CENOZOIC NONMARINE DIATOMS
FROM THE
GREAT BASIN

Thesis by

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ABSTRACT

The wide distribution in the Great Basin area of the Western United States, both geographically and geologically, of the Cenozoic nonmarine diatoms would make them particularly useful for stratigraphic correlation and age determination if their geologic ranges were better known. For this reason, diatoms were collected from some well known vertebrate collecting localities in Nevada, Idaho, and Utah, and the geologic ranges of the individual species established.

Of the 353 different species and varieties of nonmarine diatoms identified from the six stratigraphic units chosen, ranging from late middle Miocene to late Pleistocene in age, 85 have been described and illustrated as new, 40 have been known previously only as fossils, and 228 have been recorded previously from living assemblages elsewhere.

Paleoecological interpretations of the environmental conditions which obtained during the deposition of the sediments studied were made on the basis of the 228 species and varieties of diatoms in the last category.

The investigation has shown that many of the fossil nonmarine diatoms have satisfactorily short ranges in geologic time, and therefore are valuable guides for stratigraphic correlation and age determination of the sediments in which they occur. Furthermore, the Recent species in each assemblage have been shown to supply much useful data on which to base paleoecological interpretations, limited principally to published ecologic data on the living organisms.

TABLE OF CONTENTS

Stratigraphy and locality descriptions of selected areas

Systematic Paleontology

ILLUSTRATIONS

TABLES

INTRODUCTION

Although there are many active and able students of the living diatoms, the fossil nonmarine diatoms have been more or less neglected by paleontologists in recent years. In 1854 Ehrenberg, in his monumental "Mikrogeologie", laid one of the enduring corner stones of the micropaleontology of both marine and nonmarine microfossils. This truly great work covered foraminifera, radiolaria, diatoms, and silicoflagellates, as well as other types of microfossils from many localities scattered all over the world. A testimony of his thoroughness is the fact that a great proportion of his genera and species of diatoms are still valid today, over a hundred years later. In order to appreciate his contribution, one must contrast the quality of the microscopes of his day with their vastly improved counterparts available today. In addition to this huge folio volume he published numerous other papers, both before and after 1854. But his "Mikrogeologie" justly may be considered to be the first comprehensive treatise on the micropaleontology of the diatoms.

During the same period a relatively large number of able scientists and advanced amateurs were attracted to the enticing study of these beautiful organisms. The amateur microscopist flourished in the middle and late eighties, and diatoms, with their fine periodic structures were the favorite test objects for the newest developments in microscopical optics. These workers included those who studied and described Recent species of diatoms, a smaller number who specialized in fossil forms, and a host of often diligent workers who were interested in finding, describing and naming "hitherto unknown and interesting species", often including both fossil and Recent forms in the same paper, frequently failing to distinguish between the two. Thus the vast and polyglot literature on diatoms developed, some of which was truly objective scientific work of the highest value and some of which certainly bordered on the shoddy. This literature, running to many thousands of papers, must be used by the modern student of these organisms, and he is constantly faced with the necessity of sorting the wheat from the chaff.

Many were primarily interested in taxonomy, and various different classifications of the diatoms have been proposed, some based upon the enduring siliceous shell itself (equally satisfactory for both living and fossil forms), and some based upon the soft ephemeral parts and hence of no value to students of fossil forms. It is indeed fortunate that the classification based upon the structure and ornamentation of the siliceous shell was established over half a century ago and has been followed, with minor modifications up to the present time. Thus the great bulk of diatom literature is equally useful to students of both living and fossil forms. This has greatly facilitated the ease with which the students of fossil diatoms have been able to use the work of others working with Recent species, and extract much useful paleoecological data therefrom.

Relatively few of these early workers were trained geologists or stratigraphic paleontologists, and an even smaller number were so trained and interested in fossil nonmarine diatoms. One of these, M. Antoine Lauby (Lauby, 1910) published an outstanding paper on the fossil nonmarine diatoms of the Central Massif of France, in which he attempted to work out the stratigraphic ranges of a number of these organisms.

Others, (Pantocsek, 1903; Heribaud, 1902, 1903) somewhat earlier had made similar studies which also have proved extremely useful in the present investigation.

THE PRESENT PROBLEM

At the present time, with increasing interest in the stratigraphy of the Cenozoic nonmarine sediments of the Great Basin, it appears timely to inaugurate a study of the nonmarine diatoms of this region and to determine their stratigraphic ranges. In many parts of the Great Basin and contiguous areas, diatoms are the most abundant and widespread fossils available. In order to use the fossil nonmarine diatoms intelligently for age determination and for stratigraphic correlation, a knowledge of the stratigraphic range of each species is essential. In spite of the good work done by the early workers mentioned above, these ranges are only imperfectly known for some species and not known at all for the great majority which occur in the Cenozoic sediments of this region. Vertebrate fossils provide the most widely acceptable dating for these nonmarine sequences, but, unfortunately, do not often occur where most needed. It appeared obvious that the best procedure for arriving at the stratigraphic ranges of the diatoms would be to collect diatomaceous sediments in known association with the vertebrate faunas upon which our best dating depends. Many such localities are known from widely separated parts of the Great Basin area and this seemed to be a logical place in which to start.

Previous work on fossil nonmarine diatoms of the Great Basin and adjoining areas

Previous published works on the fossil nonmarine diatoms of the Great Basin and bordering areas fall into two distinct types: (1) those in which the diatoms were considered only in the aggregate as diatomites for industrial applications and (2) those in which assemblages of diatoms were discussed in connection with local geology and particularly stratigraphy. Borderline cases in which both aspects are discussed will be placed in the second of the two categories.

(1) The following is a brief listing of those papers in which at least some mention is made of Great Basin occurrences: Davis (1925), Smith (1932), Moore (1934), Cummins and Mulryan (1937), Eardley-Wilmot (1928), Calvert (1930), Hatmaker (1931), and Powers (1947).

(2) Except for the early European workers mentioned in the introduction, who occasionally touched on the Great Basin and surrounding areas by virtue of collections sent to them, one of the earliest papers was a brief one by Barbour (1895) in which he listed and illustrated 80 species and varieties of fossil nonmarine diatoms from the central Nebraska, which were identified by Clarence J. Elmore. They appear to have come from a Pleistocene deposit, mixed with volcanic ash.

Blake (1902) described a diatomite from the San Pedro Valley, Arizona, followed (1903) by an illustrated paper listing the diatoms as identified by Messrs. Ward and Edwards. The finding of a number of species from what were formerly thought to be marine genera caused both Ward and Edwards to postulate a marine origin for the deposit. I have since found these same supposedly "marine" species in the Furnace Creek formation in Death Valley, California.

Mann (1926) listed 85 species and varieties of diatoms from the Miocene Latah formation near Spokane, Washington, including 11 which he described as new. The diatoms indicated a high mineral content in the lake, not only of salines, but a high alkali content as well. This was suggested by the distorted shape of many of the diatoms, which find it difficult to extract silica from highly alkaline water.

Elmore (1926) published a large report on the diatoms of Nebraska, both living and fossil, which was illustrated with wholly inadequate and often inaccurate pen drawings. He listed occurrences as far west as Sacramento, California.

Hanna and Grant (1929) published a well illustrated paper on some Pliocene diatoms from the Etchegoin formation in the Kettleman Hills, California. The bed from which the diatoms came has since been assigned to the Tulare formation of Plio-Pleistocene age as the result of detailed later mapping (Woodring, Stewart, and Richards, 1940, p. 103).

Another paper by Hanna and Grant (1931) on the Diatoms of Pyramid Lake, Nevada, although dealing entirely with Recent species is included here on account of its value from an ecological point of view. 13 species of nonmarine diatoms are recorded as living in the lake, which has a salinity of 3486 parts per million, about one-tenth that of sea water. During the present investigation, four of these species turned up as fossils in various parts of the Great Basin.

Hanna (1932) published a paper on the Pliocene diatoms of Wallace County, Kansas, in which he described and illustrated 26 species (2 of which were described as new) from two collections in the Ogallala formation of middle to late Pliocene age. 14 of these species were found in the Pliocene formations studied during the present investigation.

Mann (1932) listed a number of species and varieties of nonmarine diatoms from 5 samples of the Pliocene Panaca formation near Pioche, Nevada, none of which were described as new. Many of them, however, also occur in the other Pliocene formations studied for this report.

Lohman (1934) listed and discussed 55 species and varieties of nonmarine diatoms from the Miocene Mascall formation at Tipton and Austin, Oregon, 33 of which were found in the Virgin Valley beds of similar age during the present investigation.

Lohman (1935) made a paleoecological study of 88 species and varieties of nonmarine diatoms from a clay and sand in Quaternary lake beds near Clovis, New Mexico, which indicated a progressive increase in salinity from lower to higher beds in the basin, based upon percentages of saline species found.

Patrick (1936) studied the diatoms from some borings made with a peat sampler around the edges of the Great Salt Lake in Utah. Although the samples came from presumably shallow depths, a surprising proportion of freshwater diatoms was obtained, together with a number of the expected brackish water forms. Some samples taken from bottom muds under the lake water yielded no diatoms, nor did the water itself yield any, which is not surprising. Other, apparently deeper samples from under the lake water did yield a few diatoms. A very small percentage of the diatoms found in the Great Salt Lake borings are also present in the Provo formation, representing a late Pleistocene deposit, but still very much older than the material studied by Patrick. Unfortunately, the depths below the surface from which Patrick's samples came were not given.

Lohman (1936A) listed 23 species and varieties of nonmarine diatoms from the Miocene Upper Cedarville formation near 49-Camp, Nevada, many of which also occur in the Virgin Valley beds a few tens of miles to the east. Coscinodiscus subaulacodiscoidalis Rattray, a very distinctive species which was not found in any of the Great Basin collections studied for the present report, occurs frequently to commonly in both the 49-Camp material and in the Latah formation (Mann, 1926).

Lohman (1936B) listed three assemblages of nonmarine diatoms from Brown County, Nebraska; Beaver County, Oklahoma; and Logan County, Kansas, which appear to be near the Pliocene-Miocene boundary. The different assemblages showed affinities for the Upper Virgin Valley beds of Nevada on the one hand, and for the Esmeralda formation on the other.

Lohman (1937) listed and illustrated the principal species of fossil nonmarine diatoms from 14 localities in eastern Oregon in connection with an economic report on the same area by Moore (1937). Many of these species have turned up again during the present investigation, and it is gratifying to note that many of the age assignments made then (the work was done in 1931) agree with the current assignments.

Patrick (1938) studied some Quaternary diatoms from the Mammoth Pit, between Clovis and Portales, New Mexico, where artifacts and vertebrate fossils were obtained, and found a large assemblage of dominantly freshwater diatoms, with a fair proportion of brackish water types in a series of 8 samples. The increase in salt concentration going upward through the section postulated by Lohman (1935) was duplicated in the Pit.

Lohman (1938) listed a total of 232 species and varieties of both marine and nonmarine diatoms, including 5 new species which were described, from three Pliocene formations in the Kettleman Hills, California. The diatoms in four assemblages from the Plio-Pleistocene Tulare formation, the youngest of the three, indicated an interesting change from marine to freshwater conditions; the uppermost collection carrying nonmarine diatoms exclusively. Both of the purely marine formations, the San Joaquin and the Etchegoin, contained some nonmarine species that were probably introduced by streams. The Tulare formation assemblages contain many species in common with the Hagerman formation of Idaho, one of those studied for the present investigation. The most characteristic species from each formation in the Kettleman Hills were illustrated.

Lohman (1941B) listed 36 species and varieties of nonmarine diatoms from the lower Pliocene and Miocene Laverne formation of southeastern Seward County, Kansas, which indicated unusually saline conditions during deposition of the formation. As a result, the correlation with either the Upper Virgin Valley beds or the Esmeralda formation is not very good. This is further aggravated by the fact that the Laverne assemblage gave strong evidence of reworking.

Patrick (1946) studied the diatoms from the upper five feet of a 22-foot peat bog in Lee County, Texas. 17 species and varieties of dominantly cool-water, acid-loving diatoms were found in what the author considers to be all Recent material, here included for its ecological significance.

Field work

In 1938, four months were spent in visiting a great many vertebrate fossil collecting localities in eastern Washington, eastern Oregon, southeastern California, Nevada, and southern Idaho. Stratigraphic sections were measured at each locality in order to establish the stratigraphic relations between the diatom collections and the vertebrate horizons. During this field season hundreds of collections were made and the time-consuming laboratory work of preparing and studying this mass of material began in the fall. It was interrupted within a year on account of pressure of other duties, followed by the much longer interruption caused by World War II. The project was finally resumed in 1950, when a number of the old localities were revisited and a host of new ones added. It was early recognized that all of this material could not be worked up in form for publication, but much was learned of the field relations and distribution of the nonmarine diatoms that can probably be most accurately described as background information.

A number of the most promising localities from the point of view of the excellence and completeness of their vertebrate faunas proved, after much fruitless effort had been expended upon them, to be barren of diatoms. These include the John Day formation (late Oligocene to early Miocene) in Oregon, the Fish Lake Valley locality of the Esmeralda formation (early Pliocene) in western Nevada, the Ricardo formation (early Pliocene) in southeastern California, the Barstow formation (late Miocene) in the Mojave Desert, California, and others.

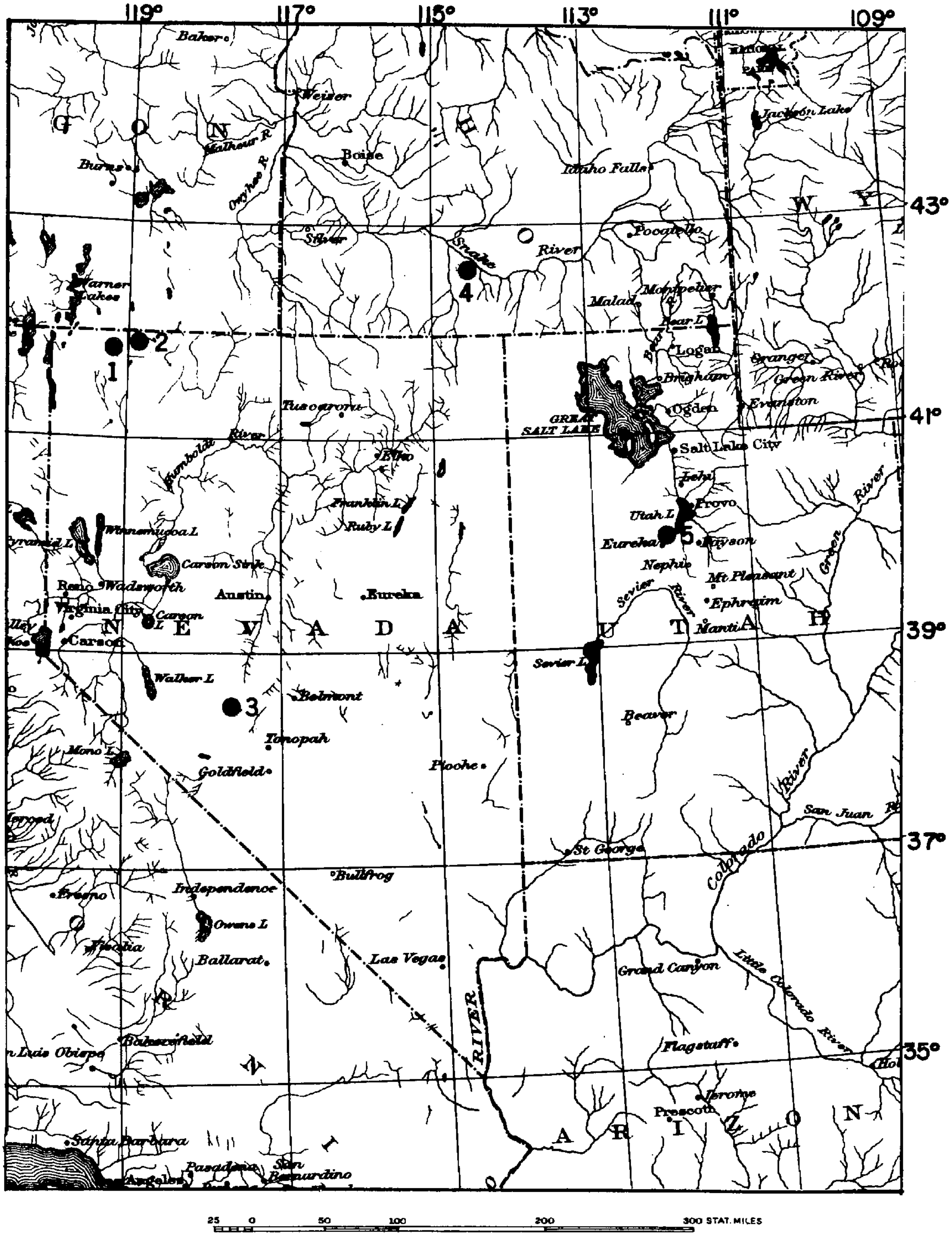
The project was again interrupted in the spring of 1952, when virtually full-time participation in the Mojave Salines Project of the Mineral Deposits Branch of the Geological Survey began and continued through 1954. During this interval between a quarter and a third of the time was spent in the field in the general area covered by the Mojave Desert and Death Valley, California. Many stratigraphic sections were measured and over 1000 collections, a fair proportion of which contain diatoms, were made. This included a detailed study of the Barstow formation (middle and late Miocene) which yielded diatoms from one of several measured sections, but only from beds 1500 feet stratigraphically below the well-known late Miocene Barstow fauna of Merriam (1915, 1919), and hence not definitive for the present investigation. The results of this series of investigations are scheduled for publication as a separate Professional Paper.

The following localities (see Plate 1) were finally selected as representing the best combinations of well dated vertebrate faunas, abundant and well preserved diatoms, and having local geology with a minimum of structural complexity, so that the stratigraphic relations between the vertebrate and diatom collections could be established unequivocally.

Lower Virgin Valley beds, N.W. Nevada	Late middle Miocene
Upper Virgin Valley beds, N.W. Nevada	Late Miocene
Esmeralda formation, Cedar Mtn., Nevada	Early Pliocene
Thousand Creek beds, N.W. Nevada	Middle Pliocene
Hagerman formation, southern Idaho	Early Pleistocene
Provo formation, central Utah	Late Pleistocene

In selecting these localities out of the much larger number from which collections were made, some were eliminated for reasons previously stated, and some because it appeared that the additional value to be gained by including them was incommensurate with the added time required in the preparation of the material, study, and final writing. Many of

PLATE 1



Index map showing location of areas

1	Virgin Valley beds	3	Esmeralda formation
2	Thousand Creek beds	4	Hagerman formation
5	Provo formation		

these will be the subject of separate contributions in the future without delaying further the completion of the present report.

Collections from the first four of the above localities are the result of unaided field work by myself. The Hagerman formation was sampled in 1938 and a section measured. The collections unfortunately contained very few diatoms, and through the kindness of Howard A. Powers of the Geological Survey, who has been mapping the area in detail, much better material was obtained and is used in this report.

The Provo formation was thoroughly sampled by Harold J. Bissell in 1949 who was at that time a member of the Geological Survey and submitted the collections to me for study. I visited Mr. Bissell in the field in 1950, at which time he showed me the localities and field relations.

Reworking

The nonmarine diatoms are, on the average, smaller than the marine ones. The maximum dimensions of those studied for this report, for example, varied from a minimum of 10mu to a maximum of 200mu, with the mean well below 70mu. When working with organisms as minute as these, great care must be taken to avoid contamination from one sample to another, beginning with the collection of the sample in the field, and continuing through the preparation and final mounting. This is discussed under "Preparation of material for study".

Another kind of contamination, known as reworking, may take place before, during, and after deposition of the sediment containing the diatoms. Today, for example, over vast areas in the Great Basin, diatomaceous sediments are being eroded and the component diatoms are being mixed with those now living in lakes and streams and finally deposited as a mixture of unknown proportions. There is no reason to believe that similar processes were not operating at many times during the past, and it is therefore pertinent to explore (1) the possibilities that this might have occurred during the periods during which the sediments here studied were deposited, and (2) to determine what criteria may be used to detect such reworking and thus guard against being misled into confusing reworked material with an original deposit.

In order for diatoms to be reworked from an earlier diatomaceous sediment into a basin of deposition there must have been "an earlier diatomaceous sediment". In the case of the oldest deposits studied for this report, the Lower Virgin Valley beds, there would have had to be a nonmarine pre-middle Miocene diatomaceous sediment exposed to erosion during Virgin Valley time and within the watershed area of Virgin Valley. There is no known evidence for the existence of any such diatomaceous sediment -- in fact, all existing evidence is opposed to it.

In the case of the Esmeralda formation the situation is, at first sight, somewhat cloudy. The early faunas collected by Buwalda (see p. 44 of this report) came from several areas within his areal extention of Turner's Esmeralda formation. When Merriam first studied these fossils they appeared to be Miocene in age, but with a number of more advanced forms of probable early Pliocene age. Stirton (1932, p. 60), after restudying the faunas and visiting the localities found that at no single locality does a mixed fauna occur, but that all of the middle Miocene forms came from "a lens of rewashed material found in a small area of brown sandstone". This proved to be U.C. Loc. 2027, near Stewart Spring, on the opposite side of Cedar Mountain from the localities carrying the lower Pliocene fauna (as well as the diatom assemblages). It can be argued that if middle Miocene vertebrate fossils could be reworked into the lower Pliocene Esmeralda formation, it would be even easier for diatoms also to be reworked. An analysis of Table 7 reveals the fact that of 37 new species and varieties of diatoms described from both the Lower and Upper Virgin Valley beds, 13 species and varieties, or 35 percent, are also found in the Esmeralda formation. 27 new species and varieties have been described from the Esmeralda formation that have not been found in older beds. All of the above figures are exclusive of the long-ranging species that extend to the Recent. This evidence suggests that although there may have been sediments older than the Esmeralda available for erosion and redeposition in Esmeralda time (on account of the reworked vertebrate fossils) they may not have diatomaceous within the watershed of the Esmeralda basin. It appears equally logical to assume that the 13 species and varieties common to the Lower and Upper Virgin Valley beds and the Esmeralda formation are those whose known geologic range is from upper middle Miocene to lower Pliocene.

In the case of the Thousand Creek beds, the reworking hypothesis has been carefully explored, with even more conclusively negative results (See discussion of Thousand Creek assemblages, page 65 of this report.)

The only locality studied for this report in which there might have been a reasonable probability of large scale reworking from an earlier deposit, is the one in the Hagerman formation in Idaho. This deposit, the geologic age of which (allowing for all reasonable uncertanties) is certainly between the limits of late Pliocene and early Pleistocene, might conceivably have been made up in part of reworked diatomaceous sediments from the older Payette formation of late Miocene age, or the Salt Lake formation of early Pliocene age. Both of these earlier formations were probably exposed to erosion within the watershed of the Hagerman basin. Collections from them have been examined, however, and the diatom assemblages are conspicuously different than the Hagerman assemblage. In view of the fact that both the Payette and the Salt Lake formations attain very considerable thicknesses, it might be argued that the collections from them which have been examined did not come from the critical parts of the sections (that may have yielded those reworked into the Hagerman formation). No adequate answer can be given to this question with the data available, but in view of an analysis of the Hagerman assemblage in the light of the criteria mentioned under (2) below, it appears unlikely that the Hagerman collection studied for this report carries reworked diatoms in a significant amounts.

(2) Diatomsare composed of two valves which together form a frustule. The attachment between the two valves is quite secure during the life of the organism and usually takes the form of an encircling band of opaline silica (known as the "girdle") which, together with the two valves, is held in place by living protoplasm. At death, the protoplasm disappears quickly, and any considerable subsequent movement (such as is implied in reworking) of the diatoms is almost certain to separate the two valves and the encircling girdle. Thus the presence in a sediment of even an appreciable number of whole frustules is a strong argument against reworking -- at least of those diatoms represented by the whole frustules.

Almost all diatomaceous deposits, whether diatomites (made up dominantly of fossil diatoms without or with only minor amounts of clay, volcanic ash, etc.), or clastic sediments, pyroclastics, limestones, etc., in which the diatoms are the minor constituent, contain a fair percentage of broken diatoms. In either case, the various processes of sedimentation, compaction, orogenic movements, the various chemical and mechanical actions involved in preparing the material for study, usually result in a fair percentage of the diatoms being broken. Fortunately the degree of symmetry of most diatoms is such that accurate identification can be made on broken specimens. If all of the valves are separated and a great majority of them are broken, reworking may at least be suspected. If they are as above and the sediment is fine grained in regular bedding with no signs of local deformation on the beds, the chances are even better that the material has been reworked, at least in part. The question of extensive scavenger activity has been raised and requires consideration. Scavengers, such as crustaceans and some mollusks, probably eat many diatoms, either directly or while attached to aqueous plants. This probably results in separation of the component valves and in some breakage, thus giving the appearance of reworking. Thus one might be led to suspect reworking when in fact it had not taken place. The possibility of scavengers consuming so nearly the total population of diatoms in a lake, however, appears to be a remote one. Furthermore, no significant disturbance of the relative stratigraphic position of the diatoms being deposited would appear likely. Thus even the most active kind of scavenger action could only have the tendency to mislead one into thinking that some stratigraphic reworking had taken place when this was not really so. Another criterion whose evaluation requires some care and experience, is the nature of the assemblage itself. If the fractures are clean, and both large and small fragments are present in about the right amounts to contain all of the material in the diatoms, the material does not appear to have been reworked. If, however, the fragments are all very large or very small, the logical inference is that there has been some sorting, and this strongly implies the type of mechanical activity associated with reworking.

A third criterion is an examination of the different species comprising an assemblage in order to determine, if possible, the presence of one or more species which are obviously out of place and hence represent contamination of some sort. An example would be the finding of some marine species known to have become extinct in early Miocene time in a late Pliocene nonmarine sediment. Marine Eocene diatoms from the Kreyenhagen formation were found in core samples of the Tulare formation of Plio-Pleistocene age in the San Joaquin Valley of California. This represents a clear and unequivocal case of reworking.

Many other examples of obvious reworking could be cited, but the difficult cases, are, of course, those that have no obvious solution. Some assurance can be drawn from the fact that in no known case where reworking is clear and unequivocal are the reworked diatoms as abundant as those not reworked. This does not imply that it would be impossible to have reworked forms appearing abundantly -- it merely has not been demonstrated in any known assemblages. In general, therefore, the greater the abundance a species attains in any assemblage, the greater is the reliability that may be placed on any interpretation based upon its presence. Finally, all possible criteria for detecting reworking must be applied to each and every assemblage studied if either stratigraphic or paleoecologic interpretations based upon it are to have any real value.

Paleoecology

One of the major difficulties in working with the nonmarine diatoms is the fact that the range of environmental conditions under which different diatom assemblages live today is vastly greater than the variations in similar conditions occupied by the marine diatoms. In fact, it may be said that compared with the many and varied complexities of the nonmarine habitats, the ocean almost represents a physical constant.

For example, considering first lake basins, as they supply the maximum volume of diatomaceous nonmarine sediments: the pH may vary from less than 4 to more than 10, the salinity may vary from virtually zero to 3500 parts per million (Clarke, 1924, p. 160) and the content of various other salts may vary in like amounts. The temperature of the different lake basins, particularly the shallower ones, follows fairly closely the prevailing atmospheric temperature of the region. Turbidity varies over a tremendous range, in part seasonal, particularly near the mouths of major streams feeding the lake. Some lakes, particularly shallow ones in arid regions, are subjected to varying concentrations of contained salts, caused by the rate of evaporation exceeding the recharge during parts of the year. Furthermore, what appear to be purely lacustrine assemblages are often greatly modified by fluviatile elements brought in by streams.

Considering secondly fluviatile deposits -- the diatoms now living in swift streams and the smaller rivers are different in many respects from those living in the larger lakes and other bodies of still nonmarine water. The fluviatile habitats, especially those having swiftly flowing water, such as mountain streams and large rivers with a high gradient, are populated by diatoms growing attached to water plants, bottom stones, and the like, by means of gelatinous stipes. A significant difference exists between the diatoms living in swiftly moving streams (particularly cold mountain streams) and relatively sluggish rivers.

Other and somewhat bizarre variants of the nonmarine habitat are the groups of diatoms that live in moist soil, on damp rocks, and even in nearly dry puddles. As for temperature range, nonmarine diatoms are now living in pools of water in ice-floes at freezing temperatures, and others are living in hot springs at temperatures up to 150° F. (66° C.).

In contrast, the composition of sea water and its physical properties vary (by comparison with nonmarine water bodies) relatively little from place to place, and have changed very little during geologic time (Rubey, 1951).

At first, any attempt properly to evaluate all of the variables inherent in the nonmarine environments and to arrive at an adequate measure of the stratigraphic ranges of these organisms appeared hopeless. But, fortunately, a great deal of work has been done by many competent investigators who have studied the living nonmarine diatoms and have concerned themselves with the types of environment in which they prosper. Much of this work has been qualitative rather than quantitative, but a vast store of valuable ecological data has nevertheless accumulated. Part of the lack of quantitative data is in the paucity of temperature, pH, and salinity measurements of lakes and other bodies of water whose diatoms have been studied. Another part of the lack of the quantitative approach has been the tendency of some biologists to lump what is frequently a wide range of physical characteristics of the diatoms into one species. This two-fold blurring of the data renders paleoecological interpretations somewhat hazardous unless the ecological data recorded for the living organisms are carefully scrutinized.

Each assemblage of fossil diatoms (at least within the Cenozoic) contains a number of species which are still represented in living assemblages. As is the case with other groups of fossils, the percentage of living species decreases progressively in the older rocks. Each assemblage is thus a mixture of species which lived for varying lengths of geologic time but are now extinct, and some which are still represented in living assemblages. The former are obviously most valuable for determining the age of the rocks in which they occur (once their geologic ranges are known), and the latter are naturally the only ones useful for paleoecological interpretations. In making such interpretations it is always necessary to utilize, insofar as is possible, the assemblage as a whole and to be alert to the possibility of mixing, contamination, reworking, etc.

The brief paleoecological interpretations at the end of the general discussion of each area represent an effort to extrapolate the meager and often conflicting data available on those species in each assemblage that are still living today. In some cases these data appear to be definitive and some assurance can be felt in the interpretations offered. In others, they are of so conflicting a nature that one wonders how a particular assemblage of diatoms having such diverse habitats today could have lived and prospered in the same body of water. To extend these extrapolations further would indeed be entering the realm of pure speculation. All of this points forcibly to the need for more quantitative data from students of living diatoms.

Preparation of material for study

All of the collections were subjected to as nearly as possible the same treatment in preparing them for microscopical study. This was necessary in order for the relative abundances of the different species in each assemblage to be meaningful and have comparative value. Furthermore, scrupulous care was taken in all operations to prevent contamination from one sample to another, as any such contamination would obviously vitiate any conclusions drawn from a study of the final assemblages. In order to eliminate possible contamination it was long ago decided to avoid the use of all complicated (and hence hard to clean) glassware and use only 150ml Pyrex beakers, which can be thoroughly and easily scrubbed with soap and water after each use. The original collections are all stored in 2-oz. screw-capped glass jars with the U.S.G.S. diatom locality number written on the cap in India ink. This number is written on the 150ml beaker and identifies the collection throughout all subsequent operations, a brief outline of which follows:

A small, roughly cubical fragment of the sample about 3 to 4 cubic centimeters in volume is removed from the numbered glass jar with freshly washed forceps and placed in a similarly numbered 150ml Pyrex beaker. It is first tested for presence of calcareous material with hydrochloric acid. If any is present the sample is covered with a 1:1 solution of hydrochloric acid, a watch glass placed on top, and four of such beakers placed under a low glass bell jar. Usually five bell jars, each covering four beakers are used, and the beakers are always kept under the bell jars except when some operation is being performed on them. Thus 20 samples can be in some stage of preparation continuously. If much lime is present the cold hydrochloric acid will not only remove it but will also disintegrate the rock. If not, boiling is necessary, using a simple reflux condenser consisting of a 50ml Pyrex extraction flask fitted with a 2-hole rubber stopper and short pieces of glass tubing, one of which is connected to the cold water supply and the other to a drain by appropriate rubber tubing, so that cold water can be circulated through the flask. The outside diameter of the flask is, fortunately, about 3mm smaller than the inside diameter of the 150ml Pyrex beaker, forming a loose fit when it is lowered into the beaker, and held by a clamp so as to be well above the surface of the acid in the bottom of the beaker. With this simple arrangement, the contents of the beaker may be boiled for hours if necessary without attention, as there is no appreciable loss of liquid, and no <u>acid fumes in the laboratory</u>.

After cooling, the beaker is filled with distilled water and the contents allowed to settle for 40 minutes, after which the supernatant liquid is carefully decanted and more distilled water added. This is repeated at 40 minute intervals until the liquid is neutral to methyl orange. Next, 10ml of a 4% solution of Calgon (trade name for sodium hexametaphosphate) is added, and the beaker again filled with distilled water. This has proved to be the best dispersing agent among many that have been tried, furthermore it is cheap, readily obtainable, and easily prepared. A series of timed decantations will remove clay and all fine clastic material that is either colloidal or has a settling time longer than 40 minutes. The end point is reached when the supernatant liquid is clear after 40 minutes and the solution will turn a drop of Bromthymol Blue yellow. Bromthymol Blue is blue at a pH of 7.6 and yellow at a pH of 6.0; the latter is slightly above the pH of freshly distilled water in equilibrium with the CO_2 in the atmosphere of the laboratory.

Non-calcareous clayey or silty rocks containing diatoms are soaked for periods of several hours to several days in a somewhat stronger solution of Calgon, aided when necessary with a mechanical stirrer, and usually can be disintegrated without trouble.

In some instances, particularly with some of the more indurated tuffaceous shales, the methods outlined above will not disintegrate the rock sample. One method that has proved effective for such rocks, and indeed for any rocks having any porosity at all, is to place the sample in a 150ml Pyrex beaker and cover it with sodium acetate crystals (the tri-hydrate, $NaC_2H_3O_2.3H_2O$), heat on a steam bath or warm (not hot) plate until the sodium acetate melts (m.p. 58.8° C.). It is advisable to add a few drops of distilled water before placing the beaker on the hot plate and to cover the beaker with a watch glass to prevent loss of water. As soon as the mass is completely melted, place the beaker in a shallow tray of cold water (a photographic tray in which cold water is kept circulating is excellent). As soon as the melt has cooled, forming a clear supercooled liquid, it is seeded with a crystal of sodium acetate (most easily introduced by tapping the stopper of the stock bottle of sodium acetate over the beaker). A single crystal thus introduced will start crystallization of the entire mass, which require 1 or 2 seconds. After cooling again (the crystallization is exothermic), the whole process is repeated until the rock is completely disintegrated. The slight, but powerful, volume change on a crystallization will disintegrate any rock with sufficient pore space to allow of the entrance of the liquid sodium acetate. As many as 10 or even 15 complete cycles may be required for a hard, well cemented rock. At the end, the sodium acetate, being very soluble in water, is removed easily by repeated timed decantations.

