakly ornamented with faint pitting.

Hinge of left valve consists of terminal, elongate teeth formed of valve edge and an interterminal groove into which the edge of the right valve fits. Hinge of right valve consists of corresponding terminal sockets with the connecting valve edge and a faint groove ventrad to it. Inner lamellae of moderate width, sloping fairly steeply toward interior of valves; line of concrescence and inner margin nearly coincide. Radial canals and normal canals both present, rather widely spaced. Muscle scar slightly anterad to midlength consisting of an arcuate row of four spots with one or two additional anterior spots. Dimorphism typically occurs with the presumed males shorter and ovate.

Type species—*Norcanolella parryi* Loranger.

Geologic Range—Middle Jurassic. Representatives of this genus have as yet been reported from only the Bathonian Shaunavon formation of Saskatchewan.

Relationship—This genus shows rather close relationship to *Monoceratina* Roth as both genera have alate extensions and grooved left valves for reception of the right valves. *Norcanolella*, however, has a pronounced valve overlap and its hinge structure includes definite terminal dental units.

Norcanolella shows considerable similarity in outline, surface features and hingement to *Klieana* Martin from the Wealden of north Germany, but the hinge structures are located in opposite valves in the two genera. The valve overlap is also the reverse in the two genera.

Norcanolella and *Aparchitocythere* Swain and Peterson have similar hingement with the elements located in identical valves, but the overlap of the valves is the reverse in the two genera, and *Aparchitocythere* lacks the ventral alate extensions.

NORCANOLELLA PARRYI Loranger

Plate 20, figures 1-12

Norcanolella parryi Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, pp. 51-52, pl. 9, figs. 1, 2.

Shell subovate to subquadrate in lateral view. Dimorphism prominently exhibited with presumed males shorter and more ovate than females. Dorsal margin strongly convex in males or at least in juveniles, nearly straight in females where it is about three-fifths of shell length. Ventral margin slightly convex in males, slightly sinuous in females. Anterior margin broadly rounded, slightly extended below; posterior margin less broadly rounded, particularly in males.

Right valve larger than left extending beyond it along free margins, but left overlaps right along dorsal margin. Valves moderately convex, greatest thickness median in males, postmedian in females.

Anterior end strongly compressed bearing a prominent marginal rim; posterior end only gently compressed with a less conspicuous marginal rim. Surface of valves weakly ornamented with faint pitting. A prominent, subtriangular, alate extension, with posterior sweep and rather sharp terminus, originates from the central ventral area of each valve. A shallow, wide, subvertical sulcus occurs slightly anterior to the dorsomedian area.

Hinge of left valve consists of terminal, elongate teeth formed of valve edge, and an interterminal groove into which the edge of the right valve fits. Hinge of right valve consists of corresponding terminal sockets, the anterior one appearing as a reëntrant in the valve edge as viewed dorsally, and the connecting valve edge with a faint groove ventrad to it.

Inner lamellae of moderate width, sloping fairly steeply toward interior of valves; line of concrescence and inner margin nearly coincide. Normal canals rather large, not too closely spaced; radial canals not branched, distributed such that there are 10 or 12 around the anterior end. Muscle scar slightly anterad to midlength, consisting of an arcuate row of four spots with one or two additional anterior spots.

Length of hypotype (figs. 1, 2), an adult male? carapace, 0.80 mm.; height, 0.51 mm.; maximum thickness (including alae), 0.50 mm.

Length of hypotype (figs. 3, 4), a juvenile male carapace, 0.62 mm.; height, 0.39 mm.; maximum thickness (including alae), 0.37 mm.

Length of hypotype (figs. 5, 6), an adult female carapace, 0.92 mm.; height, 0.45 mm.; maximum thickness (including alae), 0.42 mm.

Length of hypotype (figs. 7, 8), a male? left valve, 0.77 mm.; height, 0.47 mm.

Length of hypotype (figs. 9, 10), a male? right valve, 0.77 mm.; height, 0.50 mm.

Length of hypotype (fig. 11), an adult male left valve, 0.71 mm.; height, 0.40 mm.

Length of hypotype (fig. 12), an adult female right valve, 0.90 mm.; height, 0.50 mm.

Locality of hypotypes (carapaces; valves, figs. 7-10): Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian Saskatchewan, Canada, between depths of 3580 and 3607 feet, in green shale of the upper member of the Shaunavon formation, 0 to 27 feet above the base.

Locality of hypotypes (valves, figs. 11, 12): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3597 and 3601 feet, in green shale of the upper member of the Shaunavon formation, 0 to 4 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1212-19, 0-1212-20, 0-1213-1, 0-1213-2, 0-1213-3, 0-1213-4, 0-1213-5.

Stratigraphic distribution: This species is common to abundant in the upper member of the Shaunavon formation of west-central Saskatchewan, and was recorded in the Kelstern, Rush Lake and Johnston Lake wells. It seems rather rare at this level in the southwestern area, where it was identified in the Instow, Eastend and Frontier wells. This species is present in equivalent strata at the Carlyle well of eastern Saskatchewan and may be present in one of the Wapella wells.

Remarks: The relationship of the various molt stages and the differentiation of the dimorphs in this species present a confusing and difficult problem which requires more detailed study.

NORCANOLELLA sp. A

Plate 21, figures 1-5

Shell subovate to subquadrate in lateral view, greatest height at anterocardinal angle. Dimorphism developed with the presumed males shorter and more ovate than females. Hinge margin located posterior to point of greatest height, nearly straight, about three-fifths of shell length in females, slightly less in males; ventral margin sinuous and subparallel to dorsum in females, slightly sinuous and converging rather strongly toward posterior with respect to dorsum in males. Anterior margin broadly rounded in both dimorphs; posterior margin more narrowly rounded, extended medially or above midheight in females.

Right valve larger than left, extending beyond it along free margins, but left overlaps right along dorsal margin. Valves moderately convex, greatest thickness slightly postmedian in males, about one-third from posterior end in females.

Anterior end strongly compressed bearing a prominent, broad marginal rim; posterior end gently compressed, the right valve with a narrow marginal rim. Surface of valves ornamented with very fine pits. A blunt, alate-like swelling projects from the central ventral area of each valve. A broad, shallow, oblique sulcus traverses the dorsal area about one-third from anterior end.

Hinge of left valve consists of terminal, elongate teeth formed of valve edge and an interterminal groove into which the edge of the right valve fits. Hinge of right valve, as viewed in a small, not fully developed specimen, consists of terminal sockets and the connecting valve edge.

Inner lamellae of moderate width, sloping fairly steeply toward interior of valves; line of concrescence and inner margin slightly separated. Normal canals rather large, fairly common on valve surfaces; radial canals often readily visible, not branched, spaced such that 10 or 12 occur around the anterior end. Muscle scar at about midpoint of shell consisting of an arcuate row of four spots and possibly one or two anterior spots.

Length of specimen (figs. 1, 2), a male carapace, 0.70 mm.; height, 0.42 mm.; maximum thickness, 0.31 mm.

Length of specimen (figs. 4, 5), a female carapace, 0.77 mm.; height, 0.39 mm.; maximum thickness, 0.29 mm.

Length of specimen (fig. 3), a female left valve, 0.75 mm.; height, 0.39 mm.

Locality of figured specimens: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3601 and 3607 feet, in green shale of the upper member of the Shaunavon formation, 0 to 6 feet above the base.

Figured specimens: Univ. of Missouri Nos. 0-1213-6, 0-1213-7, 0-1213-8.

Stratigraphic distribution: This form occurs in association with *N. parryi* Loranger in the Upper Shaunavon of west-central Saskatchewan.

Remarks: This form has been tentatively designated as *Norcanolella* sp. A, because of considerable doubt that it is sufficiently different from *N. parryi* to be proposed as another species. It lacks the prominent alate extensions of *N. parryi* and is more elongate, but otherwise it seems identical. *Norcanolella* sp. A may well represent an instar of *N. parryi*, as the molt relationships of the latter have not been satisfactorily determined.

NORCANOLELLA? sp. B

Plate 21, figures 6-9

Shell subovate to subquadrate in side view. Dimorphism apparently developed with presumed males shorter, higher and more ovate than females. Hinge margin in males straight, located largely posterior to point of greatest height, comprising slightly more than half of shell length; hinge margin in females gently convex, about three-fifths of shell length. Ventral margin slightly convex in males, slightly sinuous in females. Anterior margin broadly rounded in both dimorphs, less so in females; posterior margin less broadly rounded, slightly extended above midheight in both dimorphs.

Right valve larger than left extending beyond it along free margins, but left overlaps right along hinge margin. Valves moderately convex, greatest thickness slightly postmedian.

Anterior region strongly compressed just posterior to the margin, giving a "pinched-in" effect in dorsal view; posterior end only gently compressed, the right valve bearing a narrow marginal rim. A poorly defined, shallow depression lies in the anterodorsal area of each valve, about one-fourth from anterior end. Surface of valves ornamented with weak fine pits.

Hinge of one available right valve consists of terminal, elongate sockets and the connecting valve edge. No free left valve found. Inner lamellae do not seem very wide; normal canals visible on valve exteriors, rather large, not too closely spaced. Muscle scar slightly anterad to mid-length, consisting of an arcuate row of four spots.

Length of specimen (figs. 6, 7), a male carapace, 0.87 mm.; height, 0.60 mm.; maximum thickness, 0.42 mm.

Length of specimen (figs. 8, 9), a female carapace, 0.91 mm.; height, 0.50 mm.; maximum thickness, 0.40 mm.

Locality of figured specimens: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3582 and 3585 feet, in green, yellow and reddish-brown shale of the upper member of the Shaunavon formation, 16 to 19 feet above the base.

Figured specimens: Univ. of Missouri Nos. 0-1213-9 and 0-1213-10.

Stratigraphic distribution: This form was observed only at the level and locality of the figured specimens, where it is fairly common.

Remarks: Although this form lacks the ventral alate extensions characteristic of *Norcanolella*, it is similar in outline, valve relationships and internal features to this genus, and probably can be assigned to it. This form may bear varietal relationship to *N. parryi* or *N.* sp. A of this study, differing from these species in having a pinched anterior end, and in lacking the ventral alae.

Genus ORTHONOTACYTHERE Alexander, 1933

ORTHONOTACYTHERE DORSOCONVEXA Peterson

Plate 26, figures 10-13; Plate 28, figures 10, 11

Orthonotacythere dorsoconvexa Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, p. 164, pl. 17, figs. 9-11.

Shell small, subrhomboidal-caudate in outline, greatest height in anterior third; hinge margin convex, about three-fourths of shell length; anterocardinal angle obtuse, rounded, posterocardinal angle not defined because of caudation; ventral margin slightly converging posteriorly toward dorsum, making a fairly well defined posteroventral angle with the bluntly acuminate posterior end; anterior margin broadly rounded, slightly extended below.

Valves equal in size. Valves weakly convex, greatest thickness about one-fourth from posterior end.

Anterior end moderately compressed; posterior end and postero-ventral margin strongly compressed. Surface of valves ornamented in an irregular pattern of ridges with reticulations in intervening areas; a prominent ridge runs near and parallel to much of the dorsal margin curving downward near both ends of shell. A well-defined tubercle, tending to be sharply pointed in some individuals, lies inside the postero-

ventral marginal angle of each valve. A broad, faint vertical sulcus lies just anterad of the median line. Valve edges often depressed on hinge line forming a narrow furrow as seen in dorsal view of carapace.

Hinge of left valve consists of terminal, hemispherical, small sockets connected by the weakly crenulate, thin valve edge. Hinge of right valve consists of terminal, small, faintly notched dental units connected by the weakly crenulate valve edge. Further details of hingement obscure. Internal features obscured by poor preservation but inner lamellae seem fairly wide; line of concrescence and inner margin coincident or nearly so.

Length of hypotype (Pl. 26, figs. 10, 11), a carapace, 0.39 mm.; height, 0.18 mm.; greatest thickness, 0.17 mm.

Length of hypotype (Pl. 28, figs. 10, 11), a carapace, 0.35 mm.; height, 0.17 mm.; greatest thickness, 0.15 mm.

Length of hypotype (Pl. 26, fig. 12), a left valve, 0.42 mm.; height, 0.18 mm.

Length of hypotype (Pl. 26, fig. 13), a right valve, 0.40 mm.; height, 0.19 mm.

Locality of hypotype (carapace, Pl. 26): Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3538 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 7 feet above the base.

Locality of hypotype (carapace, Pl. 28): Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4303 and 4311 feet, in green shale of the middle member of the Vanguard formation, 3 to 8 feet below the top.

Locality of hypotype (valves): Tidewater Atlas Crown No. 2 well in Lsd. 13, Sec. 11, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3344.5 and 3347 feet, in green shale of the lower member of the Vanguard formation, 68 to 70.5 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1213-11, 0-1213-12, 0-1213-13, 0-1213-14.

Stratigraphic distribution: This species occurs sporadically in the lower member of the Vanguard formation in the Kelstern, Rush Lake and Atlas wells of west-central Saskatchewan. One isolated occurrence was recorded in the Instow well of the southwestern area in the middle member of the Vanguard.

The species was first published by Peterson (1954a) from the Rierdon formation of extreme south-central Montana (Carbon County).

Roberts (1934, pp. 43-44, pl. 1, figs. 13, 14) described and illustrated but left unnamed this species, which he reported as rather rare in various Sundance samples collected in the vicinity of Lander, Wyoming.

Remarks: Nearly all of the Saskatchewan specimens have more prominent ridge elements in their ornamentation patterns than the holotype, and this may indicate varietal or greater difference. The Instow individual, however, shows the dominantly reticulate nature of the ornamentation design in the holotype.

Peterson has commented on the uncertainty of his assigning this species to *Orthonotacythere*, but the discovery of a few free valves in the

Saskatchewan material with the typical hingement of this genus tends to confirm the correctness of Peterson's assignment.

Genus PROCYTHERIDEA Peterson, 1954

PROCYTHERIDEA CRASSA Peterson

Plate 25, figures 7, 8

Procytheridea crassa Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, pp. 172, 174, pl. 19, figs. 1-5.

Shell subelliptical in lateral view. Hinge margin nearly straight, almost three-fifths of shell length, cardinal angles broadly obtuse, the posterior better defined; ventral margin nearly straight and subparallel to dorsum. Anterior margin broadly rounded, extended below and subtruncate above; posterior margin more narrowly rounded, extended medially.

Left valve larger than right, extending rather prominently beyond the other along the dorsal margin and cardinal slopes but only slightly overlapping along the ventral margin. Convexity pronounced with moderate ventral overhang; greatest thickness in posterior third of shell.

Anterior end of shell compressed and bearing a narrow marginal rim; median extension of posterior end compressed to form a narrow caudal process. Surface ornamentation is coarsely and randomly reticulate, passing into longitudinal ridges along the ventral overhang of the carapace, the ridges continuing along the ventral surface. Shell wall thick.

Hinge of left valve consists of terminal, elongate, denticulate sockets connected by a weakly crenulate narrow bar, which is bounded dorsally by an accommodation groove. No free right valves found but presumably these consist of terminal dental processes matching sockets of left valves.

Inner lamellae fairly broad, sloping gently inward. No other internal features observed.

Length of hypotype, 0.64 mm.; height, 0.35 mm.; maximum thickness, 0.37 mm.

Locality of hypotype: Tidewater Rush Lake Crown No. 1 well in Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3548 and 3556 feet, in green shale from the base of the type section of the lower member of the Vanguard formation.

Hypotype: Univ. of Missouri No. 0-1213-15.

Stratigraphic distribution: This species is restricted in Saskatchewan to the lower member of the Vanguard formation, where it occurs rather rarely in the southwestern and west-central areas of the province. It has been recorded from the Frontier, Rush Lake and Kelstern wells.

Peterson (1954a, p. 174) reported this species as relatively common to abundant in the Rierdon formation of south-central Montana, and in the "lower Sundance" formation of north-central Wyoming.

This species is also present in the Sundance formation of west-central Wyoming, from where Roberts (1934, pp. 32-33, pl. 2, figs. 12, 13) described an apparent male dimorph under the *ms.* name, *Cythereis brevicula.*

Remarks: The measurements of the Saskatchewan hypotype are very close to those of the female paratype illustrated by Peterson. It seems that all of the Saskatchewan specimens found belong to the elongate, and presumed female, dimorph.

PROCYTHERIDEA EXEMPLA Peterson

Plate 25, figures 1-6

Procytheridea exempla Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, pp. 171-172, pl. 19, figs. 6-14; text fig. 2e, f.

Procytheridea exempla Peterson. Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, pl. 8, figs. 3, 4; pl. 10, figs. 5, 6 (omitted from text).

Shell subtriangular in side view; hinge margin slightly convex, about three-fifths of shell length; cardinal angles broadly obtuse, the posterior better defined; ventral margin nearly straight, converging strongly toward posterior with respect to dorsum; anterior margin broadly rounded, slightly extended below, subtruncate above; posterior margin narrowly rounded, extended medially.

Left valve much larger than right, extending beyond the other, particularly along the dorsal and ventral margins; valves moderately convex, greatest thickness one-third to one-half the distance from the posterior end.

Ends compressed and bearing narrow marginal rims; posterior end slightly extended medially. Surface ornamented in a rather fine reticulate manner, the pits wanting in the outer region of the shell. A shallow sulcus, directed obliquely forward, lies near anterodorsal angle. A prominent ridge originates in the central dorsal area, runs obliquely backward to the posterocentral area, and is bounded dorsally by a broad, shallow sulcus. There are three rather prominent, roughly parallel, longitudinal ridges in the lower half of the shell, the longest of which is situated most ventrally and nearly parallels the ventrum over much of the shell length. A second, much shorter ridge lies in the posterocentral area, and dorsad to it, a longer ridge extends into the central area.

Hinge of left valve consists of terminal, elongate, elliptical, denticulate sockets opening terminally into valve interior and connected by a short, weakly crenulate, narrow bar; a well-developed, broad, rather deep accommodation groove, about two-thirds of hinge length, lies dorsad of hinge bar. Hinge of right valve consists of elongate, crenulate, elevated dental areas with seven to eight rather prominent teeth in each unit, connected by the valve edge which bears a weakly crenulate groove.

Inner lamellae broad, sloping rather steeply toward interior in left valve, somewhat less steeply in right. Line of concrescence and inner margin nearly coincide. Muscle scar consists of a slightly arcuate row of four spots, slightly anterad of midlength, and two more anterior spots. Pore canals not observed.

Dimorphism exhibited prominently with the presumed males shorter, more triangular in outline and more strongly ornamented, particularly with respect to the ridges; females are elongate, more evenly convex, and rather weakly ornamented with the ridges poorly developed to almost wanting. The accommodation groove in the male is much more prominent than in the female.

Length of hypotype (figs. 1, 3), a male carapace, 0.65 mm.; height, 0.40 mm.; maximum thickness, 0.35 mm.

Length of hypotype (figs. 2, 4), a female carapace, 0.62 mm.; height, 0.31 mm.; maximum thickness, 0.28 mm.

Length of hypotype (fig. 5), a male left valve, 0.65 mm.; height, 0.39 mm.

Length of hypotype (fig. 6), a male right valve, 0.61 mm.; height, 0.32 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3538 and 3545 feet, in green shale of the lower member of the Vanguard formation, 0 to 7 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1213-16, 0-1213-17, 0-1213-18, 0-1213-19.

Stratigraphic distribution: This species is the most common ostracode in the lower member of the Vanguard formation of Saskatchewan and is found at this level throughout the province. It was also recorded from the basal beds of the middle member of the Vanguard at Kelstern in the west-central area. Loranger (1955) included this species with the J2B or Lower Shaunavon fauna as well as with the J1C or lower Vanguard assemblage, but the former occurrence probably resulted from caving contamination.

Peterson (1954a, p. 172) reported this species as abundant to very abundant in the Rierdon formation, south-central Montana, and in the "lower Sundance" formation in north-central Wyoming.

Roberts (1934, pp. 25-27, pl. 1, figs. 1-3, 6) described and figured this species as *Isocythere trilineata* (*ms.* name) from the Sundance of the Lander area in west-central Wyoming, where it was reported as abundant in some outcrop samples.

PROCYTHERIDEA MINUTA Peterson

Plate 25, figures 9-12

Procytheridea minuta Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, p. 174, pl. 19, figs. 15-19.

Shell small, elongate-ovate in lateral view, highest near anterior end; hinge margin nearly straight, about two-thirds of shell length, cardinal angles broadly obtuse; ventral margin nearly straight and subparallel to but slightly convergent with dorsum toward posterior; anterior margin broadly rounded, subtruncate above; posterior margin narrowly rounded, extended medially.

Left valve larger than right, the overlap generally quite even but more pronounced along dorsal margin; valves not strongly convex, greatest thickness close to posterior end.

Posterior end strongly compressed and bearing a low, rounded marginal rim; anterior end compressed and provided with a narrow marginal rim. Surface ornamentation consists mainly of five horizontal ridges, two in the ventral area paralleling the ventral margin, the lower merging with the latter feature; a third much shorter ridge dorsad to these, in the posterocentral area; a fourth long ridge further dorsad, traversing most of the central axis and tending to merge with the most ventral ridge in the anterocentral area; and a fifth ridge, originating in the central posterior area, running anteriorly parallel to the posterocardinal slope, the hinge margin, the anterocardinal slope, and terminating in the central anterior area. In some specimens, a short, oblique ridge extends from a point on the dorsal lateral ridge, just posterad of the anterior cardinal angle, subvertically to the next ridge ventrally situated. Spaces between the ridges smooth except for scattered pits, the external expressions of the pore canals.

Hinge of right valve consists of terminal, elongate, crenulate teeth with an interterminal weakly crenulate groove. No satisfactorily pre-

served left valves found but hingement of same presumably consisting of terminal, elongate sockets connected by a crenulate bar formed by the extended valve edge.

Inner lamellae broad and sloping fairly steeply toward interior. Line of concrescence and inner margin very nearly coincide. Pore canals present, their positions denoted by pits on exterior surface. Muscle scar consists of a slightly arcuate row of four spots, slightly anterad of mid-length, and two additional anterior spots.

Length of hypotype (figs. 9, 10), 0.43 mm.; height, 0.21 mm.; greatest thickness, 0.19 mm.

Length of hypotype (figs. 11, 12), 0.47 mm.; height, 0.25 mm.; greatest thickness, 0.20 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3533 and 3538 feet, in green shale of the lower member of the Vanguard formation, 7 to 12 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1213-20 and 0-1214-1.

Stratigraphic distribution: This species is confined to the lower member of the Vanguard formation in Saskatchewan, and was recorded from the Instow and Frontier wells in the southwestern area, and from the Kelstern, Rush Lake and Atlas No. 1 wells in the west-central area. It is rather rare at all except the Kelstern locality, where a fair concentration of specimens was obtained from the basal Vanguard.

Peterson (1954a, p. 174) reported this species as relatively common in the Rierdon formation of south-central Montana.

Roberts (1934, pp. 38-39, pl. 2, figs. 7, 8) described and figured this species as *Cythereis quadrilineata* (*ms.* name) from the Sundance of the Lander area in west-central Wyoming.

Remarks: The Saskatchewan specimens lack the fine reticulations between the ridges of the type material, but as they are identical in all other respects, they are referred to this species.

PROCYTHERIDEA RADVILLIA Loranger

Plate 27, figures 15-19

Procytheridea radvillia Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 53, pl. 10, figs. 17, 18.

Shell subquadrate in side view; hinge margin slightly convex, about three-fifths of shell length; cardinal angles broadly obtuse, the posterior better defined; ventral margin slightly convex; anterior margin broadly rounded, subtruncate above; posterior margin narrowly rounded, extended below midheight.

Left valve much larger than right, extending beyond the other, particularly along the dorsal and ventral margins. Valves not strongly convex, greatest thickness in posterior fifth of carapace. Maximum height in anterior fifth of shell.

Ends compressed bearing narrow marginal rims; posterior end slightly extended medially. Surface ornamentation characterized by four prominent ridge elements, (1) a long horizontal ridge in the ventral area paralleling the ventrum, (2) a similar ridge traversing the central axis dorsad and parallel to the first, converging toward and uniting with the

latter in the central anterior area, (3) a ridge originating in central posterior area paralleling but separated from the posterior cardinal slope by a shallow wide sulcus, continuing near the dorsal margin forward to a point about one-third of the distance from the anterior end, where it is separated by a shallow sulcus from (4) an oblique ridge arising close to the anterior cardinal angle and running roughly parallel to the anterior cardinal slope ventrally to the central anterior area—a fork is directed obliquely posteriorly and merges with the horizontal ridge traversing the central axis. The spaces between the ridges are occupied by discontinuous, fairly coarse series of reticulations.

Hinge of left valve consists of terminal, elongate, elliptical, denticulate sockets opening terminally into valve interior and connected by a fairly short, weakly crenulate, narrow bar; a well-developed, broad accommodation groove, about two-thirds of hinge length, lies dorsad of hinge bar. Hinge of right valve, obscure because of poor preservation, consists of elongate, raised, crenulate, terminal dental units and the intervening valve edge, which seemingly bears a weakly crenulate groove.

Inner lamellae broad, sloping rather steeply toward interior. Line of concrescence and inner margin seem to nearly coincide. Muscle scar consists of a nearly vertical row of four small spots in the central area of the shell (shows through wall on hypotype, fig. 17).

Dimorphism suspected in one Kelstern locality suite where two less tall, more elongate forms were observed. It is presumed that the higher, squarer hypotypes are males.

Length of hypotype (figs. 15, 16), 0.55 mm.; height, 0.35 mm.; maximum thickness, 0.28 mm.

Length of hypotype (figs. 17-19), 0.55 mm.; height, 0.35 mm.; maximum thickness, 0.25 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3389 and 3396 feet, in green shale of the middle member of the Vanguard formation, 1 to 8 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1214-2 and 0-1214-3.

Stratigraphic distribution: Nearly all (17) of the representatives of this species were found at the Kelstern locality of west-central Saskatchewan in the basal beds of the middle member of the Vanguard formation. One specimen was recorded in the Instow well of southwestern Saskatchewan from the basal beds of the upper member of the Vanguard. Loranger proposed the species on the basis of material from the Vanguard formation in the Norcanols Radville well in south-central Saskatchewan.

PROCYTHERIDEA sp. A

Plate 28, figures 1-3

Shell sublanceolate in side view; highest about one-fourth from anterior end; hinge margin nearly straight, about two-thirds of shell length, ventral margin slightly convex, converging posteriorly toward dorsum; cardinal angles broadly obtuse, the posterior seems better defined; anterior margin rounded, extended below; posterior margin more pointed, extended medially.

Left valve larger than right, extending beyond the other around entire periphery, but most strongly along dorsal and ventral margins. Valves

moderately convex, greatest thickness about one-fourth from posterior end.

Ends slightly compressed and bearing low marginal rims; median extension of posterior end compressed to form a short caudal process. Surface ornamented by four longitudinal low ridges traversing the middle two-thirds of each valve—a dorsal ridge which is highest medially; two median ridges, the more dorsal one twice the length of the other; a long ventral ridge which may merge with the ventral surface of valve. A low arcuate ridge or swelling parallels the anterior margin of the shell uniting with the ventral ridge and almost connected to the dorsal ridge. A shallow, oblique sulcus lies just posterad of this arcuate ridge in each valve. A few pits are scattered over the valve surfaces.

Hinge of left valve consists of terminal, elongate, elliptical, denticulate sockets connected by a short, weakly crenulate, narrow bar; an accommodation shelf lies dorsad of the bar. Hinge of right valve consists of terminal, elongate, crenulate teeth connected by the valve edge which is faintly grooved and weakly crenulate.

Inner lamellae of moderate width, sloping fairly steeply toward interior; line of concrescence and inner margin coincident or nearly so. Radial pore canals present, apparently not branching, about 15 observed around anterior end. Muscle scar consists of a slightly arcuate row of four small spots located in the central area at or slightly anterad of midlength with a cluster of two anterior spots.

Length of specimen (figs. 1, 2), 0.62 mm.; height, 0.36 mm.; maximum thickness, 0.30 mm.

Length of specimen (fig. 3), 0.65 mm.; height, 0.32 mm.; maximum thickness, 0.29 mm.

Locality of figured specimens: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4192 and 4207 feet, in green shale of the upper member of the Vanguard formation, 49 to 64 feet below the top.

Figured specimens: Univ. of Missouri Nos. 0-1214-4 and 0-1214-5.

Stratigraphic distribution: This species was found in the Upper Vanguard of the Frontier well in southwestern Saskatchewan, and in the basal beds of the middle member of the Vanguard of the Kelstern well in the west-central area. This species is represented by about 12 specimens.

Remarks: This species resembles the female dimorph of *P. exempla* Peterson but is more robust, has more pronounced horizontal ridges, and lacks the numerous pits of the latter species. Nevertheless, its relationship to *P. exempla* seems close.

Genus PROGONOCYTHERE Sylvester-Bradley, 1948

PROGONOCYTHERE ANODA Peterson

Plate 24, figures 14-18

Progonocythere anoda Peterson, 1954a, Jour. Paleontology, vol. 28, no. 2, p. 166, pl. 18, figs. 1, 2; text fig. 2a.

Prognocythere anoda Peterson. Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, pl. 10, figs. 13, 14 (generic name misspelled, omitted from text).

Shell subquadrate in side view, greatest height near anterior end; hinge margin nearly straight, about two-thirds of shell length; cardinal angles broadly obtuse; ventral margin nearly straight in short carapaces

(males?), broadly sinuous in elongate carapaces (females?), converging slightly posteriorly with dorsum. Anterior margin broadly rounded and slightly extended below, subtruncate above; posterior margin narrowly rounded, extended medially.