Samples containing much organic matter (such as those from the carbonaceous shales in Virgin Valley) are given additional treatment. If the diatoms are in good mechanical shape, i.e., they have not been altered by alkaline ground water, the concentrate from the previous treatments is boiled in concentrated sulphuric acid until blackened, after which sodium nitrate crystals are added cautiously to the boiling mixture. This effects complete oxidation of all organic matter present and yields beautifully cleaned diatoms. Where the organic matter is not so high and particularly where the diatoms have been leached somewhat by alkaline ground water, a somewhat less drastic procedure is used. The concentrate is boiled for about an hour in a strong solution of potassium permanganate acidulated with dilute sulphuric acid. The resulting soluble salts in each case are washed out by timed decantations as before and the manganese dioxide remaining after the permanganate treatment is dissolved in sulphurous acid. The second procedure gives excellent results where the amount of organic matter is not too great, and is much less damaging to somewhat altered diatoms. After either of the oxidizing procedures, the residue is sometimes flocculated; in this case another treatment with the Calgon solution is indicated.

After the necessary combination of the above mentioned procedures has been performed on the sample, the result should be a concentration of virtually all of the diatoms in the original sample, minus all acid-soluble constituents, organic matter, and all clay and other fine clastic constituents having a settling time in water greater than that of the diatoms. The coarse material (coarse sand, undisintegrated fragments, etc.) can be removed easily by reversing the settling process. With the material still in the original 150ml beaker, after the last settling, the supernatant clear water is carefully decanted so that the remainder is about 1 centimeter high. The contents are swirled by holding the beaker flat on a smooth surface and rotating it rapidly about a radius of about 2 centimeters for a few seconds. This motion causes the heavy and coarser particles to form a low mound in the center of the bottom of the beaker. After the liquid comes to rest (20 to 40 seconds) the supernatant liquid (now containing the diatoms) is carefully decanted into a second 150ml beaker, and the process repeated until the second beaker has been filled. The effectiveness of the separation can be checked by examining a drop of the final coarse fraction under the microscope. If the operations have been carried out properly and the timing has been correct, the final residue should be free of diatoms and consist only of coarse quartz, heavy acid-insoluble minerals and (occasionally) aggregates of undisintegrated material. The suspension in the second beaker is allowed to settle and the concentrate is stored in a 2-dram cork stoppered homeopathic vial with the locality number written on the stopper in indelible ink. A drop of 40% formalin solution is added to the vial to prevent the growth of a peculiar mold which can prosper on a bleak diet of silica and water!

In order to obtain strewn slides having good distribution of the diatoms present, the concentrated suspension usually requires dilution before a satisfactory slide can be made from it. This is an operation calling for a considerable amount of judgment that can only be gained from experience. In general, if the completely settled suspension in the vial is over a millimeter deep, dilution is indicated. A clean pipette, made by drawing out a portion of 6 mm soft glass tubing in a blast lamp, is used to draw out a portion of the suspension after vigorously shaking the vial to ensure that the entire contents are in suspension. This is added to distilled water in a second similar vial and the slide is prepared from this second, dilute, suspension. The second (diluted) vial is shaken vigorously and some of the suspension drawn out by means of the pipette. This is evenly spread over an 18mm round cover glass, which has just been washed in 95% alcohol and dried on a clean towel. The spreading is most easily done under a low power binocular microscope with a magnification low enough to enable the entire cover glass to be seen in the field of view at one time. The pipette is discarded after being used once, as it is impossible to clean it with certainty. The suspension on the cover glass is evaporated to dryness in a vacuum desiccator in order to prevent the agitation and consequent piling up of the diatoms caused by drying by heat. The cover glass with its uniform coating of diatoms is mounted on a slide in any one of a number of resinous mounting media, keeping the hotplate temperature just below the boiling point of the solvent used. A temperature of 120° C. is excellent for xylol-balsam. The locality number should be marked on one end of the slide with a diamond marking pencil. It is essential that all of the solvent (usually xylol) be evaporated from the mounting medium before the slide and cover glass are brought together; otherwise the resulting mounted slide will not be hard enough to obviate the possibility of movement of the diatoms in the medium.

The choice of mounting medium depends largely on the nature of the material being mounted and the degree of contrast desired. As most suspensions resulting from the preparation of any type of rock except a pure diatomite is likely to contain some fine clastic quartz as an impurity, it is advisable to make routine mounts in Canada Balsam, or one of the newer synthetic resins having the same index of refraction. These media closely approximate the refractive index of quartz, with the important result that the quartz virtually disappears. It is practically impossible to remove this fine quartz (when present) during the timed decantations without incurring a loss of the smaller diatoms. Some of these smaller diatoms, having a maximum dimension of less than 10mu, have proved valuable as stratigraphic indicators and their elimination cannot be considered.

The entire area under the cover glass on each slide was scanned by traversing at a magnification of 200 diameters, using a graduated mechanical stage on the microscope and recording the diatoms by genera in terms of the coordinates of the mechanical stage. After all of the slide had been thus traversed, the specific identifications were made at magnifications between 1000 and 1500.

All of the material is recorded and deposited in the U. S. Geological Survey diatom collection in Washington, D. C.

STRATIGRAPHY AND LOCALITY DESCRIPTIONS OF SELECTED AREAS

Virgin Valley, Humboldt Co., Nevada

Virgin Valley is situated in the northwestern corner of Humboldt County, northwestern Nevada. It is shown on the northeast corner of the Long Valley Quadrangle, 1/250,000, surveyed in 1882 and published in 1894 by the U. S. Geological Survey. A portion of this quadrangle, together with a portion of the Disaster Quadrangle, immediately to the east, is shown in Plate 2, taken from Merriam's pioneer paper on this region and its fossils (Merriam, 1910, pl. 2) giving both Merriam's vertebrate collecting localities and also those from which diatoms were collected and studied for the present report. The diatom collections were made during five days spent in Virgin Valley in September, 1938.

The local geology is simple, consisting of a gentle syncline in which the oldest rocks exposed are the upper beds of the Canyon rhyolite of Merriam, on both the southwestern and northeastern sides of the valley. Merriam, with some reservations, considered that the Canyon rhyolite might be a correlative of the Columbia Rivera lavas of Oregon, Washington, and Idaho. Unconformably overlying the Canyon rhyolite are the Virgin Valley beds, totaling about 1500 feet in thickness and consisting of three fairly well defined units as described by Merriam (1911, p. 204);

Upper Zone	White to buff beds. Ashes and diatomaceous beds.	Upper Virgin Valley
		Unconformity?
Middle Zone	Gray to yellow and brown shales and clays, carbonaceous shales, lignites, diatomaceous beds.	Lower Virgin Valley
Lower Zone	White to green, purple and red clays and ashes.	

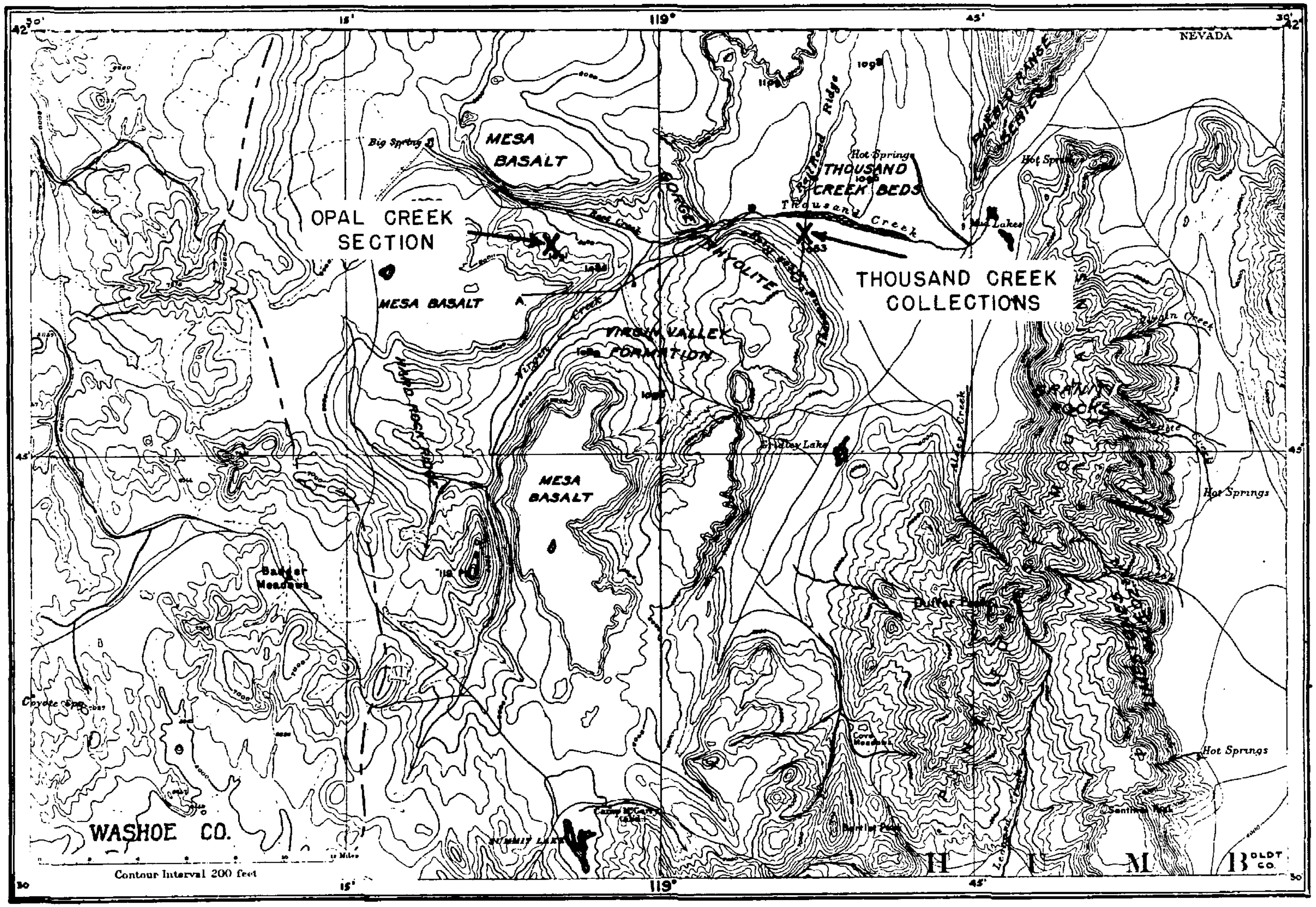
Virtually all of Merriam's vertebrate collections were obtained from a zone about 100 feet thick in the center of the middle zone. A few imperfect fragments were found in the upper zone and nothing was obtained from the lower zone.

The upper zone is capped by a virtually horizontal basalt of wide extent, which Merriam named the Mesa Basalt. It forms the large flat highland areas shown on the topographic map on both sides of Virgin and Beet Creeks.

The search for diatoms in these beds very nearly paralleled Merriam's search for bones. The lower zone, composed of hard white and varicolored tuffs, was carefully sampled, but yielded no diatoms.

The middle and upper zones, as Merriam indicated, contain diatomaceous beds, and a total of eight collections over a stratigraphic interval of 107 feet in the middle zone and one from the upper zone were found to contain diatoms. All of the collections from the middle zone came from a section in a small tributary to Beet Creek, and south of it, here called Opal Creek, on account of the opal and opalized wood found there. The beds here are practically horizontal and the section covers the same stratigraphic interval in which Merriam's localities 1085 and 1091 occur, so there can be little doubt regarding the age equivalence of the diatoms and the vertebrate fossils. The location of this section is shown in Plate 2. The section, covering all of the exposed portion of the middle zone of Merriam was examined in some detail and is given on page 30. Views of portions of this section are given in Plate 3.

PLATE 2



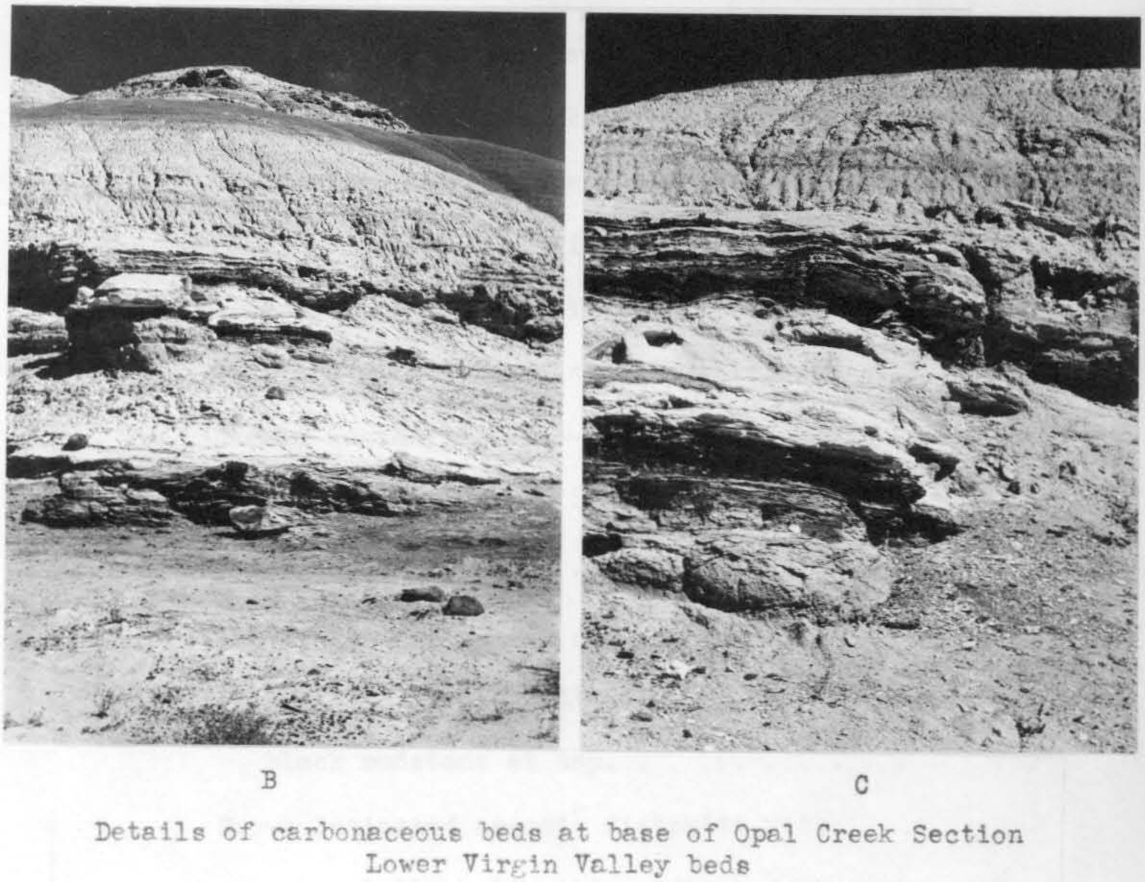
Topographic map of Virgin Valley and Thousand Creek localities

Adapted from U.S.G.S. topographic maps and J.C.Merriam

PLATE 3

A

Looking N. 40° E. at lower part of Opal Creek section from Opal Creek Wash
Lower Virgin Valley beds



B C

Details of carbonaceous beds at base of Opal Creek Section
Lower Virgin Valley beds

29 - omitted in page numbering only

Section of Lower Virgin Valley beds in Opal Creek, Nevada

Middle Zone

USGS diat loc.		Interval, ft.	Total interval above base, ft.
	Rhyolitic gravels -- base of Upper Virgin Valley beds		
	Unconformity (Disconformity?)		
	Siltstone, mudstone, and tuffs, generally poorly exposed	45	152
3537	Fine white diatomaceous mudstone	¼	107
	Alternating beds 1 to 2 inches thick of brown lignite, diatomite, and coarse sand.	18	106 3/4
3536	Thin bed of lighter brown lignitic diatomite	¼	88 3/4
	Alternating beds 1 to 2 inches thick of brown lignite, diatomite and coarse sand	4½	88½
3535Top 3534Bot	Pale chocolate brown lignitic diatomite with very light and fissile corky bed at top	1	84
	Mudstone with interbedded brown lignite	3	83
	Hackly weathering blue-gray mudstones with thin bed of partially silicified mudstone at top	27	80
	Soft white ash.	5	53
	Ashy silt and tuff containing 1 inch bed of black mudstone at top.	7	48
	Brown laminated organic diatomite with several black lignitic seams.	3	41

3531	Light chocolate brown organic diatomite	¼	38
	Same, very light in weight	2	37 3/4
3530	Pure white punky massive diatomite	¼	35 3/4
	Brown-black muddy siltstone	1	35½
3529	White weathering chocolate brown diatomite containing many plant fragments	½	34½
3528	Black weathering, highly fissile, brown organic diatomite with leaves	½	34
	Silty to sandy ash	4	33½
3527	Punky chocolate brown lignitic diatomite	½	29½
	Silty to sandy ash	5	29
3526top	Chocolate brown diatomaceous lignite, hard	1½	24
3525top	Chocolate brown diatomaceous lignite, softer and much lighter in weight	3	22½
3524top	Chocolate brown lignitic, more highly diatomaceous silt	2	19½
3523	Chocolate brown highly organic, somewhat lignitic diatomaceous silt	½	17½
	Greenish, fairly hard sand and sandy silt, poorly bedded	7	17
	Soft greenish sandstone, badland weathering by leaching of finer particles	10	10
	Stream bottom — lowest exposure available	0	

Upper Virgin Valley beds

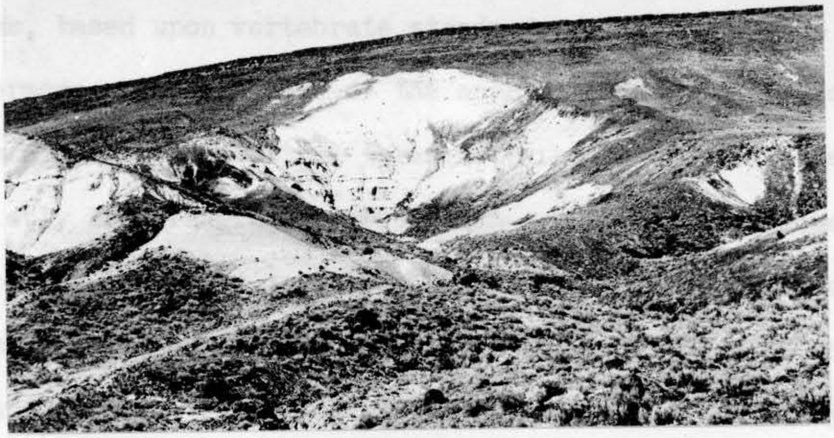
The Upper Virgin Valley beds of Merriam, lying between the rhyolite sand at the top of the preceding section and the Mesa Basalt, are, together with portions of the Mesa Basalt, involved in landsliding on an extensive scale, both on the south side of Beet Creek and on both sides of Virgin Creek. These slides, some of which must be fairly old, have exposed nearly vertical cliffs of the Upper Virgin Valley beds in many places, some of which are accessible. A photograph of the site selected is shown in Plate 4A. Merriam's plate 9 shows a photograph of the same exposure, made sometime before 1910. A number of collections were made from the Upper beds, beginning at the top, immediately beneath the Mesa Basalt, and extending downward for over 300 feet stratigraphically. Only one collection, from locality 3540, 200 feet stratigraphically below the basalt, yielded diatoms. This one was a fairly pure white massive diatomite, from which 77 species and varieties of diatoms were identified.

Age

Merriam (1911, p. 218) considered the age of the Virgin Valley formation to be middle Miocene. Subsequent work by others has been summarized by Stirton (1940, p. 628) and is in agreement with Merriam's original assignment. Wood et al (1941, p. 35, and pl. 1) have placed the Virgin Valley formation (Lower beds) as late Hemingfordian or early Barstovian, equivalent to late middle Miocene or early upper Miocene, and have so indicated on their correlation chart.

As virtually all of Merriam's fossils came from the Middle Zone of the Lower Virgin Valley beds, the diatom assemblages from the Middle Zone (U.S.G.S. diatom localities 3523 to 3537 inclusive) will be here considered to be late middle Miocene in age, and the assemblage from the

PLATE 4



A

U.S.G.S. diatom locality 3540 on north side of Virgin Creek
Upper Virgin Valley beds

B

Looking across Virgin Valley from locality 3540

Upper Virgin Valley beds (Upper Zone) (U.S.G.S. diatom locality 3540) will be considered to be early upper Miocene in age. This may appear to be a trifling distinction, but inasmuch as the main purpose of the present investigation has been the determination of the geologic ranges of the diatoms, based upon vertebrate standards, this appears to be justified. Furthermore, although some of the species common in the lowermost beds of the Middle Zone continue through to the Upper Zone, they are almost invariably long-ranging species which are still represented in living assemblages. What is more significant is the fact that some of the short ranging species which first appear in the upper beds of the Middle Zone continue into the Upper Zone. A time interval, even though of possibly short duration, is most certainly represented by the unconformity and the influx of rhyolitic gravels between the Middle and Upper Zones.

The distribution and relative abundances of all of the diatoms found in both the Lower and Upper Virgin Valley beds are given in the following table. Relative abundances are indicated by: A = abundant; C = common; F = frequent; and R = rare.

Table 1

Diatoms from Virgin Valley, Nevada		Lower							Upper
	Feet above base	17	20	23	30	36	84	89	107
	U.S.G.S. diatom locality	3523	3524	3525	3527	3530	3534	3536	3537	3540
		1	2	3	4	5	6	7	8	9
Melosira arenaria Moore									R	F
binderana Kützing										C
denticulata Lohman, n.sp.							F			
distans var. lirata (Ehrenberg) Bethge										F
granulata (Ehrenberg) Ralfs									F	F
hyalina Lohman, n.sp.					F					
italica (Ehrenberg) Kützing C		C	C	F	C	A	F	C		
italica var. irregularis Lohman, n.var.		C		F		F	F	F		
italica subsp. subarctica Muller		F								
margaritata Lohman, n.sp							C	R		
margaritata var. laevis Lohman, n.var.							C			
micropunctata Lohman, n.sp.				F	F		F	C		
ponderosa Lohman, n.sp.									A	A
ponderosa var. curta Lohman, n.var.									F	F
ponderosa var. elongata Lohman, n.var.									C	A
punctissima Lohman, n.sp.						A				
punctissima var. curvata Lohman, n.var.						F				
sculpta (Ehrenberg) Kützing									F	F
triannula Lohman, n.sp.							C			
undulata (Ehrenberg) Kützing									C	C
Fragilaria brevistriata var inflata (Pantocsek) Hustedt										R

	1	2	3	4	5	6	7	8	9
Fragilaria construens var. binodis (Ehrenberg) Hustedt						C		F	
crassa Lohman, n.sp.								F	F
crassa var. capitata Lohman, n.var.								F	
delicata Lohman, n.sp.									R
intermedia Grunow					R	F			
leptostauron var. capitata Lohman, n.var.									F
leptostauron var. dubia Grunow									R
leptostauron var. obesa Lohman, n.var.									F
nevadensis Lohman, n.sp.	C	C	C		F	C			F
cf. F. nitzschioides Grunow	R								
virescens Ralfs		F				F	F		
virescens var. subsalina Grunow					F				
Opephora lanceolata Lohman, n.sp.								R	
martyi Heribaud								F	
Meridion circulare (Greville) Agardh	F	F			F	C	F		F
circulare var. constricta (Ralfs) Van Heurck						C	R		
Diatoma enormis Lohman, n.sp.						C			
Tetracyclus calceus Lohman, n.sp.						F		F	F
cf. T. calceus Lohman,n.sp.									R
duplus Lohman, n.sp.						F		F	
ellipticus (Ehrenberg) Grunow, fa. minor						F			
constricta (Hustedt) Lohman, n.comb.						R		F	
circularis Lohman, n.sp.									F
ellipticus var. latissima Hustedt								F	
horus Lohman, n.sp.						C		F	F

	1	2	3	4	5	6	7	8	9
Tetracyclus irregularis Lohman, n.sp.						A		F	F
javanicus Hustedt						F		F	F
lacustris Ralfs						F		R	R
lacustris var. rhombicus Hustedt						R			
parallelus Lohman, n.sp.						F		R	F
peragalli var. major Heribaud								R	
peragalli var. eximia Heribaud								R	
quadrus Lohman, n.sp.									F
cf. T. quadrus Lohman, n.sp.								R	
virginicus Lohman, n.sp.						F			R
Eunotia faba (Ehrenberg) Grunow							R		
lineata Lohman, n.sp.								F	
lunaris (Ehrenberg) Grunow			F		F				
cf. E. lunaris (Ehrenberg) Grunow							R		
lunaris var. subarcuata (Naegeli) Grunow			F						
pectinalis (Kützing) Rabenhorst	F						F		
cf. E. pectinalis (Kützing) Rabenhorst									R
pectinalis var. minor (Kützing) Rabehhorst			F			F			
polydentula var. perpusilla Grunow									R
praerupta Ehrenberg	F								R
valida Hustedt		F		R			R		
veneris (Kützing) Muller		F							
Achnanthes basaltensis Lohman, n.sp.									R
lanceolata (Brebisson) Grunow		F							F
lanceolata var. elliptica Cleve									F
lapidosa Krasske								F	F

	1	2	3	4	5	6	7	8	9
Achnanthes linearis Wm. Smith						R			
robusta Lohman, n.sp.						R			
Cocconeis placentula Ehrenberg								F	F
placentula var. euglypta (Ehrenberg) Cleve								R	
Neidium affine var. amphirhynchus (Ehrenberg)Cleve	R						R		
iridis var. ampliata (Ehrenberg) Cleve									R
Frustulia rhomboides var. amphipleuroides Grunow						R			
rhomboides var. saxonica (Rabenhorst) De Toni						R			
Caloneis bacillum (Grunow) Mereschkowsky								F	
rostrata Lohman, n.sp.						F			
schumanniana (Grunow) Cleve								R	
Stauroneis anceps Ehrenberg		F		F		F	R	R	
gregorii Ralfs	F	F							
irregularis Lohman, n.sp.	F	F					R		
obesa Lohman, n.sp.	F	F							
phoenicenteron Ehrenberg	R	F		R	F		R		R
Navicula amphibola Cleve					R	R	F	F	F
amphibola var. capitata Lohman, n.var.	F	C	F	F		F		F	
cf. N. bacilliformis Grunow		F							
bacillum Ehrenberg		F				F			F
cf. N. bituminosa var. latecapitata Pantocsek						R			
bulloides Lohman, n.sp.	R								
citroides Lohman, n.sp.								F	F
cf. N. cryptocephala var. intermedia Grunow									F
dicephala (Ehrenberg) Wm. Smith					F	F			
dicephala var. rostrata Lohman, n.var.	F	F	F	F		C	F		

	1	2	3	4	5	6	7	8	9
Navicula gastriformis Hustedt									F
gastrum Ehrenberg								F	F
cf. N. hassiaca Krasske		F							
inflata Donkin								R	
jentzschii Grunow								R	F
mutica var. tropica Hustedt								R	
opalensis Lohman, n.sp.						R			
cf. N. placentula (Ehrenberg) Grunow									R
pupula var. rectangularis (Gregory)Grunow	R	F		R					
radiosa Kützing						R		F	
scutelloides Wm. Smith								C	C
semen Ehrenberg	F	F				R			
similis Krasske									F
Pinnularia cf. P. acuminata var. subarcuata (Naegeli) Grunow			F						
braunii var. amphicephala (Mayer) Hustedt	R								
brevicostata Cleve		C		F	F		F		
cf. P. brevicostata Cleve				F					
brevicostata var. leptostauron Cleve	R								
curvata Lohman, n.sp.	R	F	R						
dactylus Ehrenberg	F	F	F	C	F	F			
debesi Hustedt							R		
denticulata Lohman, n.sp.		R							
angusta Lohman, n.sp.	F	F	F		C	F	F		
cf. P. angusta Lohman, n.sp.		F							
esox Ehrenberg	R			R					
flexuosa Cleve	R								

	1	2	3	4	5	6	7	8	9
Pinnularia gentilis (Donkin) Cleve	F								
gibba var. hyalina (Kützing) Cleve				F					
gibba var. linearis Hustedt			R						
hartleyana Greville				F					
cf. P. hartleyana Greville	F				F				
hemiptera var. interrupta Cleve							F		
cf. P. hyalina Hustedt	F								
latevittata Cleve	R								
cf. P. lacunarum Hustedt									R
major Kützing	F				F	F			
cf. P. major Kützing									R
microstauron (Ehrenberg) Cleve	R	F		F			R		
nebulosa Lohman, n.sp.						F			
nobilis Ehrenberg				C					
cf. P. nodosa Ehrenberg					R				
nodosa var. constricta Mayer							F		
obscura Krasske				R					
pseudopunctata Lohman, n.sp.	C	F	C						
schweinfurthii (Ehrenberg) Hustedt		F		F					
virginica Lohman, n.sp.	C	F	C	F	F	F	F		F
virginica var. brevicostata						R			
viridis (Nitzsch) Ehrenberg	F	C		F	F	F	F		
cf. P. viridis (Nitzsch) Ehrenberg			F						

Comparisons with other diatom assemblages

The Virgin Valley assemblages compare closely with those obtained from the lower part of the Barstow formation in the Barstow Syncline, San Bernardino County, California. The Barstow diatoms occur in a zone 1500 to 1750 feet stratigraphically below the fossiliferous tuff member from which Merriam (1911, pp. 167-169; 1919, pp. 438-585) and others obtained the vertebrate collections known as the Barstow fauna. Merriam first correlated the Barstow with the Virgin Valley formation, but Wood et al (1941, p. 12, 14, pl. 1) in using the Barstow Syncline as the type locality of the Barstovian provincial stage placed it in the upper Miocene, where it has remained. Subsequent work has indicated that another, Hemingfordian fauna (middle Miocene) occurs in the lower part of the Barstow formation, and it is actually below this part of the section, but still within the same cartographic unit that the diatoms mentioned above came. Therefore, the similarity in the diatom assemblages is in close agreement with the independent age assignment based on vertebrate faunas.

Diatom assemblages from the Mascall formation of early upper Miocene age at Tipton and Austin, Oregon (Lohman, 1934, p. 9) are remarkably similar to those from Virgin Valley. 60 percent of the Tipton and Austin forms also occur in the Virgin Valley formation.

Paleoecology

Lower Virgin Valley beds

The extensive and varied diatom assemblages from the Lower beds suggest a large, shallow, fresh water lake. The shallowness of the lake is indicated by the fact that bottom dwelling genera such as Achnanthes, Cymbella, Gomphonema, and Navicula are well developed, both in speciation and number of individuals. The large amount of volcanic ash which occurs in a considerable part of the section would have kept the water sufficiently turbid to retard photosynthesis in a deep lake. The dominance of the pelagic genera, such as *Melosira*, *Fragilaria*, and others, suggests that even in a shallow lake the turbidity was frequently great enough to favor those species which could live close to the surface. The lake was probably well supplied with organic matter (the carbonaceous shales give independent evidence of this), and as a result the pH was probably low, favoring such acid loving genera as *Pinnularia*, which is represented by 36 species and varieties, most commonly in the lower beds representing the period when the organic matter was at its maximum. It is highly probable that the recurrent volcanic ash falls also contributed toward the lowering of the pH of the water. The temperature suggested by the diatoms must have been moderate to warm, except for two zones mentioned below. Many species of diatoms can prosper in waters varying in temperature through fairly wide limits, but *Melosira granulata* and its closely related species appear to prefer moderate to warm water.

No evidence of hot spring activity in the region is indicated, as the hot water forms characteristic of thermal springs are entirely absent. The salinity of the water was probably very low as species characteristic of saline lakes are also absent.

At U.S.G.S. diatom locality 3530, 36 feet stratigraphically above the base of the Opal Creek section, a thin bed $\frac{1}{4}$ inch thick of pure white diatomite occurs in which several species of *Melosira*, a pelagic genus, are so abundant as to dominate the assemblage, suggesting increased turbidity to the extent that the bottom dwelling forms did not get enough light to reproduce in significant amounts.

At U.S.G.S. diatom locality 3534, 84 feet stratigraphically above the base of the Opal Creek section, the genus *Tetracyclus* makes its first appearance in Virgin Valley and dominates the assemblage, both in number of species and number of individuals. The striking thing about this virtual flood zone is the fact that the lower part of the section contains assemblages suggestive of moderate to fairly warm water, whereas the genus *Tetracyclus*, of which a number of different species still living elsewhere are present, is a cool to cold water genus. It is most commonly found living in Alpine lakes and in Scandanavia. *T. javanicus*, which occurs frequently in both the Lower and Upper Virgin Valley beds, was described from "Java" by Hustedt (Hustedt in Schmidt, Atlas der diatomaceenkunde, pl. 294, figs. 42, 43, 1913), who, unfortunately, did not state whether this form was living or fossil. Its presence in the Virgin Valley beds, therefore, gives neither ecologic nor stratigraphic information. Its apparently close relationship to some of the fossil forms having known ranges of middle Miocene to early Pliocene, however, suggests that *T. javanicus* may be a fossil form. The sudden appearance of these cold water forms in such diversity and numbers strongly suggests a climatic change of some magnitude. The thickness of the bed in which they occur is too great for this to represent a seasonal change, as many years would be required for its accumulation. This *Tetracyclus* flood is duplicated in the highest collection made from the Lower beds (U.S.G.S. diatom locality 3537), 107 feet stratigraphically above the base of the Opal Creek section, with the same paleoecological implication.

Upper Virgin Valley beds

As mentioned previously, only one collection from the Upper beds (U.S.G.S. diatom locality 3540) contained diatoms, and this again represents a flood zone of which Melosira ponderosa and two varieties of it, all new, are the dominant diatoms. Tetracyclus is represented about the same relative abundance as in the two collections from the Lower beds, The assemblage suggests a large, cold, shallow lake, with a somewhat higher pH than the earlier beds of the Lower zone.

Esmeralda formation, early Pliocene

Nye Co., Nevada

The Esmeralda formation was named by Turner (1900A, pp. 168-170) for some coal-bearing lake deposits at the north end of the Silver Peak Range, Esmeralda County, Nevada. This was followed in the same year by a larger paper (1900B, pp. 197-208, pl. 24-29) containing detailed description, photographs, and a map of the north half of the Silver Peak Quadrangle (1/125,000) showing the areal distribution of the Esmeralda formation. Turner described the beds as "sandstones, shales, and lacustral marls, with local developments of breccia and conglomerate on a large scale", and gave an estimated total thickness of 14,800 feet, which even he thought was "incredible". It so appears today, but the total thickness may be as much as one third to one half of this figure. As shown on Turner's map, the Esmeralda formation consists of scattered erosional remnants, each from a fraction of a square mile to 2 square miles in extent in many parts of the west slope of the Silver Peak Range, a large area of perhaps 10 square miles at the north end of the range, a patch of about 5 square miles southeast of Red Mountain, and a larger area of perhaps 30 square miles at the southeastern end of Big Smoky Valley. It appears probable that there is some duplication in Turner's composite section of these scattered areas, accounting for his extravagant total thickness for the formation.

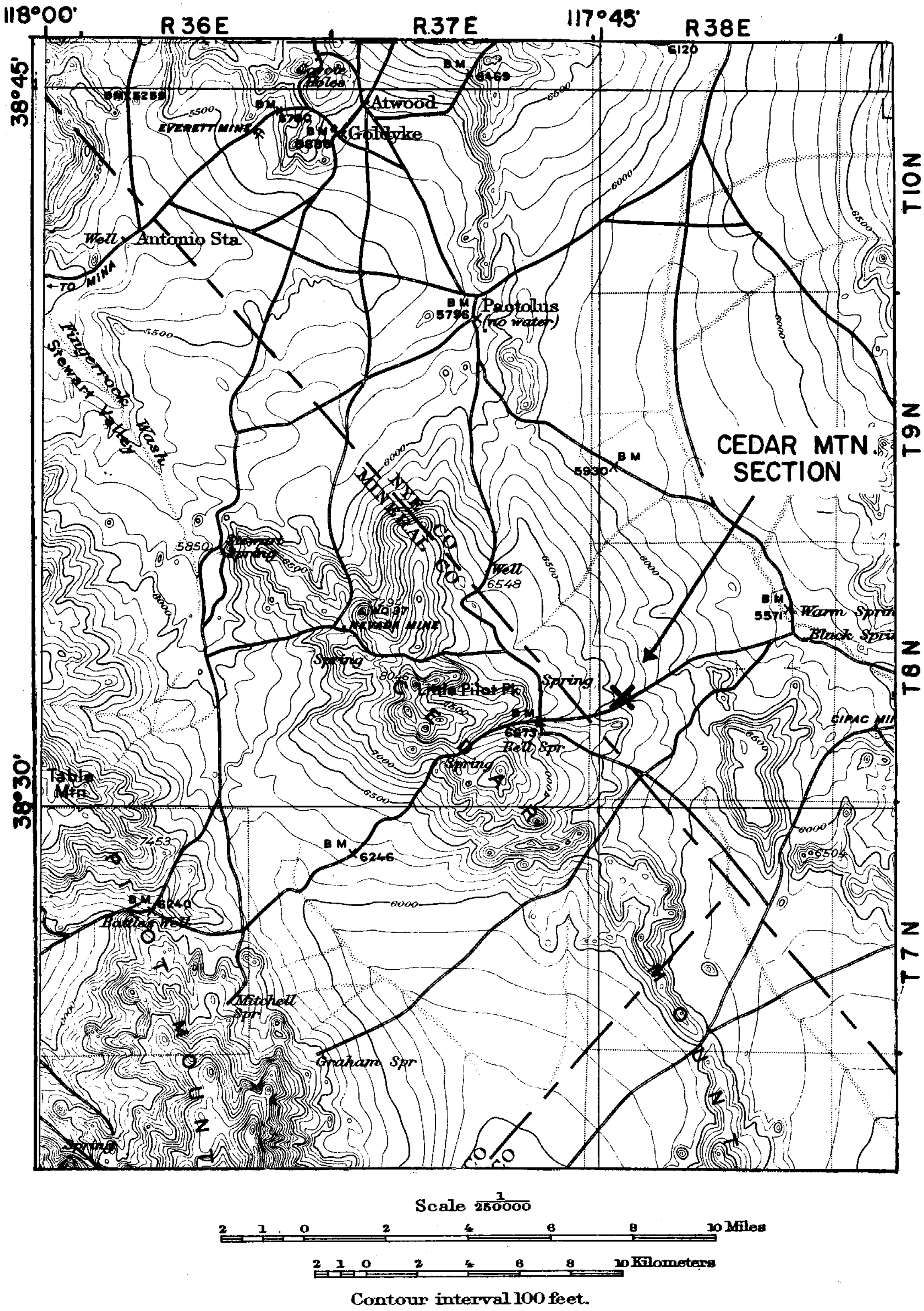
Fourteen forms of fossil plants were described by Knowlton (1900, pp. 209-220, pl. 30), who pointed out the Miocene and Eocene affinities of one species and described the balance as new with affinities to Recent genera. Knowlton felt that the plant remains from the Esmeralda formation were not adequate for an age assignment. Lucas (1900, pp. 223-224, pl. 31) described a new species of fossil fish from the Esmeralda formation, but gave no estimate of age. Buwalda (1914) traced the Esmeralda northward from the type locality into the southern flank of the Monte Cristo Range; farther northward into Stewart Valley and the east flank of Cedar Mountain from the southern end northward into Ione Valley, all on the Tonapah Quadrangle (1/250,000) of the U. S. Geological Survey. His estimates of thicknesses of the Esmeralda formation of about 1000 feet in the Stewart and Ione Valleys, and about 700 feet on the east slope of Cedar Mountain, appear to be the right order of magnitude, and apparently are much closer to the true thickness (at least in the areas mentioned) than Turner's much larger firgure. Buwalda was the first to make extensive collections of mammalian remains from the Esmeralda formation, principally in the Stewart Spring area at the north end of Stewart Valley and from the east slope of Cedar Mountain. These collections were subsequently studied by J.C.Merriam (1916), who considered both the Stewart Spring and Cedar Mountain areas to be of late Miocene age. Stirton (1932, pp. 60-61), after a season of collecting in the region by himself and his students, first noticed that there were two separate faunas in the Esmeralda formation; one of late Miocene age, mainly from the vicinity of Stewart Spring, which Teilhard de Chardin and Stirton (1934, p. 285) subsequently called the Stewart Spring fauna, and one from the east slope of Cedar Mountain between Bell Spring and Black Spring, which they called the Esmeralda fauna. They correlated the former with the Virgin Valley formation, of middle Miocene age, and restricted the name Esmeralda formation for the latter and the Fish Lake Valley fauna, which occurs in a tuffaceous sequence just west of Turner's type locality and has been traced into it. The Esmeralda formation, on the east slope of Cedar Mountain and in Fish Lake Valley, was considered to be of early Pliocene age on vertebrate evidence. Wood et al (1941, p. 19, pl. 1) have followed Stirton and this age assignment has been accepted for the present report.

Nolan (1943, p. 166) has summarized some of the problems connected with the Esmeralda formation:

> "The name Esmeralda, as commonly used, probably applies to beds that contain the younger of the two faunas and is often used in that sense, but it has also been used as a group name for both units. The nature of the contact between the beds containing the two faunas is apparently unknown; the unfossiliferous Tonopah formation in the mining district (Nolan, 1935) of that name may represent the lower beds, is overlain with angular unconformity by the basal member of a section that has been correlated with the Esmeralda, but as this cannot be closely dated, the significance of the unconformity remains uncertain."

Diatom collections for the present investigation were made in 1938 and additional material was obtained in 1950. The locality chosen (Plate 5) is on the east slope of Cedar Mountain, 2 miles N. 59° E. of Bell Spring, on the north side of the road between Bell Spring and Black Spring, T. 8 N., R. 38 E., Tonopah Quadrangle (1/250,000), Nye County, Nevada. The Esmeralda here rests unconformaly on the Luning formation of late Triassic age (Ferguson and Muller, 1949, p. 7, pl. 1). The lower part of the Esmeralda as here exposed is intruded by rhyolite stocks and is so badly distorted and altered that it could not reliably be included

PLATE 5



Map showing location of Cedar Mtn. Section
Nye County, Nevada
Adapted from U.S.G.S. Tonopah Quadrangle

in a measured section which includes all of the diatom collections from Cedar Mountain studied for this report. It is estimated that between 50 and 100 feet (stratigraphically) represents the order of magnitude of the interval between the true base of the Esmeralda formation and the base of the measured section. The lower 325 feet of the section, containing all of the collections that yielded diatoms, consists of alternating pumiceous tuff, diatomaceous tuff, silty shale, diatomite, and sandstone, with minor amounts of limestone, all usually well bedded with dips varying from 28 to 47 degrees. The upper, non-diatomaceous part of the section, having a thickness of 110 feet, consists of ash, silt, sand, and is capped by thick beds of limestone bearing abundant freshwater mollusks in a poor state of preservation. The upper part of the section flattens out, with dips varying from 20° to nearly zero at the top, where the dip remains less than the eastward slope of Cedar Mountain. The vertebrate fossils collected by Buwalda and studied by Merriam, as well as those collected by Stirton and his students, known as the Upper Cedar Mountain fauna, came from either within the measured section or from stratigraphically equivalent beds which strike into it. The details of the section and the stratigraphic positions of the diatom collections are given below:

Measured section of part of the Esmeralda formation as exposed 2 miles N. 59° E. of Bell Spring, on north side of Bell Spring-Black Spring road, T. 8 N., R. 38 E., Tonopah Quadrangle, Nye Co., Nevada.

USGS diat. loc.		Thickness of unit	Total thickness above lowest bed exposed
	Alternating beds of white to buff siltstone with thick beds of fossiliferous limestone	93	438
	Gray siltstone with occasional pebbles	11	345
	Hard ocherous coarse, pebbly sandstone	1	334
	Yellow ocherous silty shale	7	333
	Gray ash	1	326
3410*	White, punky diatomite interbedded with tuffaceous silt. Sample from top.	4	325
	Gray to buff tuffaceous silt with a prominent hard white limestone in center	21	321
3408	White to cream punky diatomite	1	300
	Gray to buff tuffaceous silt	8	299
3407* top	Greenish fine sandstone with 1 inch bed of white powdery diatomite at top, flood of *Melosiras*	5	291
3406	Buff, somewhat clayey diatomite	½	286
	Greenish fine sandstone	1½	285½
3405*	Buff, somewhat clayey laminated diatomite	2	284
3404*	Buff to cream colored, massive to laminated, diatomaceous clay shale grading upward to		

	white punky diatomite of preceding unit, sample from top	6	282
3403*	Buff to cream colored massive diatomite	1	276
3402	Buff diatomaceous silty clay shale	½	275
	White weathering greenish to buff tuffaceous shale	11	274½
	Thin beds of hard siliceous limestone, in part concretionary	½	263½
	White weathering greenish tuffaceous? shale	14	263
3401	White weathering buff hard limestone	½	249
	White weathering greenish tuffaceous? shale	14½	248½
3400	White weathering greenish, conchoidally fracturing shale, somewhat limy	1/4	234
	Thin gray tuff	1/4	233 3/4
	Hard diatomaceous shale with a very few hard limestones	27½	233½
3399	Hard diatomaceous shale	17	206
	Reef-forming greenish buff sandstone alternating with gray ash beds	14½	189
	Prominent silver-gray ash, well laminated in lower 1/3, massive in upper 2/3	1½	174½
	Pale buff to gray tuffaceous silt	15	173
3398	White weathering buff diatomaceous silt	½	158
	Soft, well bedded white tuff	15½	157½
	Prominent very hard porous white tuff	5	142

3397*	White weathering buff to drab tuffaceous diatomaceous clay	1	137
	Zone of alternating 3" beds of coarse pumiceous tuff, 3" beds of silver gray ash, and 1" beds of very hard tuffaceous sandstone with thicker beds up to 1 ft. of white, very fine grained tuff, in part somewhat diatomaceous, in part reef-forming	104	136
	White weathering light gray pumiceous tuff	1	32
3396*	White weathering light weight diatomite	1	31
	White weathering light gray pumiceous tuff	10	30
3395	White diatomaceous tuff	5	20
3394*	White diatomaceous tuff	1	15
3393	White weathering light gray pumiceous tuff containing a very few scattered diatoms and one 2-foot bed of coarse sandstone about midway	14	14
	Lowest exposure of Esmeralda formation at this locality -- indeterminate amount above real base.	0	0

All of the above collections were prepared for study and all were given a preliminary microscopic examination. The proportion of diatoms was low in some of the collections, particularly in the more tuffaceous ones. Furthermore, many of the adjacent collections contained diatom assemblages so similar that to have thoroughly studied all of them would merely have increased the time required without a commensurate gain in information. Those finally selected for this report are indicated in the above section by asterisks after the locality numbers.

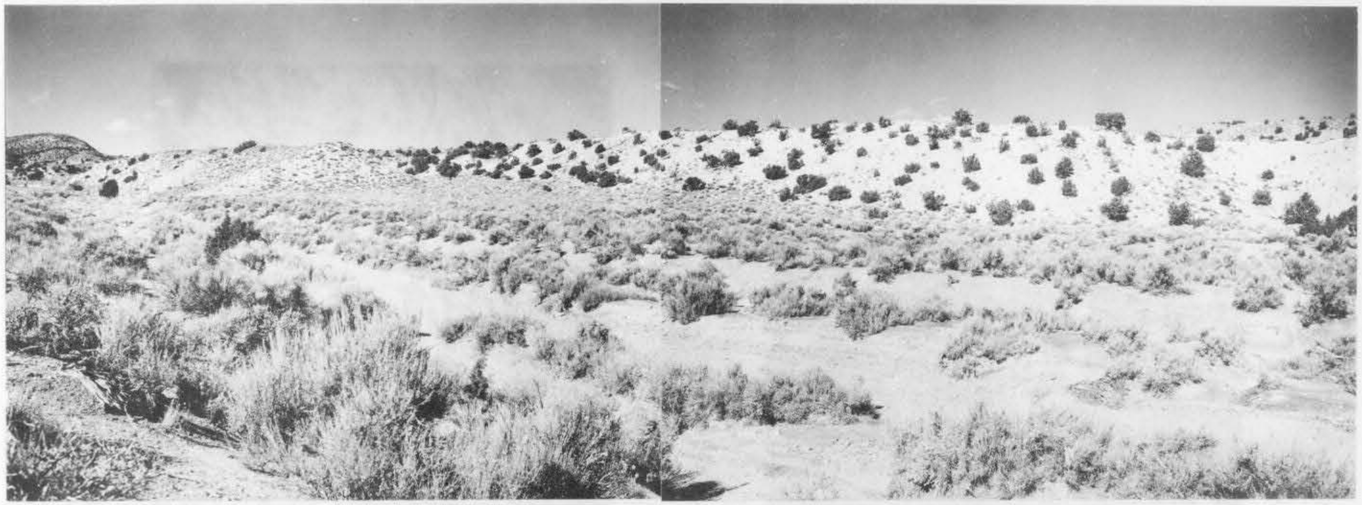
In Plate 6 is shown a panoram of the Cedar Mountain section looking N. 85° W. to N. 80° E., from left to right respectively, from a point along the Bell Spring - Black Spring road. The darker rounded hill at the extreme left is the Luning formation of late Triassic age. The hard fossiliferous limestone beds forming the top of the section are shown about an inch to the right of center of the lower of the two halves of the panoram. A close-up of this same limestone bed is shown in Plate 7B, with a detail of the most highly fossiliferous part shown in Plate 7C.

A detail of tuff and diatomite near locality 3396, in the lower part of the section is shown in Plate 7A. In this view, the head of the hammer is lying across two thin hard tuff beds and the end of the handle lies across a soft punky diatomite.

The eight assemblages from the Esmeralda formation yielded a total of 107 different species and varieties of diatoms, of which 38 are new. They are listed in Table 2, beginning on page 51.

The relative abundances are indicated by A = abundant; C = common; F = frequent; and R = rare.

PLATE 6



Cedar Mountain section, Nye Co., Nevada. West half.

Cedar Mountain section, Nye Co., Nevada. East half.

PLATE 7

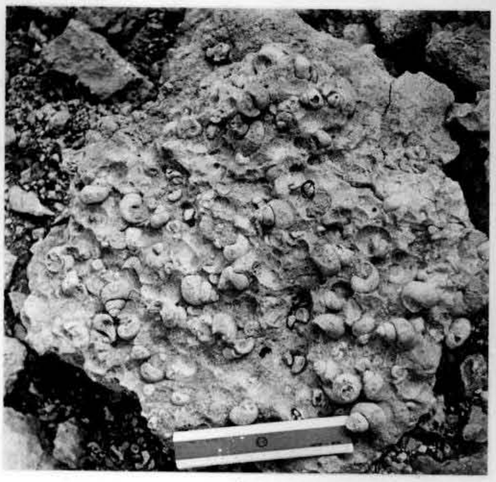
Details of Cedar Mountain section, Nye Co., Nevada

A

Tuff and diatomite near locality 3396

B

Fossiliferous limestone at top of section



C

Detail of fossiliferous limestone showing mollusks

Table 2

Diatoms
from
Cedar Mountain Section
Nye County, Nevada

	U.S.G.S. DIATOM LOCALITY							
	3394	3396	3397	3403	3404	3405	3407	3410
	1	2	3	4	5	6	7	8
Melosira arenaria Moore		F	F	F	F	R	F	
cf. M. binderana Kützing			F					
crassa Lohman, n.sp.	F			F				
distans (Ehrenberg) Kützing	C				C			
granulata (Ehrenberg) Ralfs	C	A		F	D	F		C
granulata var. jonensis Grunow			F	F		F		
granulata var. muzzanénsis (Meister) Bethge			C	F				
italica (Ehrenberg) Kützing			R	F				
micropunctata Lohman, n.sp.			F			R		
paucipunctata Lohman, n.sp.			F		C	F		
ponderosa Lohman, n.sp.	F	A	C	F		F	D	A
ponderosa var. curta Lohman, n.var.			F				A	
ponderosa var. elongata Lohman, n.var.						F	C	A
solida Eulenstein	F			F		F		
undulata (Ehrenberg) Kützing	F			F				
Cyclotella anomala Lohman, n.sp.	R							
sp.		R		R				
Coscinodiscus lacustris Grunow					F	F	F	C
mobilis Lohman, n.sp.			F	F				
Cestodiscus apiculatus Lohman, n.sp.			C					
canalis Lohman, n.sp.			R					
cedarensis Lohman, n.sp.	R	R		F		R		
fasciculatus Lohman, n.sp.	A		C	F		F		

	1	2	3	4	5	6	7	8
Cestodiscus simplissimus Lohman, n.sp.			F	F				
stellatus Lohman, n.sp.	F		F					
Fragilaria brevistriata Grunow			F					
construens (Ehrenberg) Grunow			C	F	F	C		F
crassa Lohman, n.sp.			C	C	F	C	F	
crassa var. capitata Lohman, n.var.			F	F		R		
inflata (Heiden) Hustedt			F					
pinnata Ehrenberg				C				C
Synedra ulna (Nitzsch) Ehrenberg			F	F		C		
ulna var. spathulifera Grunow			F	C				
Opephora martyi Heribaud						R		
Meridion circulare (Greville) Agardh			F					
Tetracyclus calceus Lohman, n.sp.			F	F		F		F
clypeus (Ehrenberg) Lohman, n.comb.	F			R				
ellipticus (Ehrenberg) Grunow	F			F		R	R	
ellipticus var. constricta Hustedt	F		F	F		F		F
ellipticus var. lancea (Ehrenberg) Hustedt	F							
horus Lohman, n.sp.						F		
irregularis Lohman, n.sp.			R					
javanicus Hustedt			R		F	F		
cf. T. javanicus Hustedt					F		F	F
parallelus Lohman, n.sp.	F		R		F	F		F
cf. T. pergalli Heribaud					R			
radiatus Lohman, n.sp.	F							
rupestris (Braun) Grunow						F		R

	1	2	3	4	5	6	7	8
Eunotia clevei Grunow	F		R			R		
valida Hustedt					R			
Achnanthes lanceolata var. rostrata (Oestrup) Hustedt								F
Cocconeis placentula Ehrenberg			C	C		F		F
Diploneis ovalis var. oblongella (Naegeli) Cleve							R	
Caloneis bacillum (Grunow) Mereschkowsky				R		F		F
silicula var. tumida Hustedt						R		
Stauroneis anceps Ehrenberg			R					
debilis Lohman, n.sp.			F					
parvula var. prominula Grunow			R					
Anomoeoneis cubita Lohman, n.sp.			F					
lanceolata Lohman, n.sp.			F					
malinvaudii (Heribaud) Lohman, n.comb.			R					
nyensis Lohman, n.sp.			C		R			
sphaerophora (Kützing) Pfitzer			R					
sphaerophora var. guntheri Muller				R				
turgida Lohman, n.sp.			F					
sp.			F					
Navicula amphibola Cleve			F		R	R	R	F
bacillum Ehrenberg							R	F
citroides Lohman, n.sp.			R	F		R		F
cf. N. cuspidata Kützing			F					
dicephala (Ehrenberg) Wm. Smith			F	F		R		
cf. N. gastrum Ehrenberg			F					
gastriformis Hustedt				F				
isolata Lohman, n.sp.			R	F				R
placentula (Ehrenberg) Grunow							R	

	1	2	3	4	5	6	7	8
Navicula radiosa Kützing			C					R
soodensis Krasske						R		
Pinnularia cf. P. dactylus var. sumatrana Hustedt			F					
esmeraldensis Lohman, n.sp.			F					
esmeraldensis var. constricta Lohman, n.var.			F					
cf. P. hemiptera (Kützing) Cleve			R					
legumen Ehrenberg			F	R				
cf. P. microstauron (Ehrenberg) Cleve								R
virginica Lohman, n.sp.			R					
spp.	R		R		R		R	
Gomphonema acuminatum var. turris (Ehrenberg)Cleve						R		
angustatum Kützing			C	C				
constrictum var. capitata (Ehrenberg) Cleve					R	R		
cf. G. duostriata Lohman, n.sp.						R		
intricatum Kützing			C	C		F	F	C
lanceolatum Ehrenberg			F					
parvulum (Kützing) Grunow			F					
parvulum var. micropus (Kützing) Cleve						F		
quadratum Lohman, n.sp.			R	F		F		F
subclavatum Grunow				F				
tergestinium (Grunow) Fricke	F		F					F
Cymbella affinis Kützing								F
cistula (Hemprich) Grunow			C	F	F	A	F	F
cistula var. maculata (Kützing) Van Heurck	C							F
cymbiformis (Agardh) Kützing)			C	F	F			
cf. C. ehrenberg Kützing				C				

	1	2	3	4	5	6	7	8
Cymbella lanceolata (Ehrenberg) Van Heurck				F				
mexicana (Ehrenberg) Cleve						A		
sinuata var. antiqua Grunow	F							
ventricosa Kützing				R		C		C
Amphora sparsa Lohman, n.sp.			R					
sp.	R		R					
Nitzschia spp. (fragments only)			F	R				
Hantzschia amphioxys var. vivax (Hustedt) Grunow			F					
Surirella pallida Lohman, n.sp.			A					
spicula Lohman, n.sp.			A					
spicula var. lineata Lohman, n.var.			F					

The assemblages from the Esmeralda formation are among the most interesting and definitive of those studied from the Great Basin. Pelagic species are well represented and virtually dominate several thin zones in the section. It is the only formation among those studied for this report in which the two discoid genera Coscinodiscus and Cestodiscus occur, the latter being particularly abundant in the lower part of the formation. This represents the first recorded occurrence of nonmarine species of Cestodiscus and makes an interesting chapter in the evolution of this genus. It began at least as far back as the Eocene, having been recorded from Barbadoes by Ehrenberg (1854), from the middle Miocene of Maryland (Lohman, 1948, p. 165), from the late Miocene of Java (Reinhold, 1937, p. 89), and from a Recent ocean (Castracane, 1886, p. 122), but always under strictly marine conditions.

Castracane recorded the only known Recent occurrence of the genus from the Pacific Ocean. He gave no further geographic or ecologic data, but both his descriptions and illustrations of 6 new species and 3 new varieties are quite adequate for identification of the genus as Cestodiscus. His collections came from the Challenger Expedition and would appear to be from strictly marine waters in the mid Pacific. All of the many reported occurrences of the genus as fossils have always been in assemblages of other marine species. Its sudden appearance in great quantities in the lower Pliocene Esmeralda formation and its equally sudden extinction is therefore very surprising, as the balance of the diatoms in the Esmeralda assemblages are nonmarine saline, brackish and fresh water species only. Therefore, the best deduction that can be made regarding this occurrence is that the Esmeralda Cestodisci were able to tolerate much lower salinity than any other known members of the genus. A similar case exists in the genus Coscinodiscus, which is dominantly a marine genus, but does have about half a dozen fresh water species out of a total of several hundred.

The possibility that these Cestodisci are homeomorphs has been considered, but after examining many hundreds of individuals of the several species here described, they have been found to be quite consistent in having the characteristics of the genus; furthermore, homeomorphy has not been demonstrated in any of the diatoms.

Cestodiscus fasciculatus, one of the Esmeralda species, has also been found in beds assigned to the lower Pliocene in Cassia County, Idaho (Lohman, Report on referred collections, 1953), and from rocks also considered to be early Pliocene in age from the Silvies Valley in Central Oregon (Lohman, Report on referred collections, 1956). The comparison between the Esmeralda assemblages and those mentioned from Idaho and

Oregon is also fair in other respects. The Esmeralda assemblages bear no significant resemblance to one from the Ogallala formation in Kansas of middle to late Pliocene age (Hanna, 1932), or to one from the Laverne formation of early Pliocene age in Kansas (Lohman, 1941B, pp. 402-403). The diatoms from the Laverne suggest not only saline water, but also quite alkaline conditions, as is indicated by the misshapen nature of many of the diatoms.

Paleoecology

Lake Esmeralda was obviously one of great lateral extent, as it has been traced (Buwalda, 1914) over an area covering many hundreds of square miles. The rather uniform distribution of pelagic diatoms in the assemblages, throughout the Cedar Mountain section at least, in addition to several flood zones where they are more than usually abundant, suggests that lake was fairly deep. The water must have been very clear between ash falls as there are also many species of attached, littoral forms which require clear water to live at depth. The periodic ash falls (indicated in the stratigraphic section) apparently wiped out the diatoms almost entirely a number of times. Abundance of soluble silica, however, made it possible for the diatoms to quickly reach maxima again during quiescent periods. The gradual diminution in frequency of Tetracyclus, a cold water genus, going up in the section suggests that the temperature increased from cold to moderate during the lake's history. Most of the Esmeralda assemblages contain many species that now live in saline and brackish lakes, suggesting that the water was far from fresh. This may explain the introduction of several new species of the normally marine genus Cestodiscus. The minor development of such acid loving species as many members of the genus Pinnularia suggests that the pH of the lake water may have been at least as high as 7.0 and possibly higher.

Thousand Creek beds

Middle Pliocene

The Thousand Creek beds are situated in the northwestern corner of Humboldt County, northwestern Nevada and the area is shown in the northwestern corner of the Diaster Quadrangle, 1/250,000, published in 1893 by the U. S. Geological Survey. A portion of this quadrangle, together with a portion of the Long Valley Quadrangle immediately to the west, is shown in Plate 2, taken from Merriam's pioneer paper on this region and its vertebrate fossils (Merriam, 1910, pl. 2), giving both Merriam's vertebrate collecting localities and also those from which diatoms were collected for the present report. The diatom collections were made during five days spent in the Virgin Valley and Thousand Creek areas in September, 1938.

The Thousand Creek beds form an irregularly shaped flat area known as Thousand Creek Flats. Thousand Creek takes its name from the braided distributary of Virgin Creek and its tributary Beet Creek after they have come through the gorge in Thousand Creek Ridge, which bounds the Flats on the southwest. The Pine Forest Mountains bound it on the east and a series of low tongue-like flat lava-capped ridges, of which Railroad Ridge is the most prominent, bound it on the north. The Canyon rhyolite forming Thousand Creek Ridge separates Thousand Creek Flats from Virgin Valley to the southwest and has been faulted up, elevating the Virgin Valley beds and the Canyon rhyolite by at least 400 feet above the Flats.

The Thousand Creek beds are practically flat-lying and consist largely of tuffaceous silt, almost pure volcanic ash, and silty sand. Most of the beds seen in 1938 were dominantly white, gray to buff in color, although Merriam (1910, p. 44) mentions that they are also red to dark brown.

In no instance was anything approaching a diatomite found; the diatoms from the Thousand Creek beds came from fine-grained tuffaceous mudstone of siltstone. Although a large part of the Thousand Creek Flats were investigated and sampled, the diatoms were found in only one locality, 1000 feet south of the road, and S. 18° E. of the southernmost tip of Railroad Ridge, on the line of Merriam's section C-D (see Plate 2), very near his vertebrate locality 1063 and only a very few feet lower stratigraphically. The maximum section exposed here is as follows:

USGS diat. loc.		Thickness of unit	Total thickness above base
	Coarse to medium grained gray sand, crossbedded in lower part	4' 0"	9' 0"
3545	Thin buff mudstone and ash	0' 3"	5' 0"
	Crossbedded gray medium-grained sand	2' 0"	4' 9"
	Well-bedded gray silty sand	1' 0"	2' 9"
3544	Cream colored hackly fracturing tuffaceous mudstone	0' 4"	1' 9"
	Gray tuffaceous sand	0' 3"	1' 5"
3543	Cream colored tuffaceous mudstone	0' 2"	1' 2"
	Gray sand	1' 0"	1' 0"
	Base of exposure		0' 0"

A total of 96 species and varieties of diatoms was obtained from the three collections, of which the assemblage from locality 3545 proved to be the most diversified.

The collections from the above section, although the best of all made from the Thousand Creek beds, actually contained the lowest concentration of diatoms per unit volume of sediment of any studied from the Great Basin. It appeared highly desirable, however, to obtain diatoms from these beds as (1) they occupy a strategic place in the succession of the nonmarine Tertiary beds that have been satisfactorily dated by means of vertebrate fossils, and (2) it appeared probable that by obtaining a good assemblage of diatoms from these beds, some of the questions raised by Merriam (1910, pp. 43-50; 1911, ppl 220-224) regarding the origin of the Thousand Creek beds could be further explored and possibly solved. Accordingly, the collections which at first inspection appeared to be hopeless, proved after prolonged effort in separating the small proportion of diatoms in them from an unusual amount of both clastic material and glassy ash, to yield a total assemblage of 96 species and varieties. In all other collections studied for this report great care was exercised in their preparation to arrive at (within reasonable limits) the same degree of concentration, in order that the relative abundances indicated for the individual species in the different assemblages would be comparable from one locality to another. Of necessity, a departure from this policy was made in the case of the collections from the Thousand Creek beds. To have done otherwise would have meant that those species indicated in Table 3 as common and frequent would all have been reported as rare, and those listed as rare would not have been found at all. Thus the relative abundances listed for the Thousand Creek beds represent the relative abundances of the species in the <u>assemblages</u> after unusually great concentration, but not in the rock as found in the field, and furthermore are <u>not</u> comparable to the relative abundances listed for the assemblages from other localities studied. As in other lists, C = common; F = frequent; and R = rare.

Table 3

Diatoms from the Thousand Creek beds

	U.S.G.S. diatom locality		
	3543	3544	3545
Melosira ambigua (Grunow) Muller		R	F
distans (Ehrenberg) Kützing			F
distans var. lirata (Ehrenberg) Bethge			R
granulata (Ehrenberg) Ralfs	R	F	F
granulata var. jonensis Grunow			F
granulata var. curvata Grunow		F	
italica (Ehrenberg) Kützing			F
Fragilaria leptostauron var. dubia Grunow			F
pinnata var. lancettula (Schumann) Hustedt		R	F
nitzschioides Grunow			R
Synedra ulna (Nitzsch) Ehrenberg			R
Meridion constrictum Ralfs			F
Diatoma vulgare Bory			F
vulgare var. breve Grunow			R
Tetracyclus ellipticus Grunow		R	F
ellipticus var. lancea (Ehrenberg) Hustedt			F
emarginatus (Ehrenberg) Wm. Smith		R	
horus Lohman, n.sp.			R
cf. T. javanicus Hustedt		R	R
circularis Lohman, n.sp.			R
rupestris (Braun) Grunow			R
Tabellaria cf. T. fenestrata (Lyngbye) Kützing			R

	3543	3544	3545
Eunotia monodon var. tropica Hustedt			R
pectinalis (Kützing) Rabenhorst			F
praerupta Ehrenberg			F
valida Hustedt		R	
Achnanthes lanceolata Brebisson			R
Cocconeis placentula Ehrenberg			R
placentula var. euglypta (Ehrenberg) Cleve	R		
Neidium bisulcatum (Lagerstedt) Cleve		F	
iridis (Ehrenberg) Cleve			F
Frustulia cf. F. rhomboides (Ehrenberg) De Toni			R
Caloneis bacillum (Grunow) Mereschkowsky			F
cf. C. schumanniana var. trinodis Lewis			R
Stauroneis anceps Ehrenberg			F
anceps var. linearis (Ehrenberg) Cleve			R
gregorii Ralfs			R
Anomoeoneis polygramma (Ehrenberg) Pfitzer	R	F	
cf. A. sphaerophora (Kützing) Cleve		F	R
Navicula ambigua Smith			F
amphibola Cleve			F
dicephala (Ehrenberg) Wm. Smith			F
dicephala var.			F
gibbula Cleve			F
mutica Kützing			C
mutica var. cohnii (Hilse) Grunow			F
radiosa Kützing			F
cf. N. ruttneri Hustedt			F

	3543	3544	3545
Navicula semota Schmidt			F
semen Ehrenberg			F
thienemanni Hustedt		R	R
Pinnularia angulata Lohman, n.sp.			F
appendiculata (Agardh) Cleve			F
cf. P. brevicostata Cleve			R
brevicostata var. leptostauron ,			F
borealis Ehrenberg		F	C
divergentissima (Grunow) Cleve	R		R
microstauron (Ehrenberg) Cleve		R	C
cf. P. microstauron (Ehrenberg) Cleve			F
molaris Grunow			F
obscura Krasske			R
virginica Lohman, n.sp.			F
cf. P. virginica Lohman, n.sp.			R
viridis (Nitzsch) Ehrenberg		R	
Gomphonema angustatum (Kützing) Rabenhorst			F
augur Ehrenberg			R
bohemicum Reichelt and Fricke		R	
duostriata Lohman, n.sp.			F
grovei M. Schmidt			R
intricatum Kützing			F
longiceps var. subclavata Grunow		R	F
olivaceum (lyngbye) Kützing			F
parvulum var. micropus (Kützing) Cleve			F

	3542	3544	3545
Cymbella aequalis Wm. Smith	R		R
angularis Lohman, n.sp.		F	
cistula (Hemprich) Grunow			R
mexicana (Ehrenberg) Cleve		F	F
cf. C. naviculiformis Auerswald			R
cf. C. tumida (Brebisson) Van Heurck		F	
turgida (Gregory) Cleve			F
ventricosa Kützing			F
Amphora sp.			R
Epithemia sorex Kützing	F	F	F
sorex var. gracilis Hustedt		R	
turgida (Ehrenberg) Kützing		R	
turgida var. granulata (Ehrenberg) Kützing			R
zebra Kützing			F
zebra var. porcellus (Kützing) Grunow		F	
Rhopalodia gibba (Ehrenberg) Muller			F
gibberula (Ehrenberg) Muller			F
gibberula var. margaritifera Rabenhorst			R
Nitzschia amphibia Grunow			R
palea (Kützing) Wm. Smith			R
Hantzschia amphioxys (Ehrenberg) Grunow			C
amphioxys var. vivax (Hantzsch) Grunow			R
aff. H. robusta Hustedt			R
Surirella cf. S. ovata Kützing		R	
Campylodiscus anastomosus Lohman, n.sp.		C	

A brief analysis of the occurrence of diatoms in the Thousand Creek assemblages compared with those from other localities is shown in the following table:

Table 4

Occurring in both Virgin Valley and Thousand Creek beds only	17
Occurring in both Esmeralda formation and Thousand Creek beds only	9
Occurring in Virgin Valley, Esmeralda, and Thousand Creek only	16
Occurring in Thousand Creek beds only (including a small number that also occur in the Hagerman and Provo formations)	52
Occurring in all five localities	3
Total species and varieties in Thousand Creek beds	96

Merriam (1910, pp. 43-50; 1911, pp. 220-224) considered several hypotheses in attempting to explain the relationship between the Virgin Valley beds and the Thousand Creek beds. In the second paper cited above, beginning on page 221, he stated the alternatives:

> "The Thousand Creek beds may be:
> (1) Upper Virgin Valley beds, faulted down.
> (2) Post- Virgin Valley and pre-Mesa Basalt, faulted down.
> (3) Post-Mesa Basalt; formed from older wash of Virgin Valley, faulted down.
> (4) Post-Mesa Basalt; formed from younger wash of Virgin Valley, not moved far by faulting.
> (5) Composite, partly Virgin Valley and partly Pleistocene."