Left valve the larger, extending beyond the right around the entire periphery but the amount of overlap is small, particularly along the ventrum. Valves inflated ventrally; convexity of valves rather strong, greatest thickness about one-third from posterior end.

Anterior extremity compressed and bearing a marginal rim; posterior end compressed to form a short, blunt caudal process. General surface of valves randomly reticulate, the reticulations however tending to become aligned horizontally in the ventral region.

Hinge of right valve consists of terminal, elongate, crenulate, raised dental areas and the interconnecting grooved valve edge, which is weakly crenulate. Hinge of left valve consists of corresponding shallow, crenulate sockets and the interterminal narrow, weakly crenulate valve edge.

Inner lamellae of moderate width. Pore canals randomly distributed over shell surface. Radial canals not observed in material available. Muscle scar consists of a vertical row of four spots just anterad of mid-length and a cluster of two more anterior spots.

Length of hypotype (figs. 14, 15), a carapace, 0.72 mm.; height, 0.40 mm.; maximum thickness, 0.40 mm.

Length of hypotype (figs. 17, 18), a carapace, 0.87 mm.; height, 0.42 mm.; maximum thickness, 0.40 mm.

Length of hypotype (fig. 16), a valve, 0.67 mm.; height, 0.35 mm.

Locality of hypotypes (carapaces): Tidewater Instow Crown No. 1 well in Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4532 and 4535 feet, in green shale of the lower member of the Vanguard formation, 0 to 3 feet above the base.

Locality of hypotype (valve): Tidewater Atlas Crown No. 1 well in Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3288 and 3292 feet, in green shale of the lower member of the Vanguard formation, 73 to 77 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1214-6, 0-1214-7, 0-1214-8.

Stratigraphic distribution: This species was found in only the lower member of the Vanguard formation in Saskatchewan, with most (nine) of the specimens recorded from the base of the Vanguard in the Instow well of the southwestern area. A few individuals were obtained from the Kelstern, Rush Lake and Atlas wells in west-central Saskatchewan, with, however, only one occurrence each at the last two localities.

Peterson (1954a, p. 166) proposed the species on the basis of material from the Rierdon formation in the Big Snowy Mountains area of central Montana.

Remarks: The present author (1958) merely compared this Saskatchewan suite with *P. anoda*, but after examining the types of the latter, believes that the shorter Saskatchewan specimens, and probably the elongate ones as well, belong to this species. A comparison is difficult because there is no carapace among the types, as the species was proposed on the basis of only two valves. The anterocardinal sulcus mentioned by

Peterson in the types apparently is not present in the Saskatchewan specimens, but neither was this feature obvious to the present author when examining the types.

Roberts (1934, pp. 30-32, pl. 2, figs. 9-11) described and figured a species, *Cythereis sundancensis* (*ms.* name), from the Sundance formation near Lander, Wyoming, which is closely related to *P. anoda.*

Dimorphism may be developed in the Saskatchewan material, with the females presumably the more elongate individuals, exemplified by the hypotype (figs. 17, 18).

PROGONOCYTHERE CROWCREEKENSIS Swain and Peterson

Plate 28, figures 4-7

Progonocythere crowcreekensis Swain and Peterson, 1951, Jour. Paleontology, vol. 25, no. 6, p. 802, pl. 114, figs. 1-4.

Progonocythere crowcreekensis Swain and Peterson, 1952, U.S. Geol. Surv. Prof. Paper 243-A, p. 13, pl. 2, figs. 22-25.

Shell subquadrate in lateral view, highest near anterior end; hinge margin nearly straight, about three-fourths of shell length; cardinal angles broadly obtuse; ventral margin nearly straight, subparallel to dorsum, passing rather sharply into terminal margins; anterior margin broadly and nearly uniformly rounded; posterior margin more narrowly rounded, extended medially.

Left valve slightly larger, extending slightly beyond the right at the cardinal angles. Valves rather strongly convex, with greatest thickness about one-third from posterior end.

Anterior end compressed in a narrow zone bearing a low, weakly nodose marginal rim. Extended median portion of posterior end forms a narrow, compressed, slightly caudate process. A shallow, oblique sulcus lies shortly posterad of the anterodorsal angle. Ventral surface somewhat swollen, slightly overhanging ventral margin when viewed laterally. General surface of valves strongly reticulate, appearing nearly spinose in dorsal view; surface pustulose in some specimens. A knife-like ridge parallels the posterior half of the dorsal hinge margin in each valve; several such ridges are present in the ventral area running parallel to the full length of the ventral margin.

No free valves found, thus details of hinge structure and internal features are not available.

Dimorphism probably developed, one sex (the female?, following questionable assignment by the original authors), longer as shown by the hypotype of this study (figs. 4, 5), while the presumed male is shorter as exhibited by the hypotype (figs. 6, 7).

Length of hypotype (figs. 4, 5), 0.70 mm.; height, 0.34 mm.; maximum thickness, 0.32 mm.

Length of hypotype (figs. 6, 7), 0.57 mm.; height, 0.33 mm.; maximum thickness, 0.31 mm.

Locality of hypotypes: Tidewater Kelstern Crown No. 1 well in Lsd. 5, Sec. 28, Tp. 15, Rge. 6, W. 3rd Meridian, Saskatchewan, Canada, between depths of 3384 and 3396 feet, in green shale of the middle member of the Vanguard formation, 1 to 13 feet above the base.

Hypotypes: Univ. of Missouri Nos. 0-1214-9 and 0-1214-10.

Stratigraphic distribution: This species was recorded in west-central Saskatchewan from the basal beds of the middle member and from the upper beds of the lower member of the Vanguard formation in the Kelstern and Rush Lake wells, respectively.

Swain and Peterson (1952) reported this species from the Redwater shale member of the Sundance formation in the Black Hills area of South Dakota and northeastern Wyoming; from the Redwater shale in extreme north-central (Sheridan County) Wyoming; from the Sundance formation in the Big Horn Mountains of north-central Wyoming and in the Laramie Mountains of southeastern Wyoming (Peterson, 1954a, p. 156); from the Swift formation in northwestern Wyoming and at various localities in central Montana extending from the extreme south-central (Carbon County) to the north-central (Phillips County) areas.

Remarks: The Saskatchewan representatives of this species are considerably smaller than the types and lack the elongate node which occupies the dorsal portion of the valves slightly anterad of midlength in the latter. These differences, however, are probably not sufficient to preclude an assignment to this species.

PROGONOCYTHERE HIEROGLYPHICA Swain and Peterson

Plate 28, figures 8, 9

Progonocythere hieroglyphica Swain and Peterson, 1951, Jour. Paleontology, vol. 25, no. 6, pp. 800-802, pl. 113, figs. 10-18.

Progonocythere hieroglyphica Swain and Peterson, 1952, U.S. Geol. Surv. Prof. Paper 243-A, pp. 12-13, pl. 2, figs. 18-20.

Progonocythere hieroglyphica Swain and Peterson. Loranger, 1955, Geol. Assoc. Canada, Proc., vol. 7, pt. 1, p. 52, pl. 10, figs. 7-8.

Shell elongate-subrhomboidal in lateral view; hinge margin nearly straight, about two-thirds of shell length, cardinal angles broadly obtuse; ventral margin nearly straight, subparallel to dorsum; anterior margin broadly rounded, slightly extended below, subtruncate above; character of posterior margin obscured because of damage.

Overlap not ascertainable as only one right valve available. Convexity of valves moderate with maximum thickness appearing to be one-third to one-half from posterior end.

Anterior and presumably the posterior end compressed, bearing a knife-edged marginal rim. General surface of valves ornamented by strong ridges, consisting of two concentric but discontinuous outer ridges, about five posteromedian vertical ridges, and several shorter, variously arranged anteromedian ridges. A short, oblique sulcus lies near the anterocardinal angle. The posteroventral surface of the available valve is somewhat inflated and overhangs the ventral margin when viewed laterally.

Hinge of right valve consists of terminal, elongate, narrow, crenulate dental areas, connected by the narrow, grooved, faintly crenulate valve edge. No left valve available.

Inner lamellae of moderate width; line of concrescence and inner margin appear nearly coincident. Muscle scar not observed.

Length of hypotype, 0.57 mm.; height, 0.32 mm.; estimated maximum thickness of carapace, 0.40 mm.

Locality of hypotype: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada,

between depths of 4192 and 4197 feet, in green shale of the upper member of the Vanguard formation, 49 to 54 feet below the top.

Hypotype: Univ. of Missouri No. 0-1214-11.

Stratigraphic distribution: The collections of the present study yielded only the illustrated valve and a few fragmentary specimens from the Upper Vanguard in the Frontier well of southwestern Saskatchewan. Loranger (1955) reported the species from the Lower Vanguard of the Norcanols Wilcox well in south-central Saskatchewan, but its occurrence at this level may well have resulted from hole cavings.

Swain and Peterson (1952) reported this species from the Redwater shale member of the Sundance formation in the Black Hills area of South Dakota and northeastern Wyoming, and in extreme north-central Wyoming; from the Sundance formation in the Big Horn Mountains of north-central Wyoming and in the Laramie mountains of southeastern Wyoming (Peterson, 1954a, p. 156); from the Swift formation in northwestern Wyoming and at various localities in central Montana.

PROGONOCYTHERE sp. A

Plate 28, figures 12-15

Shell elongate-subrhomboidal in lateral view; hinge margin slightly convex, about half of shell length; cardinal angles broadly obtuse, the posterior better defined; ventral margin nearly straight and subparallel to dorsum but converging rapidly toward the latter near posterior end; anterior margin broadly rounded, slightly extended below; posterior margin extended into a blunt point slightly dorsad of midheight, truncate above and below.

Left valve larger than right, overlap not pronounced except along hinge margin. Valves moderately convex, greatest thickness in posterior half of shell.

Ends compressed bearing narrow marginal rims; medial extension of posterior end compressed to form a short, rather sharp caudal process. Surface of valves ornamented by strong ridges, the most prominent appearing as a wide horseshoe, the arc running along the ventral surface with the terminal limbs in the central anterior and central posterior areas. Within this horseshoe ridge lie four or five discontinuous, arcuate vertical ridges. Two rather prominent sulci present on each valve, a short, oblique one just posterad of the anterocardinal angle, separated by a ridge from a longer, more nearly vertical sulcus posterad to the first. A large, conspicuous node is present in the anterocentral area, just anterad of ventral terminus of the second or longer sulcus. The central ventral surface of each valve is strongly swollen, overhangs the ventral margin and imparts a rather alate appearance to the shell.

Hingement obscure as no complete free valves found. Partial and not very well preserved units indicate left valve consists of terminal, elongate, weakly denticulate sockets connected by a narrow, weakly crenulate bar dorsad to which lies an accommodation groove. Hinge of right valve consists of terminal, elongate, weakly crenulated dental units connected by the valve edge which bears a shallow groove.

Inner lamellae of moderate width. Line of concrescence and inner margin seem nearly coincident. Other internal features not observed or too indistinct to warrant description.

Dimorphism may well be demonstrated by the two figured specimens, one sex shorter and slightly thicker (figs. 12, 13) and the other more elongate and slightly thinner (figs. 14, 15).

Length of specimen (figs. 12, 13), 0.50 mm.; height, 0.32 mm.; maximum thickness, 0.25 mm.

Length of specimen (figs. 14, 15), 0.60 mm.; height, 0.32 mm.; maximum thickness, 0.22 mm.

Locality of figured specimens: Tidewater Frontier Crown No. 1 well in Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian, Saskatchewan, Canada, between depths of 4192 and 4197 feet, in green shale of the upper member of the Vanguard formation, 49 to 54 feet below the top.

Figured specimens: Univ. of Missouri Nos. 0-1214-12 and 0-1214-13.

Stratigraphic distribution: This species was not recognized beyond its rather rare occurrence at the level and locality of the figured specimens.

Remarks: Because of the lack of material, of satisfactory free valves in particular, this species is left unnamed. The two figured specimens were the only complete adult carapaces available for study.

REFERENCES

Arkell, W. J., 1956, Jurassic geology of the World: Hafner Publishing Co., New York, 806 pp., 46 pls., 102 text figs., 28 tables.

Baker, A. A., Dane, C. H., and Reeside, J. B. Jr., 1936, Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U.S. Geol. Surv. Prof. Paper 183.

Barnard, T., 1950, Foraminifera from the Upper Lias of Byfield, Northamptonshire: Geol. Soc. London, Quart. Jour., vol. 106, pt. 1, pp. 1-36, pls. 1-3, text figs. 1-17.

————, 1953, Foraminifera from the Upper Oxford Clay (Jurassic) of Redcliff Point, near Weymouth, England: Geol. Assoc. Proc., vol. 64, pt. 3, pp. 183-197, figs. A, B.

Bartenstein, H. and Brand, E., 1937, Mikro-palaontologische Untersuchungen zur Stratigraphie des nordwest-deutschen Lias und Doggers: Senckenberg. Naturf. Ges., Abh. 439, pp. 1-224, pls. 1-20, figs. 1-20.

Bernard, F., Bizon, J. J., and Oertli, H. J., 1957, Ostracodes lacustres du Bathonien du Poitou (Bassin de Paris): Soc. Geol. France, Bull., ser. 6, tome 6, fascicule 6, pp. 753-770, pls. 21-23 (1956).

Bielecka, W., and Pozaryski, W., 1954, Micropaleontological stratigraphy of the upper Malm in central Poland [Polish, Russian and English] : Poland, Instytut Geologiczny Prace (Trans.), Warsaw, tom 12, pp. 3-206, pls. 1-12, figs. 1-4, tables 1-2.

Bolin, E. J., 1956, Upper Cretaceous Foraminifera, Ostracoda, and Radiolaria from Minnesota: Jour. Paleo., vol. 30, no. 2, pp. 278-298, pls. 37-39, 5 text figs.

Cifelli, R., 1960, Variation of English Bathonian Lagenidae and its phylogenetic significance: Jour. Paleo., vol. 34, no. 3, pp. 556-569, 6 text figs.

Cobban, W. A., 1945, Marine Jurassic formations of Sweetgrass arch, Montana: Amer. Assoc. Petrol. Geol., Bull., vol. 29, no. 9, pp. 1262-1303, 6 figs.

Cobban, W. A., Imlay, R. W., and Reeside, J. B. Jr., 1945, Type section of Ellis formation (Jurassic) of Montana: Amer. Assoc. Petrol. Geol., Bull., vol. 29, no. 4, pp. 451-453.

Cushman, J. A., 1948, Foraminifera, their classification and economic use: Harvard Univ. Press, Cambridge, Mass., 605 pp., 55 pls. (fourth edition).

Ellis, B. F., and Messina, A. R., 1940 *et seq.*, Catalogue of Foraminifera: Amer. Mus. Nat. Hist., spec. pub., vols. 1-30 and supplements.

Francis, D. R., 1954, The Jurassic sediments of Saskatchewan: Sask. Dept. of Mineral Resources, Rept. No. 13.

————, 1956, Jurassic stratigraphy of the Williston Basin area: Sask. Dept. of Mineral Resources, Rept. No. 18.

————, 1957, Jurassic stratigraphy of Williston Basin area: Amer. Assoc. Petrol. Geol., Bull., vol. 41, no. 3, pp. 367-398, 13 figs., 1 table.

Franke, A., 1936, Die Foraminiferen des deutschen Lias: Preuss. Geol. Landesanst., Abh., N. F., Heft 169, pp. 1-138, pls. 1-12.

Frebold, H., 1953, Correlation of the Jurassic formations of Canada: Geol. Soc. Amer., Bull., vol. 64, no. 10, pp. 1229-1246, 1 pl., 1 fig.

————, 1957, The Jurassic Fernie group in the Canadian Rocky Mountains and Foothills: Geol. Surv. Canada, Mem. 287.

Galloway, J. J., 1933, A manual of Foraminifera: James Furman Kemp Memorial series, pub. no. 1, Principia Press, Bloomington, Indiana, 483 pp., 42 pls.

Gilluly, J. and Reeside J. B. Jr., 1928, Sedimentary rocks of the San Rafael Swell and some adjacent areas in eastern Utah: U.S. Geol. Surv. Prof. Paper 150-D, pp. 61-110, pls. 15-21.

Glaessner, M. F., 1947, Principles of micropaleontology: John Wiley and Sons, New York, 296 pp., 14 pls., 64 figs., 7 tables.

Grekoff, N., 1956, Guide pratique pour la determination des ostracodes post-Paleozoiques: Institut Francais du Petrole, Division Sedimentologie, Societe des editions Technip., 95 pp., 16 pls., 30 text figs.

Hadley, H. D., and Milner, R. L., 1953, Stratigraphy of Lower Cretaceous and Jurassic, northern Montana-southwestern Saskatchewan: Billings Geol. Soc., Guidebook, fourth ann. field conf., pp. 85-86, 2 pls.

Hedgpeth, J. W., 1951, The classification of estuarine and brackish waters and the hydrographic climate: U.S. Nat. Res. Council, Rept. Comm. Treatise Marine Ecology and Paleoecology, 1950-1951, no. 11, pp. 49-56, 6 figs., 2 tables.

Hoare, R. D., 1953, The ostracode genus *Metacypris* in North America: Unpublished A. M. thesis, Univ. of Missouri, Columbia, 76 pp., 3 pls.

Howe, H. V., 1955, Handbook of ostracod taxonomy: Louisiana State Univ. Studies, Physical Sci. ser. no. 1, 389 pp.

Imlay, R. W., 1945, Occurrence of Middle Jurassic rocks in western interior of United States: Amer. Assoc. Petrol. Geol., Bull., vol. 29, no. 7, pp. 1019-1027, 1 table.

————————, 1947, Marine Jurassic of Black Hills area, South Dakota and Wyoming: Amer. Assoc. Petrol. Geol., Bull., vol. 31, no. 2, pp. 227-273, 3 figs.

————————, 1948, Characteristic marine Jurassic fossils from the western interior of the United States: U.S. Geol. Surv. Prof. Paper 214-B, pp. 13-33, pls. 4-9.

————————, 1949, Paleoecology of Jurassic seas in the western interior region of the United States: U.S. Nat. Res. Council, Rept. Comm. Treatise Marine Ecology and Paleoecology, 1948-1949, no. 9, pp. 72-104, 8 figs., 1 table.

————————, 1952, Correlation of the Jurassic formations of North America, exclusive of Canada: Geol. Soc. Amer., Bull., vol. 63, no. 9, pp. 953-992, 4 figs., 2 tables.

————————, 1953, Callovian (Jurassic) ammonites from the United States and Alaska; Part I, western interior United States: U.S. Geol. Surv. Prof. Paper 249-A, pp. 1-39, pls. 1-24, 2 text figs., 3 tables.

————————, 1957, Paleoecology of Jurassic seas in the western interior of the United States: Geol. Soc. Amer., Mem. 67, pp. 469-504, 8 figs., 1 table.

Kesling, R. V., 1951, Terminology of ostracod carapaces: Contr. Mus. Paleo. Univ. Michigan, vol. 9, no. 4, pp. 93-171, 18 pls., 6 text figs., 5 charts.

Khan, M. H., 1950, Note on the depth and temperature of the Gault sea as indicated by Foraminifera: Geol. Mag., vol. 87, no. 3, pp. 175-180.

Klingspor, A. M., 1958, Jurassic stratigraphy of the Sweetgrass arch—Manitoba section: John Andrew Allan Memorial volume, "Jurassic and Carboniferous of Western Canada", Amer. Assoc. Petrol., Geol., Tulsa, Oklahoma, pp. 27-51, 13 figs.

Lalicker, C. G., 1950, Foraminifera of the Ellis group, Jurassic, at the type locality: Univ. of Kansas Paleontological Contr., Protozoa, Article 2, pp. 3-20, pls. 1-4, figs. 1-5.

————————, 1951, *Pealerina*, new name, replacing *Ellisina* Lalicker: Jour. Paleo., vol. 25, no. 2, p. 237.

Loeblich, A. R. Jr., and Tappan, H., 1950a, North American Jurassic Foraminifera: I, The type Redwater shale (Oxfordian) of South Dakota: Jour. Paleo., vol. 24, no. 1, pp. 39-60, pls. 11-16.

————————————, 1950b, North American Jurassic Foraminifera: II, Characteristic western interior Callovian species: Wash. Acad. Sci., Jour., vol. 40, no. 1, pp. 5-19, pl. 1, 4 text figs.

————————————, 1950c, Foraminifera from the type Kiowa shale, Lower Cretaceous, of Kansas: Univ. of Kansas Paleontological Contr., Protozoa, Article 3, pp. 1-15, pls. 1-2.

————————————, 1952, The foraminiferal genus *Triplasia* Reuss, 1854: Smithsonian Inst., Miscell. Coll., vol. 117, no. 15 (publication 4094), 61 pp., 8 pls.

————————————, 1954, Emendation of the foraminiferal genera *Ammodiscus* Reuss, 1862, and *Involutina* Terquem, 1862: Wash. Acad. Sci., Jour., vol. 44, no. 10, pp. 306-310, figs. 1-2.

Loranger, D. M., 1955, Paleogeography of some Jurassic microfossil zones in the south half of the Western Canada basin: Geol. Assoc. Canada, Proc., vol. 7, pt. 1, pp. 31-60, pls. 1-12.

Love, J. D. *et al.*, 1945, Stratigraphic sections and thickness maps of Jurassic rocks in central Wyoming: U.S. Geol. Surv. Prelim. Chart 14, Oil and Gas Inves. ser.

Macfayden, W. A., 1939, On *Ophthalmidium*, and two new names for Recent Foraminifera of the family Ophthalmidiidae: Roy. Micr. Soc. London, Jour., ser. 3, vol. 59, pp. 162-169.

Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: U.S. Geol. Surv. Prof. Paper 152.

Martin, G. P. R., 1940, Ostracoden des norddeutschen Purbeck und Wealden: Senckenbergiana, vol. 22, pp. 275-361, pls. 1-13, 2 text figs.

Maync, W., 1952, Critical taxonomic study and nomenclatural revision of the Lituolidae based upon the prototype of the family, *Lituola nautiloidea* Lamarck 1804: Cush. Found. Foram. Res., Contr., vol. 3, pt. 2, no. 56, pp. 35-56, pls. 9-12, 3 text figs.

Milner, R. L. and Blakslee, G. W., 1958, Notes on the Jurassic of southwestern Saskatchewan: John Andrew Allan Memorial volume, "Jurassic and Carboniferous of Western Canada", Amer. Assoc. Petrol. Geol., Tulsa, Oklahoma, pp. 65-84, 16 figs.

Milner, R. L. and Thomas, G. E., 1954, Jurassic system in Saskatchewan: Ralph Leslie Rutherford Memorial volume, "Western Canada Sedimentary Basin", Amer. Assoc. Petrol. Geol., Tulsa, Oklahoma, pp. 250-267, 6 figs.

Morey, P., 1931, Foraminifera and Ostracoda from the Sundance (Jurassic) of Wyoming (abstract): Geol. Soc. Amer., Bull., vol. 42, p. 327.

Myatliuk, E. V., 1939: Foraminifera from the Upper Jurassic and Lower Cretaceous deposits of the Middle Volga region and Obshchyi Syrt (Russian with English summary): Neftianyi geologo-razvedochnyi Institut, Trudy (Transactions of the Oil Geological Institute), Leningrad, ser. A, fasc. 120, pp. 3-76, pls. 1-4, tables 1-4, figs. 1-2.

Nordquist, J. W., 1955, Pre-Rierdon Jurassic stratigraphy in northern Montana and Williston Basin: Billings Geol. Soc., Guidebook, sixth ann. field conf., pp. 96-106, 1 pl., 1 fig.

Norton, R. D., 1930, Ecologic relations of some Foraminifera: California Univ., Scripps Inst. Oceangr., Bull., tech. ser., vol. 2, no. 9, pp. 331-388, 6 tables.

Olsen, S., 1944, Danish Charophyta, chorological, ecological, and biological investigations: Det Kongelige Danske Videnskabernes Selskab, Biologiske Skrifter, bind 3, no. 1, 240 pp. (in English), 2 pls., 44 figs., 24 tables.

Parker, F. L., 1948, Foraminifera of the Continental Shelf from the Gulf of Maine to Maryland: Harvard College, Mus. Comparative Zool., Bull., vol. 100, no. 2, pp. 211-241, pls. 1-7.

Parker, F. L., Phleger, F. B., and Pierson, J. F., 1953, Ecology of Foraminifera from San Antonio Bay and environs, southwest Texas: Cush. Found. Foram. Res., spec. pub. no. 2, 75 pp., 4 pls., 48 figs., 7 tables.

Peck, R. E., 1957, North American Mesozoic Charophyta: U.S. Geol. Surv. Prof. Paper 294-A, pp. 1-44, pls. 1-8, 7 text figs.

Peterson, J. A., 1954a, Jurassic Ostracoda from the "Lower Sundance" and Rierdon formations, western interior United States: Jour. Paleo., vol. 28, no. 2, pp. 153-176, pls. 17-19, 3 text figs.

————, 1954b, Marine Upper Jurassic, eastern Wyoming: Amer. Assoc. Petrol. Geol., Bull., vol. 38, no. 4, pp. 463-507, 1 pl., 10 figs.

————, 1957, Marine Jurassic of northern Rocky Mountains and Williston Basin: Amer. Assoc. Petrol. Geol., Bull., vol. 41, no. 3, pp. 399-440, 18 figs., 2 tables.

Phleger, F. B., 1954, Ecology of Foraminifera and associated micro-organisms from Mississippi Sound and environs: Amer. Assoc. Petrol. Geol., Bull., vol. 38, no. 4, pp. 584-647, 3 pls., 28 figs.

Reeside, J. B. Jr. *et al.*, 1957, Correlation of the Triassic formations of North America exclusive of Canada: Geol. Soc. Amer., Bull., vol. 68, no. 11, pp. 1451-1514, 1 pl., 6 figs.

Roberts, J. F., 1934, Ostracoda from the Sundance (Jurassic) formation of central Wyoming: Unpublished A. M. thesis, Univ. of Missouri, Columbia, 50 pp., 2 pls., 2 figs.

Ronai, P. H., 1955, Brackish-water Foraminifera of the New York Bight: Cush. Found. Foram. Res., Contr., vol. 6, pt. 4, no. 145, pp. 140-149, pls. 20-21, 1 table.

Roth, R., 1933, Some Morrison Ostracoda: Jour. Paleo., vol. 7, no. 4, pp. 398-405, pl. 48.

Said, R., 1950, The distribution of Foraminifera in the northern Red Sea: Cush. Found. Foram. Res., Contr., vol. 1, pt. 1, no. 3, pp. 9-29, 4 figs., 1 table.

———————, 1951, Ecology of Foraminifera: Micropaleontologist, vol. 5, no. 3, pp. 12-14.

———————, 1953, Foraminifera of Great Pond, East Falmouth, Massachusetts: Cush. Found. Foram. Res., Contr., vol. 4, pt. 1, no. 71, pp. 7-14, 3 figs., 1 table.

Sandidge, J. R., 1933, Foraminifera from the Jurassic in Montana: Amer. Midland Nat., vol. 14, pp. 174-185, pl. 1.

Schmitt, G. T., 1953, Regional stratigraphic analysis of Middle and Upper marine Jurassic in northern Rocky Mountains-Great Plains: Amer. Assoc. Petrol. Geol., Bull., vol. 37, no. 2, pp. 355-393, 13 figs.

Schwager, C., 1865, Beitrag zur Kenntniss der mikroskopischen Fauna jurassischer Schichten: Ver. Vaterl. Naturk. Wurttemberg, Jahresheft, Stuttgart, Jahrg. 21, pp. 82-151, pls. 2-7.

Sigal, J. in Piveteau, J., 1952, Ordre des Foraminifera: Traite de Paleontologie, Masson et Cie, Paris, tome 1, pp. 133-178, pls. 1-6, text figs. 1-47, tables 1-2; pp. 192-301, pls. 7-29, text figs. 55-117, tables 5-11.

Sohn, I. G., 1951, Check list of salinity tolerance of post-Paleozoic fossil Ostracoda: Wash. Acad. Sci., Jour., vol. 41, no. 2, pp. 64-66.

Spieker, E. M., 1946, Late Mesozoic and early Cenozoic history of central Utah: U.S. Geol. Surv. Prof. Paper 205-D, pp. 117-161, pls. 18-25, figs. 14-21.

Stelck, C. R., and Wall, J. H., 1955, Foraminifera of the Cenomanian *Dunveganoceras* zone from Peace River area of Western Canada: Research Council of Alberta Rept. No. 70.

Storey, T. P., 1958, Jurassic of the Williston Basin and adjacent areas: Alberta Soc. Petrol. Geol., Jour., vol. 6, no. 4, pp. 90-104, 1 pl., 5 figs.

Stott, D. F., 1955, Jurassic stratigraphy of Manitoba: Manitoba Dept. Mines and Nat. Resources, Mines Branch, pub. 54-2.

Swain, F. M., 1955, Ostracoda of San Antonio Bay, Texas: Jour. Paleo., vol. 29, no. 4, pp. 561-646, pls. 59-64, 39 text figs.

Swain, F. M., and Peterson, J. A., 1951, Ostracoda from the Upper Jurassic Redwater shale member of the Sundance formation at the type locality in South Dakota: Jour. Paleo., vol. 25, no. 6, pp. 796-807, pls. 113-114, 1 text fig.

———————————, 1952, Ostracoda from the upper part of the Sundance formation of South Dakota, Wyoming, and southern Montana: U.S. Geol. Surv. Prof. Paper 243-A, pp. 1-18, pls. 1-2, 1 text fig.