Merriam originally (1911, p. 204; reproduced on page 27 of this report) divided the Virgin Valley beds into an Upper Virgin Valley and a Lower Virgin Valley, separated by a probable unconformity. All of the vertebrate fossils have come from the upper part of the Lower Virgin Valley beds, and none from the Upper Virgin Valley beds. The Mesa Basalt caps the Upper Virgin Valley beds.

The diatom assemblages from the Virgin Valley beds (Table 1) and those from the Thousand Creek beds (Table 3) show striking differences between the two formations. This is also brought out even more clearly in Table 7, listing all of the diatoms found in all of the areas studied for this report, and is summarized briefly in Table 4 on page 65. Out of a total assemblage of 96 different diatoms found in the Thousand Creek beds, only 33 were also found in the Virgin Valley beds, although the latter contained 160 different diatoms that were not found in the Thousand Creek beds. Furthermore, the genera Epithemia and Rhopalodia first make their appearance in the geological column in the Thousand Creek beds and are completely absent in any of the Virgin Valley collections, even in the uppermost beds of the Upper Virgin Valley.

In the light of this new evidence the five hypotheses of Merriam (listed on page 65 of this report) may be reviewed:

(1) This appears to be so highly improbable that it may be called impossible. The Upper Virgin Valley beds have very distinctive assemblages which would never be mistaken for the Thousand Creek assemblages and lack, among other elements, the two genera which first appeared in the Thousand Creek beds.

(2) It should be remembered that as no vertebrate fossils were obtained from the post Middle Zone of the Lower Virgin Valley beds, the "post Virgin Valley and pre-Mesa Basalt" can mean only one thing -- the Upper Virgin Valley beds. Therefore the argument applied to (1) applies equally here and (2) therefore appears to be impossible with currently available evidence.

(3) This is a somewhat "iffy" proposition, and as the author of it is no longer available for questioning regarding it, one must make certain assumptions. The term "formed from older wash of Virgin Valley" might be taken to mean wash from the older beds (Lower Zone, unfossiliferous) which obviously could not deposit reworked fossils which did not exist. If this is the correct interpretation -- there is no answer. If by "older wash" is meant "older" in time, but not necessarily confined to "older beds", the answer is unequivocal. There is no evidence from the diatom assemblages that the Thousand Creek beds represent reworked Virgin Valley beds -- at least those that are known to contain diatoms.

(4) The answer here is unequivocal -- whatever connotation is placed on "younger wash", there is no evidence for the reworking of any substantial part of the Virgin Valley beds to form the Thousand Creek beds.

(5) The assumption that the Thousand Creek beds are "partly Virgin Valley and partly Pleistocene" might be partly true -- that is, the Thousand Creek beds might be "partly Pleistocene" (on account of the large number of Recent species present), but it could not be "partly Virgin Valley" as the characteristic and diagnostic species of the Virgin Valley beds are conspicuous by their absence.

All of Merriam's hypotheses have thus been severely questioned in the light of this new evidence, therefore something of a positive nature should be forthcoming. As Merriam stated in several places in his two papers, the geologic relation between the Virgin Valley beds and the Thousand Creek beds depend upon more and adequate field work (geologic mapping is strongly indicated), and most certainly should not be decided by the study of the diatoms from a few cubic inches of the sediments in question. As neither time nor funds were available for a mapping as part of the present investigation, one may be permitted a small speculation based upon brief observations of the field relations and a somewhat extended study of the few cubic inches of sediment which were examined in the laboratory.

An examination of the Long Valley and Disaster Quadrangles indicates that sediments of the order of magnitude of several cubic miles were removed from Virgin Valley and the smaller valley of Beet Creek since middle Miocene time, when they were deposited. A photograph (Plate 4B) taken from U.S.G.S. diatom locality 3540 (location on Plate 2) in the upper Virgin Valley beds, just below the Mesa Basalt, looking S. 45° E. across Virgin Valley and showing the capping of Mesa Basalt, which once presumably covered the area, appears in the upper right. The present course of Virgin Creek follows the white band at the bottom of the valley in the middle distance, with the Virgin Valley beds forming everything from the immediate foreground to the distant sky line. The eastern extension of the Canyon rhyolite forms the skyline at the extreme upper left of the photograph. The volume of sediment that has been removed from Virgin Valley can be seen graphically in this photograph, and must have been very great. It appears possible that at least the upper (and largest) part of these sediments were removed by a drainage toward the south sometime before the Thousand Creek Flats were down faulted by movement along the fault on the northeast face of Thousand Creek Ridge. This would eliminate the necessity of transporting this great volume of highly diatomaceous sediments through the narrow gorge cut through Thousand Creek Ridge and depositing them in Thousand Creek Flats without leaving a trace of the truly astronomical numbers of distinctive Virgin Valley diatoms. As an alternative hypothesis, the great mass of sediment that has been removed from Virgin Valley might have been deposited in the area now represented by Thousand Creek Flats in pre-Thousand Creek time (i.e., before late middle Pliocene) and the Thousand Creek beds deposited on top of them. A drilling program would be involved in the proof of this hypothesis. All that can be stated with reasonable certainty is that the Thousand Creek beds give no evidence of having been reworked from the Virgin Valley beds.

Still another hypothesis for the source of the clastic material forming a large part of the Thousand Creek beds might be that it came from either the northern side of Thousand Creek Flats or from the westward slope of the Pine Forest Mountains forming the eastern and southeastern borders of the Flats.

As mentioned previously, all of the diatoms found in the Thousand Creek beds are sparsely distributed through a mass of volcanic ash and fine to coarse sediments. Many of them are in poor shape and many are broken, which might lead one to think that they have been reworked from older sediments. It appears highly unlikely that this is the case, however, as their condition is characteristic of diatoms disseminated in sediments in this fashion. The breaking more than likely is the result of uneven compaction of the sediments, as some of the most fragile forms have come through whole, and some of the most robust are fractured. Furthermore, many whole frustules were found with the two valves still attached and this is extremely rare in reworked material, as the attachment between the valves in the fossil state is extremely tenuous and incapable of withstanding the rigors of being dislodged from one sedimentary series, transported, and redeposited.

With all these uncertainties in the local geology, Merriam (1911, p. 217) assigned a late lower Pliocene age to the Thousand Creek beds purely on the basis of the vertebrate fauna. The age of these beds was shifted somewhat by many paleontologists during the next 25 years, which culminated in an assignment of late middle Pliocene, as summarized by Stirton (1936, pp. 175, 194) and Wood _et al_ (1941, p. 33, pl. 1). This age is accepted for the present report.

Paleoecology

The diatom assemblages from the Thousand Creek beds suggest a markedly different environment than was postulated for the Virgin Valley beds nearby. The Thousand Creek lake must have been extremely shallow over much of the area, at least in the region from which the collections came. _Hantzschia amphioxys_, one of the species found there most commonly lives today in tiny pools from a fraction of an inch to a few inches in depth and is even found living in moist soil. _Fragilaria nitzschioides_ and _Pinnularia borealis_ are other Thousand Creek species frequently living under similar conditions today.

Other species in the assemblages, such as many of the _Gomphonemas_, and _Epithemia zebra_, which live attached to stones or water plants, appear to prefer swiftly running water. They are able to endure this on account of their mode of attaching themselves by means of gelatinous stipes. The genera _Epithemia_ and _Rhopalodia_ make their first appearance in the geological column in middle Pliocene time.

The acid loving _Pinnularias_ are fairly well developed and suggest a fairly low pH, probably on the acid side of neutral. Pelagic species are in a minority, particularly in respect to the number of individuals. On the basis of the above indications, the Thousand Creek lake was probably very shallow, marshy in many places, and probably only damp, mossy mud in others. In spite of hot spring activity in the region today, no typical hot spring diatoms were found.

Hagerman formation

Early Pleistocene

Vertebrate fossils were first reported from the Hagerman lake beds near Hagerman, Idaho, by Elmer Cook of Hagerman, and H. T. Stearns of the U. S. Geological Survey. An abundant vertebrate fauna was first obtained by J. W. Gidley of the U. S. National Museum (Gidley, 1930, pp. 300-303; 1931, pp. 33-40) who first gave an age of late Pliocene for these beds. Two years later Gazin (1933A, B: 1934A, B; 1935A, B) began a series of trips to the locality and greatly augmented the faunas. Wilson (1933) also obtained an extensive rodent fauna from the Hagerman beds. The results of all these investigations fixed the age definitely as late Pliocene, and so it was considered by Stirton (1936, pp. 174, 185) who placed it in the early upper Pliocene and Wood _et al_ (1941, p. 21, pl. 1) who placed it in the late upper Pliocene.

Recent geologic mapping in the region by Howard A. Powers of the U. S. Geological Survey has finally pushed the age of the Hagerman formation up to the early Pleistocene. G. Edward Lewis, U. S. Geological Survey (personal communication), is now convinced that the early Pleistocene age for the Hagerman is also indicated by the current views of the vertebrate paleontologists. Dwight W. Taylor, a specialist in nonmarine mollusks on the U. S. Geological Survey, has made extensive collections of these organisms from the Hagerman formation and is in complete agreement with the early Pleistocene dating.

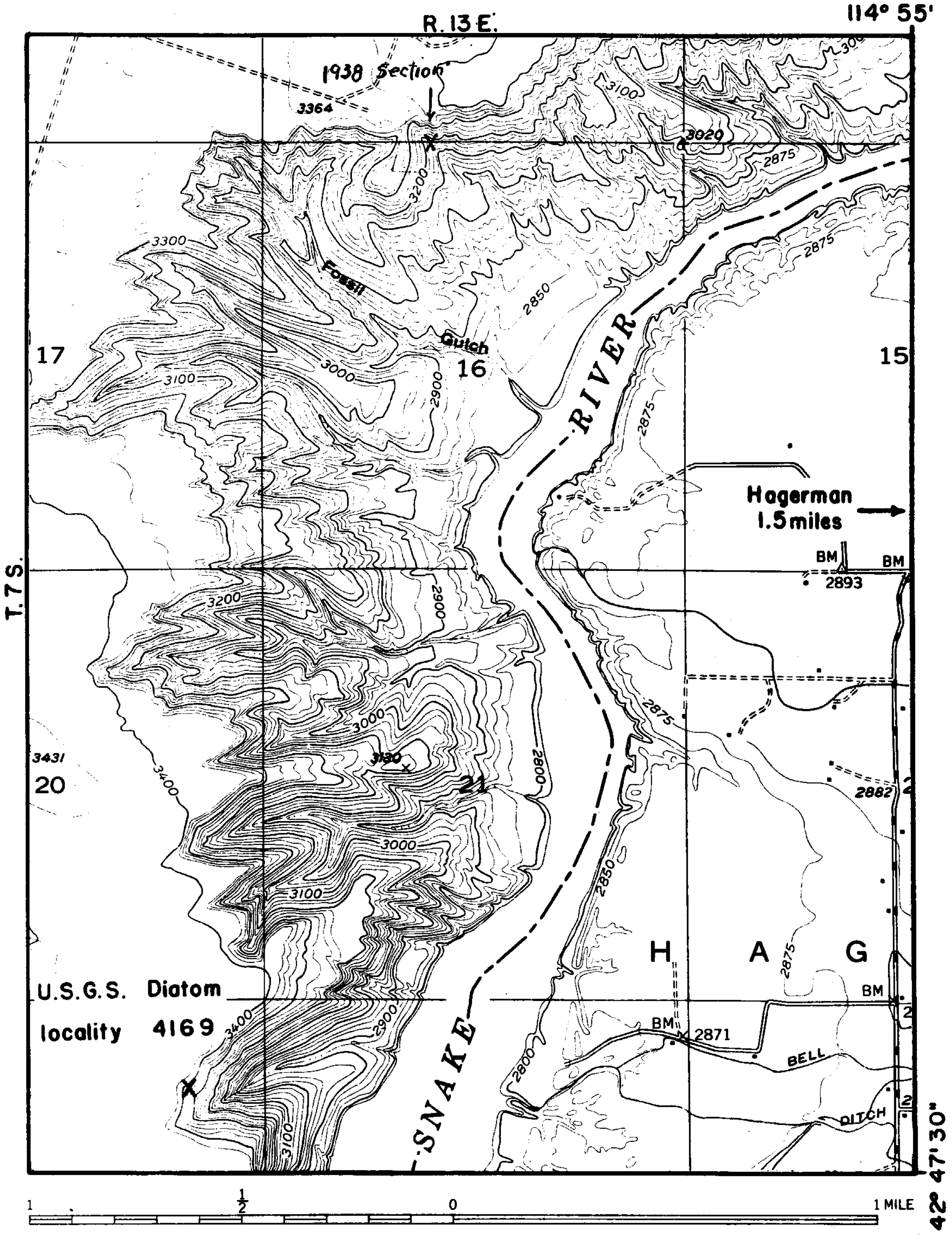
I visited the locality in 1938 and made a number of collections for diatoms in a measured section, which unfortunately contained very few diatoms. For this reason a collection made by Howard A. Powers in 1954 was used for the present investigation as it contained abundant diatoms and also came from a point closer to the type locality of the Hagerman vertebrate fauna. The locality data, kindly supplied by Dr. Powers, is as follows:

U.S.G.S. diatom locality 4169. "Hagerman vertebrate type locality near Hagerman, Idaho. Small pocket of diatomaceous sediment, Hagerman, Idaho $7\frac{1}{2}'$ Quadrangle. NE 40, NE $\frac{1}{4}$, sec. 29, T. 7 S., R. 13 E. Altitude 3360 ft. From top of Hagerman flood plain sediments, 50 ft. (stratigraphically) higher in section than type quarry of Hagerman vertebrate fauna, and just under erosion surface, and sheet of medium to coarse gravel believed to represent the change from pre-glacial to glacial climatic conditions. Coll. Howard A. Powers, 1954, Field no. 54-P-Hag 12".

The locations of both the U.S.G.S. diatom locality 4169 and the section measured in 1938 are shown on Plate 8, which is a portion of the Hagerman, Idaho 1/24,000 Quadrangle.

Locality 4169 yielded a diatom assemblage of 68 species and varieties, of which 10 are new and 5 have been first described from the Hagerman formation. They are listed in Table 5, where relative abundances are indicated by A = abundant; C = common; F = frequent; and R = rare.

PLATE 8



Map showing Hagerman locality

Adapted from U.S.G.S.
Hagerman, Idaho
Quadrangle

Diatoms from the Hagerman formation

Melosira crassa Lohman, n.spl	R
italica (Ehrenberg) Kützing	R
micropunctata Lohman, n.sp.	R
undulata (Ehrenberg) Kützing	R
Stephanodiscus carconensis Grunow	R
Fragilaria construens (Ehrenberg) Grunow	C
sp.	F
Synedra amphicephala Kützing	R
ulna (Nitzsch) Ehrenberg	F
Opephora marina (Gregory) Petit	R
martyi Heribaud	R
Tetracyclus lacustris Ralfs	R
pagesi Heribaud	R
Eunotia pectinalis (Kützing) Rabenhorst	R
Achnanthes spicula Lohman, n.sp.	R
Rhoicosphenia curvata (Kützing) Grunow	R
Cocconeis placentula var. euglypta (Ehrenberg) Cleve	A
Gyrosigma cf. G. kützingi (Grunow) Cleve.	F
sp.	R
Neidium affine var. amphirhynchus (Ehrenberg) Cleve	F
iridis (Ehrenberg) Cleve.	R
Caloneis bacillum (Grunow) Mereschkowsky.	R
schumanniana (Grunow) Cleve.	R
cf. C. silicula (Ehrenberg) Cleve	R

Stauroneis irregularis Lohman, n.sp.	R
phoenicenteron Ehrenberg	R
Anomoeoneis cf. A. sphaerophora (Kützing) Cleve	F
cf. A. sphaerophora var. guntheri Muller	R
Navicula arenaria Donkin	F
bacillum Ehrenberg	F
citroides Lohman, n.sp.	R
cryptocephala Kützing.	R
cuspidata var. ambigua (Ehrenberg) Cleve	F
dicephala (Ehrenberg) Wm. Smith.	F
mutica Kützing	F
mutica var. nivalis (Ehrenberg) Hustedt.	F
peregrina (Ehrenberg) Kützing.	A
pupula var. capitata Hustedt	F
pupula var. rectangularis (Gregory) Grunow	F
pygmaea Kützing	F
radiosa Kützing	C
rostellata Kützing	F
umbilica Lohman, n.sp.	R
Pinnularia borealis Ehrenberg	C
microstauron (Ehrenberg) Cleve	R
transversa (Schmidt) Lohman, n. comb.	R
viridis (Nitzsch) Ehrenberg	F
Gomphonema acuminatum Ehrenberg	F
augur Ehrenberg.	F
constrictum var. capitata (Ehrenberg) Cleve	C

Gomphonema intricatum Kützing	F
parvulum var. micropus (Kützing) Cleve	F
sphaerophorum Ehrenberg	C
Cymbella affinis Kützing	F
angularis Lohman, n.sp.	F
cistula (Hemprich) Grunow	R
hagermanensis Lohman, n.sp.	F
lanceolata (Ehrenberg) Van Heurck	F
mexicana (Ehrenberg) Cleve	C
prisca Lohman, n.sp.	F
ventricosa Kützing	F
Amphora ovalis Kützing	F
Epithemia galera Lohman, n.sp.	F
sorex Kützing	F
turgida (Ehrenberg) Kützing	F
zebra var. saxonica (Kützing) Grunow	C
turgida var. granulata (Ehrenberg) Kützing	F
mulleri Fricke	R
sp.	R
Hantzschia amphioxys (Ehrenberg) Grunow	C
Cymatopleura solea (Brebisson) Wm. Smith	R

This assemblage has the greatest over-all similarity to the assemblages from the Thousand Creek beds of any of the collections studied for this report. Three new species described from the Virgin Valley beds (late middle Miocene), *Melosira micropunctata*, *Stauroneis irregularis*, and *Navicula citroides* continue into the Hagerman formation, where they occur rarely. It appears probable that they became extinct sometime in the early Pleistocene. *Stephanodiscus carconensis* was found rarely in the Hagerman formation, which represents the latest known occurrence for this distinctive species. It has been known previously only from rocks of Pliocene and Plio-Pleistocene age in many places in western United States. *Tetracyclus pagesi* was first described by Heribaud (1902, p. 17, pl. 8, fig. 10) from rocks of late Pliocene age in Cantal, France, and occurs in the Hagerman formation rarely. Thus there is a suggestion from the diatoms themselves that the earlier assignment of the Hagerman to the late Pliocene may have been correct.

57 percent of the previously known diatoms found in the Hagerman formation also occur in the Tulare formation of late Pliocene age in the Kettleman Hills and the San Joaquin Valley in central California (Lohman, 1938, pp. 82-85; and in report on the Tulare formation now in preparation). This appears to be a very good agreement when the rather large difference in ecologic conditions in the two areas is considered. *Stephanodiscus carconensis* is one of the species occurring in both the Hagerman and Tulare formations.

Paleoecology

The Hagerman assemblage indicates a very shallow lake, probably discontinuous over a large part, and is in complete harmony with Power's description of the Hagerman beds as "flood plain sediments". The almost complete absence of pelagic species and the complete dominance of litoral shallow water species, many of which now live attached to water plants and stones by means of gelatinous stipes, strongly favors this type of environment. Many of the species live today in moist soil, tiny puddles and ditches. Saline species, such as *Navicula peregrina*, *N. mutica*, *Anomoeoneis sphaerophora*, and several species and varieties of *Epithemia*, suggest periodic concentrations of the shallow water of Lake Hagerman. The pH was probably somewhat higher than was the case in Thousand Creek lake, as is suggested by the poor development of the true peat bog and other acid loving types. The Recent species in the Hagerman assemblage consist of a mixture of those now living in temperate and cold waters, which may reflect the change from pre-glacial to glacial climates postulated by Powers.

Provo formation, Utah

Late Pleistocene

In this instance it was necessary to deviate from the practice of using vertebrate fossil dating for the reason that none of the late Pleistocene vertebrate collecting localities were known to contain diatoms. The Provo area has been intensively studied by Geological Survey parties headed by Chas. B. Hunt, H.J. Bissell, David Varnes, and others, and Mr. Bissell made available a series of collections in 1949, some of which contain excellent diatoms. After examining many of these collections, two were selected for this report as they contained the most varied assemblages and the diatoms in them were in the best state of preservation. The locality data follows:

U.S.G.S. diatom locality 3304. Silt facies, Provo formation, Lake Bonneville, Sec. 29, T. 9 S., R. 1 W., Goshen Valley, east of Tintic Range, Utah County, Utah. 5 ft. 10 inches below top of exposure. Coll. H. J. Bissell, August 17, 1949. Field no. 311 (a).

U.S.G.S. diatom locality 3305. Same locality and other data as above, except that sample came from 4 ft. 6 inches below top of exposure.

The area was visited for one day in 1950, when Mr. Bissell kindly showed me the localities from which the collections were obtained, and described the local geology.

Although not dated by means of vertebrate fossils, a carbon-14 determination for the Provo formation has given a dating of 14,000 years (Meyer Rubin, U.S. Geological Survey, personal communication).

Assemblages containing a total of 76 different species and varieties of diatoms, of which 10 are here described as new, were obtained from the two collections. They are listed in Table 6, where relative abundances are indicated by A = abundant; C = common; F= frequent; and R = rare.

Table 6

Diatoms from the Provo formation

Late Pleistocene

	U.S.G.S. diatom locality	
	3304	3305
Melosira nuda Lohman, n.sp.	F	F
granulata var. jonensis Grunow		R
Cyclotella antiqua Wm. Smith	F	R
kützingiana var. planetophora Fricke		F
Fragilaria brevistriata Grunow	C	R
construens var. binodis (Ehrenberg) Grunow	F	
leptostauron (Ehrenberg) Hustedt	R	R
cf. F. mormonorum (Grunow) Boyer	R	
virescens Ralfs		R
Synedra pulchella Kützing	C	F
Rhoicosphenia curvata (Kützing) Grunow	C	F
Cocconeis disculus Schumann	C	F
cf. C. grovei Schmidt	R	
placentula Ehrenberg	A	F
Mastogloia elliptica Agardh	C	F
smithii var. lacustris Grunow	C	R
Gyrosigma parkeri (Harrison) Boyer	R	R
Diploneis ovalis (Hilse) Cleve	R	R
smithii (Brebisson) Cleve	R	F
Neidium distincte-punctatum Hustedt	R	R

	3304	3305
Caloneis amphisbaena (Bory) Cleve	R	F
schumanniana (Grunow) Cleve	R	
silicula (Ehrenberg) Cleve	R	R
silicula var. tumida Hustedt		R
Anomoeoneis polygramma (Ehrenberg) Pfitzer	R	R
Navicula anglica Ralfs	R	
cuspidata var. ambigua (Ehrenberg) Cleve		F
oblonga Kützing	F	F
peregrina (Ehrenberg) Kützing	R	
pupula var. capitata Hustedt	R	
pupula var. rectangularis (Gregory) Grunow		R
radiosa Kützing	C	F
reinhardtii Grunow	R	R
tuscula (Ehrenberg) Van Heurck	R	F
utahensis Lohman, n.sp.	R	
viridula Kützing	R	
Pinnularia angulo-costata Lohman, n.sp.	F	
microstauron (Ehrenberg) Cleve	F	F
viridis (Nitzsch) Ehrenberg	C	
Scoliopleura peisonis Grunow		R
Gomphonema excentricum Lohman, n.sp.		R
Cymbella cistula (Hemprich) Grunow	A	C
cistula var.	C	R
cf. C. ehrenbergii Kützing	R	R
mexicana (Ehrenberg) Cleve	A	C
mexicana var. gracilis Lohman, n.var.	F	F

	3304	3305
Cymbella obtusiuscula (Kützing) Grunow	R	
parva (Wm. Smith) Cleve	C	F
turgida (Gregory) Cleve	F	F
bistriata Lohman, n.sp.	F	
provovoensis Lohman, n.sp.	C	F
ventricosa Kützing	F	F
Amphora ovalis var. libyca (Ehrenberg) Cleve	C	F
proteus Gregory	C	R
Epithemia argus (Ehrenberg) Kützing	A	
intermedia Fricke		F
sorex Kützing	F	R
turgida (Ehrenberg) Kützing	C	F
zebra Kützing	C	R
zebra var. porcellus (Kützing) Grunow	C	C
zebra var. proboscidea Grunow		F
zebra var. saxonica (Kützing) Grunow	C	F
Rhopalodia gibba (Ehrenberg) Muller	C	F
gibba var. ventricosa (Ehrenberg) Grunow		R
Nitzschia sigmoidea (Ehrenberg) Wm. Smith	F	
Hantzschia amphioxys var. uticensis Grunow	F	R
Surirella bifurcata Lohman, n.sp.	F	
crumena Brebisson	F	
linearis Wm. Smith	C	
oblonga Ehrenberg		F
ovata Kützing	C	
utahensis Grunow	C	C
Cymatopleura elliptica (Brebisson) Wm. Smith	R	R
solea (Brebisson) Wm. Smith	R	R

These assemblages are remarkably similar to other Pleistocene assemblages from the following localities:

U.S.G.S. diatom locality 2898. 4 miles west of Fillmore, Utah. Coll. E. Callaghan, March 4, 1938. A diatom assemblage from this locality is almost identical with that from the Goshen Valley Provo formation.

U.S.G.S. diatom locality 3266. Calcareous diatomite from the SE$\frac{1}{4}$ sec. 20, T. 9 S., R. 1 W., north of Elberta, Utah County, Utah. Provo formation. Coll. H. J. Bissell, Sept. 15, 1947.

U.S.G.S. diatom locality 3294. Oak City Quadrangle, Utah. SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 18, T. 11 S., R. 4 W. Lake Bonneville marl. Coll. David Varnes and Richard Van Horn, Oct. 17, 1948.

12 assemblages of diatoms from Quaternary lake beds near Clovis, New Mexico (Lohman, 1935, pp. 456-457), which contain 88 species and varieties of diatoms are notably different from the Provo assemblages, although they are approximately the same age on independent evidence. Of the 88 species and varieties from the Clovis beds, only 20, or 23 percent were also found in the Provo formation. Part of this difference may be explained by the fact that the Clovis beds represent a period of rapidly increasing aridity and thus increasing salinity for the basin.

Paleoecology

The diatom assemblages from the Provo formation contain a number of saline and brackish water species as well as those now living in fresh water. The salinity of the lake must have been fairly high, as two of the most abundant species, *Cymbella mexicana* and *Surirella utahensis* are living today in Pyramid Lake, Nevada (Hanna and Grant, 1931) where the salinity is nearly 3500 parts per million. Many of the others, such as most of the *Epithemias*, *Rhopalodia gibba*, and the variety *ventricosa*, *Hantzschia amphioxys* var. *uticensis* and others are also indicative of saline conditions. Mixed with them, however, is a large assemblage of species that not only prefer fresh water, but some of which could not live today in such highly saline water. It appears reasonable to suppose that Lake Bonneville was already highly saline in Provo time, at least in the locality of the Provo collections, and that the freshwater species were introduced by streams emptying into the basin nearby. There is also a great paucity of pelagic species, which suggests that the lake may have been shallow in that vicinity.

SUMMARY AND CONCLUSIONS

In Table 7 (beginning on page 86) are listed all of the species and varieties of diatoms found in the localities studied for this report. In order to make the ranges in time stand out more clearly, the species from the Lower Virgin Valley beds (8 collections), Esmeralda formation (8 collections), Thousand Creek beds (3 collections) and Provo formation (2 collections) have been combined into one column. The relative abundances, based upon D = dominant, A = abundant, C = common, F = frequent, and R = rare, have been indicated by showing the extremes in any one section. Thus RC = Rare to Common. The relative abundances from those localities where only one collection was available, Upper Virgin Valley beds, and Hagerman formation, are the same as shown in the tables of species from these localities, which form part of the discussion of the individual localities in the earlier part of this report.

In column 7 are combined symbols representing in brief some ecologic extrapolations from published data on those species still represented in living assemblages. They are admittedly incomplete, as the available data are often conflicting and inadequate. Obviously no such data are given for new species and others previously reported only as fossils. The first letter refers to the "mode of life", for which three symbols have been used: P = pelagic, A = attached, and L = litoral. The second letter refers to the salinity of the water: F = Freshwater, S = Saline (nonmarine), B = Brackish, and M = Marine. The third letter refers to temperature, summarized under three symbols: C = Cold, T = Temperate, and W = Warm. In order to keep within the page and margin limitations, the three types of symbols have been combined into one column, thus, PFC = Pelagic, Freshwater, Cold.

The temperature data **are** probably the least quantitative of the lot for the reason that the available data **are** variable and nearly always broadly qualitative, and also because many species have fairly wide tolerance for temperature; hence any attempt at further refinement could not be justified. It is felt that in spite of the uncertainties expressed above, these additional data are useful as it gives in compact form the basis for the paleoecological interpretations.

NOTE: The full heading is given on only the first page of Table 7. The seven numbered columns are similarly numbered on succeeding pages and it is understood that in final printed form the full headings will appear at the top of each page.

Key to symbols used in Table 7

Columns 1 to 6 inclusive

D = Dominant; A = Abundant; C = Common; F = Frequent; R = Rare.

Column 7

Mode of growth: P = Pelagic; A = Attached; L = Litoral.
Salinity of water: F = Freshwater; S = Saline; B = Brackish; M = Marine.
Temperature: C = Cold; T = Temperate; W = Warm.

The final results of the investigation and a discussion of the degree to which the original objectives have been achieved will be found immediately following Table 7, which contains in as brief form as possible the basis for such discussion.

Table 7

Combined list of nonmarine diatoms
from the Great Basin showing
Geologic ranges and relative abundances

1 Lower Virgin Valley
Late middle Miocene

2 Upper Virgin Valley
Late Miocene

3 Esmeralda formation
Early Pliocene

4 Thousand Creek beds
Middle Pliocene

5 Hagerman formation
Early Pleistocene

6 Provo formation
Late Pleistocene

7 Ecology

	1	2	3	4	5	6	7
Melosira ambigua (Grunow) Muller				RF			PF
arenaria Moore	R	F	RF				LF
binderana Kützing		C	F				PF
crassa Lohman, n.sp.			F		R		
denticulata Lohman, n.sp.	F						
distans (Ehrenberg) Kützing			C	F			LF
distans var. lirata (Ehrenberg) Bethge	F	F		R			LFT
granulata (Ehrenberg) Ralfs	F	F	FC	RF			PFT
granulata var. curvata Grunow				F			PFT
granulata var. jonensis Grunow			F	F		R	
granulata var. muzzanensis (Meister) Bethge			FC				PFC
hyalina Lohman, n.sp.	F						
italica (Ehrenberg) Kützing	FA		F	F	R		PLFT
italica var. irregularis Lohman, n.var.	FC						
italica subsp. subarctica Muller	F						PFC
margaritata Lohman, n.sp.	RC						
margaritata var. laevis Lohman, n.var.	C						
micropunctata Lohman, n.sp.	FC		RF		R		

	1	2	3	4	5	6	7
Melosira paucipunctata Lohman, n.sp.			RC				
ponderosa Lohman, n.sp.	A	A	FA				
ponderosa var. curta Lohman, n.var.	F	F	FA				
ponderosa var. elongata Lohman, n.var.	C	A	FA				
punctissima Lohman, n.sp.	A						
punctissima var. curvata Lohman, n.var.	F						
sculpta (Ehrenberg) Kützing	F	F					
solida Eulenstein			F				
triannula Lohman, n.sp.	C						
undulata (Ehrenberg) Kützing	C	C	F		R		LFW
Cyclotella anomala Lohman, n.sp.			F				
antiqua Wm. Smith						RF	
compta var. trinotata Heribaud						FC	
Coscinodiscus lacustris Grunow			FC				LFST
mobilis Lohman, n.sp.			F				
Stephanodiscus carconensis Grunow					R		
Cestodiscus apiculatus Lohman, n.sp.			C				
canalis Lohman, n.sp.			R				
cedarensis Lohman, n.sp.			FA				
fasciculatus Lohman, n.sp.			FA				
simplissimus Lohman, n.sp.			F				
stellatus Lohman, n.sp.			F				
Fragilaria brevistriata Grunow			F			RC	LFT
brevistriata var. inflata (Pantocsek) Hustedt		R					LFT
construens (Ehrenberg) Grunow			FC		C		LFCW
construens var. binodis (Ehrenberg) Grunow	FC					F	LFCW
crassa Lohman, n.sp.	F	F	FC				

	1	2	3	4	5	6	7
Fragilaria crassa var. capitata Lohman, n.var.	F		F				
delicata Lohman, n.sp.		R					
intermedia Grunow	RF						LFC
leptostauron (Ehrenberg) Hustedt						R	LFT
leptostauron var. capitata Lohman, n.var.		F					
leptostauron var. dubia Grunow		R		F			
leptostauron var. obesa Lohman, n.var.		F					
nevadensis Lohman, n.sp.	FC	F					
nitzschioides Grunow				R			LFC
pinnata Ehrenberg			C				LFBT
pinnata var. lancettula (Schumann) Hustedt				RF			LFBT
virescens Ralfs	F						LFC
Synedra amphicephala Kützing					R		LFT
pulchella Kützing						FC	LFBT
ulna (Nitzsch) Ehrenberg			FC		F		LFT
Opephora lanceolata Lohman, n.sp.	R						
marina (Gregory) Petit					R		LMT
martyi Heribaud	R		R		R		LFT
Meridion circulare (Greville) Agardh	FC	F	F				AFT
constrictum Ralfs	RC			F			AFT
Diatoma enormis Lohman, n.sp.	FA		F				
vulgare Bory				F			LFT
vulgare var. breve Grunow				R			LFT
Tetracyclus calceus Lohman, n.sp.	F	F	F				
cf. T. calceus Lohman, n.sp.		R					
circularis Lohman, n.sp.		F					

	1	2	3	4	5	6	7
Tetracyclus clypeus (Ehrenberg) Lohman, n.comb.			RF				
duplus Lohman, n.sp.	F		F				
ellipticus (Ehrenberg) Grunow			F	RF			
constricta (Hustedt) Lohman, n.comb.	RF		F				
ellipticus var. lancea Hustedt		F	F	F			
ellipticus var. latissima Hustedt	F		R				
emarginatus (Ehrenberg) Wm. Smith				R			LFC
horus Lohman, n.sp.	FC	F	F				
irregularis Lohman, n.sp.	FA	F	R				
javanicus Hustedt	F	F	RF				
cf. T. javanicus Hustedt	F	F	RC	R			
lacustris Ralfs	RF	R			R		LFC
lacustris var. rhombicus Hustedt	R						LFC
pagesi Heribaud				R	R		
parallelus Lohman, n.sp.	RF	F	RF				
peragalli var. major Heribaud	R		R				
peragalli var. eximia Heribaud	R						
quadrus Lohman, n.sp.		F					
cf. T. quadrus Lohman, n.sp.	R						
radiatus Lohmam, n.sp.			F				
rupestris (Braun) Grunow			RF	R			LFC
virginicus Lohman, n.sp.	F	R					
Tabellaria cf. T. fenestrata (Lyngbye) Kützing				R			PFECT
Eunotia clevei Grunow			RF				LFC
faba (Ehrenberg) Grunow	R						LFC
lineata Lohman, n.sp.	F						

	1	2	3	4	5	6	7
Eunotia lunaris (Ehrenberg) Grunow	F						LFT
cf. E. lunaris (Ehrenberg) Grunow	R						
lunaris var. subarcuata (Naegeli) Grunow	F						AFT
monodon var. tropica Hustedt				R			LFW
pectinalis (Kützing) Rabenhorst	F			F	R		LFT
cf. E. pectinalis (Kützing) Rabenhorst		R					
pectinalis var. minor (Kützing) Rabenhorst	F						AFT
polydentula var. perpusilla Grunow		R					LFT
praerupta Ehrenberg	F	R		F			AFT
valida Hustedt	RF		R	R			AFCT
veneris (Kützing) Muller	F						AFCT
Achnanthes basaltensis Lohman, n.sp.		R					
lanceolata (Brebisson) Grunow	F	F		R			LFT
lanceolata var. elliptica Cleve		F					LFT
lanceolata var. rostrata (Øestrup) Hustedt			F				LFT
lapidosa Cleve	F	F					AFC
linearis Wm. Smith	R						LFC
robusta Lohman, n.sp.	R						
spicula Lohman, n.sp.					R		
Rhoicosphenia curvata (Kützing) Grunow					R	FC	AFBT
Cocconeis disculus Schumann						FC	LFCT
cf. C. grovei Schmidt						R	LFC
placentula Ehrenberg	F	F	FC	R		FA	LFCW
placentula var. euglypta (Ehrenberg) Cleve	R			R	A		LFCW
Mastogloia elliptica Agardh						CF	LBT
smithii var. lacustris Grunow						RC	LFBT

	1	2	3	4	5	6	7
Gyrosigma cf. G. kützingi (Grunow) Cleve					F		LFT
parkeri (Harrison) Boyer						R	LFBT
Diploneis ovalis (Hilse) Cleve						R	LFST
ovalis var. oblongella (Naegeli) Cleve			R				LFST
smithii (Brebisson) Cleve						RF	LSMT
Neidium affine var. amphirhynchus (Ehrenberg) Cleve	R				F		LFT
affine var. longiceps (Gregory) Cleve	R						LFT
bisulcatum (Lagerstedt) Cleve				F			LFT
distincte-punctatum Hustedt						R	LFT
iridis (Ehrenberg) Cleve				F	R		LFT
iridis var. ampliata (Ehrenberg) Cleve		R					LFT
Frustulia cf. F. rhomboides (Ehrenberg) De Toni				R			LFT
rhomboides var. amphipleuroides Grunow	R						LFT
rhomboides var. saxonica (Rabenhorst) De Toni	R						LFT
Caloneis amphisbaena (Bory) Cleve						RF	LFST
bacillum (Grunow) Mereschkowsky	F		RF	F	R		LFT
rostrata Lohman, n.sp.	F						
schumanniana (Grunow) Cleve	R				R	R	LFT
cf. C. schumanniana var. trinodis Lewis				R			LFT
silicula (Ehrenberg) Cleve					R	R	LFBT
silicula var. tumida Hustedt			R			R	LFBT
Stauroneis anceps Ehrenberg	RF		R	F			LFT
anceps var. linearis (Ehrenberg) Cleve				R			LFT
gregorii Ralfs	F			R			LF
debilis Lohman, n.sp.			F				
irregularis Lohman, n.sp.	RF				R		

	1	2	3	4	5	6	7
Stauroneis obesa Lohman, n.sp.	F						
parvula var. prominula Grunow			RF				LFBT
phoenicenteron Ehrenberg	RF	R			R		LFT
Anomoeoneis lanceolata Lohman, n.sp.			F				
malinvaudii (Heribaud) Lohman, n.comb.			R				
nyensis Lohman, n.sp.			RC				
cubita Lohman, n.sp.			F				
polygramma (Ehrenberg) Pfitzer				RF		R	LFST
sphaerophora (Kützing) Cleve			R	RF	F		LFST
sphaerophora var. guntheri Muller			R		R		LFST
turgida Lohman, n.sp.			F				
Navicula amphibola Cleve	RF	F	RF	F			LFT
amphibola var. capitata Lohman, n.var.	FC						
anglica Ralfs						R	LFT
arenaria Donkin					F		LFT
cf. N. bacilliformis Grunow	F						LFT
bacillum Ehrenberg	F	F	RF		F		LFT
cf. N. bituminosa var. latecapitata Pantocsek	R						
bulloides Lohman, n.sp.	R						
citroides Lohman, n.sp.	F	F	RF		R		
cryptocephala Kützing					R		LFST
cf. N. cryptocephala var. intermedia Grunow		F					
cuspidata var. ambigua (Ehrenberg) Cleve				F	F	F	LFT
cf. N. cuspidata Kützing			F				
dicephala (Ehrenberg) Wm. Smith	F		F	F	F		LFT
cf. N. dicephala (Ehrenberg) Wm. Smith	R						

	1	2	3	4	5	6	7
Navicula gastriformis Hustedt		F	F				LFT
gastrum Ehrenberg	F	F	F				LFT
gibbula Cleve				F			AFT
cf. N. hassiaca Krasske	F						AFT
inflata	R						LFBT
isolata Lohman, n.sp.			RF				
jentzschii Grunow	R	F					LFC
mutica Kützing				C	F		AFST
mutica var. cohnii (Hilse) Grunow				F			AFST
mutica var. nivalis (Ehrenberg) Hustedt					F		AFST
mutica var. tropica Hustedt	R						AFST
oblonga Kützing						F	LFST
opalensis Lohman, n.sp.	R						
peregrina (Ehrenberg) Kützing					A	R	LST
placentula (Ehrenberg) Grunow			R				LFT
cf. N. placentula (Ehrenberg) Grunow	R						
pupula var. capitata Hustedt					F	R	LFT
pupula var. rectangularis (Gregory) Grunow	RF				F	R	LFT
pygmaea Kützing					F		LFST
radiosa Kützing	RF		RC	F	C	FC	LFCW
reinhardtii Grunow						R	LFT
rostellata Kützing					F		LFT
cf. N. ruttneri Hustedt				R			
scutelloides Wm. Smith	C	C					LFT
semen Ehrenberg	RF						LFT?
cf. N. semen Ehrenberg	F						

Navicula semota Schmidt				F			
similis Krasske		F					LFT
soodensis Krasske			R				LST
thienemanni Hustedt				R			
tuscula (Ehrenberg) Van Heurck						RF	LFT
umbilica Lohman, n.sp.					R		
utahensis Lohman, n.sp.						R	
viridula Kützing						R	LFBT
Pinnularia cf. P. acuminata var. interrupta Cleve	R						
cf. P. acuminata var. subarcuata (Naegeli) Grunow	F						
angulata Lohman, n.sp.				F			
angulo-costata Lohman, n.sp.						F	
appendiculata (Agardh) Cleve				F			LFT
borealis Ehrenberg				FC	C		LAFCT
braunii var. amphicephala (Mayer) Hustedt	R						LFC
brevicostata Cleve	FC						LFT
cf. P. brevicostata Cleve	F			R			
brevicostata var. leptostauron Cleve	R			F			LFT
curvata Lohman, n.sp.	RF						
dactylus Ehrenberg	FC						LFCW
dactylus var. sumatrana Hustedt			F				LFW
debesi Hustedt	R						FLT
denticulata Lohman, n.sp.	R						
divergentissima (Grunow) Cleve				R			LFC
angusta Lohman, n.sp.	FC						
esmeraldensis Lohman, n.sp.			F				
esmeraldensis var. constricta Lohman, n.var.			F				

	1	2	3	4	5	6	7
Pinnularia esox Ehrenberg	R						LFT
flexuosa Cleve	R						LFT
gentilis (Donkin) Cleve	F						LFT
gibba var. hyalina (Kützing) Cleve	F						LFT
gibba var. linearis Hustedt	R						LFT
hartleyana Greville	F						LFT
cf. P. hartleyana Greville	F						
cf. P. hemiptera (Kützing) Cleve			R				
hemiptera var. interrupta Cleve	F						LFCT
cf. P. hyalina Hustedt	F						
cf. P. lacunarum Hustedt		R					
latevittata Cleve	R						LFC
legumen Ehrenberg			RF				LFT
major Kützing	F						LFT
cf. P. major Kützing	R						
microstauron (Ehrenberg) Cleve	RF			RC	R	F	LFT
cf. P. microstauron (Ehrenberg) Cleve			R	F			
molaris Grunow				F			LFT
nebulosa Lohman, n.sp.	F						
nobilis Ehrenberg	C						LFT
cf. P. nodosa Ehrenberg	R						
nodosa var. constricta Mayer	F						LFC
obscura Krasske	R			R			
pseudopunctata Lohman, n.sp.	FC						
cf. P. pseudopunctata Lohman, n.sp.	F						
schweinfurthii (Ehrenberg) Hustedt	F						

	1	2	3	4	5	6	7
Pinnularia cf. P. schweinfurthii (Ehrenberg) Hustedt	F						
transversa (Schmidt) Lohman, n.comb.					R		LFT
virginica Lohman, n.sp.	FC	F	R	F			
cf. P. virginica Lohman, n.sp.	R			R			
virginica var. brevicostata Lohman, n.var.	R						
viridis (Nitzsch) Ehrenberg	FC	R		R	F	C	LFT
cf. P. viridis (Nitzsch) Ehrenberg	F						
Scoliopleura peisonis Grunow						R	LBT
Gomphonema acuminatum Ehrenberg					F		LAFT
acuminatum var. turris (Ehrenberg) Cleve			R				LAFT
angustatum (Kützing) Rabenhorst	F		FC	F			LFT
augur Ehrenberg				R	F		LFT
bohemicum Reichelt and Fricke				R			LFC
constrictum var. capitata (Ehrenberg) Cleve			R		C		LFT
duostriatum Lohman, n.sp.	F		R	F			
excentricum Lohman, n.sp.						R	
grovei M. Schmidt	C	C		R			
intricatum Kützing	FC	F	FC	F	F		LFT
intricatum var. fossilis Pantocsék		R					
intricatum var. pumilla Grunow	F						LFT
lanceolatum Ehrenberg	F		F				LFT
lanceolatum var. insignis Grunow	F						LFT
longiceps var. subclavata Grunow				RF			LAFT
olivaceum (Lyngbye) Kützing	F			F			LFBT
parvulum (Kützing) Grunow			F				LFT
parvulum var. micropus (Kützing) Cleve	F	R	F	F	F		LFT

	1	2	3	4	5	6	7
Gomphonema quadratum Lohman, n.sp.			RF				
sphaerophorum Ehrenberg					F		LFT
subclavatum Grunow	F		F				LFT
tergestinium (Grunow) Fricke	F		F				LFT
cf. G. tergestinium (Grunow) Fricke			R				
Cymbella aequalis Wm. Smith				R			LFC
affinis Kützing	R		F		F		LFT
cf. C. affinis Kützing	R						
angularis Lohman, n.sp.				F	F		
cistula (Hemprich) Grunow	F	F	FA	R	R	CA	LFT
cistula var.						RC	
cf. C. cistula (Hemprich) Grunow	R						
cistula var. maculata (Kützing) Van Heurck			C				LFT
cuspidata Kützing	F						LFT
cymbiformis (Agardh) Kützing			FC				LFT
ehrenbergii Kützing	RF						LFT
cf. C. ehrenbergii Kützing			C			R	
hagermanensis Lohman, n.sp.					F		
haucki Van Heurck	RF						LFW
lanceolata (Ehrenberg) Van Heurck			F		F		LFT
mexicana (Ehrenberg) Cleve		F	A	F	C	CA	LFWCW
mexicana var. gracilis Lohman, n.var.						F	
cf. C. naviculiformis Auerswald				R			LFT
obtusiuscula (Kützing) Grunow						R	LFCT
parva (Wm. Smith) Cleve						CF	LFT
prisca Lohman, n.sp.					F		

	1	2	3	4	5	6	7
Cymbella provoensis Lohman, n.sp.						FC	
sinuata var. antiqua Grunow	RF	F	F				
cf. C. tumida (Brebisson) Van Heurck	R			F			
turgida (Gregory) Cleve				F		F	LFT
ventricosa Kützing			RC	RF		F	LFT
Amphora ovalis Kützing	R				F		LAFT
ovalis var. libyca (Ehrenberg) Cleve						FC	LAFT
proteus Gregory						RC	
sparsa Lohman, n.sp.			R				
Epithemia argus (Ehrenberg) Kützing						A	LAFBT
argus var. alpestris Grunow						R	
galera Lohman, n.sp.					F		
intermedia Fricke						F	LAFT
muelleri Fricke					R		LAFT
sorex Kützing				F	F	F	LAFBT
sorex var. gracilis Hustedt				F			LAFBT
turgida (Ehrenberg) Kützing				R	F	FC	LAFBT
turgida var. granulata (Ehrenberg) Kützing				R	F		LAFBT
zebra Kützing				F		RC	LAFT
zebra var. porcellus (Kützing) Grunow				F		C	LAFT
zebra var. proboscoidea Grunow						F	LAFT
zebra var. saxonica (Kützing) Grunow					C	FC	LAFT
Eholalodia gibba (Ehrenberg) Muller				F	C	FC	LAFBT
gibba var. ventricosa (Ehrenberg) Grunow						R	LFBT
gibberula (Ehrenberg) Muller				F			LST
gibberula var. margaritifera Rabenhorst				R			LST

	1	2	3	4	5	6	7
Nitzschia amphibia Grunow				R			LFT
palea (Kützong) Wm. Smith				R			LFT
sigmoidea (Ehrenberg) Wm. Smith						F	LFT
sp.			F	R			
Hantzschia amphioxys (Ehrenberg) Grunow				C	C		LAFT
amphioxys var. uticensis Grunow						RF	LAFST
amphioxys var. vivax (Hantzsch) Grunow			F	R			LAFT
cf. H. robusta Hustedt				R			
Surirella bifurcata Lohman, n.sp.						F	
crumena Brebisson						F	LFBT
linearis Wm. Smith						C	LFT
oblonga Ehrenberg						F	LFT
ovata KüTzing						C	LFBT
cf. S. ovata Kützing				R			
pallida Lohman, n.sp.			A				
spicula Lohman, n.sp.			A				
spicula var. lineata Lohman, n.sp.			F				
utahensis Grunow						C	LFBT
spp. (fragments only)	R	R	R	R		F	
Cymatopleura elliptica (Brebisson) Wm. Smith						R	PFBT
solea (Brebosson) Wm. Smith					R	R	PFT
Campylodiscus anastomosus Lohman, n.sp.				C			

SUMMARY OF RESULTS

The primary purpose of this investigation has been to determine the ranges in geologic time during which a large number of Cenozoic nonmarine diatoms have lived, in order to find the extent to which they might be used as indicators of geologic time and hence prove useful in stratigraphic correlation. A study of Table 7 will illustrate to what extent this goal has been realized.

Out of a total of 353 species and varieties of diatoms found in beds ranging in age from late middle Miocene to late Pleistocene, 85 species and varieties, or 23 percent are here described as new. Of the 268 previously known diatoms, 40, or 15 percent have never been reported in living assemblages. Thus there are 125 species and varieties of diatoms in the Great Basin assemblages known only as fossils (35 percent). This appears to be a very significant proportion and leads one to have some confidence in the value of the nonmarine diatoms as stratigraphic indicators.

The distribution of the extinct species and varieties in the beds of various ages is also significant. Out of the 125 extinct species and varieties, 94 (or 75%) are confined to beds of one geologic age, 16 (or 13%) to beds of two geologic ages, 14 (or 11%) to beds of three geologic ages, and 1 (or 0.8%) to beds of four geologic ages. At first sight this would appear to indicate that 75% of the extinct species have very short geologic ranges, and this is probably true for most of them. An examination of the ranges in geologic time represented by the occurrences of those species still reported as living elsewhere, however, shows that certain discontinuities in the distribution of these longer ranging forms are often similar to that of the extinct ones. For example, the well known diatom, *Melosira granulata* occurs frequently in beds of late middle Miocene to middle Pliocene age inclusive, but (in the Great Basin collections) is absent in beds of both early and late Pliocene age. Yet this species is living today all over the world. Many other species exhibit this lack of continuity of occurrence, and at least two explanations appear obvious: (1) the discontinuities may represent environmental changes (temperature, salinity, pH, etc.) of sufficient magnitude to effectively inhibit the growth and reproduction of the organisms, and (2) the Miocene form here recognized as *M. granulata* may be different in some subtle way from the Recent forms assigned to the same species. A sincere effort was made to separate all forms that showed consistent differences, hence *Melosira ponderosa* and others were separated from the mass of superficially similar forms previously lumped together under *M. granulata*. These differences, once seen, are consistent and are capable of sufficiently meaningful biometric measurements to effect a reliable and defensible separation. After this was done, however, some forms remained which were indistinguishable from the living *M. granulata*, and hence were so recorded. The case for M. granulata has been presented as being one of the most difficult, as a number of previous investigators (biologists, not paleontologists) have included so many variables within the "*formenkreis*" of *M. granulata* that it became meaningless as a biologic entity, and certainly of little value in stratigraphic correlation.

On the other hand, many species of both this and other genera occur in what appears to be a much more orderly sequence. The genus *Cestodiscus*, for example, represented in the Great Basin collections by hordes of individuals which have easily been separated into six different species, occur consistently in beds of early Pliocene age only. At least one of the new species of *Cestodiscus* has also been found in beds of early

Pliocene age in both Oregon and Idaho, indicating that its occurrence is not localized geographically. As mentioned in the summaries for each area, other short-ranging species from the Great Basin assemblages have wide geographic distribution.

These discontinuities in the geologic and geographic distribution of both extinct and Recent species are not unique for diatoms, but also occur in all groups of fossils, and although they may pose a philosophical problem, they do not constitute a deterrent to the use of fossils for stratigraphic correlation. Correlations are not made on the absence of a particular species or group, but on the presence of a species or group.

The paleoecological interpretations that have been made for each of the areas studied could have been vastly more informative were it not for the uncertain and often conflicting data published by students of living nonmarine diatoms. Adequate quantitative data such as is required for anything approaching a more detailed paleoecological interpretation are not available for very many species of nonmarine diatoms.

In summary, the results of this investigation indicate clearly that the Cenozoic nonmarine diatoms are a very useful group of fossils for the purpose of stratigraphic correlation and age determination not only within the limits of a single basin, but also between basins widely separated geographically. Their widespread distribution in the nonmarine sediments of the Great Basin and other areas make them particularly useful in bridging the gap betweem the currently more acceptable datings and correlations based upon the much more poorly distributed vertebrate fossils. Furthermore, even with the inadequate ecologic data on Recent forms available, reasonably sound paleoecological interpretations can be made with nonmarine diatom assemblages.

SYSTEMATIC PALEONTOLOGY

The classification of diatoms has been the subject for study, speculation, and change among students of these organisms for over a hundred years, and many earlier classifications based upon the ephemeral soft parts have fortunately been abandoned. Only those based upon the shape, structure, and ornamention of the siliceous shell have survived. The excellent classification proposed by Schütt in Engler and Prantl's Natürliche Pflanzenfamilien, first published in 1896 was accepted, with only minor modifications, until Hendey (1937, p. 199) eliminated Schütt's two-fold division into Centricae and Pennales and proposed 10 suborders to avoid the anomalous position of having a number of genera which could properly be placed into either of Schütt's two divisions. Hendey's classification has been adopted for this report, as well as for two previous ones (Lohman, 1938; 1948).

For nearly 100 years most students of these organisms have regarded them as a class of Algae. Ehrenberg originally thought that they were animals, as did many others of his time. As early as 1860 Hogg (1860) considered the matter and decided to erect a new kingdom of organisms, the Protoctista, for those which had the characteristics of both plants and animals, including the diatoms and many other one-celled creatures. Haeckel (1866), a few years later proposed the term Protista for the same group and his term gradually gained recognition. Moore (1954) has recently reviewed the whole situation in connection with the preparation of the Treatise on Invertebrate Paleontology, of which he is the editor. In previous publications I have considered the diatoms as a class of Algae, following long established custom, but have become increasingly dissatisfied with this assignment and have finally decided to consider the diatoms as belonging to the Protista. Inasmuch as they have the properties of both plants and animals, it appears logical to admit the state of our ignorance and consider that they hover in some middle area between the two.

Diatoms are excellent organisms upon which to make precise biometric measurements, and it is upon such measurements that a large part of specific differentiation depends. One of the most comforting aspects of making such measurements is their small variation within the limits of what may be designated as a species. As in other groups of organisms, this varies from genus to genus and from species to species. The habit of some workers of lumping together a large number of individuals having consistent and easily demonstrable differences, has been one of the greatest factors in casting doubt on the value of the nonmarine diatoms as stratigraphic indicators. This approach has led some to the erroneous conclusion that the nonmarine diatoms have varied so little during geologic time that they have no value in stratigraphy. Systematic measurements of the many elements of ornamentation in the diatoms has shown consistent differences adequate for the erection of new species having short geologic ranges. This is no attempt to imply that the making of such measurements is new; they have been made by many students of diatoms for many years. The significant difference is that more such measurements have been made for the present report, and that the allowable limits of variability of a species have been narrowed whenever this could be shown to form a consistent pattern. For example, where the spacing of the transverse costae on a published species of Pinnularia have been given as 5 to 11 in 10mu, separate consistent groups of species having costae 5 in 10mu have been found to occur at a different stratigraphic position than another group having costae 10 in 10mu. Observation of many individuals has shown that once the split is made, other consistent differences appear and are equally reliable.

In making the identifications of species of diatoms for the present investigation there have been some severe handicaps. The original descriptions and illustrations of some of the previously known species have, in many instances, left much to be desired in the way of quantitative measurements. As mentioned previously, the literature of diatoms is both vast and variable in quality, and as a result it has appeared in some cases that some of the forms which have been assigned to previously known species might properly have been described as new species. The most rigid analyses of many descriptions and illustrations of what have been assigned to one and the same species in the literature, however, have made it impossible to erect new species in many instances in which this might better have been done. This difficulty is almost certainly responsible for some of the anomolous discontinuities in the geologic distribution of previously known species.

In the present form of this report, descriptions and illustrations of new species and varieties only are given, as to include synonymies and illustrations of the 268 previously known species in addition would lengthen the report out of all proportion for this purpose. In the published form, as a U. S. Geological Survey Professional Paper, the synonymies and illustrations of the previously known species and varieties will be included. Ample precedents exist for both methods.

The genera are given in systematic order; the species are in alphabetic order within each genus. The new species are illustrated in Plates 9 to 13 inclusive. The magnification for each figure has been recomputed for the illustration as shown on the plate, in order to take into account the scale changes resulting from the photographic processes involved in reducing the size of the present plates from the 7 x 9 inch format (standard for U.S.G.S. Professional Papers) to meet the Institute requirements.

The unit of the measurements is the micron, here abbreviated to mu, due to the absence of the Greek letter mu on any available typewriter.

Kingdom Protista Haeckel 1866

Subkingdom Protéctista Hogg 1861

Phylum Chrysophyta Pascher 1914

Class Diatomaceae

Order Bacillariales

Suborder Discineae

Family Coscinodisceae

Subfamily Melosiroideae

Genus Melosira Agardh 1824

Melosira crassa Lohman, n. sp.

Plate 9, figures 12, 13.

Valve cylindrical, diameter 10 to 14mu, height, 10 to 18mu, with massive mantle 2.5 to 4mu thick. Girdle end has aperture 3 to 4.5mu in diameter, valve end with coarsely denticulate margin. Mantle puncta 10 to 11 in 10mu, arranged in straight longitudinal rows, 8 to 9 in 10mu. Mantle has constant thickness for height of valve, giving smoothly cylindrical interior space. Ratio of diameter to height, variable, from 1:1 to 1:1.6. No sulcus.

This striking diatom can be confused with no other, and its massive construction renders it an ideal one to become reworked without detection. Although many specimens were found in two collections from the Esmeralda formation, none was broken. Its rare occurrence in the Hagerman formation (but still unbroken and in excellent condition) suggests the possibility that the latter occurrence may represent reworking from nearby lower Pliocene lake bed sediments, which were almost certainly undergoing erosion in Hagerman time. Two photomicrographs are used to illustrate this species, both of the same specimen. Figure 12 shows the exterior of the two valves of adjoining frustules, with the mantle puncta and denticulate connection clearly visible, and figure 13, an optical section of the same specimen, shows the massive character of the mantle and the terminal apertures.

Holotype: U.S.G.S. diatom catalog no. 2665-16, diameter, 14mu, height, 14 mu. From U.S.G.S. diatom locality 3394, 15 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in localities 3394 and 3403, Esmeralda formation. Known geologic range: Early Pliocene to early Pleistocene (?).

Melosira denticulata Lohman, n.sp.

Plate 9, figure 1.

Valve cylindrical, without mantle puncta, but with one row of teeth, 11 in 10mu, at curved end of frustule. Sulcus averaging 2mu deep. Pseudosulcus deeper than sulcus, caused by curved ends of frustules. Diameter, 8 to 12mu; height, 4 to 6mu.

This striking species usually occurs in filaments of 2 to 8 complete frustules, and the denticulate ends appear prominently even at lower magnifications. It is a very short ranging form and therefore valuable for stratigraphic correlation.

Holotype: U.S.G.S. diatom catalog no. 2703-149, diameter, 8.2mu; height, 4.4mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found frequently in locality 3534, Lower Virgin Valley beds.

Known geologic range: Late middle Miocene.

Melosira hyalina Lohman, n.sp.

Plate 9, figures 2, 3.

Valve cylindrical with very prominent sulcus, averaging 4 to 5mu deep. Mantle puncta very fine, just resolved with a 2 mm apochromat and oblique light, but in definite longitudinal, slightly spiral rows. Mantle puncta extend down into the sulcus. Diameter, 20 to 25mu; Height, 16 to 20mu.

The specimen figured consists of two frustules, each having a terminal cell (resting condition?). This condition is normal for most of those found, although an occasional string of two or three complete frustules was seen.

Holotype: U.S.G.S. diatom catalog no. 2699-18, diameter, 23mu; total height (2 frustules), 34mu. From U.S.G.S. diatom locality 3537, 29½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found frequently in locality 3527, Lower Virgin Valley beds.

Known geologic range: Late middle Miocene.

Melosira italica var. irregularis Lohman, n.var.

Plate 9, figure 4.

Valve having shape of truncated cone (instead of being cylindrical) with the smaller diameter being the highly denticulate attachment zone between frustules. All other characteristics identical with the type.

This variety, which always occurred with M. italica, was consistent in always being expanded toward the sulcus. Its occurrence in 5 out of 8 collections from the Opal Creek section in the Lower Virgin

Valley beds and nowhere else in the Great Basin collections makes this a distinctive and useful marker for the early middle Miocene.

Holotype: U.S.G.S. diatom catalog no. 2694-157, small diameter, 7 to 8mu; large diameter, 9 to 11mu. From U.S.G.S. diatom locality 3523, 17 feet stratigraphically above the base of the Opal Creek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found commonly in locality 3523, frequently in localities 3525, 3530, 3534, and 3536, all in Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Melosira margaritata Lohman, n.sp.

Plate 9, figure 5.

Valve cylindrical, with mantle puncta arranged in straight rows parallel to height of valve, 14 in 10mu; puncta in rows, 18 to 20 in 10mu, extending from end of valve to sulcus. Sulcus deep, rounded. Diameter of valve, 7 to 10mu, height, variable, even in the two valves of one frustule, 7 to 12mu.

The arrangement of the mantle puncta gives the appearance of rows of pearls (hence the name) and makes this species very easy to identify in an assemblage. The variability of the height, although not confined to this species, is nevertheless another distinguishing feature, as a string of frustules (the figure shows two complete frustules) rarely has more than two valves of the same height.

This is an excellent marker species, having been found only in the Lower Virgin Valley beds, where it occurs commonly.

Holotype: U.S.G.S. diatom catalog no. 2703-152, diameter, 9mu, from U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Crrek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found commonly in locality 3534 and rarely in 3536, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Melosira margaritata var. laevis Lohman, n.var.

Plate 9, figure 6.

Valve similar to type, but with height always less than diameter, diameter/height ratio averaging 1.4. Mantle puncta in rows 20 in 10mu, much finer than the type. Sulcus deep and rounded. Diameter 9 to 10mu, height 6.5 to 7.5mu.

This variety exhibits much more uniformity in all respects than M. margaritata and its much finer mantle puncta makes it very easy to identify. It is also an excellent marker for the late middle Miocene.

Holotype: U.S.G.S. diatom catalog no. 2703-22, diameter, 9.8mu, height, 7.1mu, from U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found commonly in locality 3534, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Melosira micropunctata Lohman, n.sp.

Plate 9, figure 7.

Valve cylindrical with triangular sulcus, 2 to 3mu deep, rounded on bottom; mantle puncta very fine, 30 to 32 in 10mu, starting at sulcus and stopping 3 to 5mu from end of valve. Diameter, 10 to 12mu; height, 14 to 18mu, very slightly denticulate at contact between frustules.

M. italica (Ehrenberg) Kützing differs from this species in having much coarser mantle puncta, a shallower sulcus, and a much more denticulate margin. The specimen illustrated was chosen for the type in spite of the fact that one of the valves is broken, as it shows all of the characteristics of the species better than any other one found.

Holotype: U.S.G.S. diatom catalog no. 2668-109, diameter, 10.5mu; height, 14.4mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Nye County, Nevada. Esmeralda formation, early Pliocene.

Found frequently in localities 3525, 3527, 3534; commonly in 3536, from the Lower Virgin Valley beds. Frequently in 3397; rarely in 3405, from the Esmeralda formation; and rarely in 4169, from the Hagerman formation.

Known geologic range: early middle Miocene to early Pliocene.

Melosira nuda Lohman, n.sp.

Plate 9, figure 11

Valve cylindrical, smooth, with no mantle puncta discernable, even under high magnification and resolution. A zone of occasional apiculi sometimes occurs on the mantle surface at about half the height of the valve. Mantle wall undulating in thickness from 1¼ to 2½mu.

No sulcus. Diameter, 13 to 17mu; height, variable even on adjacent valves of one frustule, 14 to 22mu.

The undulating mantle wall, together with the occasional zone of widely spaced apiculi, indicate the relationship of this species to M. undulata, but the complete absence of the fine mantle puncta so characteristic of the latter and the thinner mantle wall of M. nuda clearly separate the two.

Holotype: U.S.G.S. diatom catalog no. 2601-102, diameter, 16.3mu; height of the four valves figures, 14.8 to 22mu; thickness of mantle wall, 1.3 to 2.4mu. From U.S.G.S. diatom locality 3304, Provo formation, Goshen Valley, Utah Co., Utah. Late Pleistocene.

Found frequently in localities 3304 and 3305, Provo formation.

Known geologic range: late Pleistocene.

Melosira paucipunctata Lohman, n.sp.

Plate 9, figure 10

Valve cylindrical, straight or curved, height much greater than diameter, with scattered coarse puncta, often in somewhat random arrangement, averaging 3 to 5 in 10mu. Sulcus evident and about 1mu deep. Diameter, 8 to 10mu; height, 18 to 25mu.

Wherever found, both straight and curved filaments occur in the same collection, hence no distinction has been made between the two. Although possibly a tautological form, this species occurred commonly enough in one collection from the Cedar Mountain section and rarely in two others, as well as abundantly in the Mascall formation at Tipton, Oregon (Lohman, 1934, p. 10) and commonly in the Upper Cedarville formation at 49 Camp, Nevada (Lohman, 1936A, p. 97). It is worth noting that it appears somewhat anomalous for this species to occur abundantly in the Mascall formation and commonly in the Upper Cedar Ville formation and not all in the Virgin Valley beds of approximately the same age.

Holotype: U.S.G.S. diatom catalog no. 2668-112, diameter, 8.3mu; height, 20mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of the Cedar Mountain section, Nye County, Nevada. Esmeralda formation, early Pliocene.

Found commonly in locality 3404, rarely in 3397 and 3405, all from Esmeralda formation.

Known geologic range: late middle Miocene (Mascall) to early Pliocene (Esmeralda).

Melosira ponderosa Lohman, n.sp.

Plate 9, figure 14

Valve cylindrical, usually straight but occasionally slightly curved, with massive walls and deep sulcus. Mantle covered with coarse round to square puncta, 5 to 5.5 in 10mu, arranged in straight parallel rows, 5 in 10mu. Finely denticulate connection between frustules. Mantle wall very thick. Diameter, variable, 7 to 17mu; height of valve, 8.5 to 21mu; height/diameter ratio, 1:1.24.

This species apparently evolved from M. granulata, which has a much longer geologic range. The mantle puncta of M. granulata became coarser in mid-Tertiary time than they are today, culminating in M. ponderosa, which, by virtue of both its consistently coarse mantle puncta and its much thicker mantle walls, is here defined as a separate species.

On account of its definite and easy identification, due to the combination of coarse punctation and heavy mantle wall, and also because the geologic range of this species has been found to be limited to from early middle Miocene to early Pliocene, it appears to be one of the really valuable, short-ranged species.

Holotype: U.S.G.S. diatom catalog no. 2709-13, diameter, 13mu; height, 16mu. From U.S.G.S. diatom locality 3540, Upper Virgin Valley beds, Humboldt County, Nevada.

Found dominantly in locality 3407, Esmeralda formation, abundantly in locality 3537, Lower Virgin Valley beds, 3540, Upper Virgin Valley beds, 3396, 3410, Esmeralda formation; commonly in locality 3397, Esmeralda formation, and frequently in localities 3394, 3403, and 3405, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Melosira ponderosa var. curta Lohman, n.var.

Plate 9, figure 15

Similar to the type in all respects except that the diameter is much greater than the height. Mantle puncta, round to subangular, 5.5 to 6.5 in 10mu. Diameter, 18 to 33mu; height, 9 to 16mu.