Sylvester-Bradley, P. C., 1948, Bathonian ostracods from the Boueti bed of Langton Herring, Dorset: Geol. Mag., vol. 85, no. 4, pp. 185-204, pls. 12-15, 7 text figs.

Terquem, O., and Berthelin, G., 1875, Etude microscopique des Marnes du Lias Moyen d'Essey-les-Nancy, zone inferieure de l'assise a *Ammonites margaritatus*: Soc. Geol. France, Mem., Paris, ser. 2, tome 10, no. 3, pp. 1-126, pls. 11-20.

Thalmann, H. E., 1937, Mitteilungen über Foraminiferen, III: Ecologae Geol. Helv., Lausanne, Suisse, vol. 30, pp. 337-356, pls. 21-23.

Thomas, H. D., and Krueger, M. L., 1946, Late Paleozoic and Early Mesozoic stratigraphy of Uinta Mountains, Utah: Amer. Assoc. Petrol. Geol., Bull., vol. 30, no. 8, pp. 1255-1293, 10 figs.

Todd, R., and Bronnimann, P., 1957, Recent Foraminifera and Thecamoebina from the eastern Gulf of Paria: Cush. Found. Foram. Res., spec. pub. no. 3, 43 pp., 12 pls., 7 text figs., 5 tables.

Towse, D., 1954, Jurassic system in Williston Basin: Amer. Assoc. Petrol. Geol., Bull., vol. 38, no. 4, pp. 454-462, 9 figs.

Triebel, E., 1941, Zur Morphologie und Okologie der fossilen Ostracoden: Senckenbergiana, vol. 23, pp. 294-400, pls. 1-15, 2 text figs.

————————, 1949, Das Narbenfeld der Candoninae und seine paläontologische Bedeutung: Senckenbergiana, vol. 30, pp. 205-212, 1 pl.

Triebel, E., and Bartenstein H., 1938, Die Ostracoden des deutschen Juras: 1, *Monoceratina*—Arten aus dem Lias und Dogger: Senckenbergiana, vol. 20, pp. 502-518, pls. 1-3.

Wall, J. H., 1958, Jurassic microfaunas from Saskatchewan, Western Canada: Ph.D. thesis, Univ. of Missouri, Columbia, 428 pp., 28 pls., 3 figs., 2 tables (U.S. Library of Congress Card No. Mic 58-5263).

Warren, P. S., 1934, Present status of the Fernie shale: Amer. Jour. Sci., 5th ser., vol. 27, no. 157, pp. 56-70, 1 fig.

Weir, J. D., 1949: Marine Jurassic formations of southern Alberta plains: Amer. Assoc. Petrol. Geol., Bull., vol. 33, no. 4, pp. 547-563, 3 figs.

Weynschenk, R., 1950, Die Jura mikrofauna und flora des Sonnwendgebirges (Tirol) [German, English summary] : Schlern-Schriften, vol. 83, pp. 3-32, pls. 1-3, 5 figs., 1 table. Universitäts-Verlag Wagner, Innsbruck.

Wickenden, R. T. D., 1933, Jurassic Foraminifera from wells in Alberta and Saskatchewan: Roy. Soc. Canada, Trans., ser. 3, vol. 27, sec. IV, pp. 157-170, pls. 1-2.

Wisniowski, T., 1890, Microfauna of the Ornatus Clay in the vicinity of Krakow; Part I —Foraminifera of the Upper Callovian of Grojec (Polish): Akad. Umiej. Krakowie, Wydz. Mat.-Przyr., Pamietnik, Krakow, tom. 17, pp. 181-242, pls. 8-10, 2 tables.

Wood, A., and Barnard, T., 1946, *Ophthalmidium*: A study of nomenclature, variation, and evolution in the Foraminifera: Geol. Soc. London, Quart. Jour., vol. 102, pt. 2, pp. 77-113, pls. 4-10, text figs. 1-8.

APPENDIX

LITHOLOGIC DESCRIPTIONS AND MICROFAUNAL ASSEMBLAGES OF SASKATCHEWAN WELLS

INTRODUCTORY REMARKS

The locations, elevations and pertinent formation boundaries of the 13 Saskatchewan wells used as source material for this project are listed in the following section. The geographic distribution of the wells permits a natural grouping into three areas within the province, which are termed southwestern, west-central and eastern.

A research project of this nature may have more interest for stratigraphic paleontologists and others, if lithologic descriptions of some well-sections with their associated microfaunas are appended. Accordingly, a typical well from each area of Saskatchewan has been selected for which a description of the Jurassic cores, formation boundaries as determined by the present author or other workers and comprehensive microfaunal lists are offered. The Frontier, Kelstern and Carievale wells were chosen from the southwestern, west-central and eastern areas, respectively.

Relative abundances of microfossils are denoted by the following symbols:

VR —very rare; only one specimen found in section.

R —rare; 1 to 3 foraminifera or charophyta, ½ to 4 ostracode carapaces (1 to 8 valves) per sample.

S —sparse; one occurrence of from 4 to 10 foraminifera or charophyta, 4½ to 10 ostracode carapaces (9 to 20 valves) per sample plus additional occurrences in each case.

C —common; one occurrence of from 11 to 25 foraminifera or charophyta, 10½ to 25 ostracode carapaces (21 to 50 valves) per sample plus additional occurrences in each case.

A —abundant; one occurrence of more than 25 foraminifera or charophyta, more than 25 ostracode carapaces (50 valves) per sample plus additional occurrences in each case.

SOUTHWESTERN AREA WELLS

Tidewater Eastend Crown No. 1

Location: Lsd. 15, Sec. 11, Tp. 6, Rge. 20, W. 3rd Meridian.
Elevation: 3235′ K.B.

Jurassic Formation Boundaries:

Vanguard (Swift)	4380 (Francis, 1956)
Upper member of Shaunavon	4682 (Milner & Thomas, 1954)
Lower member of Shaunavon	4741 (Milner & Thomas, 1954)
Gravelbourg	4820.5 (Milner & Thomas, 1954)
Watrous	4910 (Milner & Thomas, 1954)
Mississippian	4920 (Francis, 1956)

Remarks: For lithologic descriptions of the Watrous, Gravelbourg and Shaunavon formations, see Milner and Thomas (1954, pp. 258-261).

Tidewater Instow Crown No. 1

Location: Lsd. 15, Sec. 33, Tp. 8, Rge. 17, W. 3rd Meridian.
Elevation: 3021′ K.B.

Jurassic Formation Boundaries:

Upper member of Vanguard	4234
Middle member of Vanguard	4300
Lower member of Vanguard	4355
Upper member of Shaunavon	4535
Lower member of Shaunavon	4595
Gravelbourg	4674
Watrous	4844
Mississippian	4876

Remarks: The boundaries for the middle and lower members of the Vanguard are in the original sense of Milner and Thomas (1954), and have not been adjusted to fit into the revised system of Milner and Blakslee (1958). The middle member apparently should be extended both upwards and downwards for about 20 to 25 feet.

Tidewater Frontier Crown No. 1

Location: Lsd. 13, Sec. 21, Tp. 3, Rge. 20, W. 3rd Meridian.

Elevation: 2965′ K.B.

Lithology and Micropaleontology:

3885′—"Blairmore" formation

Cored

4115′-4124′: Siltstone, light gray, grading to fine-grained sand, with many interbands and lenses of gray-black, carbonaceous shale.

4125′-4134′: Siltstone and shale, as above, in approximately equal proportions, shale content increased from cores above.

4132′—Morrison formation (Francis, 1956)

4134′-4143′: Siltstone and shale, similar to above, but with the shale predominant in basal three feet (75% or more of total).

4143′-4143′ 1″: Shale, dark grayish-brown, hard, massive, with concentrations of fine pyrite.

4143′ 1″—Swift formation of Francis
—Vanguard formation (upper member) of Milner and Blakslee
—Upper Vanguard formation of Hadley and Milner

4143′ 1″-4151′: Shale, light green, hard, fissile, non-calcareous, some fine pyrite.

4151′-4192′: Shale, medium green, fairly hard, partly fissile, non-calcareous (core recovery only 11%).

Sparse arenaceous foraminiferal fauna obtained from

4143′-4151′:

Ammobaculites venustus L. & T.
Flabellammina instowensis, n. sp.?
Haplophragmoides sp. cf. *H. linki* Nauss
H. spp.
Miliammina sp.
Triplasia dahindensa (Loranger)
Trochammina instowensis, n. sp.
Verneuilinoides tryphera L. & T.

4192′-4207′: Shale, medium green, as above (core recovery only 20%).

Foraminifera from above interval:

Conorboides hofkeri (B. & B.) (C)
Eoguttulina amygdalina L. & T. (R)
Haplophragmoides sp. cf. *H. linki* Nauss (S)
Lenticulina audax L. & T. (A)
L. dilecta L. & T. (A)
Massilina sp. (R)
Nodosaria balteata L. & T. (VR)
N. lirulata L. & T. (R)
Vaginulinopsis milneri, n. sp. (R)
V. thomasi, n. sp. (S)
V. sp. C (R)
Verneuilinoides tryphera L. & T. (C)

Ostracoda from above interval:

Leptocythere imlayi S. & P.? (VR)
Procytheridea sp. A (S)
Progonocythere hieroglyphica S. & P. (R)
P. sp. A (R)

Drilled

4207′-4410′: samples not described by present author, but apparently this interval is mainly green shale, becoming calcareous at 4290′ (Francis, 1956).

4290′—Rierdon formation of Francis

—Vanguard formation (lower member) of Milner and Blakslee
—Lower Vanguard formation of Hadley and Milner

Cored

4410′-4492′: Shale, medium green, fairly hard in places, mostly fissile, calcareous; occasional bands of grey-green, indurated, limey shale; pelecypods observed, with *Ostrea* and *Gryphaea* common at base.

Foraminifera from above interval:

Ammobaculites sp. D (R)
Ammobaculoides sp. cf. *A. phaulus* L. & T. (R)
Astacolus ectypus L. & T. (S)
Citharina entypomatus L. & T. (R)
C. latissima L. & T. (VR)
Citharinella latifolia L. & T. (VR)
Conorboides hofkeri (B. & B.) (A)
Eoguttulina amygdalina L. & T. (S)
Lenticulina audax L. & T. (A)
L. dilecta L. & T. (A)
Lingulina hathra L. & T. (R)
Marginulinopsis bandyi, n. sp. (R)
M. phragmites L. & T. (C)
Nodosaria balteata L. & T. (VR)
N. lirulata L. & T. (R)
N. mecista L. & T. (S)
N. orthostoecha L. & T. (R)
Spirillina amphelicta L. & T. (C)
Vaginulina wickendeni, n. sp. (R)
Vaginulinopsis epicharis L. & T. (R)
V. eritheles L. & T. (R)
V. loeblichorum, n. sp. (S)
V. sp. C (R)

Ostracoda from above interval:

Cythereis heteromorpha P. (R)
Paracypris projecta P. juveniles (R)
Procytheridea crassa P. (VR)
P. exempla P. (S)
P. minuta P. (VR)

Plant microfossil from above interval:

Tytthodiscus? sp. (S)

4492′-4497′: Shale, light green to gray-green, fairly hard, limey, silty, fossiliferous; two 6-inch bands of gray-buff, dense, very hard, argillaceous limestone.

Microfauna from above interval contains elements of assemblage previously listed and of assemblage to follow.

4495′ —Piper formation of Francis
—Upper Shaunavon of Milner and Thomas

4497′-4503′: Shale, green, very hard, blocky, limey, some large pyrite crystals; many silt laminae in lower portion.

Ostracoda from above interval:

Darwinula leguminella (Forbes) (C)
Limnocythere climaxia (Loranger) (C)
Metacypris sp. cf. *M. tenuimarginata* B., B. & O. (S)
Paracypris? sp. A (S)

Charophyta from above interval:

Aclistochara rotunda Peck (C-A)
Stellatochara sublaevis Peck (C-A)
S. n. sp. (A)

4503′-4508′ 6″: Limestone, buff, oölitic, sandy; rather "tight", considerable oil staining.

4508′ 6″-4510′: Shale, light to medium green, fairly hard, non-calcareous, many silty laminae; some massive, pale buff siltstone at top.

4510′-4519′: Shale, gray-green to dark green, very hard, massive, non-calcareous, silty in part; some slickensiding; some bands of pale greenish-gray, hard, argillaceous siltstone.

Foraminifera from top four feet of above interval:

Ammobaculites sp. (VR)
Eoguttulina sp. (S)
Involutina sp. (VR)
Trochammina? sp. A (C)

Ostracoda from same interval:

Darwinula leguminella (Forbes) (VR)
Metacypris sp. (R)
Paracypris? sp. A (VR)

4519′-4524′: Shale, gray-green, generally very hard, massive, non-calcareous, silty in part.

4524′-4526′: Siltstone, pale greenish-gray, very hard, argillaceous, scattered small stringers of carbonaceous material.

4525′-4528′: Shale, medium green, fissile.

4528′-4537′: Varying intervals of shale, siltstone, and limestone. The shale is gray-green to medium green, fairly fissile in part, non-

calcareous; the siltstone is pale greenish-gray, very hard, with laminae of dark shale; the limestone is buff, with fragmental texture.
Ostracoda from above interval:

Aparchitocythere sp. cf. *A. compressa* P. (S)
A. elongata P. (R)
Norcanolella parryi Loranger (VR)

4537′-4542′: Limestone, gray to brown, sandy in part becoming very argillaceous in lower portion, scattered shale laminae; considerable oil staining in top three feet, porosity poor.

4542′-4548′: Shale, gray-green to medium green, very hard, blocky, limey, becoming fissile in lower half.

Foraminifera from above interval:

Guttulina sp. A (S)
Involutina sp. (R)

Ostracoda from above interval:

Aparchitocythere sp. cf. *A. compressa* P. (A)
A. elongata P. (C)
Darwinula leguminella (Forbes) (S)
Limnocythere climaxia (Loranger) (C)
L. pustulosa, n. sp. (C)
Norcanolella parryi Loranger (VR)
N. sp. A (R)
Paracypris? sp. A. variety (S)

4548′-4549′ 6″: Limestone, gray-green, very hard, dense, argillaceous.
Ostracoda from above interval:

Aparchitocythere sp. cf. *A. compressa* P. (C)
A. elongata P. (VR)
Darwinula leguminella (Forbes) (S)
Limnocythere? sp. (VR)
Norcanolella parryi Loranger (VR)

4549′ 6″: —Middle Piper of Francis
—Lower Shaunavon formation of Milner and Thomas.

4549′ 6″-4605′: Limestone, buff to dark buff at base, dense, lithographic; some patchy oil staining, porosity poor; scattered pelecypods and gastropods.

Foraminifer from intervals above and below:

Ophthalmidium saskatchewanensis, n. sp. (S)

4605′-4624′ 6″: Limestone, buff to dark buff, dense, lithographic; some bands and a one-foot bed of grayish-brown, limey shale with irregular laminar layers of large pelecypod shells.

4624′ 6″—Lower Piper of Francis
—Gravelbourg formation of Milner and Thomas

4624′ 6″-4629′: Shale, gray, blocky, very hard in places, limey throughout, some crystalline pyrite.

Ostracoda from above interval:

Limnocythere climaxia (Loranger) (R)
Other indeterminate forms

Drilled

4629′-4669′: samples not described by present author, but this interval probably is largely gray shale with some limestone.

Cored

4669′-4688′: Shale, medium to dark gray, apparently non-calcareous, silty in part (core recovery only 15%).

Ostracoda from upper half of above interval:

Limnocythere sp. (S)
Other unidentified forms

4688′—Gypsum Spring formation of Francis

4688′-4699′: Dolomite, grayish-white, finely granular, somewhat chalky in appearance.

4699′-4701′: Shale, brownish-gray, hard, dolomitic.

4701′-4705′: Dolomite, fawn, very finely granular, shaley laminae; two patches of anhydrite.

4705′—Watrous formation of Milner and Thomas

4705′-4715′: Dolomite (70%) fawn, dense, with dark shale laminae; shale (20%), medium to dark gray, hard, blocky, dolomitic; anhydrite (10%).

4715′-4716′ 6″: Dolomite, fawn, as above.

4716′ 6″-4718′: Shale, grayish-green, blocky, with anhydrite blebs, glauconite and pyrite.

4718′-4721′: Anhydrite, mostly brownish-red, some gray, with patches of green, waxy shale.

4721′-4724′: Shale, chocolate brown, massive, dolomitic, with considerable reddish-brown anhydrite.

4724′-4726′ 6″: Anhydrite, reddish-brown.

4726′ 6″-4733′: Shale, chocolate brown and brownish-red, massive, dolomitic.

4733′-4742′: Mixture of anhydrite, red and green shale, some breccia.

4742′-4747′: Anhydritic material predominant, some green shale lenses.

4747′—Mission Canyon formation (Mississippian)

4747′: Dolomite, buff, finely granular.

WEST-CENTRAL AREA WELLS

Tidewater Atlas Crown No. 1

Location: Lsd. 6, Sec. 17, Tp. 18, Rge. 14, W. 3rd Meridian.
Elevation: 2479′ K.B.

Jurassic Formation Boundaries:

Lower member of Vanguard	3277
Upper member of Shaunavon	3365

Tidewater Atlas Crown No. 2

Location: Lsd. 13, Sec. 11, Tp. 18, Rge. 14, W. 3rd Meridian.
Elevation: 2478′ K.B.

Jurassic Formation Boundaries:

Lower member of Vanguard	3308
Upper member of Shaunavon	3415

Tidewater Johnston Lake Crown No. 1

Location: Lsd. 9, Sec. 20, Tp. 12, Rge. 2, W. 3rd Meridian.
Elevation: 2421′ K.B.

Jurassic Formation Boundaries:

Upper member of Vanguard (Upper Swift of Francis)?	3583
Middle member of Vanguard (Middle Swift of Francis)?	3604
Lower member of Vanguard (Lower Swift of Francis) (Francis, 1954)	3715
Upper member of Shaunavon (Upper Piper of Francis) Francis, 1954)	3880
Lower member of Shaunavon (Middle Piper of Francis) (Francis, 1954)	3955

Tidewater Rush Lake Crown No. 1

Location: Lsd. 13, Sec. 5, Tp. 18, Rge. 10, W. 3rd Meridian.
Elevation: 2372 K.B.

Jurassic Formation Boundaries:

Middle member of Vanguard	3380 (Milner & Thomas, 1954)
Lower member of Vanguard	3402 (Milner & Thomas, 1954)
Lower member of Vanguard	3416 (Milner & Blakslee, 1958)
Upper member of Shaunavon	3548 (Milner & Thomas, 1954)
Lower member of Shaunavon	3607

Remarks: (1) For lithologic descriptions of the middle and lower members of the Vanguard formation, see Milner and Thomas (1954, pp. 263-264). (2) This well was designated as the type section for the lower member of the Vanguard formation by Milner and Thomas. They placed the base of the member at 3548′ but in the opinion of the present author, the base would have been more accurately placed at least 14 feet lower, *i.e.*, at 3562′ or below. The microfauna and lithology of this 14-foot interval certainly suggest close relationship with the overlying Vanguard beds and not the underlying Shaunavon formation.

Tidewater Kelstern Crown No. 1

Location: Lsd. 5, Sec. 27, Tp. 15, Rge. 6, W. 3rd Meridian.
Elevation: 2417′ K.B.
Lithology and Micropaleontology:

3070′—"Blairmore" formation
3225′—Swift formation (Upper member) of Francis
—Vanguard formation (Upper member) of Milner and Thomas
—J-1 formation (J-1-A member) of Sask. Geol. Soc.
3248′—Middle member of Vanguard of Milner and Blakslee

Cored

3248′-3255′: Shale, greenish-gray, fairly hard in places, bentonitic in part, no calcareous reaction (core recovery only 36%).

Foraminifera from above interval:

Ammobaculites sp. A. (VR)
A. imlayi L. & T.? (S)
A. sp. D-variety? (C)
Ammomarginulina baryntica L. & T.? (R)
A. sp. A. (VR)
Flabellammina instowensis, n. sp. (R)

Haplophragmoides sp. cf. *H. linki* Nauss (R)
Nodosaria mecista L. & T. (VR)
Reophax sp. B? (VR)
Trochammina instowensis, n. sp. (C)
Verneuilinoides tryphera L. & T. (C)

3255'-3285': Siltstone, gray to greenish-gray, argillaceous; probably considerable shale present as core badly mudded up (core recovery only 13%).

3285'—Middle Swift of Francis
—Middle member of Vanguard of Milner and Thomas
—J-1-B member of Sask. Geol. Soc.

3285'-3320': Sandstone, light gray, medium-grained, quartzose, friable, good porosity.

3320'-3325': Sandstone, gray to greenish-gray, fine-grained, with some green shale lenses.

3325'-3329': Shale, grayish-green, fairly hard, silt-shot in places particularly at top, non-calcareous.

Arenaceous foraminiferal fauna from above shale:

Ammobaculites sp. A. (VR)
Glomospira gordialis (Jones and Parker)? (S)
Involutina sp. (VR)
Triplasia dahindensa (Loranger) (A)
Trochammina instowensis, n. sp. (C)
Verneuilinoides tryphera L. & T. (R)

3329'-3330': Sandstone, greenish-gray, fine-grained, argillaceous.

3330'-3380': Sandstone, light gray, medium-grained, quartzose, friable.

3380'-3384': Sandstone, greenish-gray, fine-grained, fairly friable, scattered fine pyrite; spots and lenses of argillaceous material, becoming prominent in basal foot.

3384'—Lower Swift of Francis
—Lower member of Vanguard of Milner and Thomas
—J-1-C member of Sask. Geol. Soc.

3384'-3396': Shale, grayish-green, fairly hard, generally fissile in lower portion, rather silty in places, bentonitic in part, calcareous reaction in part; pelecypods.

Foraminifera from above interval:

Ammobaculites cobbani L. & T. (S)
Ammobaculites imlayi L. & T. (S)
Ammomarginulina baryntica L. & T. (R)
Astacolus ectypus L. & T. (S)
Citharina entypomatus L. & T. (R)
Citharinella latifolia L. & T. (VR)
Conorboides hofkeri (B. & B.) (S)
Dentalina ectadia L. & T. (R)
D. sp. cf. *D. ejuncida* L. & T. (VR)
Eoguttulina amygdalina L. & T. (C)
Guttulina stilla Lalicker (R)
Lenticulina audax L. & T. (C)
L. dilecta L. & T. (C)
Lingulina micida L. & T. (R)
L. spp. (S)

Nodosaria balteata L. & T. (VR)
N. lirulata L. & T. (VR)
N. mecista L. & T. (R)
Spirillina amphelicta L. & T. (R)
Triplasia dahindensa (Loranger) (S)
Trochammina instowensis, n. sp. (R)
Vaginulina sp. cf. *V. cataulaca* L. & T. (S)
V. sp. cf. *V. compsa* L. & T. (R)
V. wickendeni, n. sp. (S)
Vaginulinopsis loeblichorum, n. sp. (R)
Verneuilinoides tryphera L. & T. (VR)

Ostracoda from above interval:

Cythereis robertsi, n. sp. (C)
Cytherella paramuensteri S. & P.? (R)
Eucytherura reticulata P.? (R)
Paracypris projecta P. (S)
Procytheridea exempla P. (C)
P. radvillia Loranger (S)
P. sp. A (R)
Progonocythere crowcreekensis S. & P. (R)

Drilled

3396′-3533′: samples not described but apparently this interval is mainly green shale, definitely calcareous below 3410′ (Francis, 1956)

3397′—Lower member of Vanguard of Milner and Blakslee
3410′—Rierdon formation of Francis
—Lower Vanguard formation of Hadley and Milner

Cored

3533′-3545′: Shale, grayish-green, generally fairly hard, calcareous, silty in places (core recovery 58%).

Foraminifera from the above interval:

Ammobaculites cobbani L. & T. (R)
Ammobaculites venustus L. & T. (R)
Ammobaculites sp. (S)
Ammomarginulina sp. cf. *A. baryntica* (juveniles?) (S)
Astacolus ectypus L. & T. (C)
Citharina entypomatus L. & T. (S)
Citharinella latifolia L. & T. (R)
C. rhomboidea L. & T. (R)
Conorboides hofkeri (B. & B.) (A)
Dentalina ectadia L. & T. (R)
Dentalina gracilistriata L. & T. variety (R)
Dentalina propinqua Terquem (VR)
Involutina cheradospira (L. & T.) (A)
Lenticulina audax L. & T. (R)
Nodophthalmidium sp. (S)
Nodosaria balteata L. & T. (S)
N. lirulata L. & T. (C)
Nubeculinella sp. (S)
Ophthalmidium saskatchewanensis, n. sp. (C)
Ophthalmidium sp. A (C)
Polymorphina sp. (S)
Quinqueloculina sp. (S)
Triplasia dahindensa (Loranger) (S)

Trochammina instowensis, n. sp. (S)
Vaginulina sp. B (S)
Vaginulinopsis sp. cf. *V. enodis* L. & T. (S)
V. eritheles L. & T.? (juveniles?) (R)
V. milneri, n. sp. (C)
V. thomasi, n. sp. (S)

Ostracoda from above interval:

Cythereis heteromorpha P. (R)
Eucytherura reticulata P. (R)
Monoceratina incisa P. (R)
M. pararossae P. (R)
M. vulsa (Jones & Sherborn) (R)
Orthonotacythere dorsoconvexa P. (S)
Paracypris projecta P. (C)
Procytheridea crassa P. (R)
P. exempla P. (A)
P. minuta P. (S)

Plant microfossil from above interval:

Tytthodiscus ? sp. (C)

3545'-3550': core not available

3545'—Piper formation of Francis
—Upper Shaunavon of Milner and Thomas
—J-2 formation (J-2-A member) of Sask. Geol. Soc.

3550'-3555': Shale, green, silty, a few small carbonaceous patches; pelecypods (core recovery only 40%).

Microfauna from above interval:

Involutina sp. cf. *I. southeyensis*, n. sp. (A)
Paracypris? sp. A (R)
Stellatochara sublaevis Peck (S)

3555'-3565': Limestone, greenish-gray, argillaceous, some silty patches (core recovery only 25%).

Foraminifera from above interval:

Globigerina? sp. (R)
Gümbelitria sp. (VR)

Ostracoda from above interval:

Darwinula leguminella (Forbes) (A)
Limnocythere climaxia (Loranger) (A)
Norcanolella parryi Loranger (R)
Paracypris? sp. A (R)

Charophyte from above interval:

Stellatochara sp. (R)

3565'-3569': Shale, red

3569'-3574': Shale, green, waxy, bentonitic, with considerable gray, silty material associated (core recovery only 13%).

3574'-3576': Siltstone, light gray, scattered mica flakes; considerable associated shale.

3576′-3582′: Shale, mainly green, some green and rusty brown mottled and a little maroon, some varve effect as well, generally calcareous, some bentonitic, a few carbonaceous stringers; shale fissile in basal portion.

Ostracoda from the shale, 3569′-3582′:

Aparchitocythere sp. cf. *A. compressa* P. (A)
A. elongata P. (R)
Darwinula leguminella (Forbes) (R)
Limnocythere climaxia (Loranger) (VR)
Norcanolella parryi Loranger (C)
N. sp. A (R)

3582′-3588′: Shale, green, yellowish-brown to reddish-brown, generally fissile, weak calcareous reaction for most part; some slickensiding; pelecypods.

Foraminifera from the above interval:

Guttulina sp. (S)
Involutina francisi, n. sp.? (C)
Pealerina rhomboidalis, n. sp. (A)

Ostracoda from the above interval:

Aparchitocythere sp. cf. *A. compressa* P. (A)
A. elongata P. (S)
Darwinula leguminella (Forbes) (VR)
Limnocythere climaxia (Loranger) (R)
Norcanolella parryi Loranger (S)
N. parryi? transitional to *N.* sp. A (C)
N. sp. A. (S)
Norcanolella? sp. B (C)

3588′-3593′: Siltstone, brown and gray, hard, limey, argillaceous (20%); limestone, dark grayish-brown, finely crystalline, with shelly laminae (20%); shale interspersed through core, dull green, fissile, calcareous reaction (60%); pelecypods, gastropods.

3593′-3594′: Limestone, grayish-green, very hard, generally dense, argillaceous; thin shelly laminae.

3594′-3601′: Shale, medium green, fissile, crumbly, weak calcareous reaction, appearing bentonitic in part; pelecypods.

Foraminifera from the shale, 3588′-3601′:

Guttulina sp. A (S)
Guttulina sp. (S)
Involutina francisi, n. sp. (A)
Polymorphina sp. (S)

Ostracoda from the same shale as above:

Aparchitocythere sp. cf. *A. compressa* P. (A)
A. elongata P. (R)
Darwinula leguminella (Forbes) (C)
Limnocythere climaxia (Loranger) (A)
Norcanolella parryi Loranger (A)
N. sp. A (S-C)

3601′-3602′ 6″: Limestone, gray and buff, with silt and shale in laminae.
3601′—Middle Piper of Francis
—Lower Shaunavon of Milner and Thomas
—J-2-B member of Sask. Geol. Soc.

EASTERN AREA WELLS

Tidewater Southey Crown No. 1

Location: Lsd. 4, Sec. 29, Tp. 22, Rge. 18, W. 2nd Meridian.
Elevation: 1842 K.B.

Jurassic Formation Boundary:

Shaunavon	2178 (Francis, 1956)

Remarks: Although this well is in the east-central area of Saskatchewan, it is here grouped with the wells of the eastern border area because of general similarity in lithologic and microfaunal character.