This variety has a geologic range which is identical with the type, but the relative abundances are different. The tendency toward squarish and rectangular mantle puncta is accentuated in this variety, and many individuals have square puncta containing a tiny central dot. At first this was assumed to be an optical anomaly, but the dot remains under conditions of maximum resolution and therefore appears to be real.

Holotype: U.S.G.S. diatom catalog no.2678-13, diameter, 18mu; height, 9.5mu. From U.S.G.S. diatom locality 3407, 291 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in localities 3537, from Lower Virgin Valley beds, 3540, Upper Virgin Valley beds, and in 3397, Esmeralda formation, and abundantly in locality 3407, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Melosira ponderosa var. elongata Lohman, n.var.

Plate 9, figure 15A

Similar in all respects to the type except that the height/diameter ratio varies from 2 to 3. Diameter, 8 to 11mu; height, 16 to 30mu. Round to subangular mantle puncta, 5.5 in 10mu.

Holotype: U.S.G.S. diatom catalog no. 2708-100, diameter, 9mu; height, 20mu. From U.S.G.S. diatom locality 3537, 107 feet stratigraphically above the base of the Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found commonly in locality 3537, Lower Virgin Valley beds, abundantly in locality 3540, Upper Virgin Valley beds; frequently in locality 3405, commonly in 3407, and abundantly in 3410, all from Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Melosira punctissima Lohman, n.sp.

Plate 9, figure 8

Valve cylindrical, with length/height ratio variable according to diameter, as height is fairly constant over a range of diameters. Mantle covered with very fine puncta arranged in longitudinal rows parallel to height of valve; rows 25 in 10mu. Sulcus 1mu deep, rounded. Ends not denticulate. Diameter, 7 to 16mu; height, 6 to 8mu.

This species is one of the apparently very short-ranging ones, as it occurred in only one collection in the Great Basin, and was conservatively reported as abundant. It completely dominated the one assemblage and formed a virtual flood, and its absence in other collections in the same section suggests that its geologic range is so short that it may also have a restricted geographic distribution.

Holotype: U.S.G.S. diatom catalog no. 2701-8, diameter, 7mu, height, 6mu. From U.S.G.S. diatom locality 3530, 33 3/4 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found abundantly in locality 3530, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Melosira punctissima var. curvata Lohman, n.var.

Plate 9, figure 9

Valve cylindrical, identical with the type in all respects, except that the filament is curved instead of straight, and that the height is more nearly constant -- regardless of diameter. Diameter, 7 to 15mu; height, 6 to 9mu.

Remarks concerning the type are pertinent here, although this variety occurred only frequently and not abundantly.

Holotype: U.S.G.S. diatom catalog no. 2701-89, diameter, 12mu; height, 6 to 7.5mu for the 5 complete valves in the figure. From U.S.G.S. diatom locality 3530, 33 3/4 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found frequently in locality 3530, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Melosira triannula Lohman, n. sp.

Plate 9, figure 16.

Valve cylindrical with coarse mantle puncta, 10 to 11 in 10mu, arranged in longitudinal straight, parallel rows, 10 to 11 in 10mu and forming 3 annular rows. Sulcus very shallow, not noticeable. End of frustule convex, touching adjacent frustule in a chain over about half the diameter only, forming a deep, narrow pseudosulcus. Chain of frustules frequently slightly curved. Diameter, 10 to 13mu; height, 8 to 9mu.

The curvature of a chain of frustules is probably due to the mode of attachment of the frustules by having two convex surfaces in what is often little more than tangential contact. Many individuals were examined and all had just 3 annular rows of mantle puncta, although there was frequently room for more. This is another excellent marker species for the late middle Miocene, where it occurs commonly. The sudden appearance, and equally sudden extinction of a number of distinctive species of Melosira, (and also other genera) in the late middle Miocene beds may be due to an explosive evolution of new species, or it may mean that these species were developed earlier than during Lower Virgin Valley time, but have not been found. The latter explanation appears unlikely in viewof the fact that well developed assemblages of diatoms were obtained from 5 collections stratigraphically lower and in the same section in which the new species did not appear.

Holotype: U.S.G.S. diatom catalog no. 2703-34, diameter, 12.4mu; height, 8.5mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found commonly in locality 3534, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Subfamily Coscinodiscoideae

Genus Cyclotella Kützing 1834

Cyclotella anomala Lohman, n.sp.

Plate 9, figure 17

Valve circular to slightly elliptical, with elevated annular zone at about $\frac{1}{2}$ radius, puncta 13 to 14 in 10mu, radial on part of the valve and crossing irregularly on the other parts. Central space very small, with one central punctum. 4 or 5 scattered short apiculi at about 1/6 radius in from margin. Margin very narrow, finely striated, 16 in 10mu. Diameter, 25 to 32mu.

This species is more symmetrical in cross section than it is in outline; it is flat for about half the radius with a domed central portion. Its assignment to the genus Cyclotella was made only after considering the only reasonable alternative, Coscinodiscus, and deciding that it represented a species having some of the characteristics of both genera and may be an intermediate form.

Holotype: U.S.G.S. diatom catalog no. 2665-77, major diameter, 30mu; minor diameter, 27mu. From U.S.G.S. diatom locality 3394, 15 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada.

Found frequently in locality 3394 only. Esmeralda formation.

Known geologic range: early Pliocene.

Genus Coscinodiscus Ehrenberg 1838

Coscinodiscus mobilensis Lohman, n.sp.

Plate 9, figure 20

Valve circular, convex, margin very narrow and finely striated. Round, pearly areolae 10 to 12 in 10mu in radial rows, slightly curving in somewhat random fashion. Central space small to 3mu in diameter, usually covered with small areolae in random orientation. Focussing up and down gives impression of motion and rotation of the valve, due to anastomosing and curving rows of nearly radial areaolae.
Diameter, 40 to 50mu.

This is an easily recognized species, due to the vivid apparent motion on focussing up and down, hence its name, and is difficult to confuse with any other.

Holotype: U.S.G.S. diatom catalog no. 2668-119, diameter, 43mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in localities 3397 and 3403, both from Esmeralda formation.

Known geologic range: early Pliocene.

Genus CESTODISCUS Greville 1865

Cestodiscus Greville, London Micr. Soc. Trans., new ser., vol. 13, p. 48, pl. 5, figs. 8, 9, 1865.

Grunow, in Van Heurck, Synopsis diatomees Belgique, pl. 126, 1883.

Castracane, Challenger Repts., Botany, vol. 2, p. 122, 1886.

De Toni, Sylloge Algarum, vol. 2, p. 1308, 1894.

Van Heurck, Treatise on the Diatomaceae, p. 491, 1896.

Reinhold, Nederland in Kolonien Geol.-Mijnbouwk. Genootschap Verh., Geol. Ser., Deel 12, p. 89, 1937.

Lohman, Maryland Dept. Geol. Mines and Water Res., Cretaceous and Tertiary Subsurface Geology Bull. 2, p. 165, 1948.

Coscinodiscus (Cestodisci), Pantocsek, Fossilen Bacillarien Ungarns, Tekl 1, p. 73, 1886.

Coscinodiscus (Cestodiscoidales) Rattray, Royal Soc. Edinburgh, Proc., vol. 16, p. 467, 1889.

De Toni, Sylloge Algarum, vol. 2, p. 1206, 1894.

Reasons for reviving this distinctive genus are given in my Maryland paper (see above synonymy). The several nes species of Cestodiscus found in the Cedar Mountain section of the Esmeralda formation represent the first nonmarine members of the genus. They completely dominate certain beds in the section and therefore may prove to be widespread in rocks of early Pliocene age. Most members of this genus have valves that are far from flat, and it is therefore often difficult to photograph them so that the cestodiscoid radial hyaline markings are clearly depicted at the best average focus for the valve as a whole.

Cestodiscus apiculatus Lohman, n.sp.

Plate 10, figures 1, 5

Valve circular with raised annular zone about $\frac{1}{4}$ way in from margin. Margin 2 to 3.5mu wide, finely striate, 20 in 10mu. Radial, round, pearly areolae, 10 to 11 in 10mu, non-fasciculate. Central space about 6mu in diameter, uneven, with a few scattered puncta. Cestodiscoid hyaline markings radial, narrow, averaging 4mu long, with prominent apiculi at outer end and about 16mu apart. Diameter, 60 to 100mu.

Some specimens of this species appear to grade into _C. stellatus,_ particularly in respect to the radial stellate thickenings of silica that give _C. stellatus_ its characteristic appearance. This is much more apparent when viewed at low magnifications and, in the case of _C. apiculatus,_ usually disappears at higher magnifications. The radial hyaline marginal spaces which are a generic characteristic are much narrower in _C. apiculatus._

Holotype: U.S.G.S. diatom catalog no. 2668-155 (figure 1), diameter, 91mu; Paratype: U.S.G.S. diatom catalog no. 2668-144 (figure 5), diameter, 63mu. Both from U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found commonly in locality 3397, Esmeralda formation.

Known geologic range: early Pliocene.

Cestodiscus canalis Lohman, n.sp.

Plate 10, figure 6

Valve circular, with raised annular zone about $\frac{1}{4}$ way in from margin, 2 to 3mu wide, finely striated, 20 in 10mu. Radial, round, pearly areolae, 9 to 10 in 10mu, non-fasciculate. Central space, oval, about 2 by $3\frac{1}{2}$mu, with two or three scattered puncta. Hyaline markings form radiating canals from center to margin, giving the valves a pseudo-fasciculate effect. Diameter, 60 to 75mu.

This striking species can be very easily identified, even from a fair-sized fragment, and this, coupled with its very short geologic range, renders it very useful for correlation.

Holotype: U.S.G.S. diatom catalog 2668-173, diameter, 69mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye Co., Nevada. Early Pliocene.

Found rarely in locality 3397, Esmeralda formation.

Known geologic range: early Pliocene.

Cestodiscus cedarensis Lohman, n.sp.

Plate 9, figures 21, 22

Valve circular, convex to undulating, with radial rows of angular, rarely hexagonal areolae, 8 to 10 in 10mu, becoming smaller near margin. No rosette or central space. Margin 3 to 4mu wide, with radial marginal striae, 18 to 19 in 10mu. 6 to 8 short radial hyaline spaces, averaging 1.5mu wide and 3mu long, beginning 3 to 4mu inside outer margin. Diameter, 45 to 60mu.

The short radial hyaline spaces do not show up well in figure 22, taken at the best focus for the valve as a whole. They are clearly visible in figure 21, taken at a focus which shows the hyaline markings, but not the margin. These markings are somewhat variable in different individuals of this species; figure 21 shows the best average appearance of them. They clearly place the species in the genus Cestodiscus.

This distinctive species is one of the commonest diatoms in the Esmeralda formation in the Cedar Mountain section, but has been found nowhere else. It constitutes an excellent short-ranging marker species for the early Pliocene.

Holotype: U.S.G.S. diatom catalog no. 2665-83, diameter, 60mu (pl. 8, fig. 22); paratype: U.S.G.S. diatom catalog no. 2665-18, diameter 49mu (pl. 8, fig. 21), both from U.S.G.S. diatom locality 3394, 14 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye Co., Nevada. Early Pliocene.

Found abundantly in locality 3394, frequently in localities 3396 and 3403, and rarely in 3405, Esmeralda formation.

Known geologic range: early Pliocene.

Cestodiscus fasciculatus Lohman, n.sp.

Plate 10, figures 2, 7

Plate 11, figure 1

Valve circular, flat, except for depressed annular zone near margin; round to oval detached areolae, 9 to 10 in 10mu, arranged in 6 to 8 radial fasicles, with rows parallel to the central row in each fasicle. Ragged, radial, hyaline space between each fasicle, beginning well inside broad margin and averaging 8mu long. Radial extension of single row of round areolae, 10 in 10mu from inner end of hyaline space to center of valve, sharply delineating the fascicles. Central space small, irregular, with several scattered granules. Margin 5 to 6mu wide with radial finely punctate striae, 17 to 18 in 10mu at outer edge, gradually changing to quincunx arrangement on inner part. Diameter of valve, variable from 40 to 100mu.

In some specimens (pl. 10, fig. 7) the areolae in each fascicle are arranged in rows parallel to the center row with no alignment in any other direction; in others (pl. 10, fig. 2) the arrangement of the areolae becomes somewhat random toward the margin; in others (pl. 11, fig. 1) there is in addition to the arrangement first mentioned, an alignment of the areolae in sharply tangential rows normal to the central row in each fasicle. At first it appeared possible to erect varieties for these secondary variations, but examination of hundreds of specimens indicated that it would be possible to set up a polymorphous series with virtually infinite variation between the extremes illustrated. There is also a suggestion that the tangential arrangement may indicate an evolutionary trend, as this form was more commonly found in the younger beds 250 feet stratigraphically higher in the same section.

Holotype: U.S.G.S. diatom catalog no. 2665-36 (pl. 10, fig. 7), diameter, 52mu. Paratype: U.S.G.S. diatom catalog no. 2665-8 (pl. 11, fig. 1), diameter 65mu. Paratype: U.S.G.S. diatom catalog no. 2665-59 (pl. 10, fig. 2), diameter, 94mu; all from U.S.G.S. diatom locality 3394, 14 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye Co., Nevada. Early Pliocene.

Found abundantly in locality 3394, commonly in 3397, and frequently in 3403 and 3405, Esmeralda formation.

Known geologic range: early Pliocene.

Cestodiscus simplissimus Lohman, n.sp.

Plate 9, figures 18, 19

Valve circular, nearly flat, with border averaging 2.5mu wide, having radial striae 18 in 10mu. Pearly, radial, imperfectly fasciculate rows of areolae, 8 to 9 in 10mu in mid-portion, becoming somewhat finer toward margin. Usually no central space, but occasionally a very small one. 4 to 6 radial, broad and short hyaline spaces beginning at inner edge of border. A narrow zone of very fine puncta arranged in quincunx just inside margin. Diameter, 30 to 50mu.

This species might be considered to be intermediate between *C. cedarensis* and *C. fasciculatus*; in some specimens the pearly areolae occasionally become polygonal and in some they become somewhat fasciculate.

Holotype: U.S.G.S. diatom catalog no. 2673-74 (fig. 19), diameter, 41mu; Paratype: U.S.G.S. diatom catalog no. 2673-83 (fig. 18), diameter, 34mu. Both from U.S.G.S. diatom locality 3403, 276 feet stratigraphically above base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in localities 3397 and 3403, Esmeralda formation.

Known geologic range: early Pliocene.

Cestodiscus stellatus Lohman, n.sp.

Plate 10, figures 3, 4.

Valve circular, 75 to 100 mu in diameter, with raised narrow annular zone at ½ to 2/3 radius in from margin. Margin narrow, with fine radial striae 17 to 20 in 10mu. Short radial hyaline spaces averaging 20 to 22mu apart, just inside the margin. Polygonal areolae, 9 to 10 in 10mu in non-fasciculate radial rows. Scattered short radial thickenings of silica between rows of areolae gives a sunburst effect. No central space or rosette.

Both the annular zone and the hyaline radial spaces are well illustrated in figure 3. This species can be easily spotted in an assemblate as it is the only Cestodiscus with stellate markings. Although many specimens were found, very few were found in unbroken condition on account of the fragile character of the valves. The two specimens illustrated are the most nearly perfect of those found.

Holotype: U.S.G.S. diatom catalog no. 2665-52 (fig. 4), diameter, 79mu; from U.S.G.S. diatom locality 3394, 15 feet stratigraphically above base of the Cedar Mountain section, Esmeralda formation, lower Pliocene, Nye Co., Nevada. Paratype: U.S.G.S. diatom catalog no. 2668-131, (fig. 3), diameter, 91mu, from U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in localities 3394 and 3397, Esmeralda formation. Known geologic range: early Pliocene.

Suborder Araphidineae

Family Fragilariaceae

Subfamily Fragilarioideae

Genus FRAGILARIA Lyngbye 1819

Fragilaria crassa Lohman, n.sp.

Plate 11, figure 2.

Valve lanceolate-elliptical with smooth, rounded swelling in central part; apices rostrate with rounded ends. Finely punctate parallel transverse striae, 9 in 10mu in central part, 10 in 10mu toward the ends. Pseudoraphe very narrow or absent. Length, 25 to 50mu, width, 8 to 11mu.

The much coarser striae and faint or absent pseudoraphe distinguish this robust species from the smaller _F._ _bicapitata_ Mayer (Hustedt, Kieselalgen, 1931, p. 165). _F._ _crassa_ is somewhat variable in shape, some forms being shorter and thicker than the one illustrated. It always, however, has the heavy, robust striae.

Holotype: U.S.G.S. diatom catalog no. 2676-81, length, 35mu; width, 9mu. From U.S.G.S. diatom locality 3405, 284 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality, 3537, Lower Virgin Valley beds; and 3540, Upper Virgin Valley beds; commonly in localities 3404 and 3407, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Fragilaria crassa var. capitata Lohman, n.var.

Plate 11, figure 2A

Valve elongate-lanceolate with nearly parallel sides and elongated, slightly capitate apices. Finely punctate, robust transverse striae, parallel and normal to transapical axis, 10 in 10mu. Pseudoraphe usually evident, more so than in the type. Length, 40 to 65mu; width, 10 to 11mu.

This variety is more consistent in shape and size than some of the other variants of the type. The pseudoraphe is much more prominent than in the type. The same possible confusion with F. bicapitata mentioned under the type applies with even greater emphasis to the variety.

Holotype: U.S.G.S. diatom catalog no. 2668-53, length, 59mu; width, 10mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality 3537, Lower Virgin Valley beds, and frequently in localities 3397 and 3403, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Fragilaria delicata Lohman, n.sp.

Plate 11, figure 4

Valve lanceolate with sharply rostrate apices. Transverse striae, 17 in 10mu, parallel in center, slightly radiate toward apices. Striae short, about one third width of valve, thick at margin of valve and thinning inward. Axial area lanceolate, about one-third width of valve in central portion, narrowing toward apices. Length, 22 to 28mu; width , 5 to 5½mm.

The striae are ordinarily not seen on low and medium magnification, but are quite distinct under magnifications of 1000 or over with an oil-immerision objective. This might be confused with F. construens under hasty examination, but it differs in having the heavy marginal ends to the striae, by the sharply rostrate apices. Most specimens of F. construens have somewhat coarser striae, and they are of the same thickness throughout.

Holotype: U.S.G.S. diatom catalog no. 2709-137, length, 25mu; width, 5.3mu. From U.S.G.S. diatom locality 3540, Upper Virgin Valley beds, Humboldt County, Nevada. Late Miocene.

Found rarely in locality 3540, Upper Virgin Valley beds.

Known geologic range: late Miocene.

Fragilaria leptostauron var. obesa Lohman, n.var.

Plate 11, figure 3

Valve short, circular in central portion, with produced, rostrate apices. Transverse striae, heavy, 10 in 10mu, finely punctate, and everywhere radial. Length, 13mu; width, 5 to 6mu.

The circular central portion distinguishes this variety from the type. It is a short ranging variety, easily identified, and therefore should be useful for stratigraphic correlation.

Holotype: U.S.G.S. diatom catalog no. 2709-118, length, 13mu; width, 5.5mu. From U.S.G.S. diatom locality 3540, Upper Virgin Valley beds, Humboldt County, Nevada. Late Miocene.

Found frequently in locality 3540, Upper Virgin Valley beds.

Known geologic range: late Miocene.

Fragilaria nevadensis Lohman, n.sp.

Plate 11, figures 5, 6.

Valve linear, narrow, with parallel sides and abruptly rostrate apices. Pseudoraphe indistinct and not continuous; transverse striae, 15 to 17 in 10mu. Length, 40 to 65mu; width, 3 to 4.5mu.

This very narrow species is one of the most characteristic ones in the Lower Virgin Valley beds and is also found frequently in the Upper beds. It occurs more often than not in bands of 5 to 8 complete frustules still attached.

Holotype: U.S.G.S. diatom catalog no. 2694-160, valve view (fig. 5), length, 48mu; width, 4mu. From U.S.G.S. diatom locality 3523, 17½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Paratype: U.S.G.S. diatom catalog no. 2696-113, girdle view (fig. 6), length, 45mu. From U.S.G.S. diatom locality 3524, 19½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada.

Found commonly in localities 3523,3524,3525,3534, and frequently in locality 3530, in Lower Virgin Valley beds; and frequently in 3540, Upper Virgin Valley beds.

Known geologic range: late middle Miocene to late Miocene.

Genus OPEPHORA Petit 1888

Opephora lanceolata Lohman, n.sp.

Plate 11, figure 10

Valve lanceolate with tumid middle and very slightly capitate ends, almost symmetrical. Heavy costae, parallel, 5 in 10mu, alternating on opposite sides. Axial area very narrow, especially toward the ends. Length, 70 to 85mu.

The specimen illustrated is the only whole one found, although fragments were numerous. It is a complete frustule and the lower valve is somewhat distorted, making the margin appear to be double in part of the photograph.

Holotype: U.S.G.S. diatom catalog no. 2708-45, length, 75mu. From U.S.G.S. diatom locality 3537, 107 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found rarely in locality 3537, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Subfamily Meridionioideae

Genus DIATOMA De Candolle 1805

Diatoma enormis Lohman, n.sp.

Plate 11, figures 7,8,9.

Valve flat with capitate apices. Central portion varies from circular to elongate elliptical to elongate rectangular in outline, with all variations between these extremes. Transverse finely punctate striae, variable, averaging 12 to 14 in 10mu, parallel in center, radial between center and constriction and divergent at apices. Costae, 4 to 5 in 10mu. Pseudoraphe evident but very narrow. Length, 13 to 30mu.

The specific name here assigned to this species (meaning varying, different) was chosen as it is difficult to find two specimens having identical outlines, although identical in other respects. At first an attempt was made to set up varieties or even different species for some of the different forms, but a careful study revealed all possible gradations between the end points of a polymorphic series. Hence they have all been assigned to one species with the variation noted. The specimens chosen to illustrate the species indicate the range in external shape.

This is a valuable and easily identified species and one with a short geologic range. Its distribution in the Great Basin collections is somewhat spotty, occurring abundantly to frequently in two collections from the middle of the late middle Lower Virgin Valley beds, absent in the late Miocene Upper Virgin Valley beds, and reappearing in the early Pliocene Esmeralda formation, and nowhere else.

Some individuals of this species most nearly approached D. capitata Lauby (1910, p. 205, pl. 11, fig. 23), but D. enormis has more produced apices, has finer transverse striae, and is much more variable in outline. In his description of the species, Lauby gives a length of 14mu, whereas his figure has a length of 30mu. As his drawings are excellent, and have a scale of micra attached, it would appear that the dimensions taken from his plate are more reliable than those in his description, where a typographical error could easily creep in. The spacing of the transverse striae in _D. enormis_ falls between _D. capitata_ and _D. vulgare_, and its varieties. Lauby's specimens came from both upper Miocene and lower Pliocene strata in France.

Holotype: U.S.G.S. diatom catalog no. 2703-43 (fig. 9), length, 19mu. Paratype: U.S.G.S. diatom catalog no. 2703-27 (fig. 7), length 23mu. Paratype: U.S.G.S. diatom catalog no. 2703-170 (fig. 8), length 29mu. All from U.S.G.S. diatom locality 3534, 84 feet stratigtaphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found abundantly in locality 3534, frequently in 3530, both from Lower Virgin Valley beds,and frequently in locality 3397, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Subfamily Tabellarioideae

Genus TETRACYCLUS Ralfs 1843

Tetracyclus Ralfs, Annals and Mag. Nat. History, vol. 12, p. 105, 1843.

De Toni, Sylloge Algarum, vol. 1, p. 746, 1891.

Hustedt, in Schmidt, Atlas der diatomaceenkunde, pls. 269, 273, 280-282, 297, 1911-13.

Hustedt, Bremen Naturwiss. Ver. Abh., Band 23, pp. 90-107, pl. 5, 1914.

Hustedt, Die Kieselalgen Deutschlands, Österreichs und der Schweiz, Teil II, p. 12, 1931.

Striatella Ehrenberg, K. Akad. Wiss. Berlin, Physikal. Abh., 1841, p. 136, 1843.

Biblarium, Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1844, p. 265.

Stylobiblium Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1845, p. 72.

Gomphogramma Braun, in Rabenhorst, Süsswasser Diatomeen, p. 33, 1852.

Salacia Pantocsek, Beiträge zur kenntnis der fossilen Bacillarien Ungarns, Teil II, p. 69, 1889.

Castracania De Toni, Sylloge Algarum, vol. 1, p. 750, 1891.

The genus Tetracyclus has been the subject of only one monographic study, that by Hustedt (4th citation above) who was primarily interested in Recent species. He therefore somewhat oversimplified the complexities of the genus, in which, probably more than any other among the diatoms, the external shape of the valve is the principal distinguishing characteristic for division into species. Few members of the genus have significant differences in internal structure or surface ornamentation, and hence the external shape becomes the dominant characteristic on which to differentiate species. When viewing a group of living organisms, whether from one habitat or from many, it is perhaps easy to devise a scheme in which many individuals or varying shape or geometrical proportions fall into one large group or *formenkreis*. With fossil forms, coming from rocks of different geologic ages, the *formenkreis* concept is more difficult to support, especially when certain shapes are characteristic of definite geologic periods or epochs.

Therefore, in the present report, the genus *Tetracyclus* has been divided into a number of distinct species largely on the basis of external shape. The genus is an important one in mid-Tertiary stratigraphy, and by the careful splitting of species of this genus based largely on external shape, plus minor changes in the arrangement of costae, a number of definitive forms emerge that are useful for correlation.

Hustedt has made a large number of varieties of one type form -- *Tetracyclus ellipticus*, and it would require little extension of this principle to include virtually 90 percent of the species in the genus as variants of this one supposedly original species. When the fossil record is critically examined, however, many of the variants occur earlier in geologic time than the type, which immediately leads to the absurdity of having a Miocene variety of a Recent species! Thus it would appear that the most consistently useful approach from the point of view of the stratigrapher would be to describe as separate species those morphologically different forms which appear to have consistent value as stratigraphic markers, and this course has been adopted in this report. Those varieties that do not appear to violate the above concept are retained.

Tetracyclus calceus Lohman, n.sp.

Plate 11, figure 11

Valve elongate, with narrowly pointed apices and broad, shallow, central constriction. Heavy transverse costae, parallel, usually continuous, 2½ to 3 in 10mu. Finely punctate transverse striae, 24 to 27 in 10mu, parallel to costae. Pseudoraphe very narrow and terminating 3 to 5mu from apices. Length, 40 to 70 mu; maximum width, 18 to 20 mu; width at constriction, 10 to 11mu.

This species, named from its resemblance to the pointed soles of shoes, is somewhat similar to _T. javanicus_ Hustedt, from which it differs in being narrower, usually longer, and having more pointed apices.

Holotype: U.S.G.S. diatom catalog no. 2703-140, length, 68mu; maximum width, 20mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Hunboldt County, Nevada. Late middle Miocene.

Found frequently in localities 3534, 3537, Lower Virgin Valley beds; frequently in 3540, Upper Virgin Valley beds; and frequently in localities 3397, 3403, 3405, and 3410, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Tetracyclus circularis Lohman, n.sp.

Plate 11, figure 12

Valve circular, or nearly so, with heavy transverse costae, 3 in 10mu, going entirely across the valve. Transverse, finely punctate striae, 19 to 20 in 10mu, parallel to costae. Diameter, 17 to 35mu.

The spacing between costae is the same regardless of the size of the valve, but the costae always go entirely across the valve, distinguishing it from T. clypeus and T. ellipticus var. clypeus. The short, prominent radial, spur-like costae so prominent on T. clypeus are entirely absent on T. circularis.

Holotype: U.S.G.S. diatom catalog no. 2709-50, diameter, 32mu, from U.S.G.S. diatom locality 3540, Upper Virgin Valley beds, Humboldt County, Nevada. Late Miocene.

Found frequently in locality 3540, Upper Virgin Valley beds.

Known geologic range: Late Miocene.

Tetracyclus clypeus (Ehrenberg) Lohman, n.comb.

Plate 11, figure 13

Stylobiblium clypeus Ehrenberg, K. Akad. Wiss. Berlin, Ber., 1845, p. 80.

Ehrenberg, Mikrogeologie, pl. 33, group II, fig. 18; pl. 33, group XII, figs. 28, 29, 1854.

De Toni, Sylloge Algarum, p. 749, 1891.

Tetracyclus ellipticus var. clypeus (Ehrenberg) Hustedt, in Schmidt, Atlas der diatomaceenkunde, pl. 281, fig. 23, 1912.

Hustedt, Bremen Naturwiss. Ver. Abh., Band 23, p. 101, pl. 5, fig. 12, 1914.

Ehrenberg's figures cited above are quite adequate for an accurate identification of this species and differ from Hustedt's in having the short radial marginal costae in addition to the complete ones which cross the diameter of the valve. Hustedt's figure does not show these nor does he mention them in his brief description of the species.

This species has never been reported living, but only from fossil deposits in Siberia and Oregon. Hustedt's reference to "Kolumbia-Fluss" might appear to indicate a Recent occurrence, but Ehrenberg (1854, Explanation to Plate 33, group XII), stated that the material from which he named the species came from "Brackischer Tripel von Columbia-River, Oregon", hence a diatomite or diatomaceous sediment. Many localities along the Columbia River in Oregon and Washington contain diatomaceous sediments of late Miocene to early Pliocene age, and it is probably from one of these localities that Ehrenberg's material came. Among the Great Basin collections, T. clypeus has been found only in the Esmeralda formation.

Diameter of figured specimen (U.S.G.S. diatom catalog no. 2665-47): 30mu. From U.S.G.S. diatom locality 3394, Cedar Mountain section, Nye County, Nevada. Esmeralda formation, early Pliocene.

Found frequently in locality 3394, and rarely in 3403, Esmeralda formation.

Known geologic range: early Pliocene.

Tetracyclus constrictus (Hustedt)Lohman, n.comb.

Plate 11, figure 19.

Tetracyclus ellipticus var. constricta Hustedt, in Schmidt, Atlas der diatomaceenhunde, pl. 281, fig. 9, 1912.

Hustedt, Bremen Naturwiss. Ver. Abh., Band 23, p. 101, pl. 5, fig. 7, 1914.

In line with the policy stated in the discussion of the genus, Hustedt's variety is here raised to the rank of a species. His specimen came from "Columbia River, f.(ossil) S.(üsswasser)", and is probably from one of the many beds of diatomaceous sediments of late Miocene to early Pliocene age which crop out in the vicinity. It is a distinctive form, most nearly related to T. calceus n.sp. (see page 136 of this report).

Length of figured specimen: (U.S.G.S. diatom catalog no. 2673-38), 63mu. From U.S.G.S. diatom locality 3403, Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found rarely in locality 3534; frequently in 3537, Lower Virgin Valley beds. Frequently in localities 3394, 3397, 3403, 3405, and 3510, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Tetracyclus duplus Lohman, n.sp.

Plate 11, figure 14.

Valve flat, broad, with rounded spices and shallow, short constriction, giving the effect of two intersecting spheres. Transverse costae, parallel to slightly curved, $2\frac{1}{2}$ to 3 in 10mu. Transverse striae, finely punctate, 20 to 25 in 10mu. Pseudoraphe very narrow, terminating 3 to 5mu from apices. Length, 25 to 30mu; maximum width, 15 to 16mu; width at constriction, 12 to 13mu.

The ends of this species vary slightly in different specimens, some being more broadly rounded than the one chosen for the holotype, which illustrates the dominant shape.

Holotype: U.S.G.S. diatom catalog no. 2676-36, length, 26mu; maximum width, 15mu, width at constriction, 12mu. From U.S.G.S. diatom locality 3405, 284 feet stratigraphically above the base of the Cedar Mountain section, Nye County, Nevada. Esmeralda formation, early Pliocene.

Found frequently in localities 3534, and 3537, Lower Virgin Valley beds, and frequently in 3405, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Tetracyclus horus Lohman, n.sp.

Plate 11, figure 20

Valve hour-glass shaped, with bluntly pointed apices, and deep central constriction. Heavy transverse costae usually parallel, occasionally discontinuous, 3 in 10mu; transverse striae, 26 to 28 in 10mu. Pseudoraphe, faint, and very narrow. Length, 37 to 52mu; maximum width, 17 to 19mu; width at constriction, 6 to 9mu.

This striking species, named for its hour-glass shape, is a common form in the oldest strata studied for this report, and cannot easily be confused with any other. It also occurs commonly in the Trout Creek beds of late Miocene age, 25 miles north of Denio, Oregon (Lohman, MS).

Holotype: U.S.G.S. diatom catalog no. 2703-1, length, 45mu; maximum width, 19mu; width at constriction, 6mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found commonly in locality 3534, frequently in 3537, Lower Virgin Valley beds; frequently in 3540, Upper Virgin Valley beds; frequently in localities 3405 and 3410, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Tetracyclus irregularis Lohman, n.sp.

Plate 11, figures 11, 18

Valve flat, usually elongate, obviously misshapen, sometimes symmetrically about the short axis, but more often completely distorted in all respects. Heavy transverse costae usually nearly parallel, in spite of convolution of margin. Pseudoraphe faint to robust, usually straight, even when margins are bent. Finely punctate transverse striae usually normal to pseudoraphe. Length 35 to 60mu, width quite variable.

At first sight this aberrant species appeared to be a tautological form, such as is caused by highly alkaline waters. Its occurrence from frequently to abundantly in two collections from Lower Virgin Valley beds, frequently in the Upper Virgin Valley beds, and rarely in the Esmeralda formation, always in association with a large assemblage of other, undistorted species of the same and other genera, makes it appear that whatever caused the distorted appearance of all of the individuals of this species was unique with it. The short geologic range and the frequency of occurrence when found, makes this species valuable for stratigraphic correlations and it is therefore seriously proposed as a new species.

Holotype: U.S.G.S. diatom catalog no. 2703-118 (fig. 18), length, 37mu (symmetrically distorted). Paratype: U.S.G.S. diatom catalog no. 2703-103 (fig. 17): length, 43mu (asymmetrically distorted). Both from U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found abundantly in locality 3534, frequently in 3537, Lower Virgin Valley beds; frequently in 3540, Upper Virgin Valley beds; and rarely in 3397, Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Tetracyclus parallelus Lohman, n.sp.

Plate 11, figure 27

Valve flat, with parallel or very slightly constricted sides and rounded apices. Transverse costae, $2\frac{1}{2}$ to 3 in 10mu; finely punctate transverse striae, 24 to 26 in 10mu. Pseudoraphe very narrow. Length, 20 to 40mu; width, 11 to 20mu.

T. linearis (Ehrenberg) Grunow is much longer with very blunt ends, and is the only species with which this might be confused. Hustedt (1914, p. 190, pl. 5, fig. 14) has made *T. linearis* a variety of *T. ellipticus* and has given the best figure. Comparison between his excellent figure and *T. parallelus* immediately points up the differences between the two.