Imperial-Tidewater Wapella No. 4-3

Location: Lsd. 4, Sec. 3, Tp. 15, Rge. 1, W. 2nd Meridian.
Elevation: 1949 K.B.

Jurassic Formation Boundaries:

Lower member of Vanguard (Sundance of Francis)	2155 (Francis, 1956)
Shaunavon (Piper of Francis)	2230 (Francis, 1956)

Remarks: Francis (1956, p. 59) stated these formation boundaries were uncertain. The present author obtained a lower Vanguard microfauna as high as 2197′ with no core available between this depth and 2156′.

Tidewater Wapella Crown No. 16-33

Location: Lsd. 16, Sec. 33, Tp. 14, Rge. 1, W. 2nd Meridian.
Elevation: 1962 K.B.

Jurassic Formation Boundaries:

Lower member of Vanguard	2175
Shaunavon	2243

Imperial-Tidewater Carlyle Crown No. 1

Location: Lsd. 16, Sec. 23, Tp. 7, Rge. 3, W. 2nd Meridian.
Elevation: 1941 K.B.

Jurassic Formation Boundary:

Shaunavon	3216 approximately

Remarks: The present author obtained a lower Vanguard microfauna as high as 3154′ with no core sampled above this depth.

Socony-Western Prairie-Imperial Carievale No. 1

Location: Lsd. 16, Sec. 4, Tp. 3, Rge. 32, W. 1st Meridian.
Elevation: 1617′ 1690 K.B.

Lithology and Micropaleontology:

2960′—Sundance formation (Francis, 1956)
Swift? (correlation questionable according to Francis)

Cored

3049′-3066′: Shale, green, blocky to fissile, non-calcareous, with many laminae and interbands of light gray siltstone (siltstone and shale probably about equal); a few shell fragments.

No microfossils obtained from above interval.

3066′-3076′: Shale, gray to greenish-gray, blocky to fairly fissile, non-calcareous, considerable finely disseminated silt (core recovery 53%).

A few unidentifiable small ostracodes and two *Haplophragmoides* sp. from above interval.

3076′-3098′: Shale, grayish-green, fairly hard and blocky to fissile, calcareous, generally silty.

Sparse foraminiferal fauna from above interval:

Ammobaculites sp.
Citharina entypomatus L. & T.
Haplophragmoides sp.
Lingulina spp.
Nodosaria spp.
Trochammina sp.

Plant microfossil from above interval:

Tytthodiscus ? sp.

Drilled

3098′-3161′: samples not described by present author but this section consists mainly of silty shale and siltstone after the correlation profile of Francis (1954).

Rierdon equivalent top indeterminable but probably within the above drilled interval.

Cored

3161′-3195′: Shale, gray to grayish-green, a few pale brown streaks in middle portion, hard, blocky, calcareous, silty in upper fourth; a few *Lingula, Belemnites* common near base.

Foraminifera from the above interval:

Astacolus agalmatus L. & T. (R)
A. ectypus L. & T. (R)
Citharina entypomatus L. & T. (R)
C. latissima L. & T. (R)
Citharinella rhomboidea, L. & T. (?) (R)
Conorboides hofkeri (B. & B.) (S)
Dentalina ectadia L. & T. (R)
Eoguttulina sp. (S)
Involutina cheradospira (L. & T.) (R)
Lenticulina audax L. & T. (C)
L. dilecta L. & T. (S)
Lingulina hathra L. & T. (R)
Marginulinopsis carievalensis, n. sp. (S)
M. phragmites L. & T. (C)
M. sp. B (R)
Nodosaria lirulata L. & T. (R)
Spirillina amphelicta L. & T. (A)
Triplasia dahindensa (Loranger) (R)
Tristix wapellensis, n. sp. (R)
Vaginulinopsis eritheles L. & T. (R)
V. loeblichorum, n. sp. (R)

Ostracoda from above interval:

Bythocypris ambitruncata P. (S)
Cytherella paramuensteri S. & P. (R)

Cytherelloidea recurvata P. (R)
Eucytherura reticulata P. (R)
Procytheridea exempla P. (C)

Plant microfossil from above interval:

Tytthodiscus? sp. (A)

3195′-3200′: Shale, green, fairly blocky, hard, calcareous, becoming non-calcareous in lower portion.

3197′—Piper formation of Francis
—Shaunavon of Milner and Thomas

Ostracoda from above interval:

Cythereis? sp. C (S)
Darwinula leguminella (Forbes) (C)

Charophyta from above interval:

Aclistochara rotunda Peck (A)
Stellatochara sublaevis Peck (A)

3200′-3209′: Shale, green, green and reddish-brown mottled, fissile in part, non-calcareous, silty.

3209′-3219′: Shale, green, with considerable closely associated greenish-gray and gray siltstone (core recovery only 20%).

3219′-3223′: Shale, green, green and red mottled, massive, calcareous, very silty. Charophytes at 3222′.

3223′-3228′: Shale, green, massive, calcareous, very silty.

3228′-3240′: Shale, green, some red, calcareous, very silty with many silt laminae and bands, becoming less silty in lower third.

Legend

R - rare, S - sparse, C - common, A - abundant (for numerical equivalents, see introduction to Appendix)

* no core sample coverage available in this area

** no published data on foraminiferal occurrences

*** recorded in one sample only

SPECIES	Saskatchewan: Southwestern Area: Piper: Upper Gravelbourg	Saskatchewan: Southwestern Area: Piper: Lower Shaunavon	Saskatchewan: Southwestern Area: Piper: Upper Shaunavon	Saskatchewan: Southwestern Area: Rierdon: Basal part, lower mem.	Saskatchewan: Southwestern Area: Rierdon: Main part, lower mem.	Saskatchewan: Southwestern Area: Swift: Vanguard: Middle member	Saskatchewan: Southwestern Area: Swift: Vanguard: Lower part, upper mem.	Saskatchewan: Southwestern Area: Swift: Vanguard: Upper part, upper mem.	Saskatchewan: West-central Area: Piper: Lower Shaunavon*	Saskatchewan: West-central Area: Piper: Upper Shaunavon	Saskatchewan: West-central Area: Rierdon: Basal part, lower mem.	Saskatchewan: West-central Area: Rierdon: Main part, lower mem.	Saskatchewan: West-central Area: Swift: Vanguard: Middle member	Saskatchewan: West-central Area: Swift: Vanguard: Upper member*	Saskatchewan: Eastern Area: Piper: Gravelbourg	Saskatchewan: Eastern Area: Piper: Shaunavon	Saskatchewan: Eastern Area: R.: Lower Vanguard	Montana & n.w. Wyoming: Loeblich & Tappan, 1950: Ellis gp.: Sawtooth fm.	Ellis gp.: Rierdon fm.	Ellis gp.: Swift fm. **	South Dakota & n.e. Wyoming: Loeblich & Tappan, 1950: Sundance fm.: Stockade Beaver mem.	Redwater Shale mem.
Ammobaculites cobbani L. & T.							R				S	S	S										X
A. imlayi L. & T.													S										X
A. venustus L. & T.					R		S	S			S	S	S										X
A. sp. A							S	S															
A. sp. D					R		R	S			C	S	?C										
Ammobaculoides cf. A. phaulus L. & T.					R																		
Ammomarginulina baryntica L. & T.								R					R										X
A. cf. A. baryntica L. & T.												R											
A. cf. A. cragini L. & T.								R															
A. sp. A.								S					?R										
Astacolus cf. A. agalmatus L. & T.												R					C						
A. ectypus L. & T.				S	S		S				C	C	S				C		X		X		
A. petalus L. & T.																	R		X		X		
Bulbobaculites ? sp.								S															
Citharina entypomatus L. & T.				R	R						S	S	R				S						X
C. latissima L. & T.					R						R	R					R		X		X		
Citharinella compara L. & T.												R					S		X		X		
C. latifolia L. & T.											R	R							X		X		
C. rhomboides L. & T.											R	R					R						X
Conorboides hofkeri (B. & B.)				R	A		C	R			A	C	S				S						
Dentalina ectadia L. & T.							R				R	R	R				R						X
D. cf. D. lejuncida L. & T.						R							S										
D. gracilistriata L. & T. var.											R	R											
D. cf. D. liota L. & T.							R				R	R	R				R						
D. cf. D. propinqua Terquem												R	R										
Eoguttulina amygdalina L. & T.	R	R	R	R	S	R	R				R	R	C				R						X
Flabellammina instowensis, n. sp.								S					R										
Globigerina ? sp.									S														
Giomospira gordialis (J. & P.)				R					A			C											
Glumbelitria sp.			R						C														
Guttulina stilla Lalicker						S						C	S				S	X					
G. sp. A			A	S					S						?C								
Haplophragmoides cf. H. linki Nauss							S	A					R										
H. tryssa L. & T.							?R	?R				R											X
Involutina cheradospira (L. & T.)											A	R					S		X				
I. francisi, n. sp.	R		S						A							?C							
I. cf. I. ochis Lalicker				S					A														
I. southeyensis, n. sp.																A							
I. cf. I. southeyensis, n. sp.			A						A														
Lenticulina audax L. & T.				S	A		A				C	A	A				A						X
L. dilecta L. & T.				S	A		A				C	C	C				C		X		X		
L. sp. A							C																
Lingulina bathra L. & T.				R	R						R	S					S		X		X		
L. micida L. & T.												R	R				R						X
L. tumida L. & T.												R	R										X
L. sp. B				R							R	R											
L. sp. C												R											
Marginulina cf. M. scapha Lalicker																	R						
Marginulinopsis bandyi, n. sp.					R							R					S						
M. carlevalensis, n. sp.																	C						
M. phragmites L. & T.				R	C						S	A					C		X		X		
M. sp. B																	R						
Massilina sp.							R																X
Miliammina sp.								R															
Nodophthalmidium sp.											S												
Nodosaria balteata L. & T.							R				S	R	R				R						X
N. lirulata L. & T.		S		R	R		S				C	S	R				S						X
N. mecista L. & T.					S						R		R				?R						X
N. orthostoecha L. & T.												R							X				
N. sphingothalama L. & T.											R	R							X				
N. sp. A												R											
Nubeculinella sp.											S												
Ophthalmidium saskatchewanensis, n.sp.		S									A												
O. sp. A											C	S											
Pealerina rhomboidalis, n. sp. ***									A														
Polymorphina sp.		S	S						S	S													
Quinqueloculina sp.										S													
Reophax sp. A									S	R	S												
R. sp. B									S	R													
Spirillina amphelicta L. & T.		C		C	S		R				S	S	R				A						X
Triplasia dahindensa (Loranger)							S	R		R	S	C	A				S						
Tristix nitidula L. & T.												R					R				X		
Twapellensis, n. sp.																	S						
Trochammina instowensis, n. sp.					R		C	A		A	S	S	C				R						
T. rushilakensis, n. sp.												S											
Trochammina ? sp. A		C																					
Turrispirillina ? sp.											S												
Vaginulina cf. V. cataulaca L. & T.												R	S										
V. cf. V. compsa L. & T.													R										
V. inaptasata L. & T.											R	R					R						X
V. wickendeni, n. sp.					R						R	R	S										
Vaginulina ? sp. A																	R						
Vaginulina sp. B							?R				R	S											
Vaginulinopsis cf. V. enodis L. & T.											S												
V. cf. V. epicharis L. & T.				R	R																		
V. eritheles L. & T.				R	R						S	C					C		X		X		
V. loeblichorum, n. sp.					S						S	S					S						
V. loeblichorum var. A												R											
V. loeblichorum var. B												R											
V. milneri, n. sp.				R			R				C	R											
V. thomasi, n. sp.				R	S		S				S	S					S						
V. sp. A												R											
V. sp. B					R							R											
V. sp. C					R		R					S											
Verneuilinoides tryphera L. & T.					R		C	C			R	R	C				R						X

Legend

R - rare, S - sparse, C - common, A - abundant (for numerical equivalents, see introduction to Appendix)

* north-central Wyoming occurrences included here

** no core sample coverage available in this area

*** no published data on ostracode occurrences

SPECIES	Saskatchewan: Southwestern Area: G.S. Lower Gravelbourg	Piper: Upper Gravelbourg	Piper: Lower Shaunavon	Piper: Upper Shaunavon	Rierdon: Basal part, lower mem.	Rierdon: Main part, lower mem.	Swift: Middle member	Swift: Upper member	Saskatchewan: West-central Area: Piper: Lower Shaunavon**	Piper: Upper Shaunavon	Rierdon: Basal part, lower mem.	Rierdon: Main part, lower mem.	Swift: Middle member	Swift: Upper member**	Saskatchewan: Eastern Area: Piper: Gravelbourg	Piper: Shaunavon	R.: Lower Vanguard	Central and south-central Montana*: Peterson, 1954: Ellis gp.: Piper-Sawtooth fm.***	Ellis gp.: Rierdon fm.	Ellis gp.: Swift fm.	Powder River Basin of Wyoming: Peterson, 1954: "Lower Sundance"	"Upper Sundance"	Black Hills of S. Dakota & n.e. Wyoming: Peterson, 1954: Sundance fm.: Stockade Beaver mem.	Redwater shale mem.	Wind River Basin of central Wyoming: Roberts, 1934: Sundance undifferentiated
Aparchitocythere cf. A. compressa Peterson			C	A						A															
A. elongata Peterson				A						S											X		X		
Bythocypris ambitruncata Peterson																	C		X						
Cythereis heteromorpha Peterson					R	R					R	R					R		X						
C. robertsi, n. sp.								R					C												X
C. rushlakensis, n. sp.												C					R								
C. rushlakensis var.												R					R								X
Cythereis ? sp. C																	S								
Cytherella paramuensteri S. & P.					?R								?R				S		X	X	X	X			X
Cytherelloidea recurvata Peterson					R						R	R					S		X						X
Darwinula leguminella (Forbes)	A			A						A					C	C									
Eucytherura reticulata Peterson											R	R	?R				R		X						
Limnocythere clima xia (Loranger)		S		A						A															
L. pustulosa, n. sp.				C						R															
Metacypris cf. M. tenuimarginata B., B. & O.				A						C						A									
Monoceratina incisa Peterson											R								X						
M. pararossae Peterson											R	S							X						X
M. vulsa (J. & S.)											R														
Norcanolella parryi Loranger				R						A					?R	S									
N. sp. A.				R						S															
Norcanolella ? sp. B										C															
Orthonotacythere dorsoconvexa Peterson							R				S	R							X						X
Paracypris projecta Peterson						R					C	S	C				S		X						X
Paracypris ? sp. A				C						S						R									
Procytheridea crassa Peterson						R					R	R							X						X
P. exempla Peterson					S	S					A	C	C				C		X						X
P. minuta Peterson					S						S	R							X						X
P. radvillia Loranger								R					S												
P. sp. A								S					R												
Progonocythere anoda Peterson					S							R							X						
P. crowcreekensis S. & P.												R	R							X		X		X	
P. hieroglyphica S. & P.								R												X		X		X	
P. sp. A								R													•				
Protocythere cf. P. quadricarinata S. & P.		R																	X						

PLATES 1-28

EXPLANATION OF PLATE 1

Photographs and sketches of Foraminifera from Shaunavon formation and transitional beds between Shaunavon and Vanguard formations (all photographs retouched except figures 25, 28 and 29; figures 26, 27, 30-32 are sketches)

Magnification x 60 except for figures 20-24 which are x 83

Figure		*Page*
1, 2	*Involutina francisi* Wall, n. sp., Rush Lake well, holotype, Univ. of Mo. No. F-53-1, side and peripheral views	45
3-6	*Involutina* cf. *I. orbis* (Lalicker), Rush Lake well. 3, 4: microspheric form, Univ. of Mo. No. F-53-7, side and peripheral views; 5, 6: megalospheric form, Univ. of Mo. No. F-53-8, side and peripheral views	46
7, 8	*Glomospira gordialis* (Jones and Parker), Rush Lake well, Univ. of Mo. No. F-53-9, side and peripheral views	48
9-12	*Involutina southeyensis* Wall, n. sp., Southey well. 9, 10: holotype, Univ. of Mo. No. F-53-4, side and peripheral views; 11, 12: paratype, Univ. of Mo. No. F-53-5, side and peripheral views	46
13, 14	*Involutina* cf. *I. southeyensis* Wall, n. sp., Instow well, Univ. of Mo. No. F-53-6, side and peripheral views	47
15-17	*Trochammina*? sp. A, Frontier well, Univ. of Mo. No. F-54-19, dorsal, peripheral and ventral views	61
18, 19	*Reophax* sp. B, Rush Lake well; 18—immature specimen, Univ. of Mo. No. F-53-12; 19—mature specimen, Univ. of Mo. No. F-53-13	49
20-22	*Globigerina*? sp., Johnston Lake well, Univ. of Mo. No. F-60-10, dorsal, peripheral and ventral views	108
23, 24	*Gümbelitria* sp., Johnston Lake well; 23—Univ. of Mo. No. F-60-11, 24—Univ. of Mo. No. F-60-12	109
25-28	*Pealerina rhomboidalis* Wall, n. sp., Kelstern well. 25-27: holotype, Univ. of Mo. No. F-60-5, 25—side view, 26—sketch of opposite side showing chamber arrangement, 27—apertural view (sketch) 28: paratype, Univ. of Mo. No. F-60-6	106
29-32	*Guttulina* sp. A, Eastend well, Univ. of Mo. No. F-60-4; 29—side view, 30—apertural view (sketch), 31, 32—sketches of opposite sides showing chamber arrangement	105
33, 34	*Polymorphina* sp., Rush Lake well; 33—Univ. of Mo. No. F-60-2, 34—Univ. of Mo. No. F-60-3 showing chamber arrangement on opposite side	106

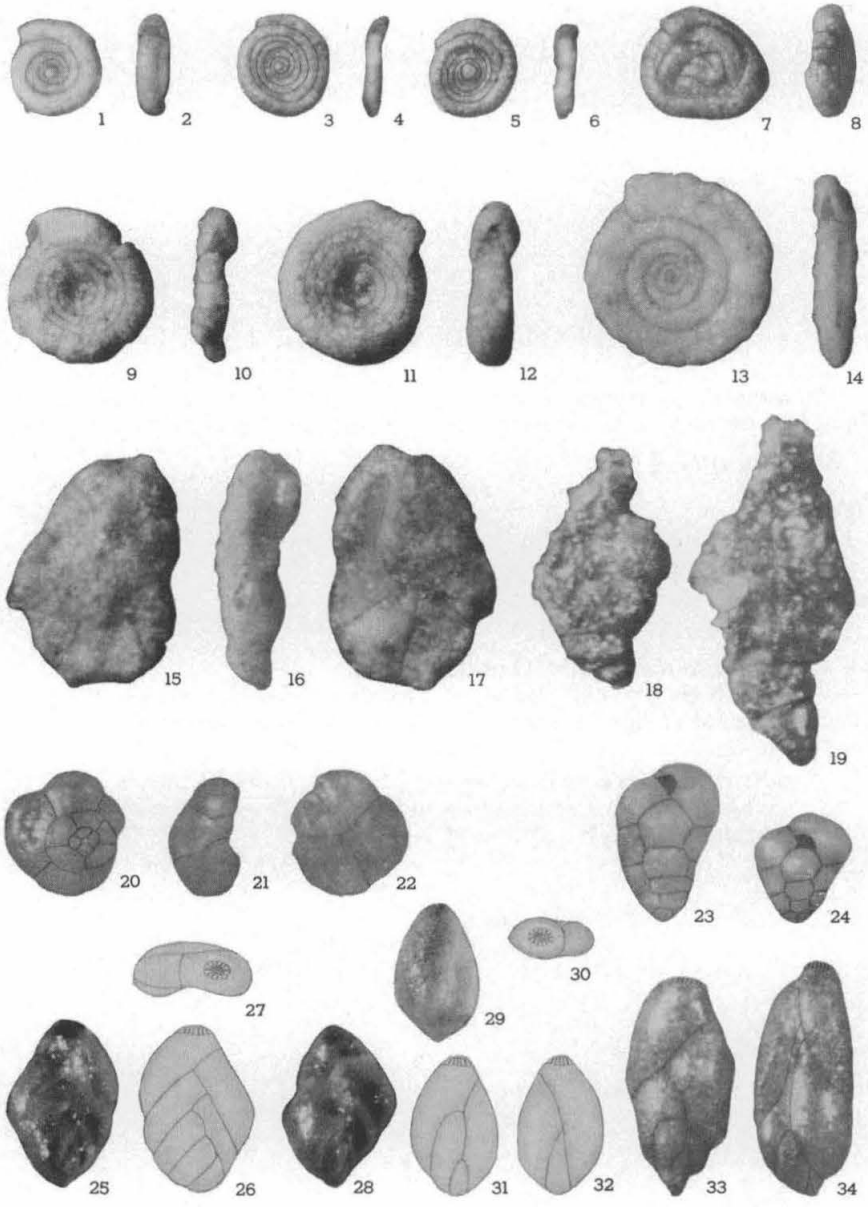

Plate 1 Bathonian-Callovian Foraminifera from Shaunavon formation and Shaunavon-Vanguard transitional beds.

EXPLANATION OF PLATE 2

Photographs of Foraminifera from basal portion of lower member of Vanguard formation (not retouched except for accentuation of apertures)

Magnification x 58

Figure		*Page*
1-3	*Involutina cheradospira* (Loeblich and Tappan), Kelstern well. 1-2: microspheric form, Univ. of Mo. No. F-53-2, side and peripheral views; 3: paratype, megalospheric form, Univ. of Mo. No. F-53-3	44
4-8	*Triplasia dahindensa* (Loranger). 4, 5: Kelstern well, Univ. of Mo. No. F-54-11, juvenile individual of fine to medium-grained form, side and peripheral views; 6-8: Rush Lake well, Univ. of Mo. No. F-54-12, adult individual of fine to medium-grained form, 6—side view, 7—peripheral view, 8—apertural view	58

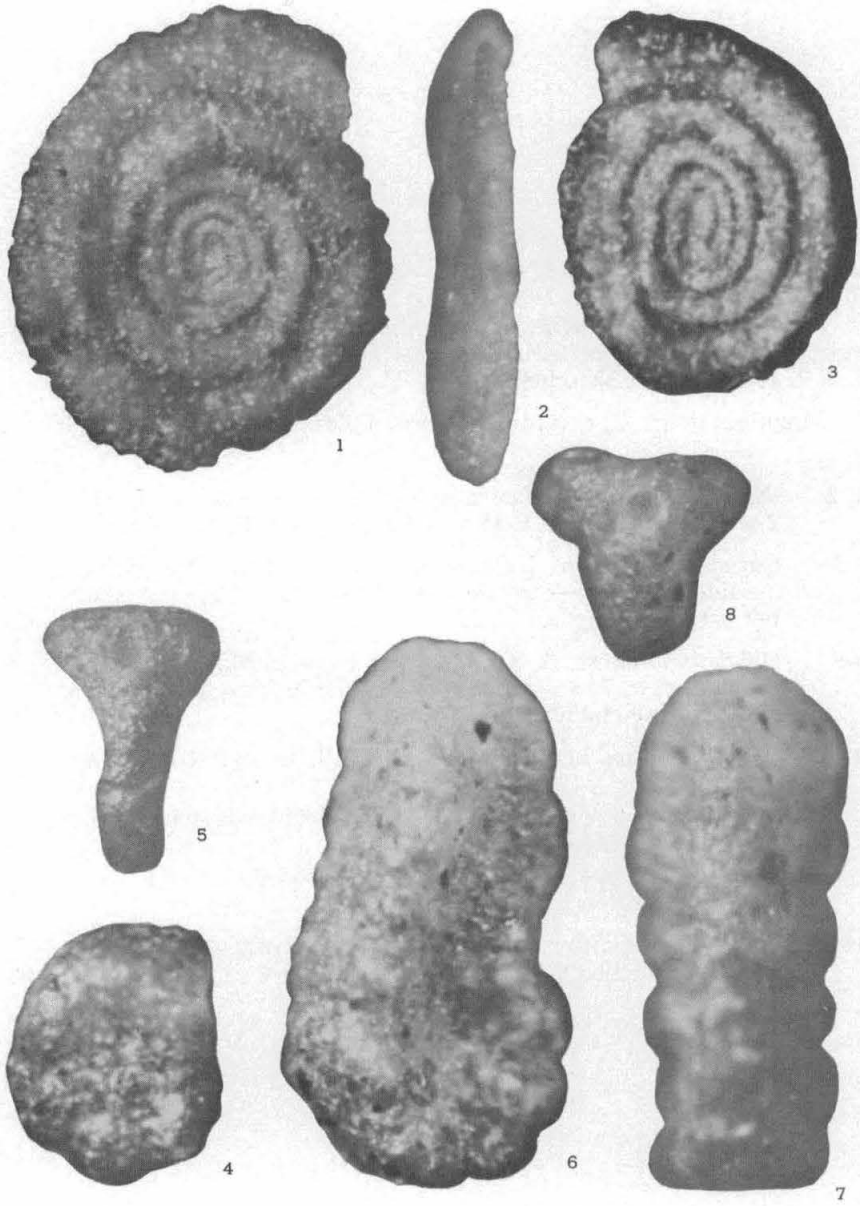

Plate 2 **Callovian Foraminifera from basal portion of lower member of Vanguard formation (Rierdon).**

EXPLANATION OF PLATE 3

Photographs and sketches of Foraminifera from basal portion of lower member of Vanguard formation (figures 3 and 6 are retouched; figures 4, 5, 7, 8, 10 and 12 are sketches)

Magnification x 60 except for figures 4 and 5 which are x 90

Figure		*Page*
1, 2	*Nubeculinella* sp., Kelstern well; 1—Univ. of Mo. No. F-55-6, 2—Univ. of Mo. No. F-55-7 (specimens attached to *Ostrea*)	65
3-5	*Quinqueloculina* sp., Kelstern well, Univ. of Mo. No. F-55-2; 3—side view, 4, 5—sketches of opposite sides showing chamber arrangement	63
6-8	*Ophthalmidium* sp. A, Kelstern well, Univ. of Mo. No. F-55-10; 6—side view, 7, 8—sketches of peripheral view and opposite side showing chamber arrangement	66
9-12	*Ophthalmidium saskatchewanensis* Wall, n. sp., Rush Lake well. 9,10: holotype, Univ. of Mo. No. F-55-8 (10 is sketch showing manner of coiling); 11, 12: paratype, Univ. of Mo. No. F-55-9, 11—side view, 12—sketch of peripheral view	65
13	*Nodophthalmidium* sp., Kelstern well, Univ. of Mo. No. F-55-5 (attached to *Ostrea*)	64

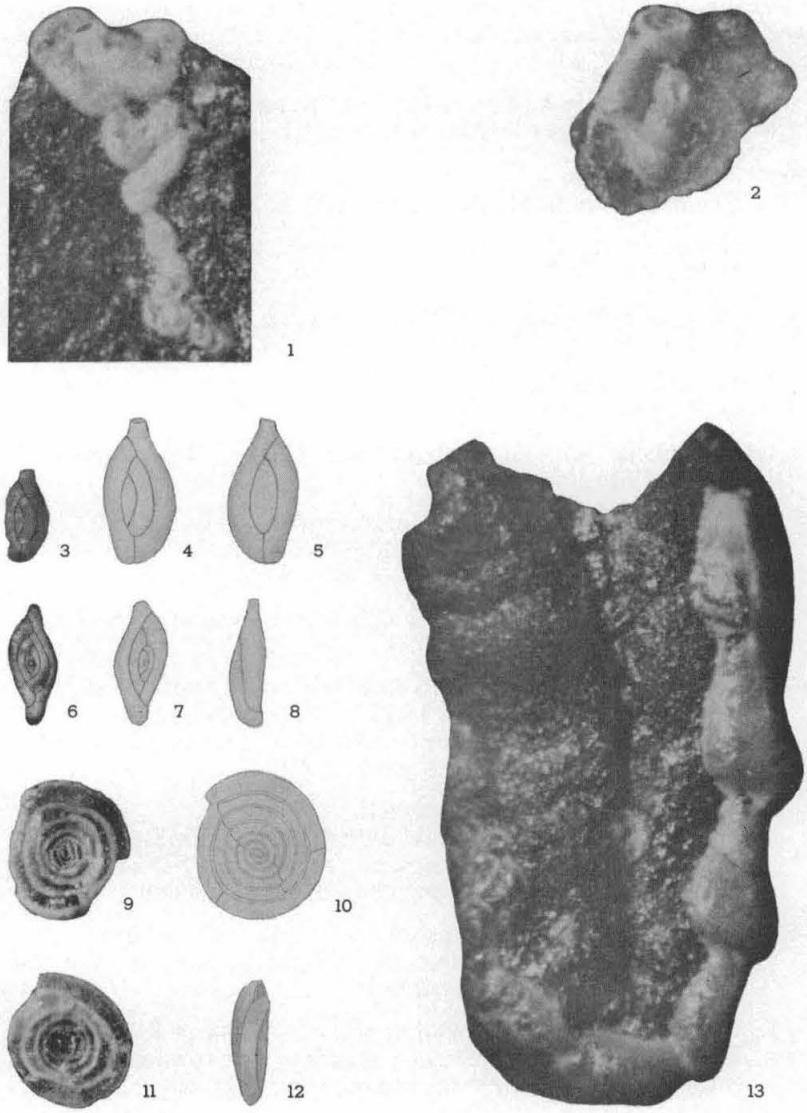

Plate 3 Callovian Foraminifera from basal portion of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 4

Photographs and sketches of Foraminifera from basal portion of lower member of Vanguard formation (figures 1, 2, 9, 12, 22 and 25 are retouched; figures 7, 13, 15, 17, 18-20, 21 and 24 are sketches)

Magnification x 58 except figures 12, 22 and 25 (peripheral views) which are 50, and figures 18-20 which are x 93

Figure		*Page*
1	*Vaginulina* sp. B, Kelstern well, Univ. of Mo. No. F-57-11	98
2	*Dentalina ectadia* Loeblich and Tappan, Kelstern well, Univ. of Mo. No. F-57-7	83
3, 4	*Nodosaria lirulata* Loeblich and Tappan, Kelstern well; 3—Univ. of Mo. No. F-57-18, 4—Univ. of Mo. No. F-57-19	87
5	*Dentalina gracilistriata* Loeblich and Tappan var., Kelstern well, Univ. of Mo. No. F-57-10	85
6	*Citharinella latifolia* Loeblich and Tappan, Kelstern well, Univ. of Mo. No. F-59-13	102
7-9	*Nodosaria balteata* Loeblich and Tappan, Kelstern well; 7, 8—hyaline specimen, Univ. of Mo. No. F-57-16 (7 is sketch); 9—pyritized specimen, Univ. of Mo. No. F-57-17	87
10	*Nodosaria sphingothalama* Loeblich and Tappan, Rush Lake well, Univ. of Mo. No. F-58-4	89
11-13	*Vaginulinopsis* cf. *V. enodis* Loeblich and Tappan, Kelstern well, Univ. of Mo. No. F-56-13; 11, 12—side and peripheral views, 13—sketch of opposite side showing chamber arrangement	76
14-17	*Lingulina* sp. B, Rush Lake well. 14, 15: microspheric form, Univ. of Mo. No. F-58-12; 16, 17: megalospheric form, Univ. of Mo. No. F-58-13 (15, 17 are sketches showing chamber arrangement)	93
18-20	*Turrispirillina* ? sp., Johnston Lake well, Univ. of Mo. No. F-60-9; 18—dorsal view, 19—peripheral view, 20—ventral view showing involute tendency	107
21-23	*Vaginulinopsis thomasi* Wall, n. sp., Rush Lake well, paratype, Univ. of Mo. No. F-57-3; 21—sketch of side to show limbate sutures, 22, 23—peripheral and opposite side views	81
24-26	*Vaginulinopsis milneri* Wall, n. sp., Kelstern well, holotype, Univ. of Mo. No. F-57-1; 24—sketch of side to show change in character of sutures, 25, 26—peripheral and opposite side views	80

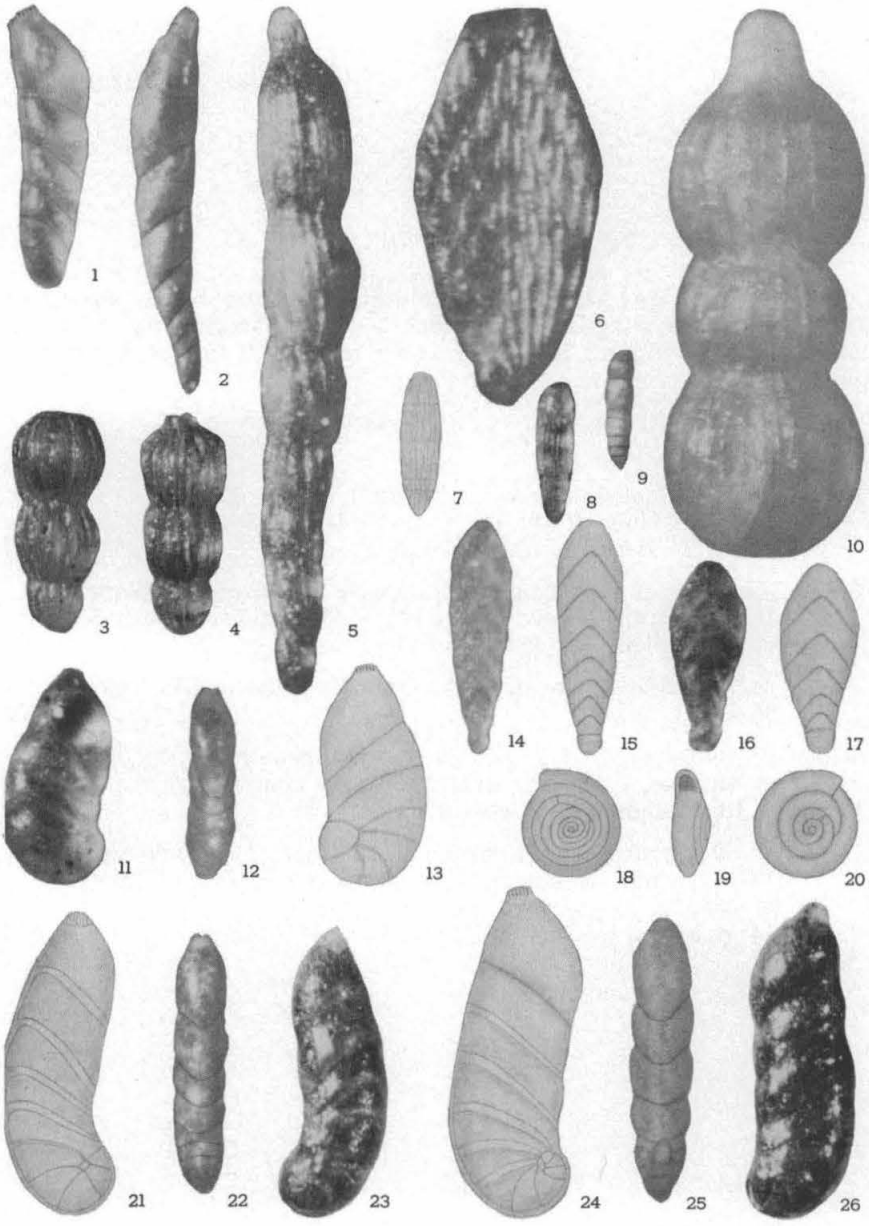

Plate 4 **Callovian Foraminifera from basal portion of lower member of Vanguard formation (Rierdon).**

EXPLANATION OF PLATE 5

Photographs and sketches of Foraminifera from basal portion of lower member of Vanguard formation—Species characteristic of eastern Saskatchewan—(figures 2, 4-7 and 13 are retouched; figures 3, 8 and 11 are sketches)

Magnification x 58 except figure 11 which is x 95.

Figure		*Page*
1-3	*Marginulinopsis carievalensis* Wall, n. sp., Carievale well, holotype, Univ. of Mo. No. F-56-11; 1, 2—side and peripheral views, 3—sketch of opposite side	73
4-6	*Astacolus* cf. *A. agalmatus* Loeblich and Tappan, Wapella 16-33 well; 4, 5—Univ. of Mo. No. F-55-20, side and peripheral views; 6—Univ. of Mo. No. F-56-1	69
7	*Marginulinopsis* sp. B, Carievale well, Univ. of Mo. No. F-56-12	75
8-10	*Marginulina* cf. *M. scapha* Lalicker, Wapella 16-33 well, Univ. of Mo. No. F-56-6; 8—sketch showing character of sutures, 9, 10—peripheral and opposite side views	72
11-14	*Spirillina amphelicta* Loeblich and Tappan, Carievale well. 11-13: hyaline specimen, Univ. of Mo. No. F-60-7, 11—sketch of side, 12, 13—side and peripheral views; 14: pyritized specimen, Univ. of Mo. No. F-60-8	107

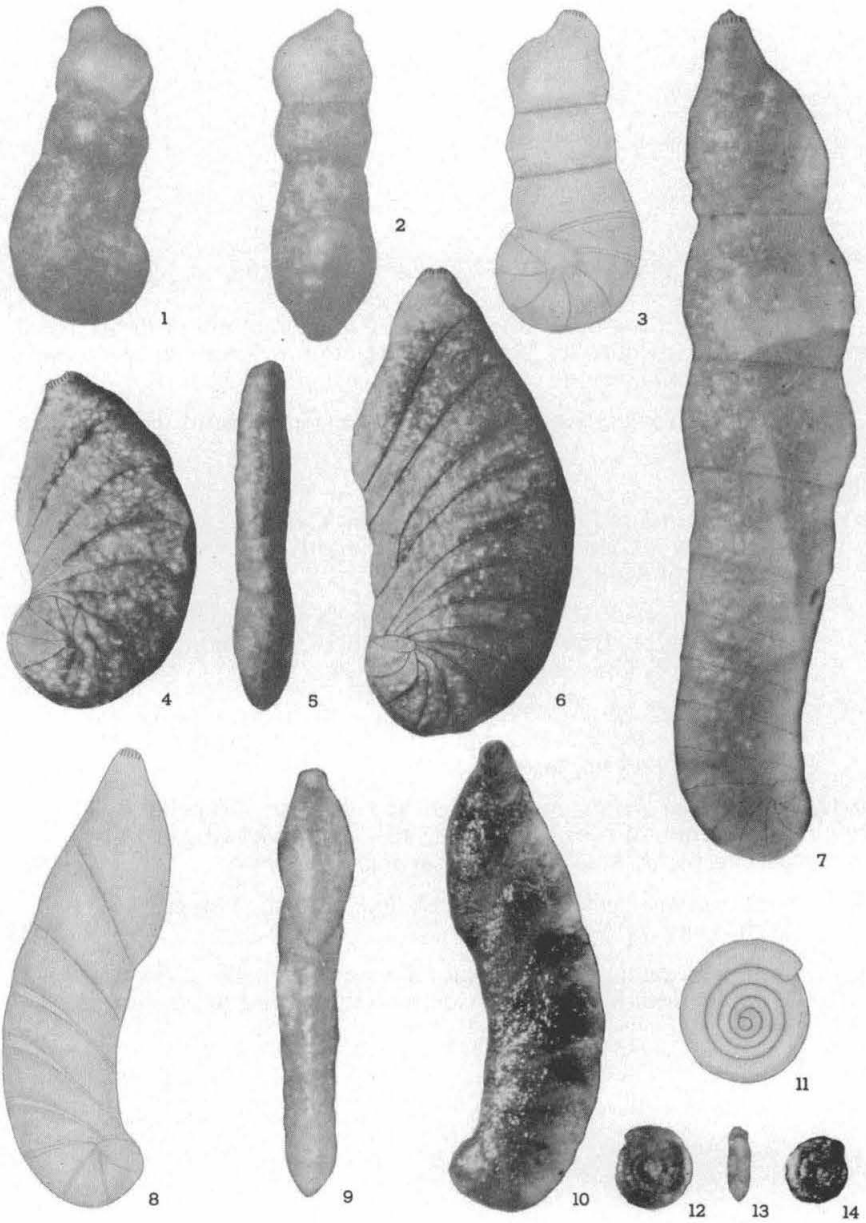

Plate 5 **Callovian Foraminifera from basal portion of lower member of Vanguard formation (Rierdon)—species characteristic of eastern Saskatchewan.**

EXPLANATION OF PLATE 6

Retouched photographs and sketches of Foraminifera from basal portion of lower member of Vanguard formation—Species characteristic of eastern Saskatchewan—

Magnification x 58 except figures 8 and 11 (peripheral views) which are x 53.

Figure		*Page*
1-3	*Tristix nitidula* Loeblich and Tappan, Carievale well. 1, 2: Univ. of Mo. No. F-58-16, side and top views; 3: Univ. of Mo. No. F-58-17	94
4-6	*Tristix wapellensis* Wall, n. sp., Wapella 16-33 well. 4, 5: holotype, Univ. of Mo. No. F-58-18, side and top views; 6: paratype, Univ. of Mo. No. F-58-19	95
7-9	*Vaginulina*? sp. A, Wapella 16-33 well, Univ. of Mo. No. F-59-5; 7—sketch showing chamber arrangement, 8, 9—peripheral and opposite side views	98
10-12	*Vaginulina inspissata* Loeblich and Tappan, Wapella 16-33 Well, Univ. of Mo. No. F-59-2; 10—sketch showing chamber arrangement, 11, 12—peripheral and side views	97
13	*Citharinella rhomboidea* Loeblich and Tappan, Wapella 16-33 Well, Univ. of Mo. No. F-59-17	103
14-16	*Astacolus petalus* Loeblich and Tappan, Wapella 16-33 well, Univ. of Mo. No. F-56-5, side, peripheral and opposite side views	71

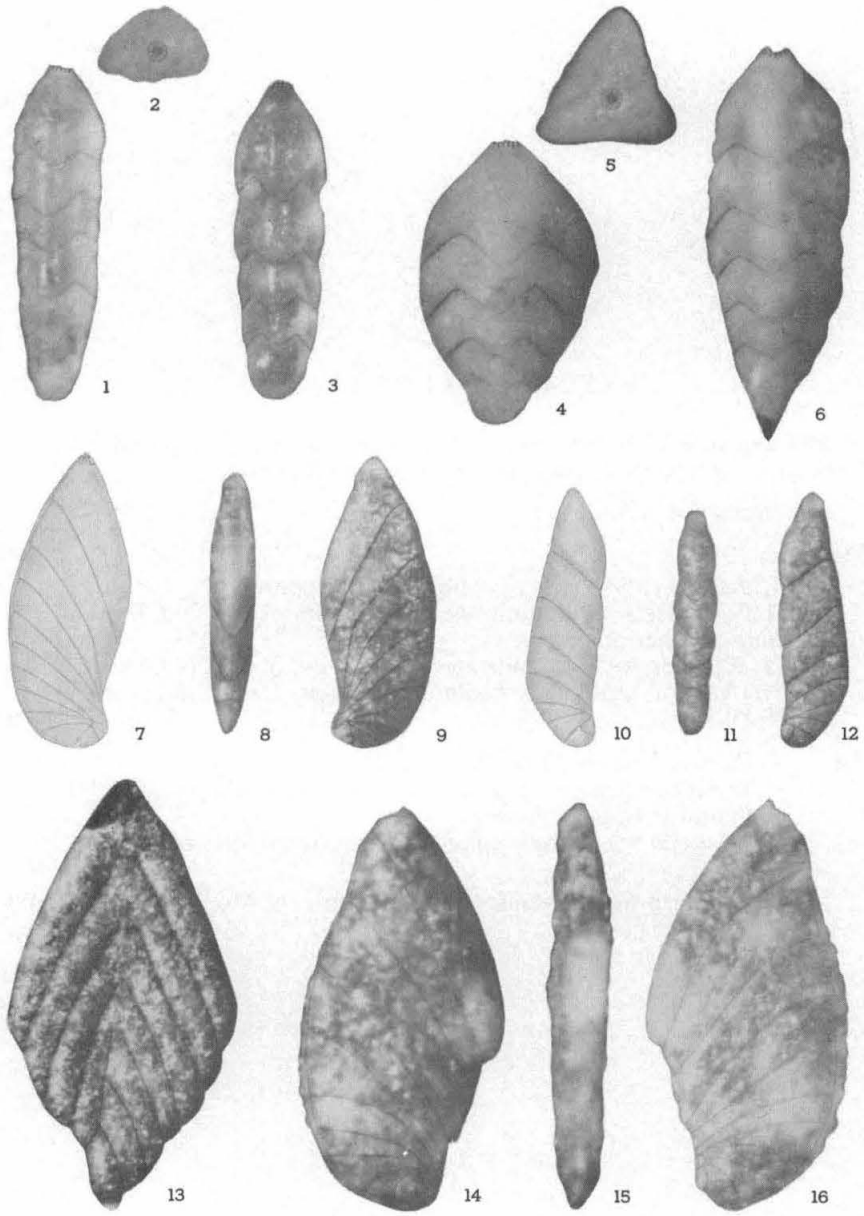

Plate 6 **Callovian Foraminifera from basal portion of lower member of Vanguard formation (Rierdon)—species characteristic of eastern Saskatchewan.**

EXPLANATION OF PLATE 7

Photographs of Foraminifera from basal portion of lower member of Vanguard formation (except figure 4 from main portion)

Magnification x 58.

Figure		*Page*
1-4	*Citharina entypomatus* Loeblich and Tappan. 1, 2: Kelstern well, adult specimen, Univ. of Mo. No. F-59-6, side and peripheral views; 3: Kelstern well, juvenile specimen, Univ. of Mo. No. F-59-7; 4: Atlas 1 well, intermediate specimen, Univ. of Mo. No. F-59-8	99
5-8	*Citharina latissima* Loeblich and Tappan. 5, 6: Kelstern well, adult specimen, Univ. of Mo. No. F-59-9, side and peripheral views; 7: Wapella 16-33 well, pyritized specimen, Univ. of Mo. No. F-59-11; 8: Kelstern well, juvenile specimen, Univ. of Mo. No. F-59-10	100

Plate 7 Callovian Foraminifera from basal and main portions of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 8

Photographs and sketches of Foraminifera from main portion of lower member of Vanguard formation (all photographs retouched except figures 2, 12, 14-16; figures 5, 13 and 17 are sketches)

Magnification x 59 except figure 5 which is x 90, and figure 12 which is x 36

Figure		*Page*
1-4	*Ammobaculites cobbani* Loeblich and Tappan, Atlas 2 well, Univ. of Mo. No. F-53-16; 1—side with evolute coil, 2—apertural view, 3—involute side, 4—peripheral view	51
5	*Ammobaculoides* cf. *A. phaulus*, Frontier well, Univ. of Mo. No. F-54-15	59
6, 7	*Ammobaculites* sp. D, Atlas 1 well, Univ. of Mo. No. F-54-3, side and apertural views	53
8, 9	*Ammobaculites venustus* Loeblich and Tappan, Atlas 1 well, Univ. of Mo. No. F-53-17, side and peripheral views	52
10, 11	*Reophax* sp. A, Atlas 2 well; 10—juvenile specimen, Univ. of Mo. No. F-53-10; 11—adult specimen, Univ. of Mo. No. F-53-11	48
12	*Ammomarginulina* cf. *A. baryntica*, Atlas 2 well, Univ. of Mo. No. F-54-8	55
13-17	*Trochammina rushlakensis* Wall, n. sp., Rush Lake well, holotype, Univ. of Mo. No. F-54-16; 13, 14—dorsal view, 15—peripheral view, 16, 17—ventral view (13 and 17 are sketches showing chamber arrangement, sutures and aperture)	61

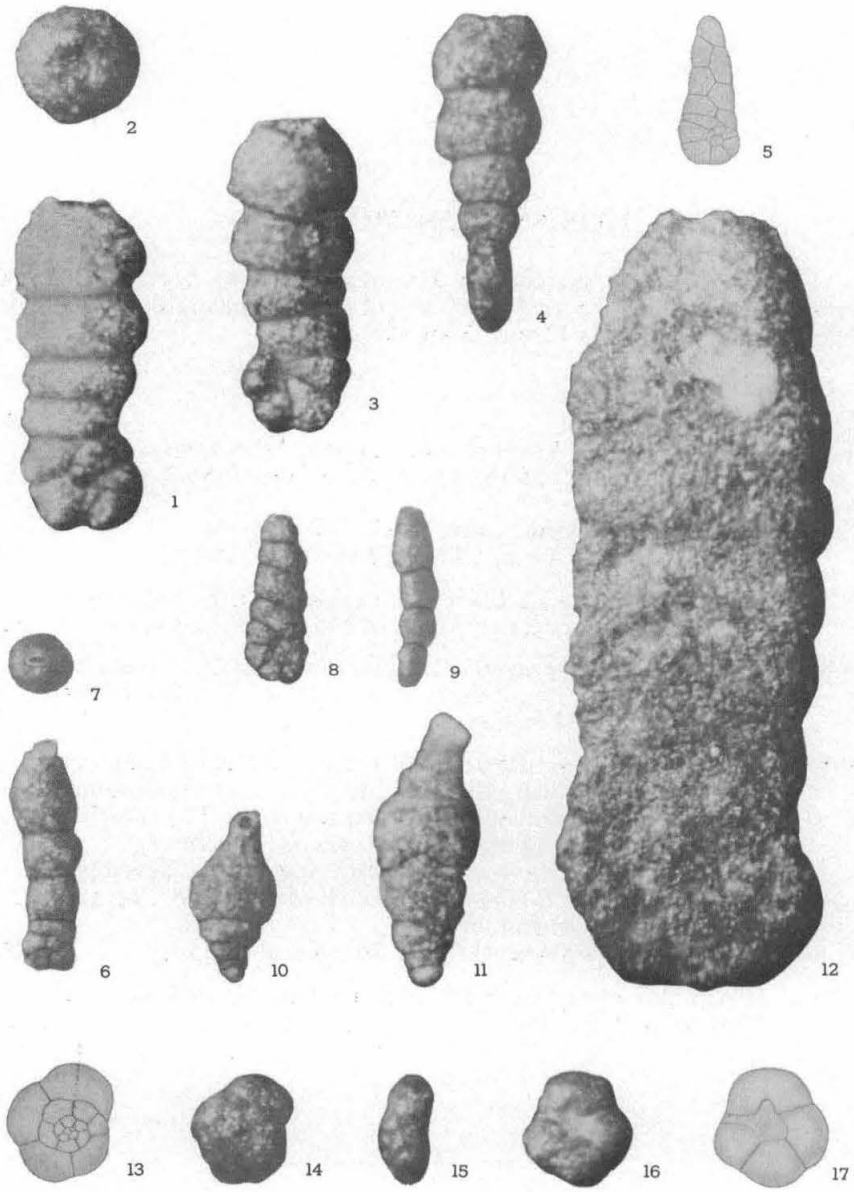

Plate 8 Callovian Foraminifera from main portion of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 9

Photographs and sketches of Foraminifera from main portion of lower member of Vanguard formation (all photographs retouched except figures 5 and 17; figures 12 and 13 are sketches)

Magnification x 56.

Figure		*Page*
1-4	*Astacolus ectypus* Loeblich and Tappan, Atlas 1 well. 1, 2: megalospheric form, Univ. of Mo. No. F-56-2, side and peripheral views; 3: microspheric form, Univ. of Mo. No. F-56-3; 4: microspheric ? form, Univ. of Mo. No. F-56-4	70
5	*Lenticulina dilecta* Loeblich and Tappan, Rush Lake well, partly uncoiled specimen, Univ. of Mo. No. F-55-15	68
6-8	*Marginulinopsis phragmites* Loeblich and Tappan, Atlas 1 well; 6—Univ. of Mo. No. F-56-7; 7, 8—Univ. of Mo. No. F-56-8, peripheral and side views	74
9-16	*Conorboides hofkeri* (Bartenstein and Brand), Rush Lake well. 9-12: adult specimen, Univ. of Mo. No. F-60-13; 9—dorsal view, 10—peripheral view, 11—ventral view, 12—sketch of ventral side showing multiple loop-shaped apertures; 13-15: intermediate specimen with high spire developed, Univ. of Mo. No. F-60-14; 13—sketch of dorsal side, 14, 15—peripheral and ventral views; 16: juvenile specimen, Univ. of Mo. No. F-60-15	109
17	*Lenticulina audax* Loeblich and Tappan, Rush Lake well, Univ. of Mo. No. F-55-11	67

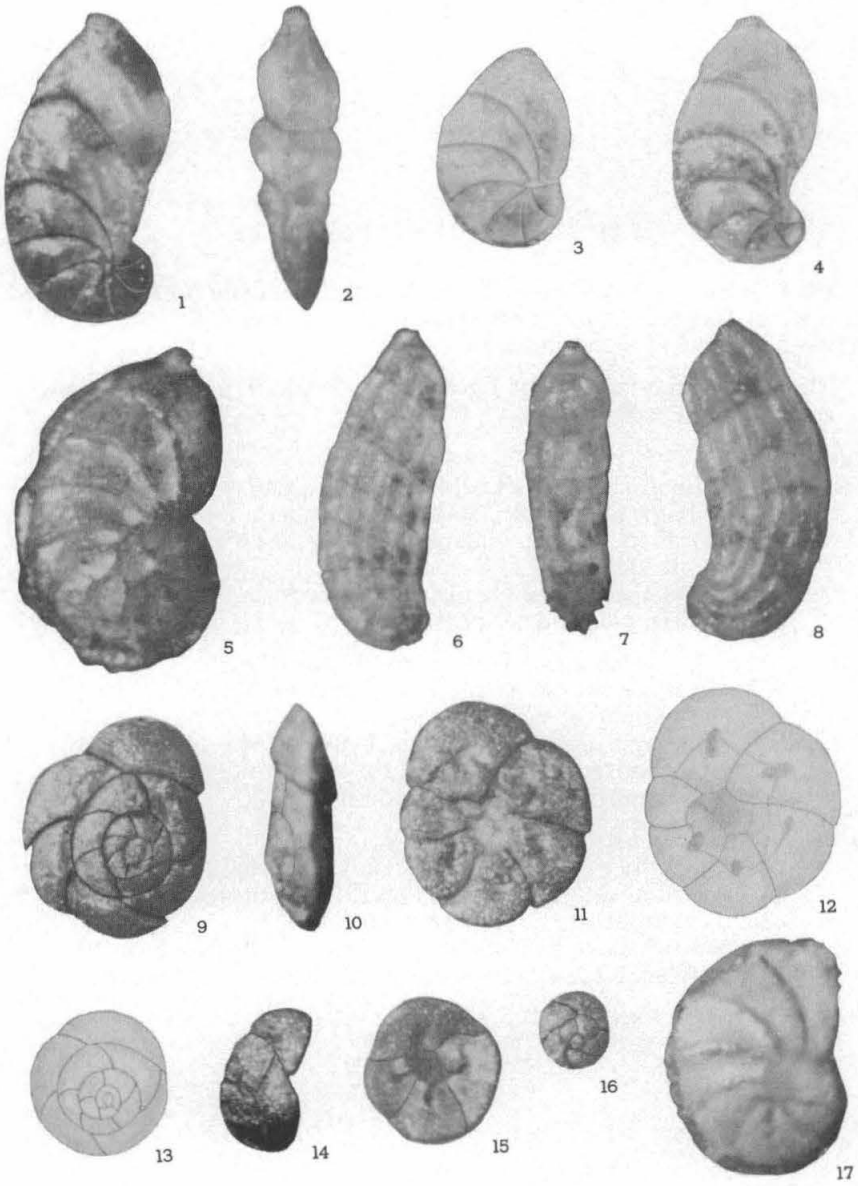

Plate 9 **Callovian Foraminifera from main portion of lower member of Vanguard formation (Rierdon).**

EXPLANATION OF PLATE 10

Photographs and sketches of Foraminifera from main portion of lower member of Vanguard formation (figures 2, 4, 12 and 14 are retouched; figures 3, 10 and 11 are sketches)

Magnification x 57, except figures 2, 4, 7 and 9 (peripheral views) which are x 51

Figure		*Page*
1-5	*Vaginulinopsis eritheles* Loeblich and Tappan. 1, 2, 3: Rush Lake well, possible microspheric form, Univ. of Mo. No. F-56-15; 1, 2—side and peripheral views, 3—sketch of opposite side; 4, 5: Atlas 1 well, possible megalospheric form, Univ. of Mo. No. F-56-16, side and peripheral views	77
6-10	*Vaginulina wickendeni* Wall, n. sp., Frontier well. 6, 7: paratype, immature specimen, Univ. of Mo. No. F-59-4, side and peripheral views; 8-10: holotype, mature specimen, Univ. of Mo. No. F-59-3; 8, 9—side and peripheral views, 10—sketch of opposite side to show chamber arrangement and pitted wall	97
11-15	*Marginulinopsis bandyi* Wall, n. sp. 11-13: Frontier well, holotype, Univ. of Mo. No. F-56-9; 11—sketch of side to show thickened flush sutures, 12, 13—peripheral and opposite side views; 14, 15: Rush Lake well, paratype, Univ. of Mo. No. F-56-10, peripheral and side views (peripheral spines on coiled portion)	72

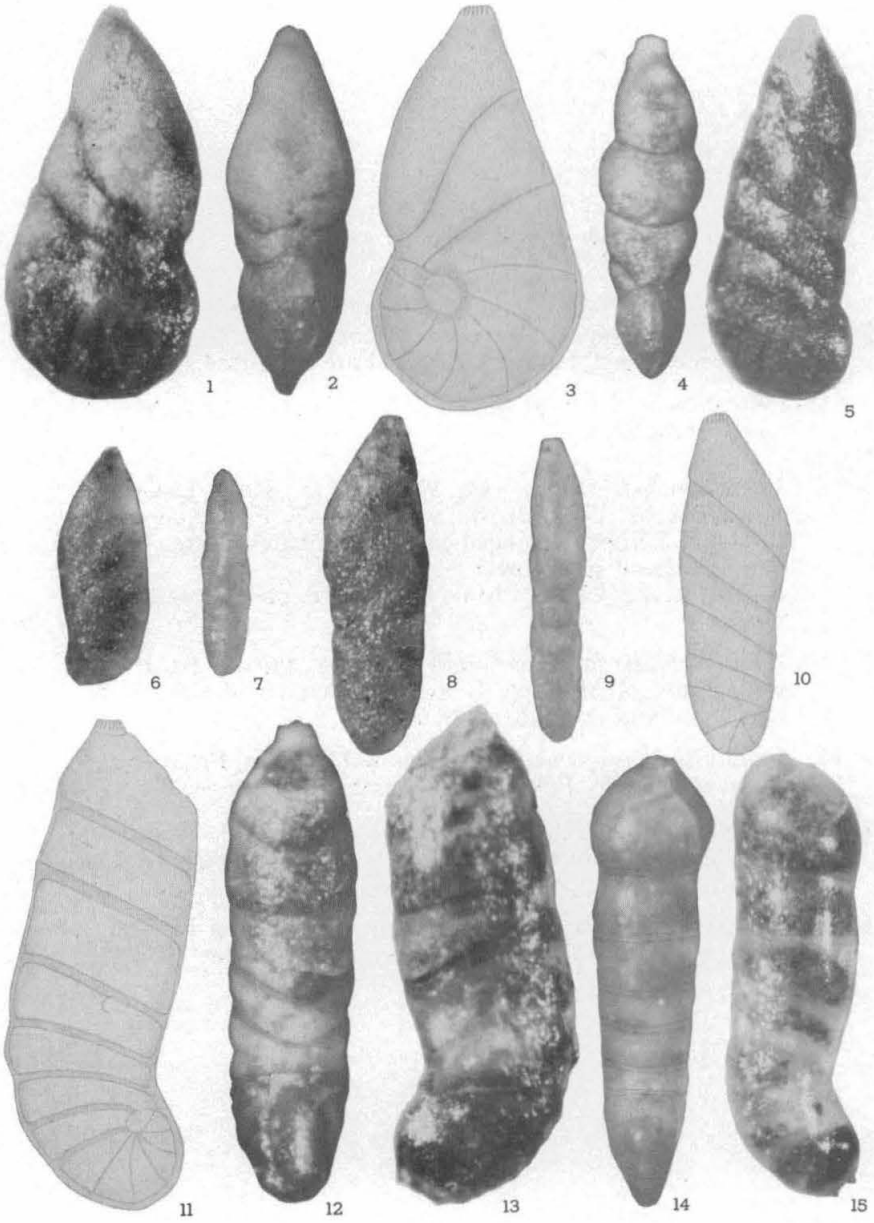

Plate 10 Callovian Foraminifera from main portion of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 11

Photographs and sketches of Foraminifera from main portion of lower member of Vanguard formation (figures 2, 4, 7, 9, 10, 12 and 14 are retouched; figures 1, 6 and 11 are sketches)

Magnification x 59 except figures 7, 9, 12 and 14 (peripheral views) which are x 52.