Holotype: U.S.G.S. diatom catalog no. 2703-98, length, 30mu; width, 13mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above the base of the Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found frequently in localities 3534, 3537, Lower Virgin Valley beds; 3540, Upper Virgin Valley beds; 3394, 3397, 3404, 3405, and 3410. Esmeralda formation.

Known geologic range: late middle Miocene to early Pliocene.

Tetracyclus quadrus Lohman, n.sp.

Plate 11, figure 15

Valve flat, nearly square, with slight constriction in middle. Apices roundly pointed, narrow, starting from opposite sides of the square. Heavy transverse costae, 3 to $3\frac{1}{2}$ in 10mu, sub-parallel. Finely punctate transverse striae, 24 to 26 in 10mu. Pseudoraphe narrow and faint, ending

3 to 5mu short of apices. Length, 25 to 30mu; width, 14 to 16mu.

Holotype: U.S.G.S. diatom catalog no. 2709-49, length, 28mu; width, 15mu. From U.S.G.S. diatom locality 3540, Upper Virgin Valley beds, Humboldt County, Nevada. Late Miocene.

Found rarely in locality 3537, Lower Virgin Valley beds and frequently in 3540, Upper Virgin Valley beds.

Known geologic range: late middle Miocene to late Miocene.

Tetracyclus radiatus Lohman, n.sp.

Plate 11, figure 21

Valve circular to slightly elliptical, with heavy radial costae 2 to 3 in 10mu, about every 2nd or 3rd of which reaches the center of the valve. Finely punctate radial striae between the costae. A central, elongate, hyaline space is not crossed by either costae or striae. Diameter, 25 to 42mu.

T. japonicus (Petit) Hustedt (in Schmidt, Atlas der diatomaceenkunde, pl. 282, fig. 1) although similar to this species in a number of respects, differs in having a serrate margin. The extremely short geologic range of this species makes it valuable for correlation.

Holotype: U.S.G.S. diatom catalog no. 2665-63, long axis, 41mu; short axis, 34mu. From U.S.G.S. diatom locality 3394, 15 feet above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality 3394, Esmeralda formation.

Known geologic range: early Pliocene.

Tetracyclus virginicus Lohman, n.sp.

Plate 11, figure 26

Valve flat, with inflated, nearly circular central portion and produced, rostrate apices, having parallel sides and bluntly rounded ends. Heavy transverse costae, parallel, 2½ to 3 in 10mu. Transverse striae faint, 25 to 28 in 10mu. Pseudoraphe very faint and narrow. Length, 30 to 35mu; width, 14 to 15mu.

The almost perfectly circular central portion and the produced, parallel sided rostrate ends clearly separate this species from _T. lacustris_ Ralfs. Smith (1856, p. 38, pl. 39, fig. 308) figured a form he ascribed to _T. lacustris_ which more nearly approaches the present form than do others. It has, however, much shorter, less produced apices, and a more inflated central portion. This species is confined to Miocene strata in the Great Basin, and is a useful stratigraphic marker.

Holotype: U.S.G.S. diatom catalog no. 2703-95, length, 35mu; width of rostrate apices, 7mu; maximum width of valve, 15mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Early middle Miocene.

Found frequently in locality 3534, Lower Virgin Valley beds and frequently in 3540, Upper Virgin Valley beds.

Known geologic range: late middle to late Miocene.

Suborder Raphidioidineae

Family Eunotiaceae

Genus EUNOTIA Ehrenberg 1837

Eunotia lineata Lohman, n.sp.

Plate 11, figure 16

Valve straight with nearly parallel sides; blung ends with prominent terminal nodule on ventral side. Transverse punctate striae, radial, varying from 12 in 10mu at one third length to 14 in 10mu in center, and at ends. Length, 35 to 55mu.

Very few specimens of this species were suitable for photography, and most were broken. Although reworking is at least suggested in such cases, the source from which they may have been reworked remains a mystery, as no pre-middle Miocene diatomaceous sediments are known from this region, or anywhere with which they might have been introduced into the watershed of the Lower Virgin Valley beds in late middle Miocene time.

Holotype: U.S.G.S. diatom catalog no. 2708-134, length of fragment, 47mu; from U.S.G.S. diatom locality 3537, 107 feet stratigraphically above the base of the Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found frequently in locality 3537, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Suborder Monoraphidineae

Family Achnanthaceae

Subfamily Achnanthoideae

Genus ACHNANTHES Bory 1822

Achnanthes basaltensis Lohman, n.sp.

Plate 11, figures 22, 23

Valve oval, length, 12 to 13mu; width, 7 to 8mu. Lower valve with straight raphe, narrow axial area; transverse striae curved, radiate, 16 to 17 in 10mu, continuous on one side, with slight central break caused by one or two shorter striae on other side. Upper valve with narrow axial area, widening at center with half stauros on one side; transverse striae, radiate, 15 to 16in 10mu.

Both the lower (figure 22) and upper (figure 23) valves are shown and they are the two valves of one complete frustule. This tiny species is one which can easily be lost in careless preparation.

Holotype: U.S.G.S. diatom catalog no. 2708-87, length, 12.3 mu; width, 7.7mu. From U.S.G.S. diatom locality 3540, Upper Virgin Valley beds, Humboldt County, Nevada, Late Miocene.

Found rarely in locality 3540, Upper Virgin Valley beds.

Known geologic range: late Miocene.

Achnanthes spicula Lohman, n.sp.

Plate 11, figures 25, 26

Valve lanceolate with pointed apices. Lower valve with lanceolate central space and straight simple raphe; radial transverse striae, 16 in 10mu, becoming parallel near ends and again radial at extreme ends. Upper valve with very narrow axial area, transverse striae parallel and normal to transapical axis, 13 in 10mu. Length 35 to 45mu.

Although this species occurred at only one locality, its distinctive character and short geologic range makes it valuable for stratigaphic correlations.

Holotype: U.S.G.S. diatom catalog no. 2950-93, length, 38mu. From U.S.G.S. diatom locality 4169, Hagerman formation, near Hagerman, Idaho.

Found rarely in locality 4169, Hagerman formation.

Known geologic range: early Pleistocene.

Suborder Biraphidineae

Family Naviculaceae

Subfamily Naviculoideae

Genus CALONEIS Cleve 1891

Caloneis rostrata Lohman, n.sp.

Plate 12, figure 1

Valve flat, linear-lanceolate, with rostrate apices. Axial area narrow near apices, widening to half the width of the valve at center. Central space slightly unsymmetrical with central nodules turning toward wider side. Transverse striae, 11 in 10mu, radiate to parallel at center, changing to convergent at apices; striae finely punctate. Raphe simple. Wide longitudinal band crossing all striae. Terminal nodules, open, with hooks turning in direction opposite to central nodules. Length, 60 to 70mu; width, 18 to 20mu.

Holotype: U.S.G.S. diatom catalog no. 2703-86, length, 67mu; width, 20mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found frequently in locality 3534, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Genus STAURONEIS Ehrenberg 1843

Stauroneis debilis Lohman, n.sp.

Plate 12, figure 2

Valve elongate-elliptical with narrow, produced, and capitate apices. Raphe straight, axial area narrow; finely punctate radiate transverse striae, 24 to 25 in 10mu. Stauros, narrow and very faint. Length, 45 to 50mu; width, 14 to 15mu.

Both the transverse striae and the stauros can only be seen with an oil immersion objective. In spite of this apparent difficulty, this species is a very easy one to spot tentatively under lower powers, as it appears to be completely structurless. Its short geologic range makes it very useful in stratigraphic correlation.

Holotype: U.S.G.S. Diatom catalog no. 2668-1, length, 48mu; width, 14mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality 3397, Esmeralda formation.

Known geologic range: early Pliocene.

Stauroneis irregularis Lohman, n.sp.

Plate 12, figure 4

Valve lanceolate with rostrate apices. Transverse striae 21 in 10mu, composed of rows of irregularly space puncta averaging 18 to 20 in 10mu, similar to the rows of puncta in Anomoeoneis. The irregularity extends to the margin of the valve. Stauros, straight, narrow. Axial area very narrow, Length, 30 to 40mu; width, 8 to 10mu.

This is one of the intermediate forms indicating a close relationship between Stauroneis and Anomoeoneis.

Holotype: U.S.G.S. diatom catalog no. 2694-103, length, 37mu; width, 9mu. From U.S.G.S. diatom locality 3523, 17½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found frequently in localities 3523, 3524; rarely in 3536, Lower Virgin Valley beds; rarely in locality 4169, Hagerman formation.

Known geologic range: Late middle Miocene to early Pliocene.

Stauroneis obesa Lohman, n.sp.

Plate 12, figure 3

Valve flat, broadly elliptical with subrostrate apices. Transverse striae, finely punctate, radial, 13 in 10mu. Raphe straight, axial area wide, up to 1/4 to 1/5 width of valve. Stauros wide, wedge-shaped. Length, 115 to 150mu; width, 32 to 38mu.

Holotype: U.S.G.S. diatom catalog no. 2695-20, length, 142mu; width, 37mu. From U.S.G.S. diatom locality 3523, 17½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found frequently in localities 3523, and 3524, Lower Virgin Valley beds.

Known geologic range: Late middle Miocene.

Genus ANOMOEONEIS Pfitzer 1871

Anomoeoneis cubita Lohman, n.sp.

Plate 12, figure 8

Valve rhomboidal in outline, with slightly concave sides and pointed apices. Axial area narrow, raphe straight. Transverse striae, parallel, 19 in 10mu. Longitudinal striae very irregular and discontinuous in central portion to form asymmetric areas on each side of central nodule. Length, 28 to 30mu; width, 14 to 15mu.

This species differs from F. rhomboides Hustedt (1942, p. 48, fig. 68) in being shorter, in having an axial area not dilated in the center, and in having the asymmetric hyaline areas on each side of the central nodule.

Holotype: U.S.G.S. diatom catalog no. 2668-24, length, 28mu; width, 15mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above the base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada, Early Pliocene.

Found frequently in locality 3397, Esmeralda formation.

Known geologic range: Early Pliocene.

Anomoeoneis lanceolata Lohman, n.sp.

Plate 12, figure 5.

Valve narrow, lanceolate, with subrostrate apices. Axial area very narrow. Central area broad, asymmetric, stauriform. Transverse striae, 21 in 10mu, with longitudinal rows irregular. Length, 60 to 75mu; width, 15 to 16mu.

This species differs from A. polygramma (Ehrenberg) Pfitzer, in being much more slender and in having much finer transverse striae.

Holotype: U.S.G.S. diatom catalog no. 2668-169, length, 73mu; width, 16mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality 3397, Esmeralda formation.

Known geologic range: early Pliocene.

Anomoeoneis nyensis Lohman, n.sp.

Plate 12, figure 6

Valve lanceolate with straight sides and pointed apices. Axial area very wide without the rows of puncta parallel to the raphe, which is common in many members of the genus. Raphe straight, simple. Irregularly punctate transverse striae, 14 in 10mu. Central area excentric, extending to margin on one side and only halfway to margin on the other side. Length, 150 to 200mu; width, 35 to 45mu.

This is one of the largest of the genus Anomoeoneis in the Great Basin collections, and is very easily spotted. Its common occurrence in the bed that contains it and its very short geologic range, make it a valuable guide fossil.

Holotype: U.S.G.S. diatom catalog no. 2668-95, length, 192mu; width, 45mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found commonly in locality 3397, and rarely in 3404, Esmeralda formation.

Known geologic range: early Pliocene.

Anomoeoneis turgida Lohman, n.sp.

Plate 12, figure 7

Valve elliptic-lanceolate with pointed apices and expanded center. Axial area 3 to 3½mu wide. Transverse, irregularly punctate striae, 13 to 14 in 10mu. Striae fairly uniformly fill valve area except for axial area and dumb-bell shaped central area. Length, 62 to 70mu; width, 26 to 28mu.

A broad, massive form with markings that are heavy for the genus, and with a short geologic range.

Holotype: U.S.G.S. diatom catalog no. 2668-148, length, 68mu; width, 28mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality 3397, Esmeralda formation.

Known geologic range: Early Pliocene.

Genus NAVICULA Bory 1824

Navicula amphibola var. capitata Lohman, n.var.

Plate 12, figure 11

Valve elliptical with small, capitate apices. Raphe slightly curved, axial area averaging 2mu wide. Central area broadly cruciform. Punctate transverse striae, radiate throughout, 7 to 8 in 10mu. Length, 45 to 55mu; width, 16 to 18mu.

Elmore (1921, pl. 9, figs. 353-354) has figured a form closely resembling this variety, calling it *N. amphibola*. Hanna (1932, pl. 33, fig. 6) has figured a form identical with this variety from the Pliocene Ogallala formation of Kansas, calling it *Navicula tuscula* Ehrenberg, from which it differs in many respects. In the Great Basin collections the variety was much more restricted geologically than *N. amphibola*, being confined to the late Middle Miocene rocks.

Holotype: U.S.G.S. diatom catalog no. 2695-3, length, 52mu; width, 18mu. From U.S.G.S. diatom locality 3523, 17½ feet stratigraphically above the base of the Opal Creek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found commonly in locality 3524, and frequently in localities 3523.

3525, 3527, 3534, and 3537, Lower Virgin Valley beds.

Known geologic range: late middle Miocene to Pliocene (Ogallala).

Navicula bulloides Lohman, n.sp.

Plate 12, figure 13

Valve broadly lanceolate with rostrate apices. Finely punctate transverse striae, 8 in 10mu, gently radiate throughout, with scattered shorter striae in central position. Axial area 1/5 the width of the valve, with transversely oval central area. Length, 75 to 85mu; width, 30 to 35mu.

A considerable search failed to yield more than a few specimens of this species, and the one used for the holotype is the best of these.

Holotype: U.S.G.S. diatom catalog no. 2675-7, length, 84mu; width, 35mu. From U.S.G.S. diatom locality 3523, 17½ feet stratigraphically above the base of the Opal Creek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found rarely in locality 3523, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Navicula citroides Lohman, n.sp.

Plate 12, figure 9

Valve lemon-shaped, with incipient rostrate apices. Finely punctate transverse striae, 11 to 12 in 10mu, radiate throughout. Axial space very narrow, widening suddenly to a small elliptical central space. Occasionally a single isolated punctum on one side of central area. Length 21 to 32mu; width, 14 to 16mu.

This small species was found in a number of localities in the Great Basin, and remained remarkably constant in all characteristics except the single isolated punctum in the central area, which was present or absent in otherwise identical specimens. The only species with which *N. citroides* could be easily confused is *N. lacustris* Gregory, from which it differs in being much smaller, and having coarser transverse striae.

Holotype: U.S.G.S. diatom locality 3410, 325 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality 3537, Lower Virgin Valley beds; 3540, Upper Virgin Valley beds. Frequently in 3403 and 3410; rarely in 3397, 3405, Esmeralda formation; and rarely in 4169, Hagerman formation.

Known geologic range: late middle Miocene to early Pleistocene.

Navicula isolata Lohman, n.sp.

Plate 12, figure 17

Valve elliptic-lanceolate with blunt, subrostrate apices. Transverse striae, 9 in 10mu, strongly radiate throughout, and finely punctate, 19 in 10mu. Axial, space very narrow, central space small, elliptical, with 3 to 5 isolated puncta forming a row on each side of the central nodule. Length, 40 to 50mu; width, 20 to 22mu.

The number of isolated puncta vary from 3 to 5 on each side, but all of the other characteristics of this species are remarkably constant. It occurs fairly well distributed through the Esmeralda formation, and has been found nowhere else, making it a good marker species for the early Pliocene.

Holotype: U.S.G.S. diatom catalog no. 2673-42, length, 50mu; width, 22mu. From U.S.G.S. diatom locality 3403, 276 feet stratigraphically above the base of the Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found rarely in locality 3397, frequently in 3403 and 3410, Esmeralda formation.

Known geologic range: early Pliocene.

Navicula opalensis Lohman, n.sp.

Plate 12, figure 10

Valve flat, elliptic-lanceolate, with rounded apices. Transverse, coarsely punctate striae, 11 in 10mu, radiate throughout. Axial area narrow with only very slight widening at center. Raphe straight. Length, 20mu; width, 6mu.

This species is probably related to N. mutica, from which it differs by having much coarser transverse striae and in not having the punctum on one side of the central area.

Holotype: U.S.G.S. diatom catalog no. 2703-187, length, 20mu; width, 6mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found rarely in locality 3534, Lower Virgin Valley beds.

Known geologic range: Late middle Miocene.

Navicula umbilica Lohman, n.sp.

Plate 12, figure 12

Valve elliptic with short rostrate apices. Very finely punctate transverse striae, 13 in 10mu, radial throughout and curved. Axial area narrow, widening to form small, nearly circular central area with a single isolated punctum on one side. Raphe complex. Terminal nodules very small. Length, 46mu; width, 14mu.

No complete specimen of this form could be found, but it is very easy to identify it from a portion of a valve as large as the one figured.

Holotype: U.S.G.S. diatom catalog no. 2950-100, length, 46mu; width, 14mu. From U.S.G.S. diatom locality 4169, Hagerman formation, near Hagerman, Idaho. Early Pleistocene.

Found rarely in locality 4169, Hagerman formation.

Known geologic range: early Pleistocene.

Navicula utahensis Lohman, n.sp.

Plate 12, figure 14

Valve elongate-elliptical with short rostrate apices. Radiate, coarsely punctate transverse striae, 15 in 10mu. Puncta nearest raphe are heavier than the others, outlining the very narrow axial area by two rows of heavier puncta. Raphe straight. Length, 42 to 45mu; width, 12 to 15mu.

Navicula tuscula, the only diatom with which this species might be confused, has coarser, elongated puncta and does not have the rows of heavy puncta on each side of the raphe.

Holotype: U.S.G.S. diatom catalog no. 2601-21, length, 44mu; width, 14mu. From U.S.G.S. diatom locality 3304, Provo formation, Goshen Valley, Utah County, Utah. Late Pleistocene.

Found rarely in locality 3304, Provo formation.

Known geologic range: late Pleistocene.

Genus PINNULARIA Ehrenberg 1840

Pinnularia angulo-costata Lohman, n.sp.

Plate 12, figure 15

Valve with nearly parallel sides, narrowing at apices. Raphe curved, oblique in part; terminal fissures comma-shaped. Axial area variable, zero at apices and 1/3 width of valve at center. Costae, 6 to 7 in 10mu, robust, clearly separated, crossed by narrow, longitudinal band. Costae, particularly those in central third of valve bend abruptly toward central nodule at inner margin of narrow band, and at angles up to 21°. Length, 130 to 160mu; width, 23-27mu.

Although clearly related to *P.major*, the sharply angular costae separate the two.

Holotype: U.S.G.S. diatom catalog no. 2601-115, length, 133mu; width, 23mu. From U.S.G.S. diatom locality 3304, Provo formation, Goshen Valley, Utah County, Utah. Late Pleistocene.

Found frequently in locality 3304, Provo formation.

Known geologic range: late Pleistocene.

P~~e~~innularia angusta Lohman, n.sp.

Plate 12, figure 16

Valve elongate, narrow, with parallel sides and rounded apices. Transverse costae, short, 7 to 8 in 10mu, radiate in central portion, parallel in median portion and divergent at apices. Raphe complex; axial area very narrow at extreme apices, but suddenly widening to over 1/3 width of valve in central portion. Length, 100 to 175mu; width, 14 to 22mu.

This narrow and elongate species occasionally has costae as fine as 9 in 10mu, although the majority of many that were measured centered around 7 in 10mu. Its frequent to common occurrence in nearly every bed sampled in the Lower Virgin Valley beds, plus its distinctive appearance, make this an excellent guide fossil for the late middle Miocene.

Holotype: U.S.G.S. diatom catalog no. 2698-28, length, 145mu; width, 20mu. From U.S.G.S. diatom locality 3524, 19½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found commonly in locality 3530, frequently in 3523, 3524, 3525, 3534, and 3536, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Pinnularia curvata Lohman, n.sp.

Plate 12, figure 21.

Valve curved with rounded to slightly pointed apices; transverse costae, 7 to 8 in 10mu, convergent in central portion, divergent at apices, with broad defined longitudinal bands. Raphe not complex; axial area 1/4 to 1/3 the width of the valve, unilaterally widened at center. Length, 100 to 160mu; width, 20 to 25mu.

The most consistent and distinguishing feature of this species is the gentle curvature of the valve. Although many individuals of this species were found, none was completely whole; the one selected for the illustration, fortunately contains all of the diagnostic features.

Holotype: U.S.G.S. diatom catalog no. 2696-39, length, 114mu; width, 20mu. From U.S.G.S. diatom locality 3524, 19½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Early middle Miocene.

Found rarely in localities 3523, 3525, and frequently in 3524, Lower Virgin Valley beds.

Known geologic range: early middle Miocene.

Pinnularia denticulata Lohman, n.sp.

Plate 12, figure 19

Valve lanceolate, gibbous in center, with tapering apices. Transverse costae, 8 in 10mu, very short except at apices. Axial area about half the width of the valve except near apices, where it becomes very narrow. Costae slightly convergent in central portion, becoming parallel to slightly divergent at apices, broken at one side in the center. Raphe simple, but sinuous. Length, 65 to 70mu; width, 10mu.

Other species of Pinnularia having short costae, such as P. braunii, P. polyonca, P. borealis var. brebicostata, P. gibba var. parva, have significant differences which distinguish them from P. denticulata.

Holotype: U.S.G.S. diatom catalog no. 2696-80, length, 67mu; width, 11mu. From U.S.G.S. diatom locality 3524, 19½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada, Late middle Miocene.

Found rarely in locality 3524, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Pinnularia esmeraldensis Lohman, n.sp.

Plate 13, figure 3

Valve broad, with parallel sides and tapering, cuneate apices. Transverse costae very short, 7 in 10mu, radial in central 3/4 of valve, and sharply divergent at apices. Axial space, very broad, over half the width of the valve, and tapering toward the apices. Raphe simple, nearly straight, with central nodules turning to one side. Axial area covered with scattered, pale, illusive punctat. Length, 110 to 170mu; width, 32 to 38mu.

This distinctive species can hardly be confused with any other, and is an excellent guide fossil for the Esmeralda formation.

Holotype: U.S.G.S. diatom catalog no. 2668-165, length, 114mu; width, 32mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality 3397, Esmeralda formation.

Known geologic range: early Pliocene.

Pinnularia esmeraldensis var. constricta Lohman, n.var.

Plate 13, figure 2

Valve similar to the type, but with a sweeping central constriction, and more sharply pointed apices. Length, 150 to 174mu; width, 38 to 40mu.

This variety occurs with the type in about the same relative abundance.

Holotype: U.S.G.S. diatom catalog no. 2668-140, length, 168mu; width, 39mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found frequently in locality 3397, Esmeralda formation.

Known geologic range: early Pliocene.

Pinnularia nebulosa Lohman, n.sp.

Plate 12, figures 18, 20

Valve linear with slightly gibbous central portion, and rounded apices. Transverse costae, 7 in 10mu, radial in center, convergent at ends. Axial area over 1/3 width of valve, widening to 1/2 at center. Costae interrupted at center forming a narrow stauros. Faint, nebuluous, coarsely punctate, extensions of costae continue into hyaline axial area. Raphe straight with slight curve in center. Length, 120 to 160mu; width, 23 to 25mu.

The nebuluous, punctate extensions of the costae, after which this species is named, are its most distinguishing features, and immediately separate it from all others. The punctate nature of these extensions indicates the close relationship between the genera Pinnularia and Navicula, and suggests that this may represent one of the transitional forms.

Holotype: U.S.G.S. diatom catalog no. 2703-87, length, 155mu; width, 25mu. From U.S.G.S. diatom locality 3534, 84 feet stratigraphically above the base of the Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found frequently in localities 3523, 3524, 3534, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Pinnularia pseudopunctata Lohman, n.sp.

Plate 12, figure 22

Valve linear-elliptical with subcuneate apices. Transverse costae, 7 to 8 in 10mu, radial in central portion, parallel in median portion, and convergent at apices; sometimes interrupted on one or both sides to form semistauros or stauros; axial area about 1/3 width of valve. Costae, under high magnification, show incipient coarse puncta. Length, 50 to 80mu; width, 12 to 15mu.

The incipient puncta on the costae are the distinguishing feature of this species, and immediately separates it from P. brevicostata var. leptostauron Cleve, which it otherwise resembles. The interruption in the costae to form a stauros or semistauros is variable in individuals otherwise identical. This species is common in the Lower Virgin Valley beds, and appears to be related to P. nebulosa n.sp., as one of the early types that may have evolved from the genus Navicula.

Holotype: U.S.G.S. diatom catalog no. 2696-85, length, 54mu; width, 12mu. From U.S.G.S. diatom locality 3524, 19½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt County, Nevada. Late middle Miocene.

Found commonly in localities 3523, 3525, and frequently in 3524, Lower Virgin Valley beds.

Known geologic range: late middle Miocene.

Pinnularia virginica Lohman, n.sp.

Plate 13, figure 1

Valve narrow, gently triundulate, with rostrate or capitate apices. Axial area broad, averaging 1/3 width of valve, and widening into a broad stauros in the central part. Transverse costae, short, 10 to 11 in 10mu, radial in center, parallel in median portion and strongly convergent at apices. Raphe sinuous. Length, 30 to 50mu; width, 7 to 8mu.

Two species which are very close to P. virginica are P. mesolepta

(Ehrenberg) Wm. Smith and P. nodosa Ehrenberg. The following comparison of the three indicates the divergence:

	P. virginica	P. nodosa	P. mesolepta
Apices	Rostrate to capitate	Always capitate	Always capitate
Transverse costae	10-11/10mu	8-11/10mu	10-14/10mu
Center	Radial	Parallel	Radial
Median portion	Parallel	Parallel	Radial
Apical portion	Convergent	Convergent	Convergent
Axial area	Broad	Very broad	Very narrow
Stauros	Large, rhomboidal	Very narrow	Large
Length	30-50mu	35-80mu	30-65mu
Width	7-8mu	9-12mu	9-11mu

Both P. nodosa and P. mesolepta vary in the spacing of the costae, in overall dimensions through fairly wide limits, but always have strongly capitate apices. P. virginica is remarkably constant in the spacing of the costae; both the length and width vary through narrow limits, and the apices vary slightly from rostrate to barely capitate. Hundreds of specimens of P. virginica were examined and all fell within the extremes given.

Holotype: U.S.G.S. diatom catalog no. 2967-61, length, 50mu; width, 8mu. From U.S.G.S. diatom locality 3525, 22½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found commonly in localities 3523 and 3525; frequently in 3524, 3527, 3530, 3534, and 3536, Lower Virgin Valley beds. Frequently in locality 3540, Upper Virgin Valley beds. Rarely in locality 3397, Esmeralda formation, and frequently 3545, Thousand Creek beds.

Known geologic range: late middle Miocene to middle Pliocene.

Family Gomphonemaceae

Subfamily Gomphonemoideae

Genus GOMPHONEMA Agardh 1824

Gomphonema duostriatum Lohman, n.sp.

Plate 13, figures 5, 6

Valve narrowly lanceolate, nearly symmetrical. Axial area narrow, raphe sinuous. Transverse striae, finely punctate, radial to nearly parallel, 10 in 10mu, interrupted on one side opposite central nodule on one valve; 5½ in 10mu on other valve, with no interruption, but radial throughout. Length, 25 to 40mu; width, 7 to 8mu.

Many whole frustules with both valves still attached were found, which is fortunate, as a single valve of the more finely marked (striae 10 in 10mu) type could easily be mistaken for G. intricatum Kützing. The photomicrographs used to illustrate this species were made from the two valves of the same frustule by optical section.

Holotype: U.S.G.S. diatom catalog no. 2696-75, length, 40mu; width, 8mu. From U.S.G.S. diatom locality 3524, 19½ feet stratigraphically above base of Opal Creek section, Lower Virgin Valley beds, Humboldt Co., Nevada. Late middle Miocene.

Found frequently in localities 3524, 3534, and 3526, Lower Virgin Valley beds. Rarely in 3405, Esmeralda formation, and frequently in 3545, Thousand Creek beds.

Known geologic range: late middle Miocene to middle Pliocene.

Gomphonema excentricum Lohman, n.sp.

Plate 13, figure 4

Valve lanceolate with tumid center and rounded apices. Axial area narrow, abruptly widening to rectangular central space offset along length of valve from center and point of maximum width. Transverse, finely punctate striae, 11 to 12 in 10mu, radial throughout. Length, 48 to 50mu; width, 8 to 9mu.

The eccentricity of the central area is the distinguishing characteristic of this species and differentiates it from all others.

Holotype: U.S.G.S. diatom catalog no. 2602-107, length, 48mu; width, 8.6mu. From U.S.G.S. diatom locality 3305, Provo formation, Goshen Valley, Utah County, Utah. Late Pleistocene.

Found rarely in locality 3305, Provo formation.

Known geologic range: late Pleistocene.

Gomphonema quadratum Lohman, n.sp.

Plate 13, figure 7

Valve spathulate with rounded ends; axial area narrow, central space stauroneiform, with 4 isolated puncta, two on each side of the central nodules. Transverse striae, radial, 9 to 10 in 10mu. Length, 38 to 55mu; width, 7 to 8mu.

The four isolated puncta, forming a square in the central space, serve to separate this species from all others. The frequent occurrence in four collections from the Esmeralda formation make it a good guide fossil for the early Pliocene.

Holotype: U.S.G.S. diatom catalog no. 2676-78, length, 43mu; width, 8mu. From U.S.G.S. diatom locality 3405, 284 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye

County, Nevada. Early Pliocene.

Found frequently in localities 3403, 3405, and 3410, and rarely in 3397, Esmeralda formation.

Known geologic range: early Pliocene

Family Cymbellaceae

Subfamily Cymbelloideae

Genus CYMBELLA Agardh 1830

Cymbella angularis Lohman, n.sp.

Plate 13, figure 8

Valve flat, ventral margin nearly straight, occasionally with straight to tumid bulge at center; dorsal margin tumid, with two virtually straight portions making an included angle of 125° to 137°. Finely punctate transverse striae, 8 to 9 in 10mu on ventral side, radial in center 2/3 of valve and parallel to slightly convergent at apices; dorsal side, radial throughout, 10 to 11 in 10mu. Axial area fairly narrow, raphe slightly curved. Length, 30 to 50mu; width, 12 to 14mu.

C. ventricosa Kützing, which this species superficially resembles, is generally smaller, does not have the angular dorsal margin, and has much finer transverse striae.

Holotype: U.S.G.S. diatom catalog no. 2601-75, length, 45mu; width, 14mu, included angle on dorsal side, 137°. From U.S.G.S. diatom locality 3304, Provo formation, Goshen Valley, Utah County, Utah. Late Pleistocene.

Found frequently in localities 3544, Thousand Creek beds, 4169, Hagerman formation, and 3304, Provo formation.

Known geologic range: middle Pliocene to late Pleistocene

Cymbella hagermanensis Lohman, n.sp.

Plate 13, figure 14

Valve slightly undulating to straight on ventral side; deeply convex on dorsal side. Transverse striae on ventral side, finely punctate, radiate in center, 8 in 10mu, and convergent, 11 to 12 in 10mu at ends; on dorsal side radiate throughout, 12 in 10mu, finely punctate. Length, 30 to 35mu; width, 11 to 13mu.

The most distinguishing characteristic of this species is the marked difference in striation on the dorsal and ventral sides. C. ventricosum, which it resembles superficially, has much finer transverse striae on both sides.

Holotype: U.S.G.S. diatom catalog no. 2950-5, length, 32mu; width, 13mu. From U.S.G.S. diatom locality 4169, Hagerman formation, near Hagerman Idaho. Early Pleistocene.

Found frequently in locality 4169, Hagerman formation.

Known geologic range: early Pleistocene.

Cymbella mexicana var. gracilis Lohman, n.var.

Plate 13, figure 9

Valve similar to type except much narrower and longer. Transverse striae, 7 in 10mu on ventral side and 6 in 10mu on dorsal side. Puncta in Transverse striae, 8 in 10mu on ventral side, and 7.5/10mu on dorsal side. Puncta usually round, except for a few rows on ventral side of central nodule. Transverse striae radial in central portion, becoming parallel between median portion and apices. Axial area narrow throughout most of valve, widening to an elongate ellipse in central portion. One isolated punctum on ventral side opposite central nodule. Length, 190 to 200mu, width, 34 to 35mu.

This graceful variety, one of the largest in the Great Basin, occurred frequently in both collections from the Provo formation and was found nowhere else.

Holotype: U.S.G.S. diatom catalog no. 2601-79, length, 190mu; width, 34mu. From U.S.G.S. diatom locality 3305, Provo formation, Goshen Valley, Utah County, Utah. Late Pleistocene.

Found frequently in localities 3304 and 3305. Provo formation.

Known geologic range: late Pleistocene.

Cymbella prisca Lohman, n.sp.

Plate 13, figure 10

Valve arcuate on dorsal side, straight on ventral side, with subrostrate apices. Axial area very narrow, scarcely widened in central portion. Finely punctate coarse transverse striae, 7 to 8 in 10mu on dorsal side, 8 in 10mu on ventral side, becoming somewhat closer toward the apices; nearly parallel in central two-thirds of valve and radial at apices, particularly on dorsal side. Raphe excentric toward ventral side at center and near apices, excentric toward dorsal side in median portion. Length, 60 to 70mu; width, 13 to 14mu.

This species differs from C. cymbiformis (Agardh) Kützing by having coarser striation and in the absence of the isolated central punctum.

Holotype: U.S.G.S. diatom catalog no. 2950-131, length, 65mu. From U.S.G.S. diatom locality 4169, Hagerman formation, near Hagerman, Idaho. Early Pleistocene.

Found frequently in locality 4169, Hagerman formation.

Known geologic range: early Pleistocene.

Cymbella provoensis Lohman, n.sp.

Plate 13, figure 12

Valve flat, with narrow apices and straight axial area, scarcely widened in the center. Ventral side with sudden, rounded tumescence in central portion; dorsal side, steeply and smoothly curved, forming a rounded bulge. Raphe nearly straight, slightly curved toward dorsal side in center. Coarsely punctate radial transverse striae, 7 to 8 in 10mu on both dorsal and ventral sides. Length, 45 to 75mu; width, 22 to 30mu.

Cymbella malayensis forma rostrata Hustedt (Hustedt, 1912, p. 102, fig. 221), with which this species might be confused, has an arcuate central space, is larger, and has a less tumid ventral margin.

Holotype: U.S.G.S. diatom catalog no. 2601-62, length, 46mu; width, 22mu. From U.S.G.S. diatom locality 3304, Provo formation, Goshen Valley, Utah Co., Utah. Late Pleistocene.

Found commonly in locality 3304 and frequently in 3405. Provo formation.

Known geologic range: Late Pleistocene.

Genus AMPHORA Ehrenberg 1840

Amphora sparsa Lohman, n.sp.

Plate 13, figure 11

Valve smoothly concave on ventral side, highly arched on dorsal wide, with produced capitate apices. Raphe straight in each half, making an angle of 150 to 155° in center. Axial area fairly broad. Radial, irregularly punctate transverse striae, 12 to 13 in 10mu, giving speckled appearance. Length, 80 to 90mu; width, 15 to 18mu.