Figure		*Page*
1-5	*Vaginulinopsis loeblichorum* Wall, n. sp., Rush Lake well. 1-3: holotype, Univ. of Mo. No. F-56-17, 1—sketch of side to show chamber arrangement and limbate sutures, 2, 3—peripheral and side views; 4, 5: paratype, Univ. of Mo. No. F-56-18, peripheral and side views	78
6-8	*Vaginulinopsis loeblichorum* Wall, n. sp., var. A, Rush Lake well, Univ. of Mo. No. F-56-19, 6—sketch of side, 7, 8—peripheral and opposite side views	79
9, 10	*Vaginulinopsis epicharis* Loeblich and Tappan, Frontier well, Univ. of Mo. No. F-56-14, peripheral and side views	76
11-13	*Vaginulinopsis loeblichorum* Wall, n. sp., var. B, Rush Lake well, Univ. of Mo. No. F-56-20, 11—sketch of side, 12, 13—peripheral and opposite side views	79
14, 15	*Vaginulina* cf. *V. cataulaca* Loeblich and Tappan, Atlas 1 well, Univ. of Mo. No. F-58-20, peripheral and side views	95

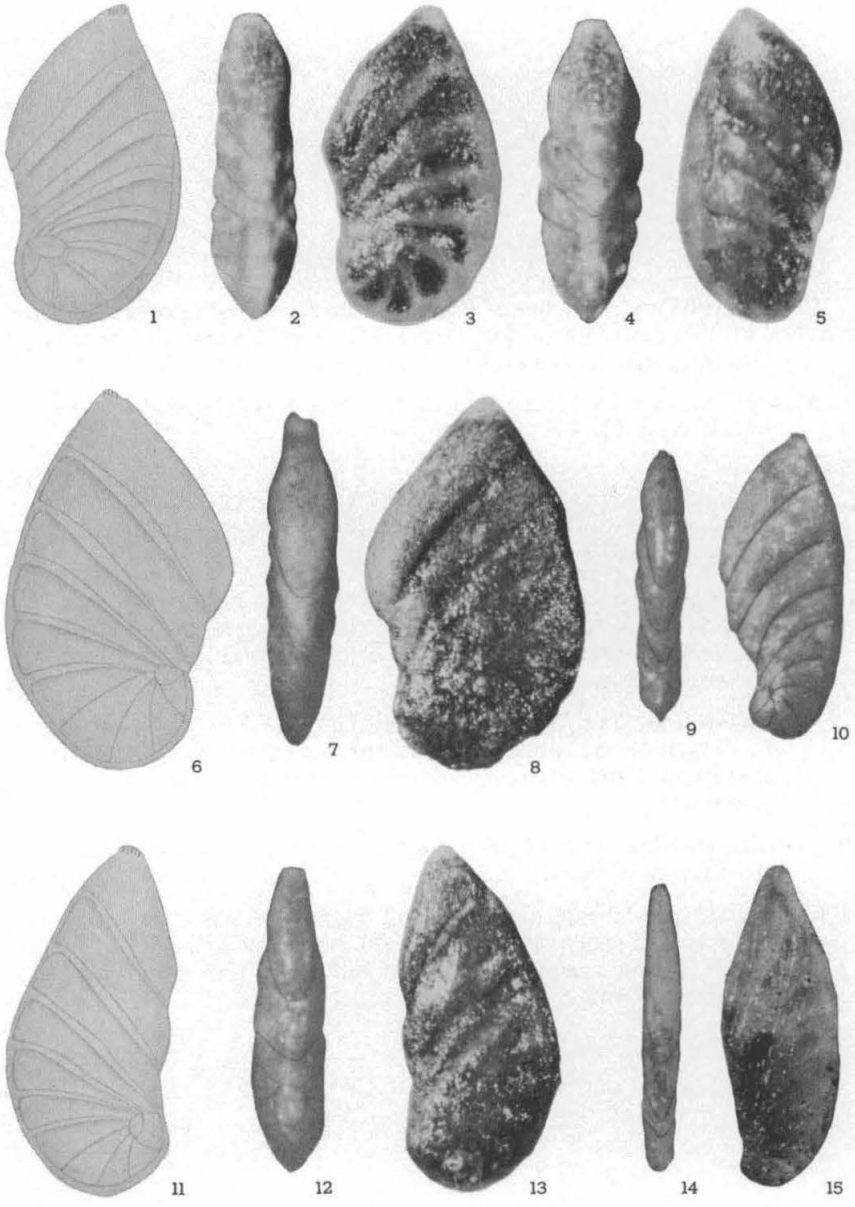

Plate 11 Callovian Foraminifera from main portion of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 12

Photographs and sketches of Foraminifera from main portion of lower member of Vanguard formation (figures 2, 5, 8, 10 and 11 are retouched; figures 1, 4 and 7 are sketches)

Magnification x 58 except figures 2, 5 and 8 (peripheral views) which are x 53.

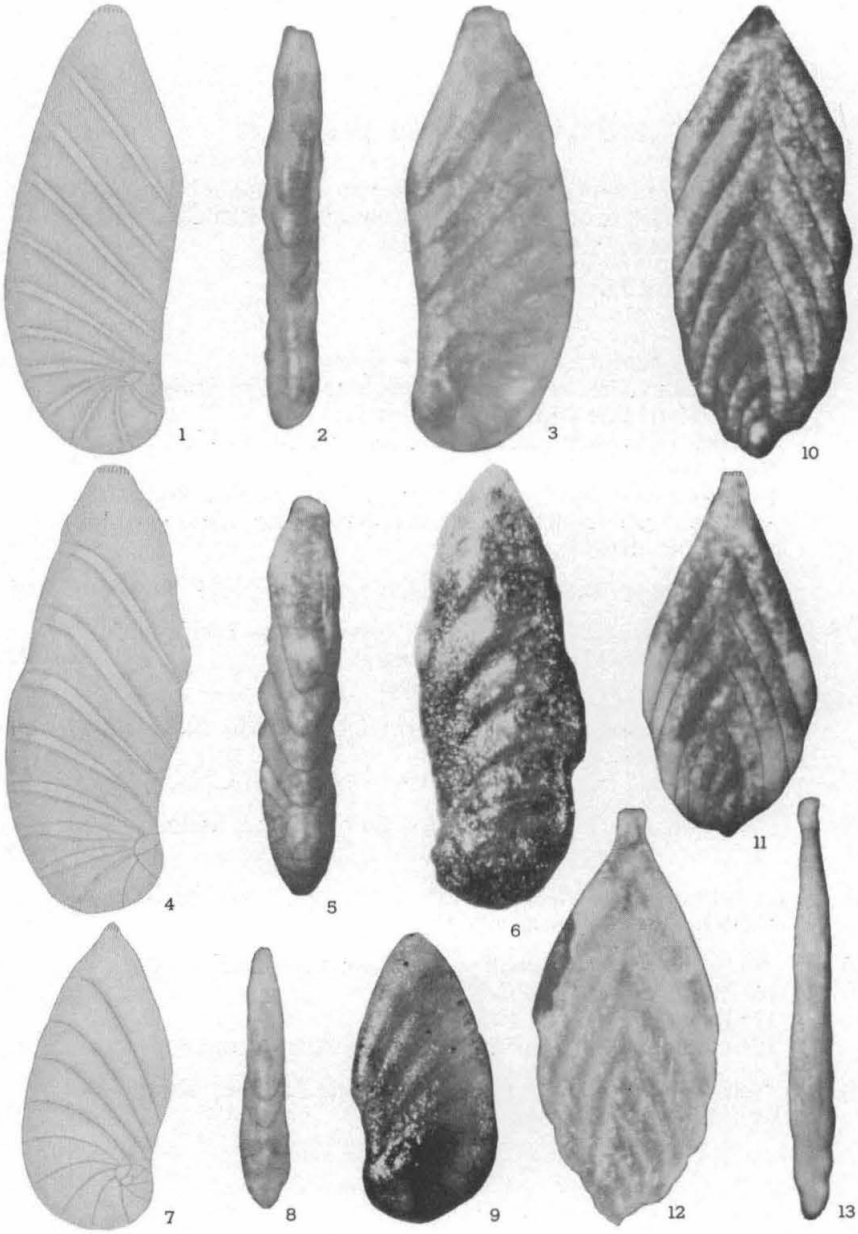

Plate 12 Callovian Foraminifera from main portion of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 13

Photographs and sketches of Foraminifera from main portion of lower member of Vanguard formation (all photographs retouched except figures 4, 5 and 19; figures 8, 9, 14-18 are sketches)

Magnification x 59.

Figure		*Page*
1-5	*Lingulina hathra* Loeblich and Tappan. 1, 2: Rush Lake well, large palmate specimen, Univ. of Mo. No. F-58-6, side and apertural views; 3: Rush Lake well, narrow elongate specimen, Univ. of Mo. No. F-58-7; 4: Atlas 1 well, pyritized specimen, Univ. of Mo. No. F-58-8; 5: Atlas 1 well, hyaline specimen showing fine striations, Univ. of Mo. No. F-58-9	91
6	*Vaginulina* sp. B, Atlas 1 well, Univ. of Mo. No. F-57-12	98
7, 8	*Lingulina micida* Loeblich and Tappan, Atlas 1 well, Univ. of Mo. No. F-58-11, side and apertural views	92
9-12	*Lingulina* sp. C, Atlas 1 well. 9-11: presumed microspheric form, Univ. of Mo. No. F-58-14, side and apertural views; 12: presumed megalospheric form, Univ. of Mo. No. F-58-15	93
13	*Dentalina* cf. *D. liota* Loeblich and Tappan, Atlas 2 well, Univ. of Mo. No. F-57-13	85
14, 15	*Guttulina stilla* Lalicker, Rush Lake well, Univ. of Mo. No. F-60-1, side and basal views	104
16-18	*Nodosaria mecista* Loeblich and Tappan, Frontier well. 16: Univ. of Mo. No. F-57-20; 17: Univ. of Mo. No. F-58-1; 18: Univ. of Mo. No. F-58-2 (later portion incomplete)	88
19	*Nodosaria orthostoecha* Loeblich and Tappan, Rush Lake well, Univ. of Mo. No. F-58-3	89

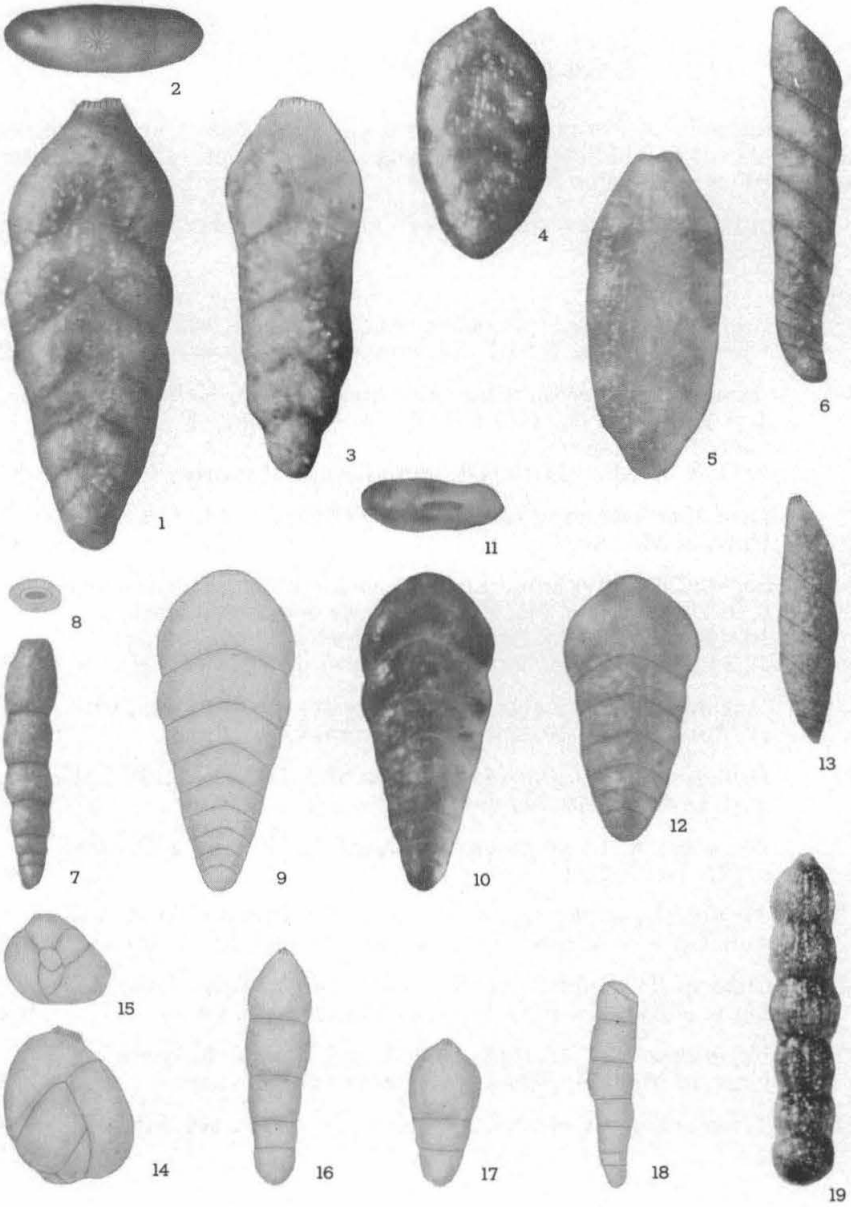

Plate 13 Callovian Foraminifera from main portion of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 14

Photographs of Foraminifera from uppermost beds of lower member and basal beds of middle member of Vanguard formation (all photographs retouched except figures 20, 21 and 24)

Magnification x 58 except figures 21 and 23 (peripheral views) which are x 53

Figure		*Page*
1, 2	*Ammobaculites imlayi* Loeblich and Tappan, Rush Lake well, Univ. of Mo. No. F-54-2, side and apertural views	52
3-6	*Ammobaculites cobbani* Loeblich and Tappan, Kelstern well. 3-5: Univ. of Mo. No. F-53-20, 3—side view, 4—apertural view, 5—peripheral view; 6: Univ. of Mo. No. F-54-1, opposite side of another specimen	51
7	*Dentalina ectadia* Loeblich and Tappan, Rush Lake well, Univ. of Mo. No. F-57-8	83
8-13	*Eoguttulina amygdalina* Loeblich and Tappan, Kelstern well. 8, 9: Univ. of Mo. No. F-59-18, views of opposite sides; 10, 11: Univ. of Mo. No. F-59-19, views of opposite sides; 12,13: Univ. of Mo. No. F-59-20, views of opposite sides	103
14, 15	*Lingulina tumida* Loeblich and Tappan, Kelstern well, Univ. of Mo. No. F-58-10, side and apertural views	92
16	*Dentalina* cf. *D. ejuncida* Loeblich and Tappan, Rush Lake well, Univ. of Mo. No. F-57-9	84
17	*Dentalina* cf. *D. propinqua* Terquem, Rush Lake well, Univ. of Mo. No. F-57-15	86
18, 19	*Haplophragmoides tryssa* Loeblich and Tappan, Rush Lake well, Univ. of Mo. No. F-53-14, side and peripheral views	50
20, 21	*Citharinella latifolia* Loeblich and Tappan, Rush Lake well, Univ. of Mo. No. F-59-14, side and peripheral views	102
22, 23	*Vaginulina* cf. *V. compsa* Loeblich and Tappan, Kelstern well, Univ. of Mo. No. F-59-1, side and peripheral views	96
24	*Nodosaria* sp. A, Rush Lake well, Univ. of Mo. No. F-58-5	90

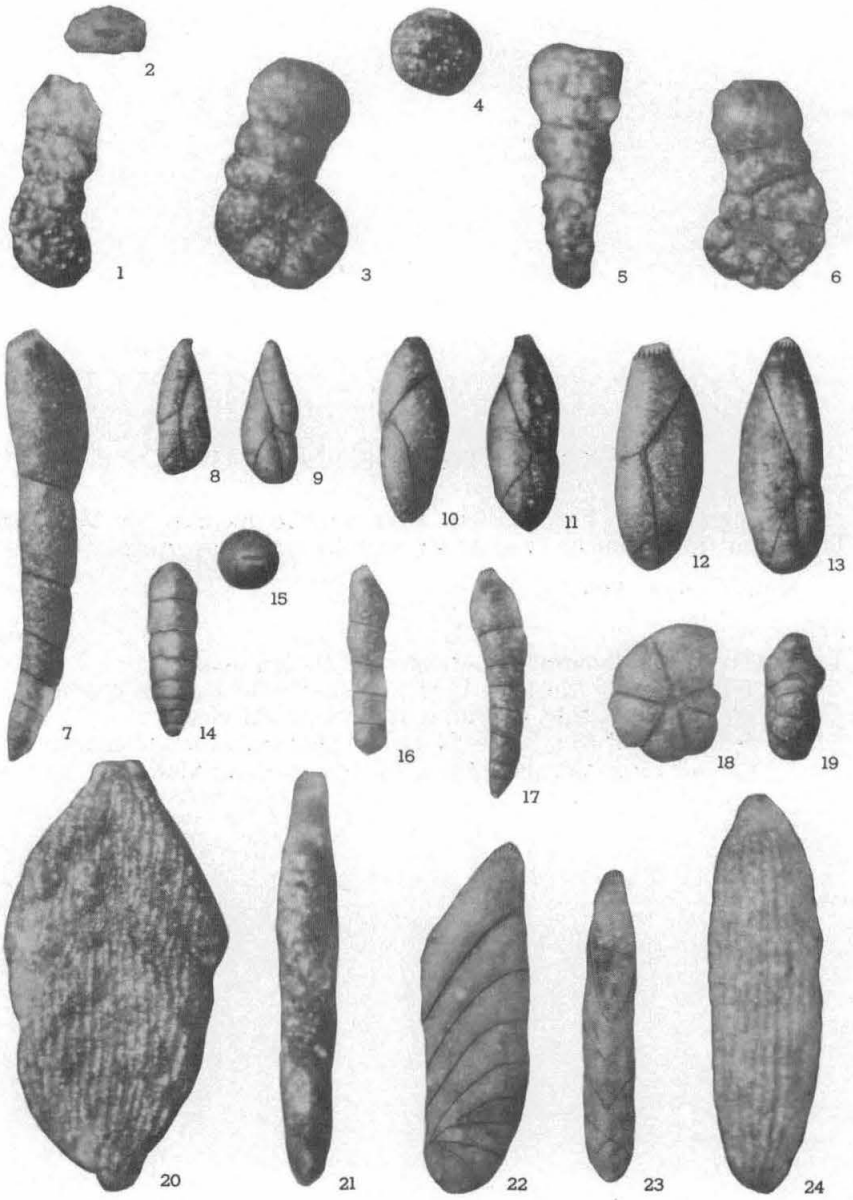

Plate 14 Oxfordian Foraminifera from uppermost beds of lower member and middle member of Vanguard formation (Swift).

EXPLANATION OF PLATE 15

Photographs of Foraminifera from middle member of Vanguard formation (not retouched except for accentuation of apertures)

Magnification x 60

Figure		*Page*
1-6	*Triplasia dahindensa* (Loranger), Kelstern well. 1-3: Univ. of Mo. No. F-54-13, adult individual of coarse-grained form, side, apertural and peripheral views; 4-6: Univ. of Mo. No. F-54-14, juvenile individual of coarse-grained form, side, peripheral and opposite side views	58

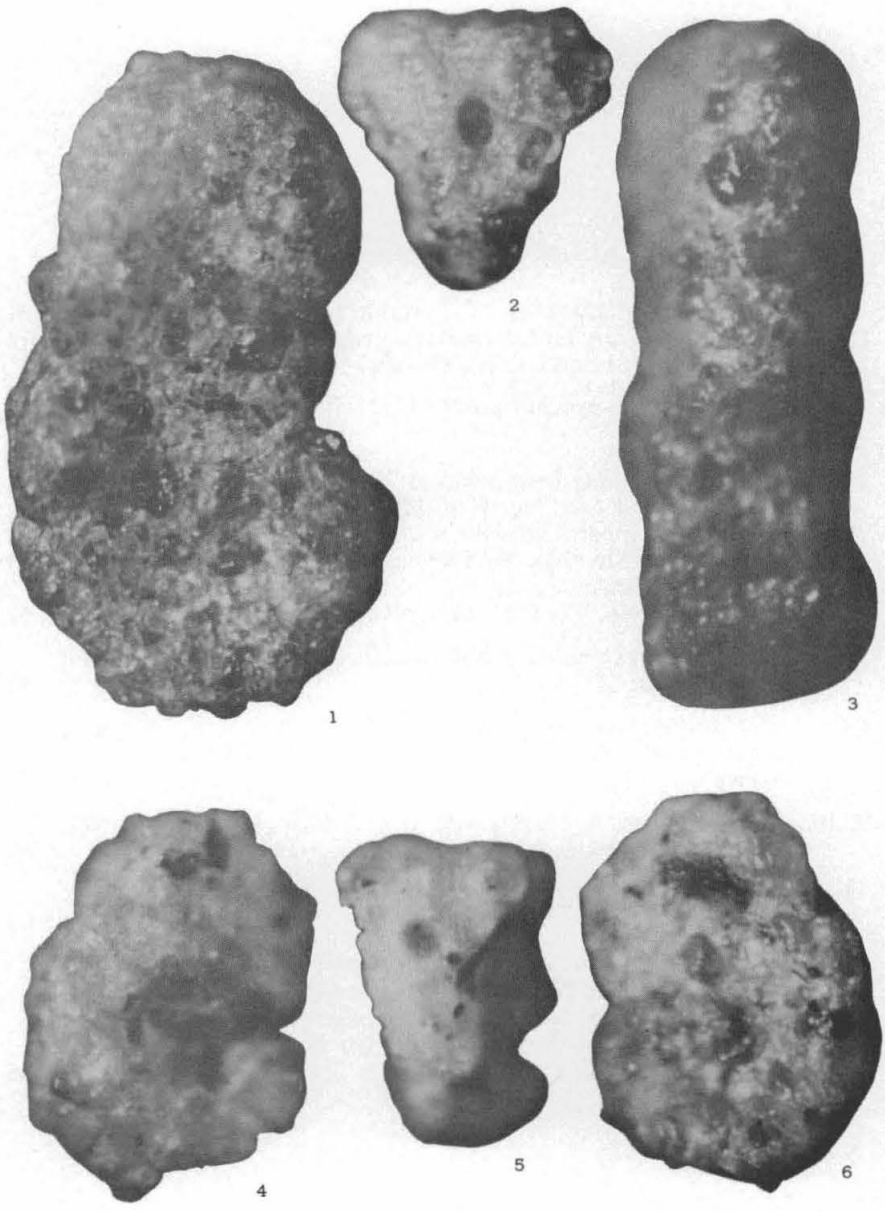

Plate 15 Oxfordian Foraminifera from middle member of Vanguard formation (Swift).

EXPLANATION OF PLATE 16

Photographs and sketches of Foraminifera from lower portion of upper member of Vanguard formation (figures 2, 5, 7, 10 and 15 are retouched; figures 6, 11 and 12 are sketches)

Magnification x 56 except figures 11, 12 which are x 92

Figure		*Page*
1-4	*Lenticulina audax* Loeblich and Tappan, Frontier well. 1, 2: Univ. of Mo. No. F-55-12, an adult hyaline specimen, side and peripheral views; 3: Univ. of Mo. No. F-55-13, a pyritized prominently umbonate specimen; 4: Univ. of Mo. No. F-55-14, a juvenile specimen	67
5	*Dentalina* cf. *D. liota* Loeblich and Tappan, Instow well, Univ. of Mo. No. F-57-14	85
6-8	*Vaginulinopsis thomasi* Wall, n. sp., Frontier well, holotype, Univ. of Mo. No. F-57-2, side, peripheral and opposite side views	81
9, 10	*Lenticulina* sp. A, Instow well, Univ. of Mo. No. F-55-19, side and peripheral views	69
11, 12	*Massilina* sp., Frontier well, Univ. of Mo. No. F-55-3, views of opposite sides	63
13-16	*Lenticulina dilecta* Loeblich and Tappan, Frontier well. 13: Univ. of Mo. No. F-55-16, a juvenile specimen; 14: Univ. of Mo. No. F-55-17, uncoiled specimen; 15, 16: Univ. of Mo. No. F-55-18, large adult specimen, peripheral and side views	68

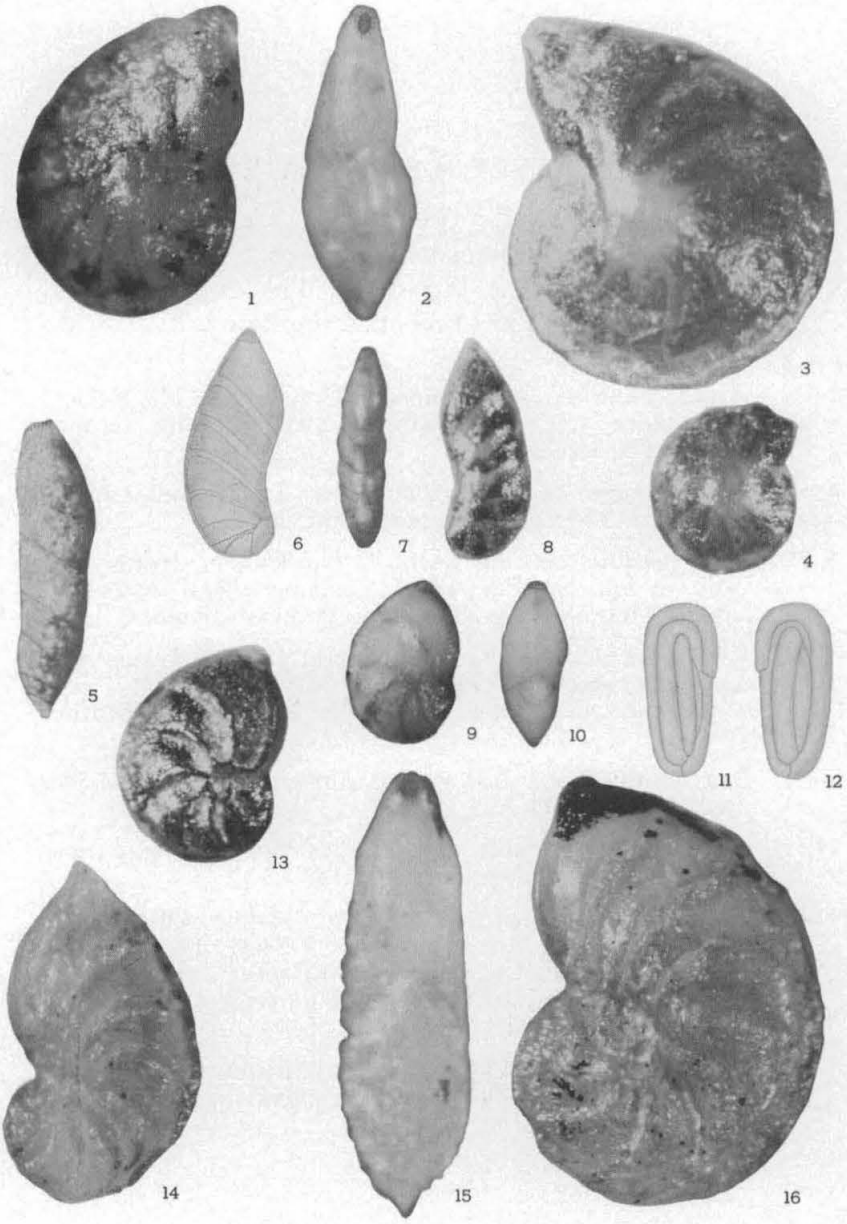

Plate 16 Oxfordian Foraminifera from lower portion of upper member of Vanguard formation (Swift).

EXPLANATION OF PLATE 17

Photographs and sketches of Foraminifera from upper portion of upper member of Vanguard formation (figures 6, 7 and 17 are retouched; figures 8-13 are sketches)

Magnification x 59 except where otherwise stated

Figure		*Page*
1-3	*Ammobaculites* sp. A, Instow well, Univ. of Mo. No. F-53-19; 1—involute side, 2—peripheral view showing terminal aperture, 3—evolute side	53
4, 5	*Haplophragmoides* cf. *H. linki* Nauss, Instow well, Univ. of Mo. No. F-53-15, side and peripheral views	49
6, 7	*Ammobaculites venustus* Loeblich and Tappan, Instow well, Univ. of Mo. No. F-53-18, side and peripheral views (two large crystals of pyrite adhering to terminal chamber)	52
8, 9	*Verneuilinoides tryphera* Loeblich and Tappan, Instow well. 8: elongate specimen, Univ. of Mo. No. F-54-20; 9: short specimen, Univ. of Mo. No. F-55-1; magnifications x 93	62
10	*Bulbobaculites*? sp., Instow well, Univ. of Mo. No. F-54-9, magnification x 93	56
11, 12	*Miliammina* sp., Instow well, Univ. of Mo. No. F-55-4, views of opposite sides, magnification x 127	64
13-17	*Trochammina instowensis* Wall, n. sp., Instow well. 13-16: holotype, Univ. of Mo. No. F-54-17, 13, 14—dorsal side, 15—peripheral view, 16—ventral view; 17: paratype, Univ. of Mo. No. F-54-18, ventral view showing prominent umbilicus	60
18-20	*Flabellammina instowensis* Wall, n. sp., Instow well, holotype, Univ. of Mo. No. F-54-10, side, peripheral and opposite side views	57

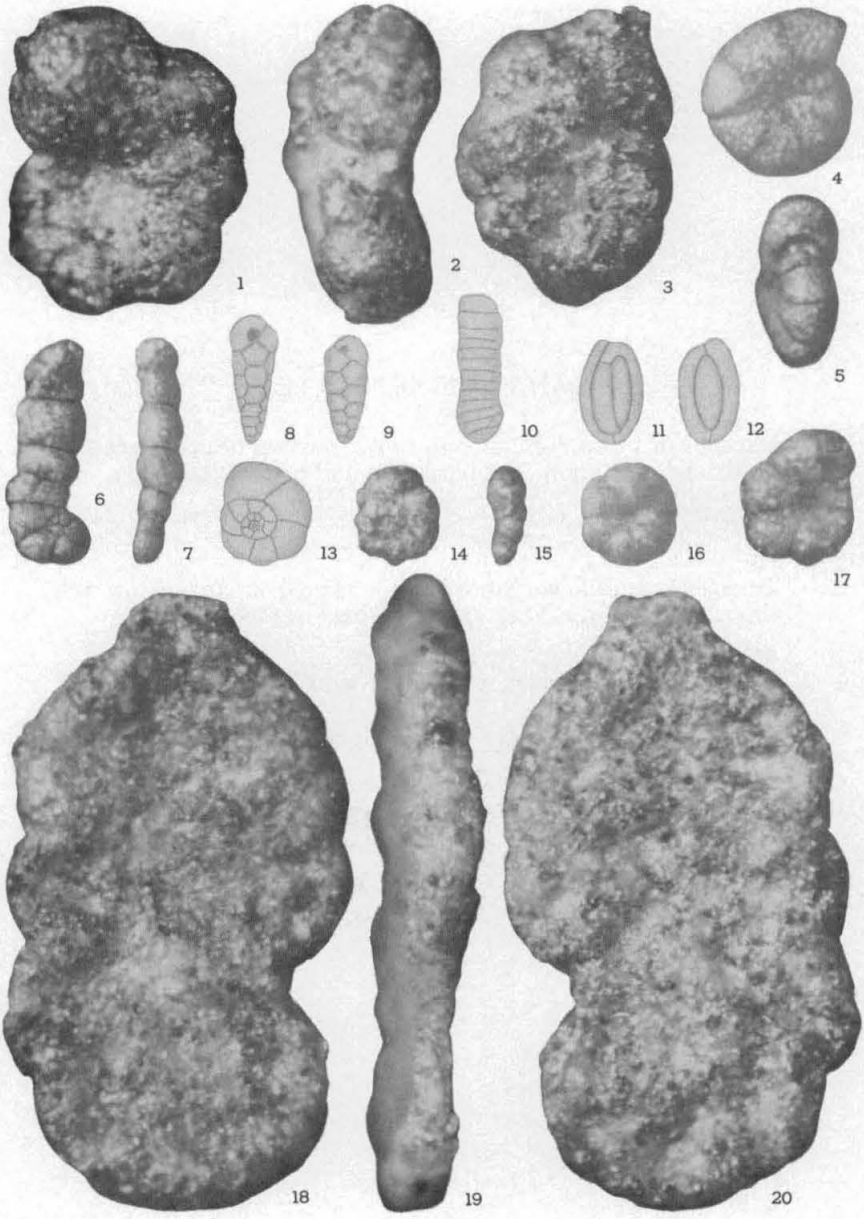

Plate 17 Oxfordian Foraminifera from upper portion of upper member of Vanguard formation (Swift).

EXPLANATION OF PLATE 18

Photographs of Foraminifera from upper portion of upper member of Vanguard formation (figures 2, 4, 5 and 8 are retouched)

Magnification x 56

Figure		*Page*
1, 2	*Ammomarginulina baryntica* Loeblich and Tappan, Instow well, Univ. of Mo. No. F-54-4, side and apertural views	54
3, 4 7-9	*Ammomarginulina* sp. A, Instow well. 3, 4: juvenile specimen, Univ. of Mo. No. F-54-5, views of opposite sides; 7-9: adult specimen, Univ. of Mo. No. F-54-6, side, peripheral and opposite side views	56
5, 6	*Ammomarginulina* cf. *A. cragini* Loeblich and Tappan, Instow well, Univ. of Mo. No. F-54-7, views of opposite sides (terminal chamber is broken)	55

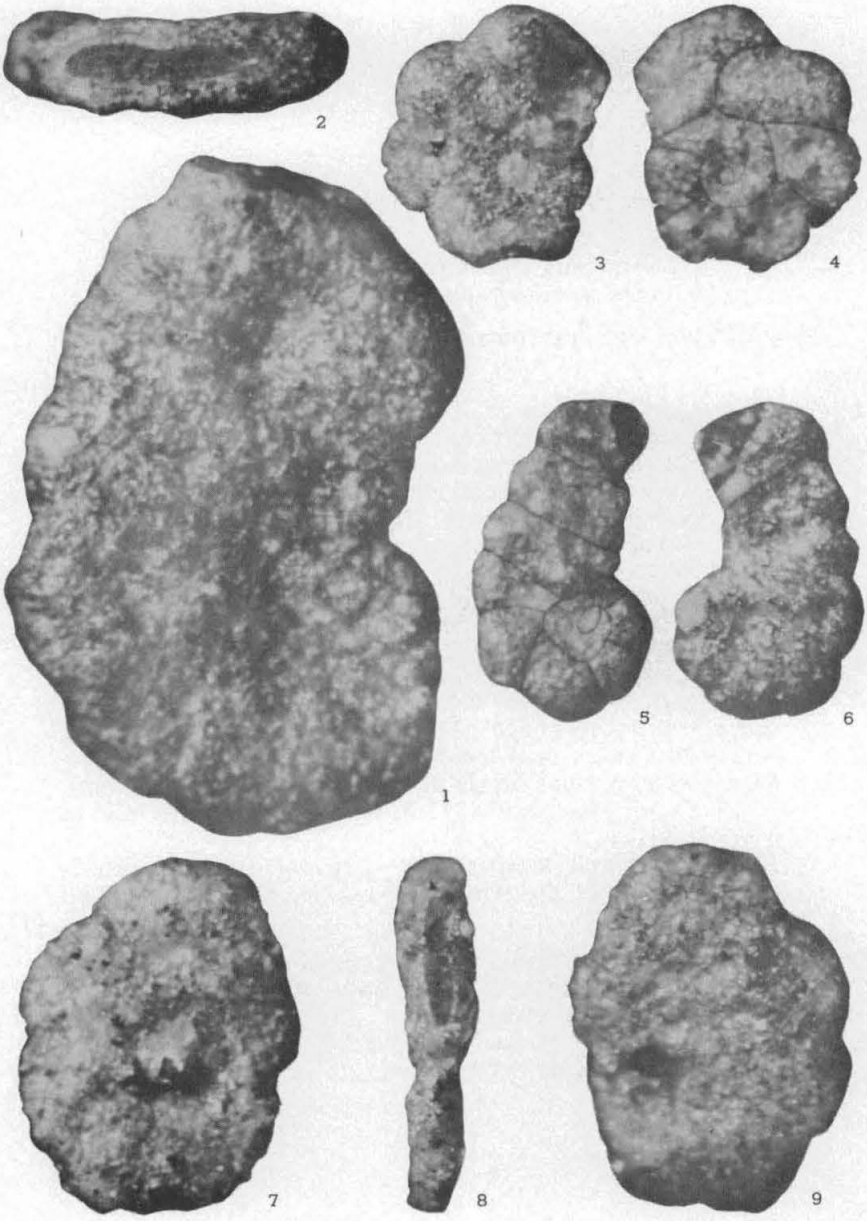

Plate 18 Oxfordian Foraminifera from upper portion of upper member of Vanguard formation (Swift).

EXPLANATION OF PLATE 19

Ostracoda from Shaunavon formation
(retouched photographs of whitened specimens)

Magnification x 55 approximately

Figure *Page*

1-13, 18-20 *Aparchitocythere* cf. *A. compressa* Peterson.
1-5: Eastend well, adult carapaces; 1, 2—male, Univ. of Mo. No. 0-1210-14, left side and dorsal views; 3, 4—female, Univ. of Mo. No. 0-1210-15, left side and dorsal views; 5—female, Univ. of Mo. No. 0-1210-16, left side view, not whitened—shows radial canals in anterior end and normal canals over shell surface.
6-9: Kelstern well, juvenile carapaces; 6, 7—male, Univ. of Mo. No. 0-1210-17, left side and dorsal views; 8, 9—female, Univ. of Mo. No. 0-1210-18, left side and dorsal views.
10-13: Kelstern well, interiors of juvenile valves; 10—male, left, Univ. of Mo. No. 0-1210-19 (shows terminal sockets connected by valve edge); 11—male, right, Univ. of Mo. No. 0-1210-20 (shows teeth connected by interterminal groove, muscle scar, normal canals and inner margin); 12—female, left, Univ. of Mo. No. 0-1211-1; 13—female, right, Univ. of Mo. No. 0-1211-2.
18-20: Instow well, carapaces; 18—Univ. of Mo. No. 0-1211-5, left side view; 19, 20—Univ. of Mo. No. 1211-6, dorsal and right side views 117

14-17 *Aparchitocythere elongata* Peterson, Eastend well.
14, 15: short carapace (male?), Univ. of Mo. No. 0-1211-3, left side and dorsal views;
16, 17: elongate carapace (female?), Univ. of Mo. No. 0-1211-4, left side and dorsal views 119

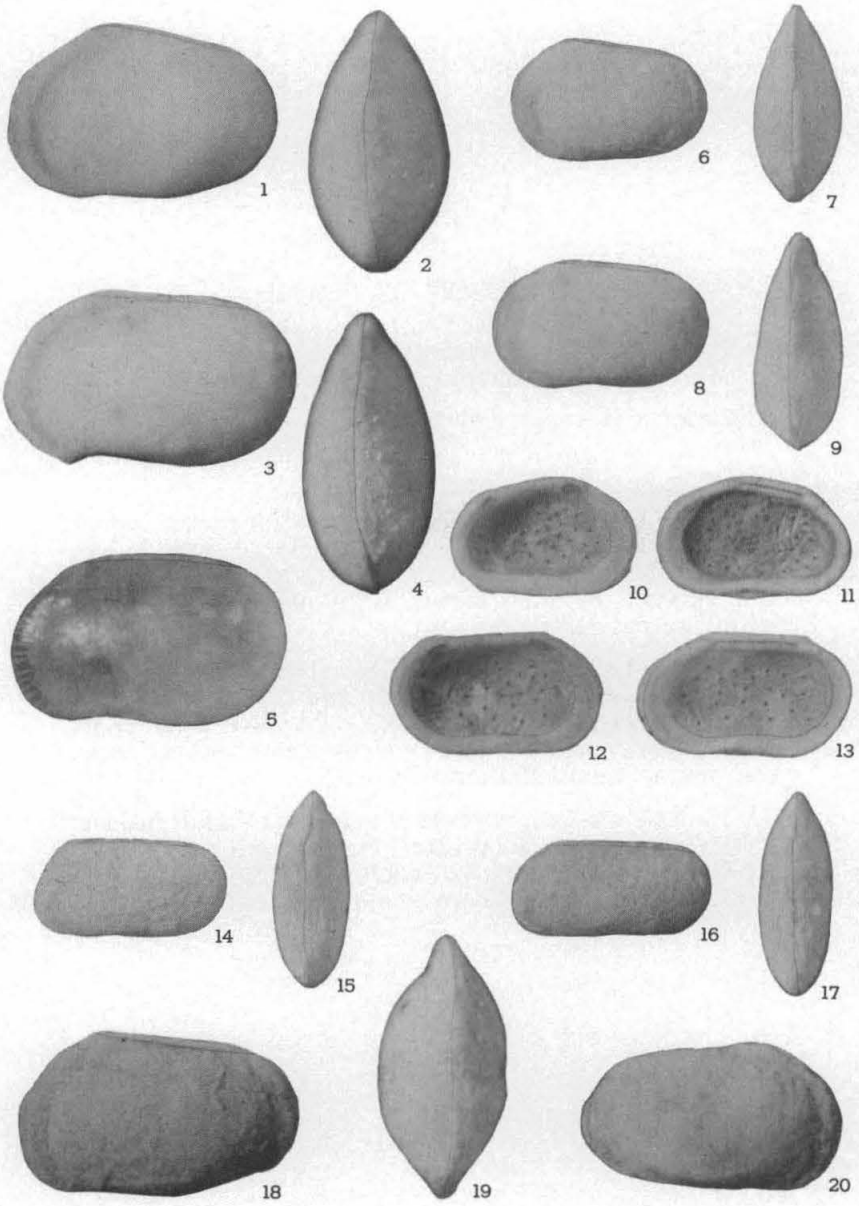

Plate 19 Bathonian Ostracoda from Shaunavon formation.

EXPLANATION OF PLATE 20

Ostracoda from upper member of Shaunavon formation
(retouched photographs of whitened specimens)

Magnification x 55 approximately

Figure *Page*

1-12 *Norcanolella parryi* Loranger.
1-6: Rush Lake well, carapaces; 1, 2—adult male?, Univ. of Mo. No. 0-1212-19, right side and dorsal views; 3,4—juvenile male, Univ. of Mo. No. 0-1212-20, dorsal and right side views; 5, 6—adult female, Univ. of Mo. No. 0-1213-1, right side and dorsal views.

7-10: Rush Lake well, adult male? valves; 7, 8—left valve, Univ. of Mo. No. 0-1213-2, interior and dorsal views (shows teeth formed of valve edge); 9, 10—right valve, Univ. of Mo. No. 0-1213-3, dorsal and interior views (shows sockets, muscle scar, normal canals and inner margin).

11, 12: Kelstern well, interiors of valves; 11—adult male left valve, Univ. of Mo. No. 0-1213-4 (shows teeth, interterminal groove and muscle scar); 12—adult female right valve, Univ. of Mo. 0-1213-5 (shows normal and radial canals) 135

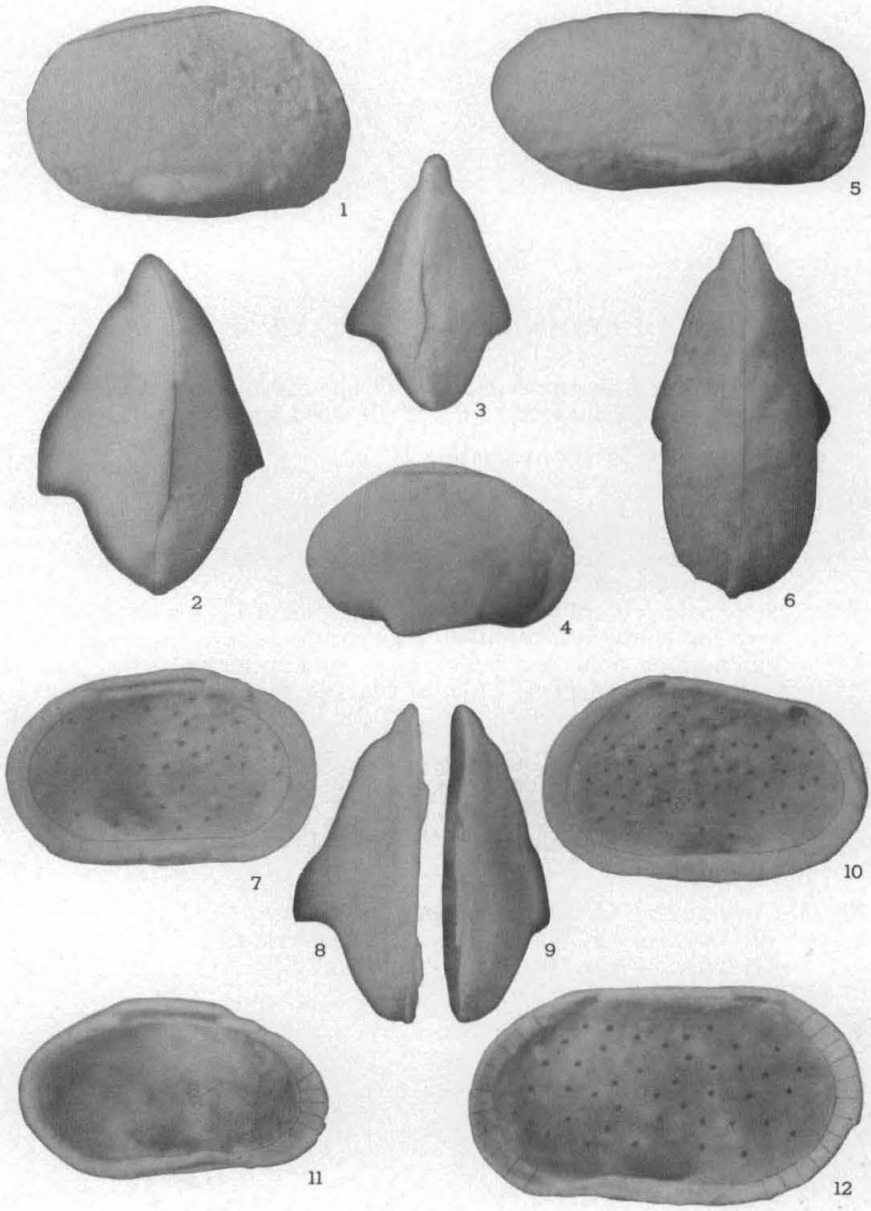

Plate 20 Bathonian Ostracoda from upper member of Shaunavon formation.

EXPLANATION OF PLATE 21

Ostracoda from upper member of Shaunavon formation
(retouched photographs of whitened specimens)

Magnification x 55 approximately

Figure *Page*

1-5 *Norcanolella* sp. A, Rush Lake well.
1, 2: male carapace, Univ. of Mo. No. 0-1213-6, right side and dorsal views;
3: female left valve, Univ. of Mo. No. 0-1213-8, interior showing teeth, interterminal groove, muscle scar, inner margin, normal canals and radial canals (in interior end);
4, 5: female carapace, Univ. of Mo. No. 0-1213-7, right side and dorsal views 136

6-9 *Norcanolella*? sp. B, Kelstern well, carapaces.
6, 7: male, Univ. of Mo. No. 0-1213-9, right side and dorsal views (muscle scar visible on wall);
8, 9: female, Univ. of Mo. No. 0-1213-10, right side and dorsal views 137

10, 11 *Cythereis*? sp. C, Carievale well, carapaces.
10: Univ. of Mo. No. 0-1211-17, left side view;
11: Univ. of Mo. No. 0-1211-18, dorsal view 125

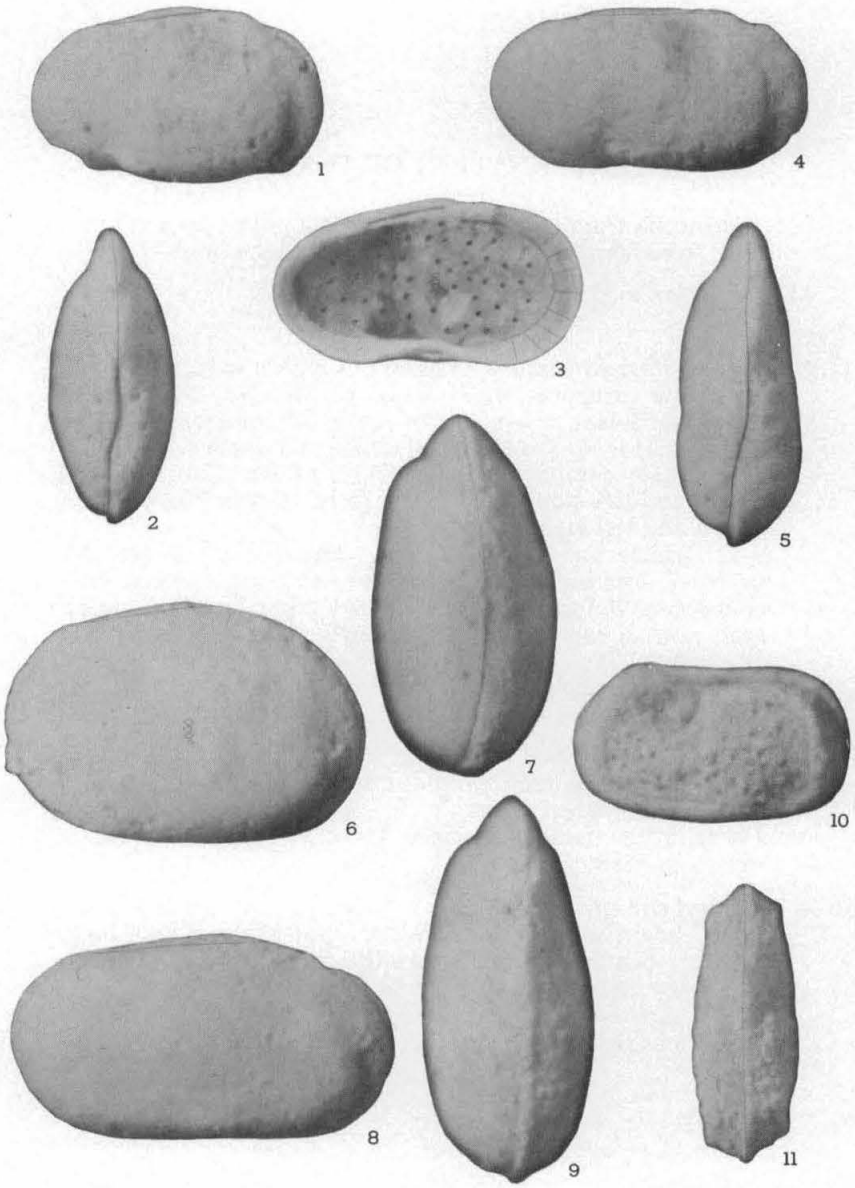

Plate 21 Bathonian Ostracoda from upper member of Shaunavon formation.

EXPLANATION OF PLATE 22

Ostracoda from upper member of Shaunavon formation
(retouched photographs of whitened specimens)

Magnification x 55 approximately

Figure *Page*

1-12 *Limnocythere climaxia* (Loranger), Kelstern well.
1-4: male carapaces; 1, 2—Univ. of Mo. No. 0-1212-3, left side and dorsal views; 3, 4—more ornamented specimen, Univ. of Mo. No. 0-1212-4, right side and dorsal view.
5-8: female carapaces; 5, 6—Univ. of Mo. No. 0-1212-5, dorsal and left side views; 7, 8—Univ. of Mo. No. 0-1212-6, dorsal and left side views.
9-12: female valves; 9, 10—left valve, Univ. of Mo. No. 0-1212-7, interior and dorsal views—showing sockets, interconnecting flange projection, broad inner lamellae, muscle scar, normal canals and radial canals (in anterior end); 11, 12—right valve, Univ. of Mo. No. 0-1212-8, dorsal and interior views—showing teeth formed of valve edge and interterminal groove 127

13-15 *Limnocythere pustulosa* Wall, n. sp., Frontier well, holotype.
13, 14: holotype, male carapace, Univ. of Mo. No. 0-1212-9, left side and dorsal views;
15: paratype, female carapace, Univ. of Mo. No. 0-1212-10, right side view 129

16-18 *Paracypris*? sp. A.
16: Kelstern well, right valve, Univ. of Mo. No. 0-1210-10, interior showing marked separation of line of concrescence and inner margin in anterior end;
17, 18: Eastend well, carapace, Univ. of Mo. No. 0-1210-9, dorsal and right side views 115

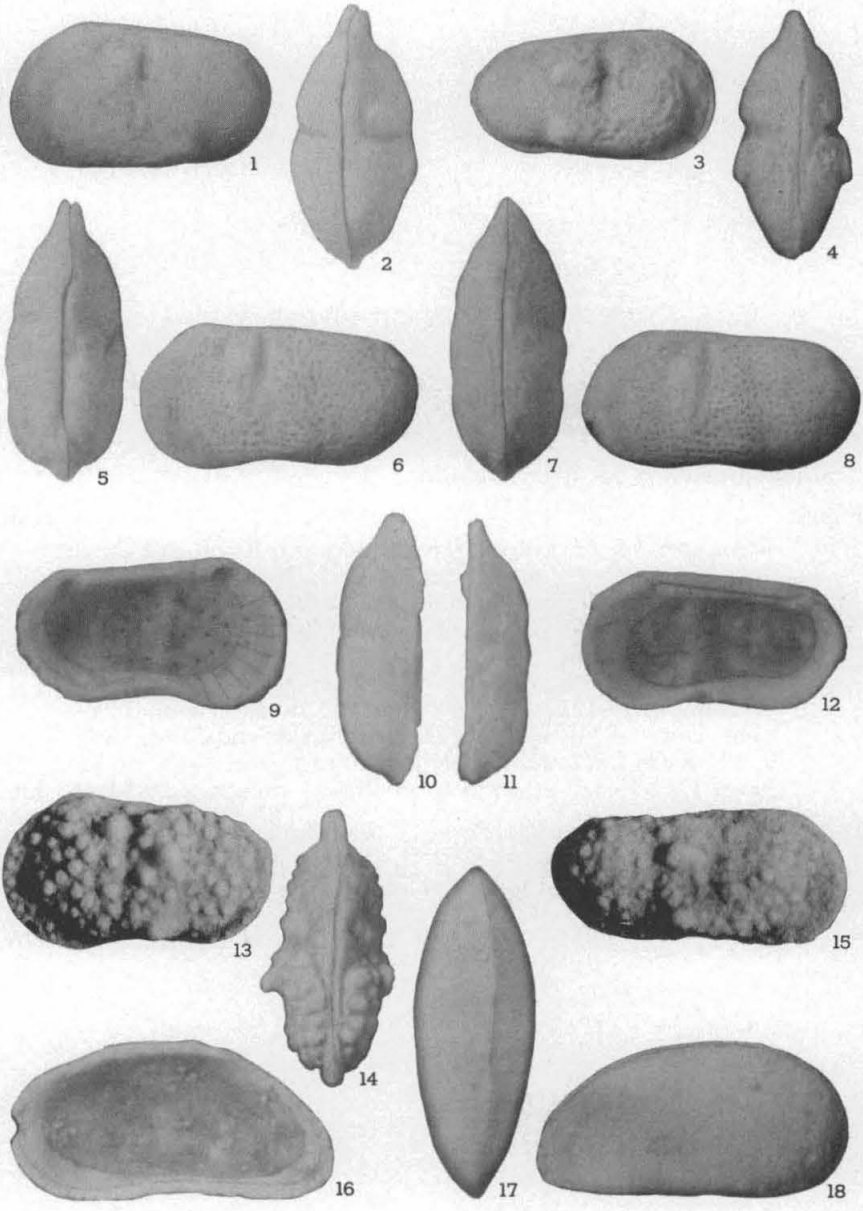

Plate 22 Bathonian Ostracoda from upper member of Shaunavon formation.