Holotype: U.S.G.S. diatom catalog no. 2668-180, length, 89mu;

width, 17mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found rarely in locality 3397, Esmeralda formation.

Known geologic range: early Pliocene.

Family Epithemiaceae

Subfamily Epithemioidea

Genus EPITHEMIA Brebisson 1838

Epithemia galera Lohman, n.sp.

Plate 13, figure 13

Valve flat with strongly concave ventral margin and very strongly concave dorsal margin. Produced, curved, capitate apices giving shape of a hat. Radial costae, 4 to 5 in 10mu, separated by 2 to 4 rows of coarse puncta. Raphe close to ventral margin in apical and median portions, suddenly arching to nearly meet dorsal side in center. Length, 35 to 45mu; width, 10 to 12mu.

One of the most distinctive and characteristic species in the Hagerman formation and found nowhere else.

Holotype: U.S.G.S. diatom catalog no. 2950-29, length 39mu; width, 11mu. From U.S.G.S. diatom locality 4169. Hagerman formation, near Hagerman, Idaho. Early Pleistocene.

Found frequently in locality 4169, Hagerman formation.

Known geologic range: early Pliestocene.

Suborder Surirellineae

Family Surirellaceae

Subfamily Surirelloideae

Genus SURIRELLA Turpin 1828

Surirella bifurcata Lohman, n.sp.

Plate 13, figure 17

Valve ovoid with sharp peak. Marginal costae 3 to 5 in 10mu, extending inward for 3 to 4mu, where they bifurcate into double costae which are much tinner and form an oval moat in the interior of the valve, with the hyaline center, 10 to 12mu wide and 12 to 14mu long forming an island. Extreme margin finely striated. Length, 35 to 38mu; width, 27 to 30mu.

Holotype: U.S.G.S. diatom catalog no. 2601-51, length, 36mu; width, 28mu. From U.S.G.S. diatom locality 3304, Provo formation, Goshen Valley, Utah Co., Utah. Late Pleistocene.

Found frequently in locality 3304, Provo Formation.

Known geologic range: late Pleistocene.

Surirella pallida Lohman, n.sp.

Plate 13, figure 16

Valve broadly oval to nearly circular, one end with a slight apex. Short, heavy radial costae extending 6 to 8mu in from margin and averaging $2\frac{1}{2}$ to 3 in 10mu. Margin crenulated and indented for each of the costae. Fine striae reaching to center of valve, 18 to 21 in 10mu, radial from the four quadrants and terminating abruptly against both major and minor axes. Major axis, 75 to 85mu; minor axis, 60 to 70mu.

Although one of the most abundant species in one collection from the Esmeralda formation, not one could be found free of adhering débris, mostly small diatoms and fragments. Under low and medium magnifications the valve surface appears pallid and structurless except for the heavy marginal costae. Its abundance in one collection in the section and its complete absence from those above and below it in the same section, suggests that this species began, went through its heyday and became extinct during the time represented by the deposition of 127 feet of sediments dominantly composed of coarse pumiceous tuff. The time interval represented by this cannot have been long, geologically speaking.

Holotype: U.S.G.S. diatom catalog no. 2668-56, major axis 80mu; minor axis 78mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye Co., Nevada. Early Pliocene.

Found abundantly in locality 3397, Esmeralda formation.

Known geologic range: Early Pliocene.

Surirella spicula Lohman, n.sp.

Plate 13, figure 15

Valve broadly egg-shaped, with short marginal costae, 2 to 3 in 10mu, which immediately merge into body of valve. Elliptical-lanceolate central space, 12 to 14mu wide and 30 to 34mu long. Fine radial and anastomosing striae, 19 in 10mu over surface of valve, frequently also covering the central space. Numerous puncta in completely random arrangement scattered over most of the valve surface, abruptly becoming absent or very scarce in elliptic-lanceolate central space. Major axis, 75 to 85mu; minor axis, 60 to 70mu.

This species, although distinctly different than S. pallida, apparently has had a similar history. It was also impossible to find a completely clean specimen.

Holotype: U.S.G.S. diatom catalog no. 2668-71, major axis, 80mu; minor axis, 63mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye Co., Nevada. Early Pliocene.

Found abundantly in locality 3397, Esmeralda formation.

Known geologic range: early Pliocene.

Surirella spicula var. lineata Lohman, n.var.

Plate 13, figure 18

Identical with the type except that the elliptical-lanceolate central space is closed to form a wavy line. Major axis, 70 to 80mu; minor axis, 50 to 60mu.

This variety, which occurred in the same collection as the type, although less abundantly, represents the end point in a group which varied in no other essential particular except the shape of the central area.

Holotype: U.S.G.S. diatom catalog no. 2668-86, major axis, 72mu; minor axis, 50mu. From U.S.G.S. diatom locality 3397, 137 feet stratigraphically above base of Cedar Mountain section, Esmeralda formation, Nye County, Nevada. Early Pliocene.

Found abundantly in locality 3397. Esmeralda formation.

Known geologic range: early Pliocene.

Subfamily Campylodiscoideae

Genus CAMPYLODISCUS Ehrenberg 1840

Campylodiscus anastomosus Lohman, n.sp.

Plate 13, figure 19

Valve broadly oval, saddle shaped. Marginal costae 5 in 10mu, which immediately run into fine, punctate anastomosing striae following no regular pattern. No central area and no heavy costae except on extreme edge. Length, 75 to 90mu, width, 60 to 70mu.

This species was common in one of the Thousand Creek collections and found nowhere else. Its saddle shape, fairly large size, and unusual fragility makes it difficult to find good specimens, but it can be readily identified from a large fragment.

Holotype: U.S.G.S. diatom catalog no. 2711-1, length, 78mu; width, 64mu. From U.S.G.S. diatom locality 3544, Thousand Creek beds, Humboldt County, Nevada. Middle Pliocene.

Found commonly in locality 3544, Thousand Creek beds.

Known geologic range: middle Pliocene.

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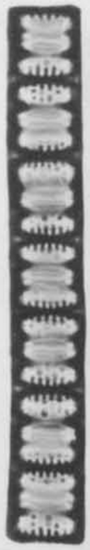
PLATE 9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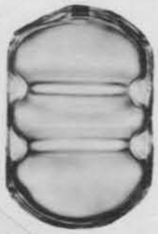
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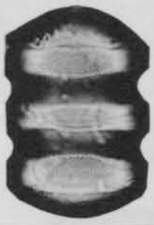
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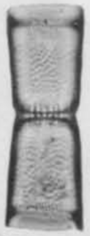
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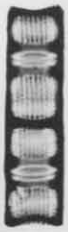
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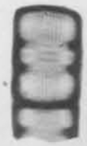
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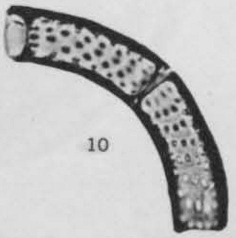
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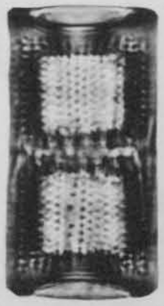
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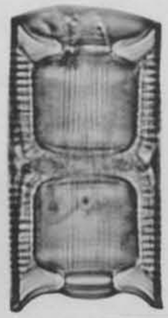
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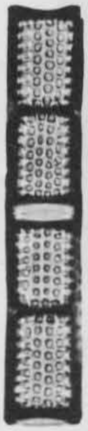
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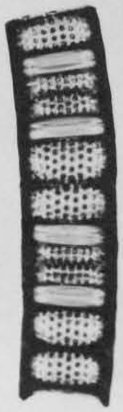
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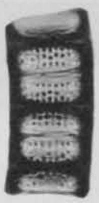
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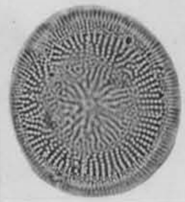
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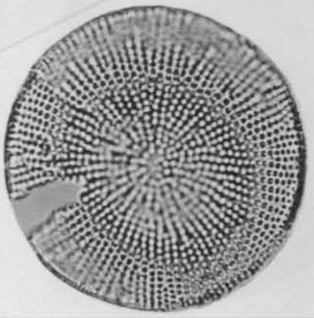
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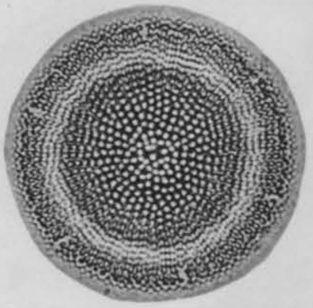
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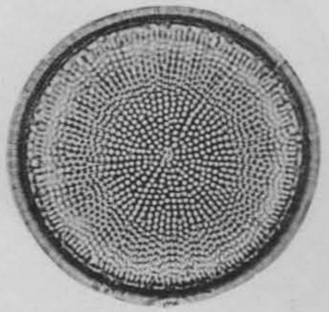
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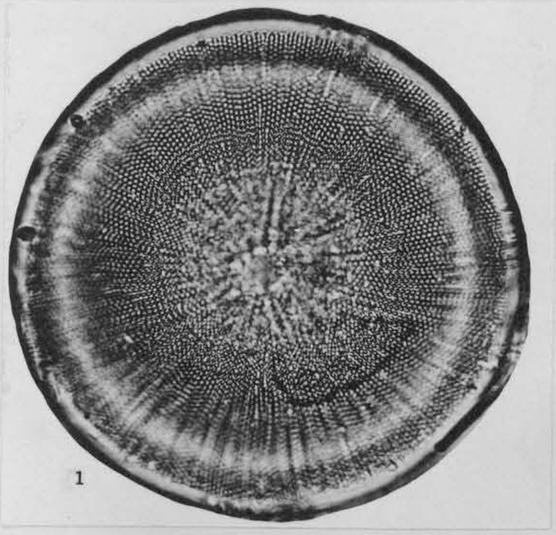
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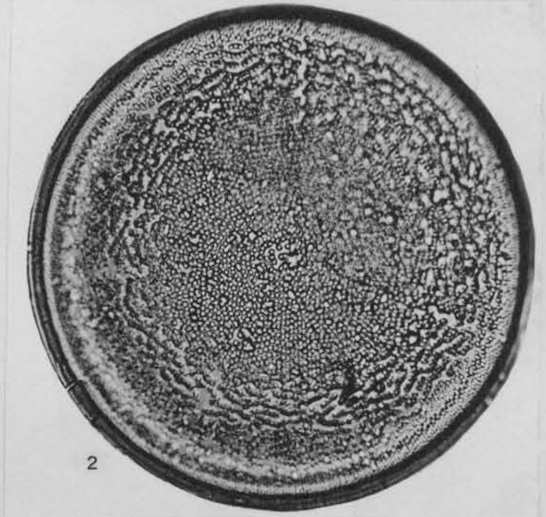
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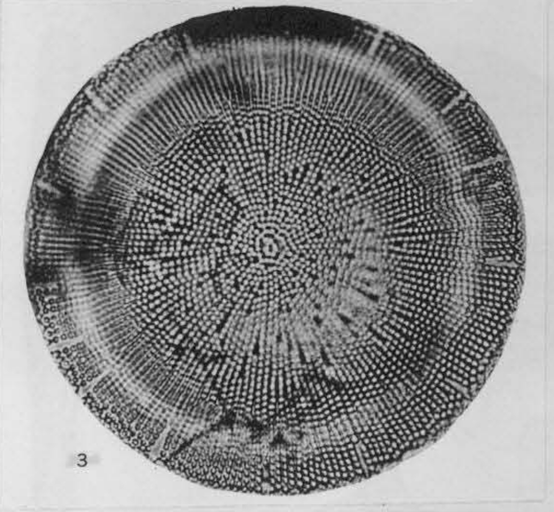
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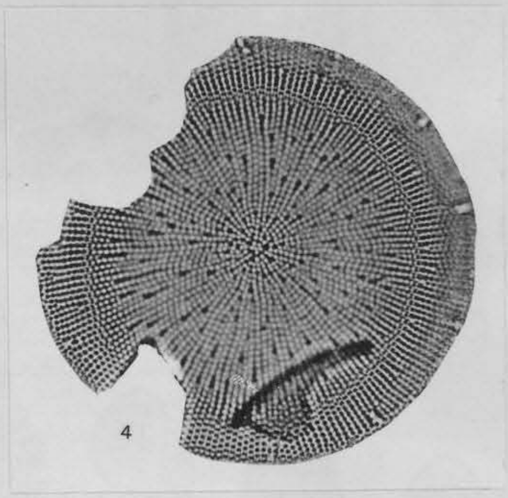
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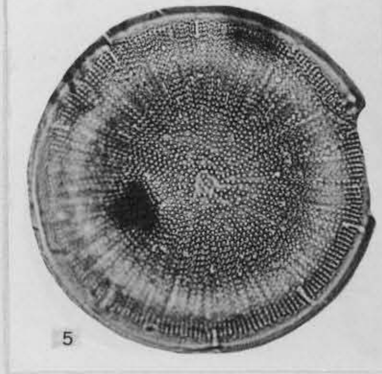
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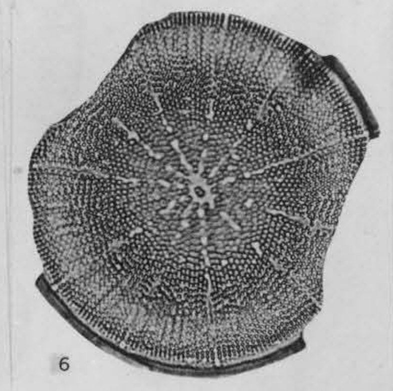
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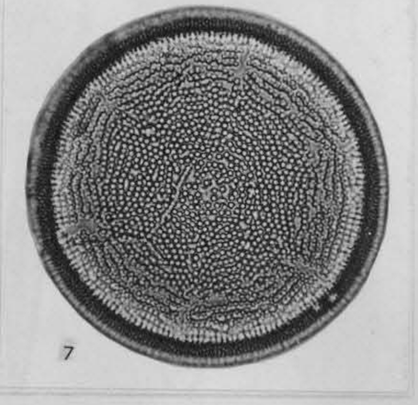
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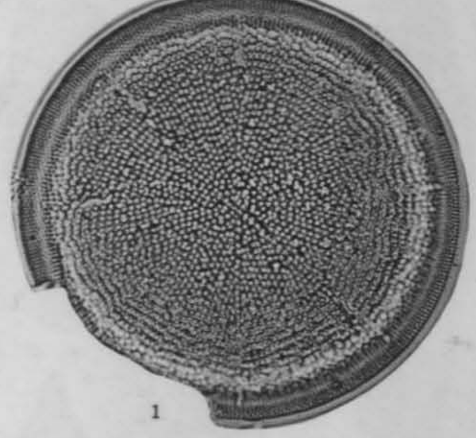
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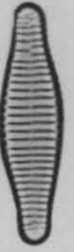
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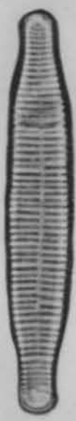
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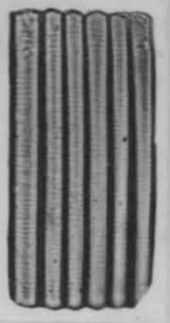
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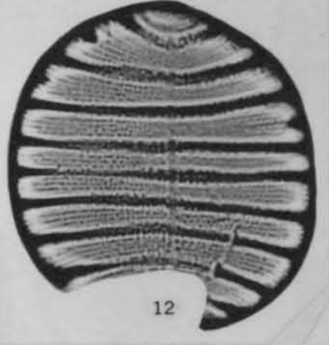
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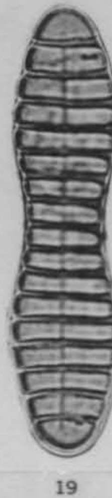
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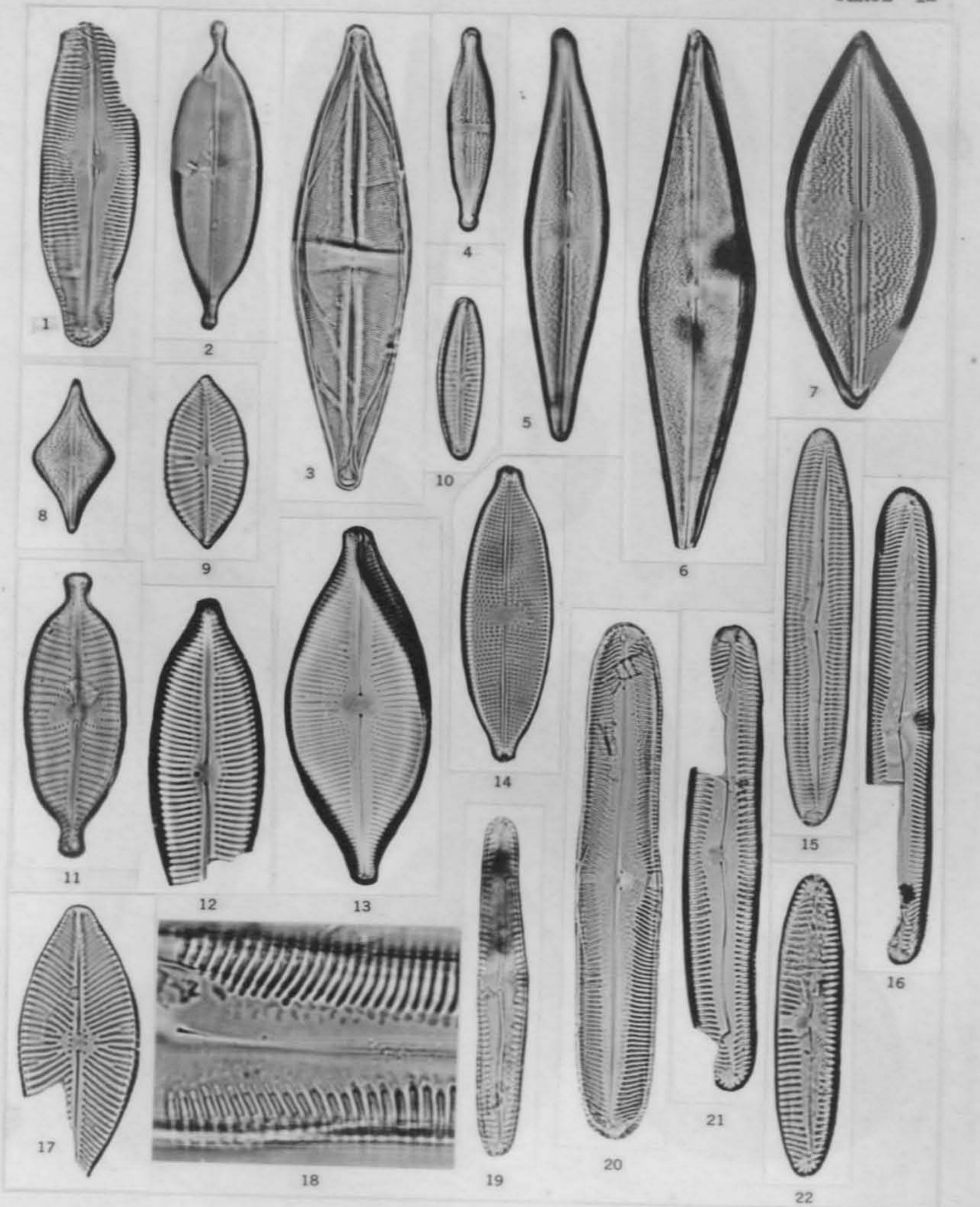

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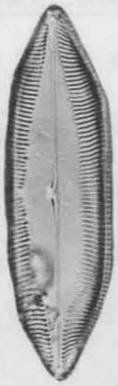
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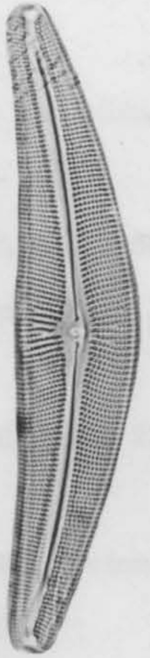
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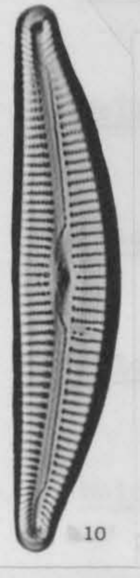
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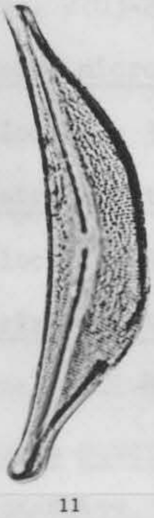
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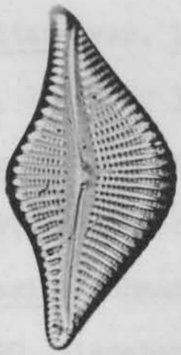
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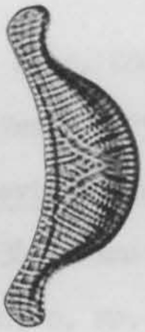
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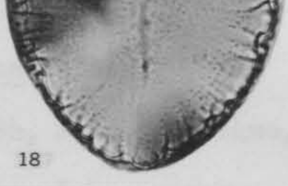
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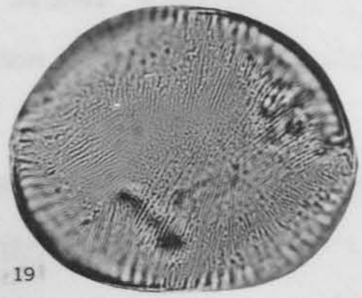
19

Plate 9

1. *Melosira denticulata* Lohman, n. sp. USGS diatom catalog no. 2703-149, locality 3534, diameter, 8mu. x1140.

2,3. *Melosira hyalina* Lohman, n.sp. USGS diatom catalog no. 2699-18, locality 3527, diameter, 23mu, x1200

4. *Melosira italica* var. *irregularis* Lohman, n. var. U.S.G.S. diatom locality 3523, USGS diatom catalog 2694-157, diameter, 7 to 11mu, x910

5. *Melosira margaritata* Lohman, n.sp. USGS diatom catalog no. 2703-152, locality 3534, diameter 9mu, x825

6. *Melosira margaritata* var. *laevis* Lohman, n. var. USGS diatom catalog no. 2703-22, locality 3534, diameter 9.8mu. x1090

7. *Melosira micropunctata* Lohman, n. sp. USGS diatom catalog no. 2668-109, locality 3397, diameter, 10.5mu. x1000

8. *Melosira punctissima* Lohman, n.sp. USGS diatom catalog no. 2701-8, locality 3530, diameter, 7mu. x930

9. *Melosira punctissima* var. *curvata* Lohman, n.var., USGS diatom catalog no. 2701-89, locality 3530, diameter 12mu. x1000

10. *Melosira paucipunctata* Lohman, n.sp. USGS diatom catalog no. 2668-112, locality 3397, diameter 8.3mu. x900

11. *Melosira nuda* Lohman, n.sp. USGS diatom catalog no. 2601-102, locality 3304, diameter, 16.3mu. x580

12, 13. *Melosira crassa* Lohman, n. sp. USGS diatom catalog no. 2665-16, locality 3394, diameter, 14mu, x1400

14. *Melosira ponderosa* Lohman, n.sp. USGS diatom catalog no. 2709-13, locality 3540, diameter, 13mu, x770

15. *Melosira ponderosa* var. *curta* Lohman, n.sp. USGS diatom catalog no. 2678-13, locality 3407, diameter, 18mu. x640

15A. *Melosira ponderosa* var. *elongata* Lohman, n.var. USGS diatom catalog no. 2708-100, locality 3537, diameter, 9mu. x880

16. *Melosira triannula* Lohman, n.sp. USGS diatom catalog no. 2703-34, locality 3524, diameter, 12.4mu. x880

17. *Cyclotella anomala* Lohman, n.sp. USGS diatom catalog no. 2665-77, locality 3394, major dia., 30mu; minor dia., 27mu, x820

18. *Cestodiscus simplissimus* Lohman, n.sp. USGS diatom catalog no. 2673-83, locality 3403, diameter, 34mu, x880

19. *Cestodiscus simplissimus* Lohman, n.sp. USGS diatom catalog no. 2673-74, locality 3403, diameter, 41mu. x940

20. *Coscinodiscus mobilis* Lohman, n.sp. USGS diatom catalog no. 2668-119, locality 3397, diameter, 43mu. x920

21. *Cestodiscus cedarensis* Lohman, n.sp. USGS diatom catalog no. 2668-18, locality 3394, diameter, 49mu. x800

22. *Cestodiscus cedarensis* Lohman, n.sp. USGS diatom catalog no. 2668-83, locality 3394, diameter, 60mu. x680

Plate 10

1. Cestodiscus apiculatus Lohman, n.sp. USGS diatom catalog no. 2668-155, locality 3397, diameter 91mu, x745.

2. Cestodiscus fasciculatus Lohman, n.sp. USGS diatom catalog no. 2665-59, locality 3394, diameter 94mu, x710

3. Cestodiscus stellatus Lohman, n.sp. USGS diatom catalog no. 2668-131, locality 3397, diameter, 91mu, x725

4. Cestodiscus stellatus Lohman, n.sp. USGS diatom catalog no. 2665-52, locality 3394, diameter, 79mu, x725.

5. Cestodiscus apiculatus Lohman, n.sp. USGS diatom catalog no. 2668-144, locality 3397, diameter 63mu. x730

6. Cestodiscus canalis Lohman, n.sp. USGS diatom catalog no. 2668-173, locality 3397, diameter, 69mu. x725

7. Cestodiscus fasciculatus Lohman, n.sp. USGS diatom catalog no. 2665-36, locality 3394, diameter, 52mu. x925.

Plate 11

1. *Cestodiscus fasciculatus* Lohman, n.sp. USGS diatom catalog no. 2665-8, locality 3394, diameter, 65mu. x925

2. *Fragilaria crassa* Lohman, n.sp. USGS diatom catalog no. 2676-81, locality 3405, length, 35mu, x915.

2A. *Fragilaria crassa* var. *capitata* Lohman, n.var. USGS diatom catalog no. 2668-53, locality 3394, length, 59mu, x905.

3. *Fragilaria leptostauron* var. *obesa* Lohman, n.var. USGS diatom catalog no. 2709-118, locality 3540, length, 13mu, x1300

4. *Fragilaria delicata* Lohman, n.sp. USGS diatom catalog no. 2709-137, locality 3540, length, 25mu, x1310

5. *Fragilaria nevadensis* Lohman, n.sp. Valve view, USGS diatom catalog no. 2694-160, locality 3523, length, 48mu, x920

6. *Fragilaria nevadensis* Lohman, n.sp. Girdle view. USGS diatom catalog no. 2696-113, locality 3524, length, 45mu, x890

7. *Diatoma enormis* Lohman, n.sp. USGS diatom catalog no. 2703-27, locality 3534, length, 23mu, x890

8. *Diatoma enormis* Lohman, n.sp. USGS diatom catalog no. 2703-170, locality 3534, length, 29mu, x930

9. *Diatoma enormis* Lohman, n.sp. USGS diatom catalog no. 2703-43, locality 3534, length, 19mu. x840

10. *Opephora lanceolata* Lohman, n.sp. USGS diatom catalog no. 2708-45, locality 3537, length, 75mu. x890.

11. *Tetracyclus calceus* Lohman, n.sp. USGS diatom catalog no. 2703-140 locality 3534, length, 68mu, x730

12. *Tetracyclus circularis* Lohman, n.sp. USGS diatom catalog no. 2709-50, locality 3540, diameter, 32mu. x1250

Plate 11 (cont.)

13. *Tetracyclus clypeus* (Ehrenberg) Lohman, n.comb. USGS diatom catalog no. 2665-47, locality 3394, diameter, 30mu. x835.

14. *Tetracyclus duplus* Lohman, n.sp. USGS diatom catalog no. 2676-36, locality 3405, length, 26mu. x920

15. *Tetracyclus quadrus* Lohman, n.sp. USGS diatom catalog no. 2709-49, locality 3540, length, 28mu, x1210

16. *Eunotia lineata* Lohman, n.sp. USGS diatom catalog no. 2708-134, locality 3537, length of fragment, 47mu, x830.

17. *Tetracyclus irregularis* Lohman, n.sp. USGS diatom catalog no. 2703-103, locality 3534, length, 43mu, x890

18. *Tetracyclus irregularis* Lohman, n.sp. USGS diatom catalog no. 2703-118, locality 3534, length, 37mu, x935

19. *Tetracyclus constrictus* (Hustedt) Lohman, n.comb. USGS diatom catalog no. 2673-38, locality 3403, length, 63mu x945.

20. *Tetracyclus horus* Lohman, n.sp. USGS diatom catalog no. 2703-1, locality 3534, length, 45mu x700

21. *Tetracyclus radiatus* Lohman, n.sp. USGS diatom catalog no. 2665-63, locality 3394, major axis, 41mu, x880

22-23. *Achnanthes basaltensis* Lohman, n.sp. USGS diatom catalog no. 2708-87, locality, 3540, length, 12.3mu. x1260

24-25. *Achnanthes spicula* Lohman, n.sp. USGS diatom catalog no. 2950-93, locality 4169, length, 38mu, x805.

26. *Tetracyclus virginicus* Lohman, n.sp. USGS diatom catalog no. 2703-95, locality 3534, length, 35mu, x885.

27. *Tetracyclus parallelus* Lohman, n.sp., USGS diatom catalog no. 2703-98, locality 3534, length, 30mu, x855.

Plate 12

1. *Caloneis rostrata* Lohman, n.sp. USGS diatom catalog no. 2703-86, locality 3534, length, 67mu. x805
2. *Stauroneis debilis* Lohman, n.sp. USGS diatom catalog no. 2668-1, locality 3397, length, 48mu, x1070
3. *Stauroneis obesa* Lohman, n.sp. USGS diatom catalog no. 2659-20, locality 3523, length, 14mu. x547
4. *Stauroneis irregularis* Lohman, n.sp. USGS diatom catalog no. 2694-103, locality 3523, length, 37mu. x920
5. *Anomoeoneis lanceolata* Lohman, n.sp. USGS diatom catalog no. 2668-169, locality 3397, length, 73mu. x940.
6. *Anomoeoneis nyensis* Lohman, n.sp. USGS diatom catalog no. 2668-95, locality 3397, length, 192mu. x450
7. *Anomoeoneis turgida* Lohman, n.sp. USGS diatom catalog no. 2668-148, locality 3397, length, 68mu. x910
8. *Anomoeoneis cubita* Lohman, n.sp. USGS diatom catalog no. 2668-24, locality 3397, length, 28mu. x910
9. *Navicula citroides* Lohman, n.sp. USGS diatom catalog no. 2861-47, locality 3410, length, 31mu. x935
10. *Navicula opalensis* Lohman, n.sp. USGS diatom catalog no. 2703-187, locality 3534, length, 20mu. x1350
11. *Navicula amphibola* var. *capitata* Lohman, n.var. USGS catalog no. 2695-3, locality 3523, length, 52mu. x905
12. *Navicula umbilica* Lohman, n.sp. USGS diatom catalog no. 2950-100, locality 4169, length, 46mu. x1020

Plate 12 cont.

13. *Navicula bulloides* Lohman, n.sp. USGS diatom catalog no. 2675-7, locality 3523, length, 84mu. x706.

14. *Navicula utahensis* Lohman, n.sp. USGS diatom catalog no. 2601-21, locality 3304, length, 44mu. x1110

15. *Pinnularia angulo-costata* Lohman, n.sp. USGS diatom catalog no. 2601-115, locality 3304, length, 133mu. x500

16. *Pinnularia angusta* Lohman, n.sp. USGS diatom catalog no. 2696-28, locality 3524, length, 145mu. x550

17. *Navicula isolata* Lohman, n.sp. USGS diatom catalog no. 2673-42, locality 3403, length, 50mu. x900

18. *Pinnularia nebulosa* Lohman, n.sp. USGS diatom catalog no. 2703-87, locality 3534, detail of structure, x1400

19. *Pinnularia denticulata* Lohman, n.sp. USGS diatom catalog no. 2696-80, locality 3524, length 67mu. x835

20. *Pinnularia nebulosa* Lohman, n.sp. USGS diatom catalog no. 2703-87, locality 3534, length, 155mu. x550

21. *Pinnularia curvata* Lohman, n.sp. USGS diatom catalog no. 2696-39, locality 3524, length, 114mu. x680

22. *Pinnularia pseudopunctata* Lohman, n.sp. USGS diatom catalog no. 2696-85, locality 3524, length, 54mu. x930.

Plate 13

1. *Pinnularia virginica* Lohman, n.sp. USGS diatom catalog no. 2967-61, locality 3525, length, 50mu. x1380

2. *Pinnularia esmeraldensis* var. *constricta* Lohman, n.var. USGS catalog no. 2668-140, locality 3397, length, 168mu. x440

3. *Pinnularia esmeraldensis* Lohman, n.sp. USGS diatom catalog no. 2668-165, locality 3397, length, 114mu. x430

4. *Gomphonema excentricum* Lohman, n.sp. USGS diatom catalog no. 2602-107, locality 3305, length, 48mu. x1120

5, 6. *Gomphonema duostriatum* Lohman, n.sp. USGS diatom catalog no. 2696-75, locality 3524, length, 40mu. x910

7. *Gomphonema quadratum* Lohman, n.sp. USGS diatom catalog no. 2676-78, locality 3405, length, 43mu. x910

8. *Cymbella angularis* Lohman, n.sp. USGS diatom catalog no. 2601-75, locality 3304, length, 45mu. x960

9. *Cymbella mexicana* var. *gracilis* Lohman, n.var. USGS diatom catalog no. 2601-79, locality 3304, length, 190mu. x450

10. *Cymbella prisca* Lohman, n.sp. USGS diatom catalog no. 2950-131, locality 4169, length, 65mu. x1100

11. *Amphora sparsa* Lohman, n.sp. USGS diatom catalog no. 2668-180, locality 3397, length, 89mu. x710

12. *Cymbella provoensis* Lohman, n.sp. USGS diatom catalog no. 2601-62, locality 3304, length, 46mu. x980

13. *Epithemia galera* Lohman, n.sp. USGS diatom catalog no. 2950-29, locality 4169, length, 39mu. x1090

Plate 13, cont.

14. Cymbella hagermanensis Lohman, n.sp. USGS diatom catalog no. 2950-5, locality 4169, length, 32mu. x1350

15. Surirella spicula Lohman, n.sp. USGS diatom catalog no. 2668-71, locality 3397, major axis, 80mu, x450.

16. Surirella pallida Lohman, n.sp. USGS diatom catalog no. 2668-56, locality 3397, major axis, 80mu. x440.

17. Surirella bifurcata Lohman, n.sp. USGS diatom catalog no. 2601-51, locality 3304, major axis, 36mu. x970

18. Surirella spicula var. lineata Lohman, n.sp. USGS diatom catalog no. 2668-86, locality 3397, major axis, 72mu. x770

19. Campylodiscus anastomosus Lohman, n.sp. USGS diatom catalog no. 2711-1, locality 3544, major axis, 78mu. x580.