EXPLANATION OF PLATE 23

Ostracoda from upper member of Shaunavon formation
(photographs of whitened specimens—
figures 1, 3, 5, 7, 9, 11, 12 and 13 are retouched)

Magnification x 55 approximately

Figure		*Page*
1-10	*Metacypris* cf. *M. tenuimarginata* Bernard, Bizon and Oertli. 1-4: Frontier well, adult carapaces; 1, 2—female, Univ. of Mo. No. 0-1212-11, right side and dorsal views; 3, 4—male, Univ. of Mo. No. 0-1212-12, right side and dorsal views—muscle scar visible. 5-8: Frontier well, juvenile carapaces; 5, 6—female, Univ. of Mo. No. 0-1212-13, right side and dorsal views; 7, 8—male, Univ. of Mo. No. 0-1212-14, right side and dorsal views. 9, 10: Rush Lake well, adult female carapace, Univ. of Mo. No. 0-1212-15, left side and dorsal views—muscle scar visible	130
11-13	*Darwinula leguminella* (Forbes), Rush Lake well, carapaces. 11: Univ. of Mo. No. 0-1210-11, left side view showing pronounced overlap of right valve and rosette pattern of muscle scar; 12, 13: Univ. of Mo. No. 0-1210-12, left side and dorsal views	116

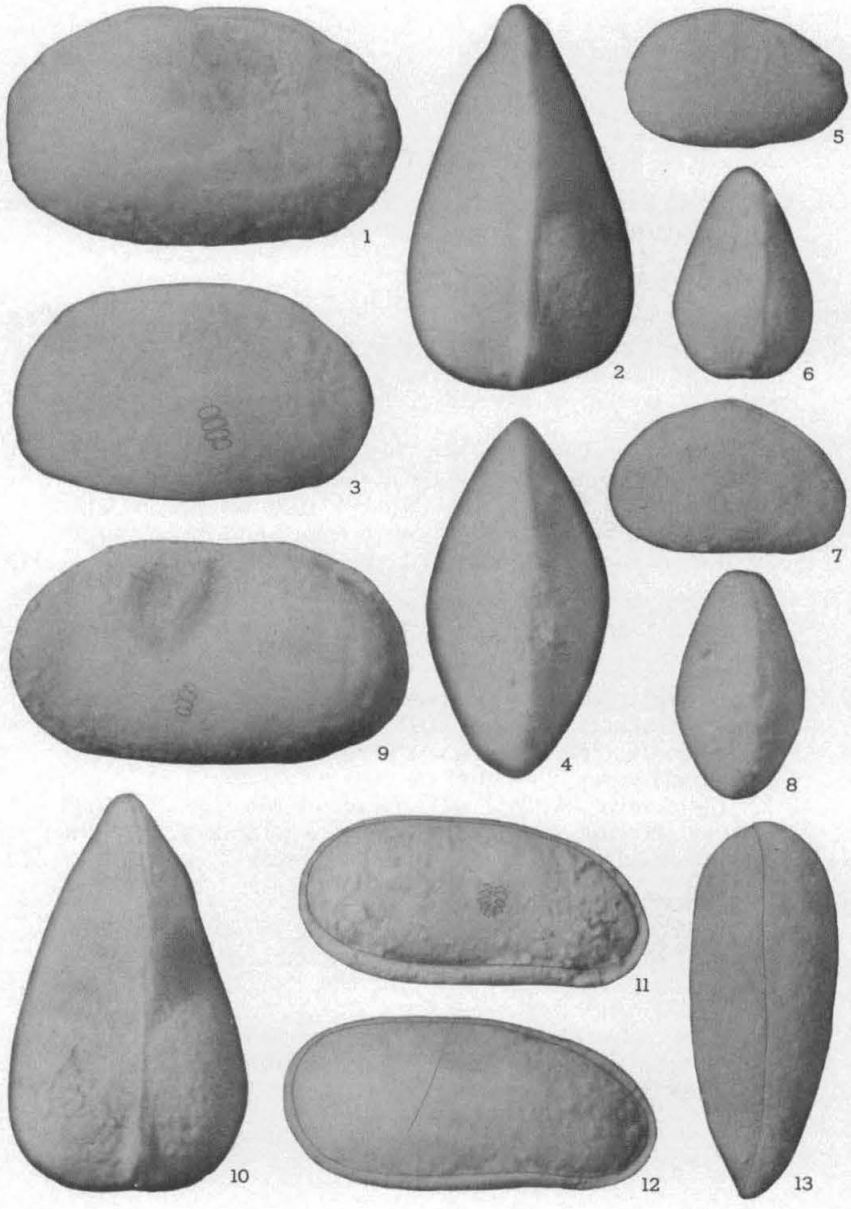

Plate 23 Bathonian Ostracoda from upper member of Shaunavon formation.

EXPLANATION OF PLATE 24

Ostracoda from basal and main portions of lower member of Vanguard formation (retouched photographs of whitened specimens)

Magnification x 55 approximately

Figure — *Page*

1-7 *Bythocypris ambitruncata* Peterson, Carievale well.
1-3: carapace, Univ. of Mo. No. 0-1210-4, 1—right side view showing overlap of left valve, 2—left side view, 3—dorsal view;
4-6: carapace, Univ. of Mo. No. 0-1210-5, 4—right side view, 5—left side view, 6—dorsal view;
7: right valve, Univ. of Mo. No. 0-1210-6, interior showing marked separation of line of concrescence and inner margin around anterior and posterior ends 113

8, 9 *Cytherella paramuensteri* Swain and Peterson, Carlyle well, carapace, Univ. of Mo. No. 0-1210-1, left side and dorsal views 110

10-13 *Cytherelloidea recurvata* Peterson.
10-12: carapace, Wapella 16-33 well, Univ. of Mo. No. 0-1210-2; 10—left side view showing right valve overlap, 11—dorsal view, 12—right side view.
13: right valve, Atlas 1 well, Univ. of Mo. No. 0-1210-3, interior showing groove around entire periphery, and the median circular elevation of the muscle scar 111

14-18 *Progonocythere anoda* Peterson.
14, 15, 17, 18: carapaces, Instow well, 14, 15—short (male?), Univ. of Mo. No. 0-1214-6, right side and dorsal views; 17, 18—elongate (female?), Univ. of Mo. No. 0-1214-7, right side and dorsal views.
16: right valve, Atlas 1 well, Univ. of Mo. No. 0-1214-8, interior showing hinge teeth, interconnecting grooved valve edge, muscle scar and normal canals 145

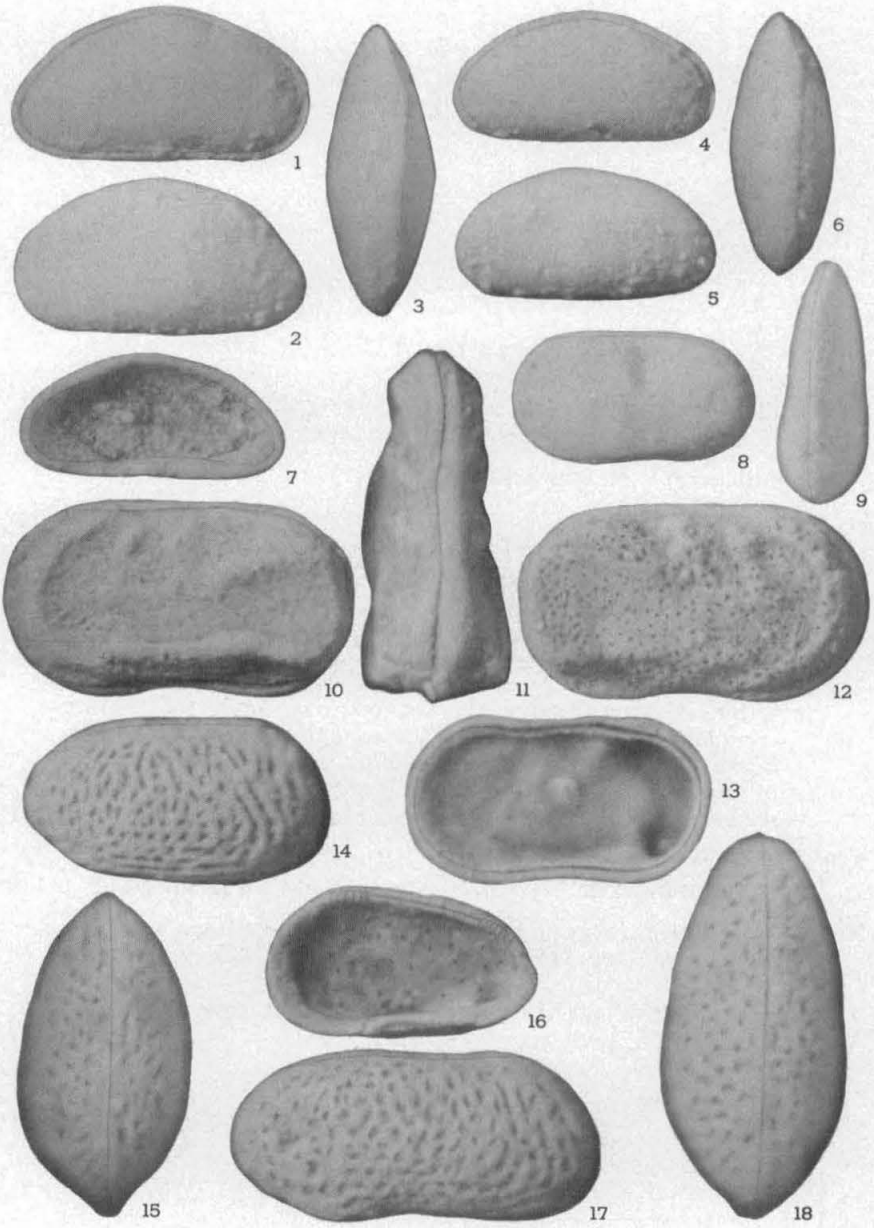

Plate 24 Callovian Ostracoda from basal and main portions of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 25

Ostracoda from basal portion of lower member of Vanguard formation (retouched photographs of whitened specimens)

Magnification x 74 approximately

Figure		*Page*
1-6	*Procytheridea exempla* Peterson, Kelstern well. 1, 3: male carapace, Univ. of Mo. No. 0-1213-16, right side and dorsal views; 2, 4: female carapace, Univ. of Mo. No. 0-1213-17, right side and dorsal views; 5, 6: male valves; 5—left, Univ. of Mo. No. 0-1213-18, interior showing denticulate sockets connected by weakly crenulate bar, the prominent accommodation groove and the broad inner lamellae; 6—right, Univ. of Mo. No. 0-1213-19, interior showing hinge teeth connected by grooved valve edge, the muscle scar and the broad inner lamellae	141
7, 8	*Procytheridea crassa* Peterson, Rush Lake well, carapace, Univ. of Mo. No. 0-1213-15, right side and dorsal views	140
9-12	*Procytheridea minuta* Peterson, carapaces, Kelstern well. 9, 10: Univ. of Mo. No. 0-1213-20, right side and dorsal views; 11, 12: Univ. of Mo. No. 0-1214-1, right side and dorsal views	142

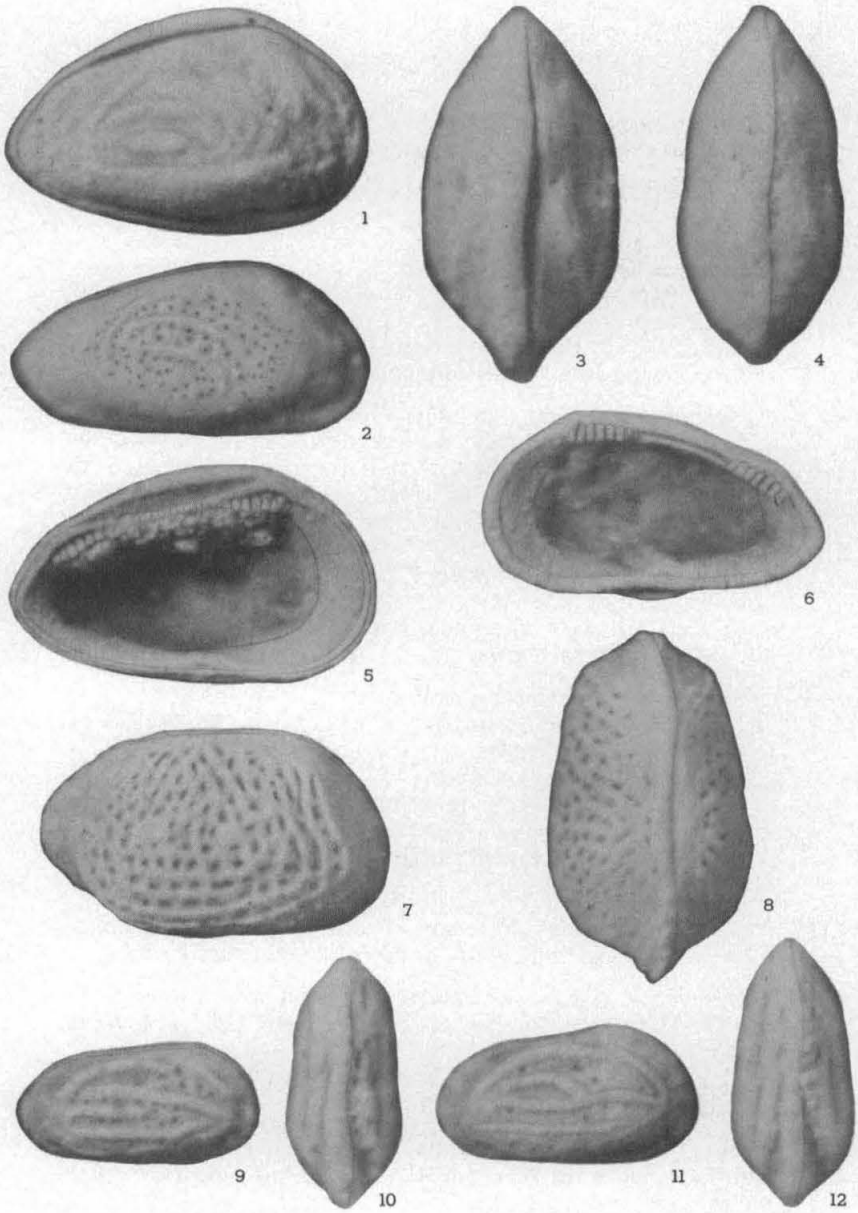

Plate 25 Callovian Ostracoda from basal portion of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 26

Ostracoda from basal and main portions of lower member of Vanguard formation (retouched photographs of whitened specimens)

Magnification x 74 approximately

Figure		*Page*
1-3	*Cythereis heteromorpha* Peterson. 1, 2: Kelstern well, carapace, Univ. of Mo. No. 0-1211-7, left side and dorsal views; 3: Atlas 2 well, right valve, Univ. of Mo. No. 0-1211-8, interior showing small teeth connected by grooved valve edge	121
4-9	*Eucytherura reticulata* Peterson. 4, 5: Atlas 1 well, valves; 4—left valve, Univ. of Mo. No. 0-1212-1, interior showing terminal sockets connected by arched bar (inner side of valve edge); 5—right valve, Univ. of Mo. No. 0-1212-2, interior showing small teeth connected by grooved valve edge. 6, 7: Atlas 1 well, carapace, Univ. of Mo. No. 0-1211-20, dorsal and right side views. 8, 9: Kelstern well, carapace, Univ. of Mo. No. 0-1211-19, left side and dorsal views	126
10-13	*Orthonotacythere dorsoconvexa* Peterson. 10, 11: Kelstern well, carapace, Univ. of Mo. No. 0-1213-11, left side and dorsal views; 12, 13: Atlas 2 well, valves; 12—left, Univ. of Mo. No. 0-1213-13, interior showing terminal sockets connected by weakly crenulate valve edge; 13—right, Univ. of Mo. No. 0-1213-14, interior showing small teeth connected by weakly crenulate valve edge	138
14, 15	*Monoceratina incisa* Peterson, Rush Lake well, carapace, Univ. of Mo. No. 0-1212-16, dorsal and right side views	131
16-19	*Monoceratina pararossae* Peterson, Atlas 1 well, carapaces. 16, 17: Univ. of Mo. No. 0-1212-17, right side and dorsal views; 18, 19: left side and dorsal views of a well-preserved pyritized specimen lost after being photographed	132
20, 21	*Monoceratina vulsa* (Jones and Sherborn), Rush Lake well, carapace, Univ. of Mo. No. 0-1212-18, left side and dorsal views	133
22	*Paracypris projecta* Peterson, Johnston Lake well, carapace, Univ. of Mo. No. 0-1210-7, right side view showing left valve overlap	114

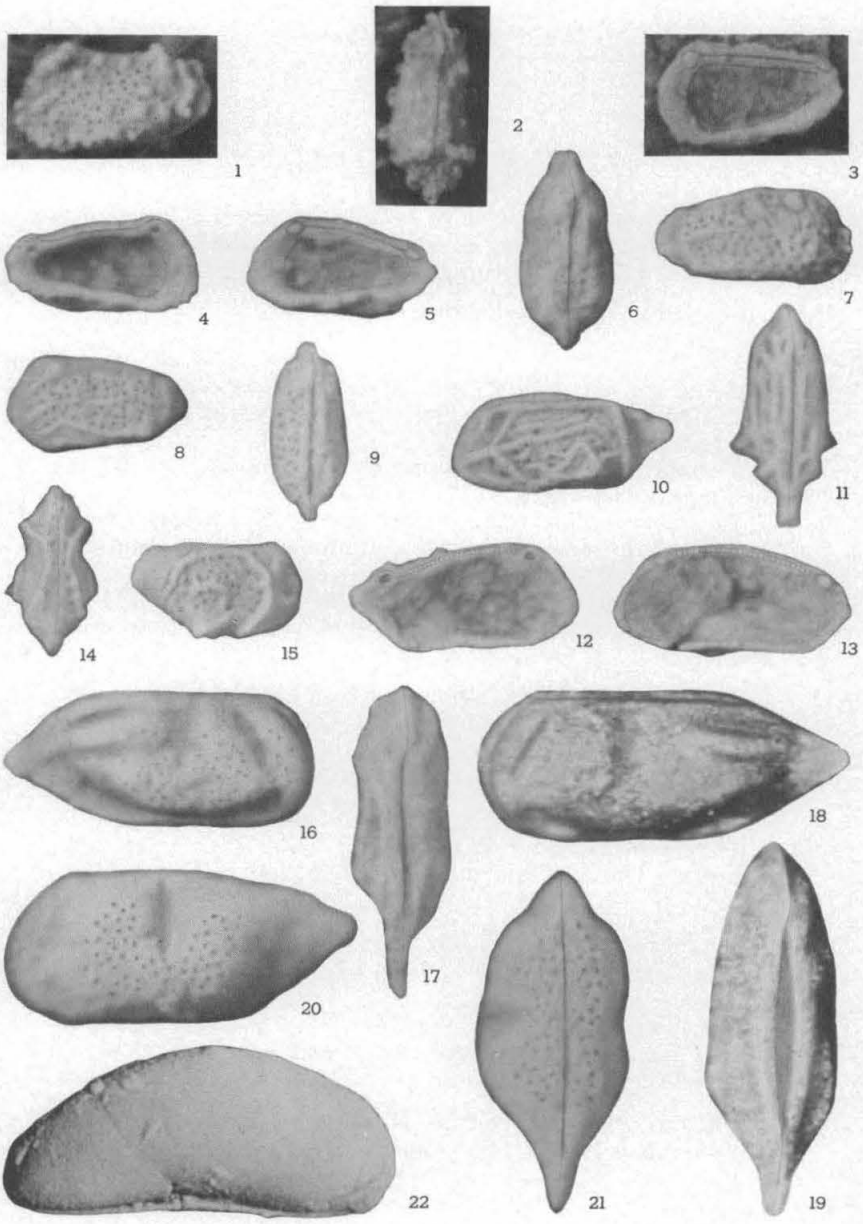

Plate 26 Callovian Ostracoda from basal and main portions of lower member of Vanguard formation (Rierdon).

EXPLANATION OF PLATE 27

Ostracoda from uppermost beds of lower member and basal beds of middle member of Vanguard formation
(retouched photographs of whitened specimens)

Magnification x 74 approximately

Figure *Page*

1-8 *Cythereis robertsi* Wall, n. sp., Kelstern well.
1, 2: holotype, carapace, Univ. of Mo. No. 0-1211-9, left side and dorsal views;
3, 4: paratype, carapace, Univ. of Mo. No. 0-1211-10, left side and dorsal views;
5, 7: paratype, left valve, Univ. of Mo. No. 0-1211-11, interior and dorsal views showing terminal sockets connected by valve edge;
6, 8: paratype, right valve, Univ. of Mo. No. 0-1211-12, interior and dorsal views showing weakly incised dental units connected by grooved valve edge 122

9-12 *Cythereis rushlakensis* Wall, n. sp., Rush Lake well, carapaces.
9, 10: holotype, Univ. of Mo. No. 0-1211-14, left side and dorsal views;
11, 12: paratype, Univ. of Mo. No. 0-1211-15, left side and dorsal views 123

13, 14 *Cythereis rushlakensis* Wall, n. sp., var., Rush Lake well, carapace, Univ. of Mo. No. 0-1211-16, left side and dorsal views 124

15-19 *Procytheridea radvillia* Loranger, Kelstern well, carapaces.
15, 16: Univ. of Mo. No. 0-1214-2, right side and dorsal views;
17-19: Univ. of Mo. No. 0-1214-3; 17, 18—right side view (18 is not whitened—muscle scar visible in central area), 19—dorsal view 143

20, 21 *Paracypris projecta* Peterson, Kelstern well, carapace, Univ. of Mo. No. 0-1210-8, right side and dorsal view 114

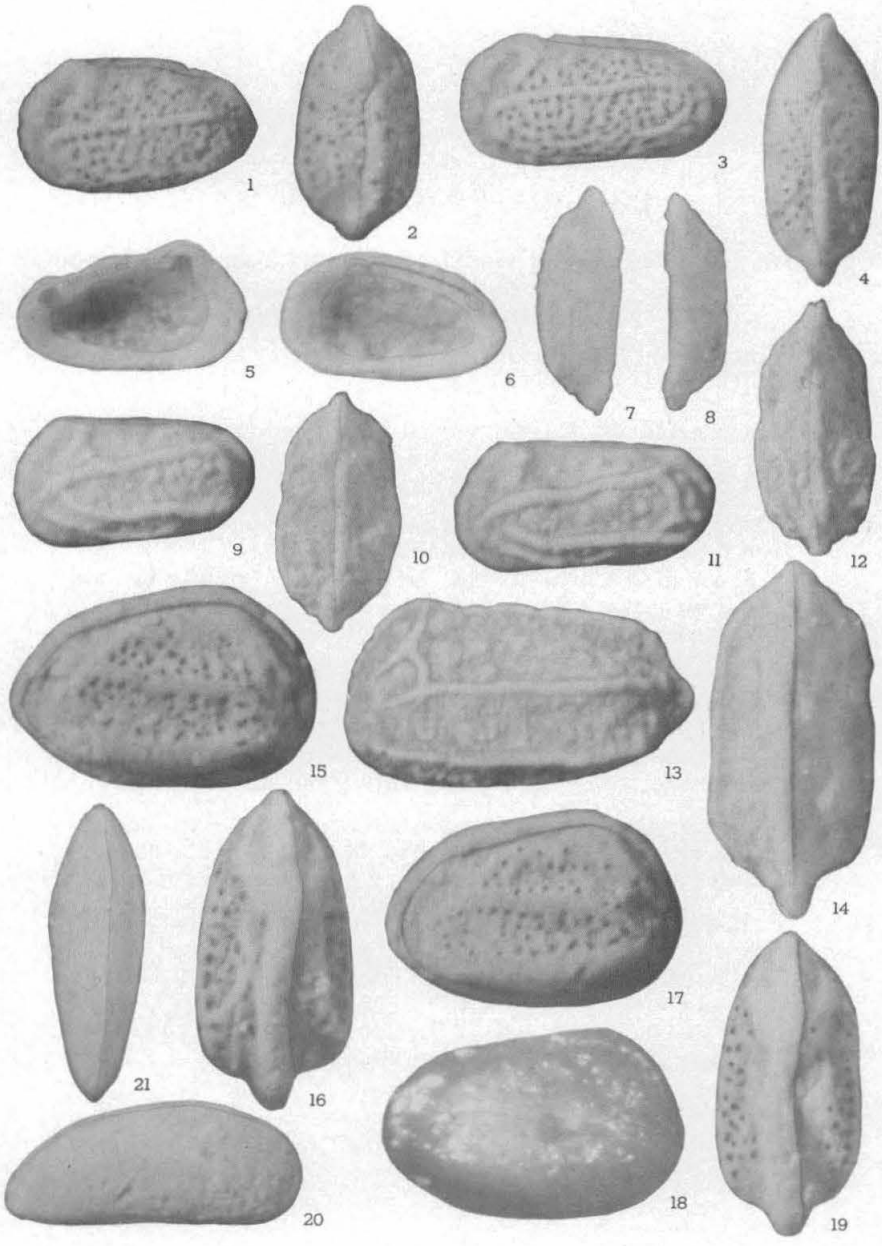

Plate 27 Oxfordian Ostracoda from uppermost beds of lower member and basal beds of middle member of Vanguard formation (Swift).

EXPLANATION OF PLATE 28

Ostracoda from basal beds of middle member and from upper member of Vanguard formation
(retouched photographs of whitened specimens)

Magnification x 73 approximately

Figure *Page*

1-3 *Procytheridea* sp. A, Frontier well (upper member), carapaces. 1, 2: Univ. of Mo. No. 0-1214-4, right side and dorsal views; 3: Univ. of Mo. No. 0-1214-5, right side view 144

4-7 *Progonocythere crowcreekensis* Swain and Peterson, Kelstern well (basal beds of middle member), carapaces. 4, 5: female?, Univ. of Mo. No. 0-1214-9, right side and dorsal views; 6, 7: male?, Univ. of Mo. No. 0-1214-10, left side and dorsal views 147

8, 9 *Progonocythere hieroglyphica* Swain and Peterson, Frontier well (upper member), valve, Univ. of Mo. No. 0-1214-11; 8—external view, 9—internal view showing crenulate dental units connected by faintly crenulate, grooved valve edge 148

10, 11 *Orthonotacythere dorsoconvexa* Peterson, Instow well (middle member), carapace, Univ. of Mo. No. 0-1213-12, right side and dorsal views 138

12-15 *Progonocythere* sp. A, Frontier well (upper member), carapaces. 12, 13: short carapace (male?), Univ. of Mo. No. 0-1214-12, right side and dorsal views; 14, 15: elongate carapace (female?), Univ. of Mo. No. 0-1214-13, right side and dorsal views 149

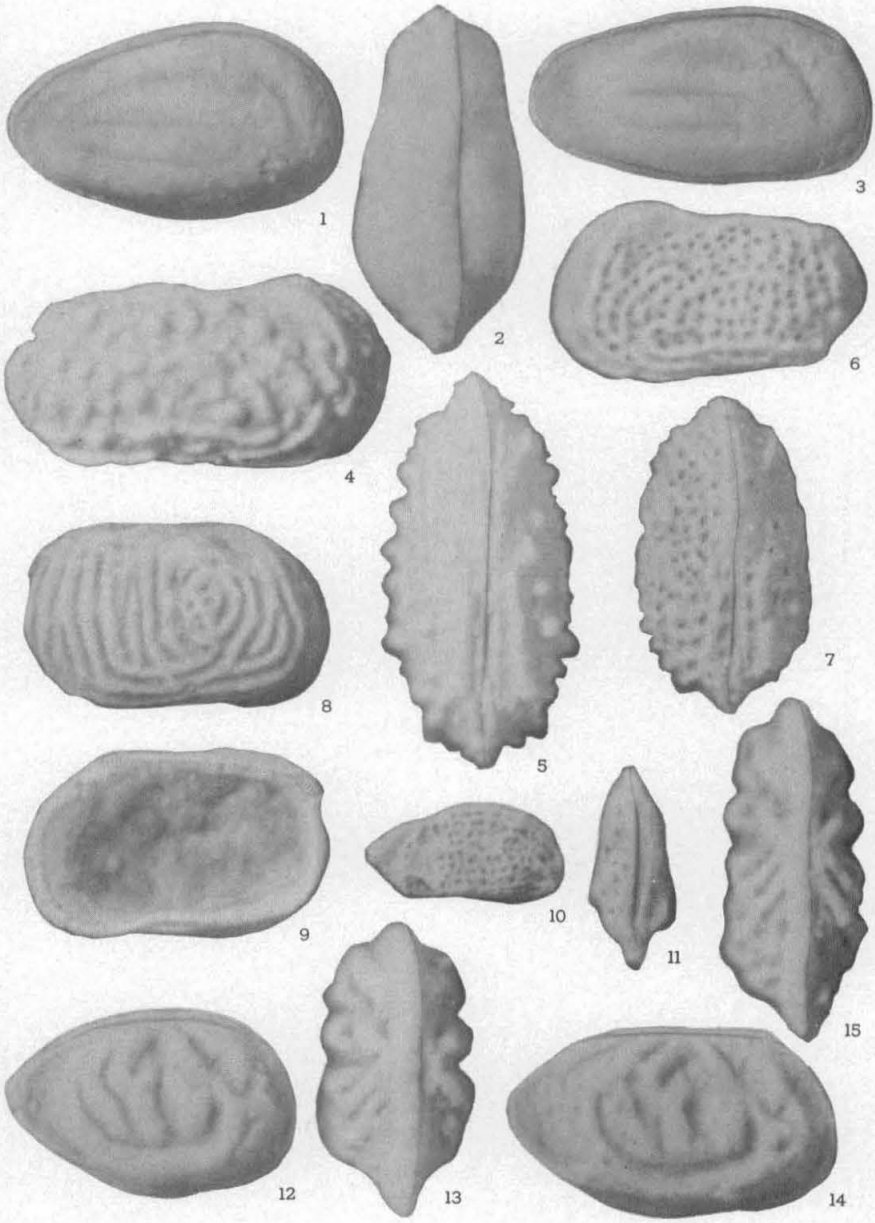

Plate 28 Oxfordian Ostracoda from basal beds of middle member and upper member of Vanguard formation (Swift).