

Pacific Northwest Tertiary Foraminiferal Collections of the U.S. Geological Survey and the State of Washington

by Weldon W. Rau

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INTRODUCTION

Since 1950, more than 6000 slides of fossil foraminifers have accumulated in connection with biostratigraphic studies I have conducted. These efforts have been largely in support of approximately 80 geologic mapping and stratigraphic projects conducted in western Washington and Oregon, although a few from California and Alaska are included as well. Most of the slides are contained in two collections, involving either U.S. Geological Survey (USGS) or Washington Division of Geology and Earth Resources (DGER) projects. In connection with both collections, a formidable library of foraminiferal literature with a large group of files has been assembled. In addition, a database (RauPaleo.xls) listing the salient features of each slide has been established for all assemblage slides of the USGS collection.

The purpose of this report is to describe the general content of the slide collections, foraminiferal library, and files. Each component of the database is listed below, together with my complete scientific bibliography.

The slide collections, foraminiferal library, and files now reside at the Burke Museum of Natural History and Culture at the University of Washington. To gain access to the collection, contact the curator of paleontology, Liz Nesbitt, at (206) 543-5949 or lnesbitt@u.washington.edu.

U.S. GEOLOGICAL SURVEY COLLECTION

History

This collection began when I joined the Geologic Division of the U.S. Geological Survey in 1950. I was assigned to a field group of the Fuels Branch that was conducting geologic investigations in connection with coal reserves in the Centralia Coal District of southwest Washington State. This group of approximately six geologists, led by Parke D. Snively, Jr., was in the process of compiling a geologic map of the area from which we were to determine the approximate coal reserves. The resultant report was U.S. Geological Survey Bulletin 1053, "Geology and Coal Resources of the Centralia-Chehalis District, Washington" (Snively and others, 1958).

My duty, besides assisting with the general field work of geologic mapping, was to provide information regarding the geologic age and stratigraphic relationships of foraminiferal assemblages contained in the Tertiary strata of the area. My background at the time was largely a masters thesis describing the Foraminifera contained in the Lincoln Creek Formation exposed at the Porter Bluffs (Rau, 1948) and a Ph.D. dissertation, later published (Rau, 1951), on the Foraminifera found in the Tertiary section exposed in the Willapa River valley. In the latter study, the stratigraphic significance of the various assemblages was discussed.

As time progressed, additional projects were undertaken by the Fuels Branch and other Geologic Division groups mapping in western Oregon and Washington. During this time, I continued to supply stratigraphic information based on Foraminifera for these various projects. All assemblages were mounted on slides and saved. These slides constitute the USGS collection. Trays containing them are marked with pink-colored tabs. Over a period of more than 50 years, some 80 geologic projects (see References) were provided with biostratigraphic as well as paleoecologic information from studies of these (some 3500) microfossil assemblages. Reports were prepared for each assemblage studied and submitted to the collector. The original carbon copy of each of these reports is housed with the collection at the Burke. The library of the Washington State Division of Geology and Earth Resources also has a set of copies of the original carbons.

The Database

Information about each assemblage has, in recent years, been placed in a computer database. Originally the information was assembled on a modified version of a DOS program known as Revelation. After entries were completed, it was converted to a set of Excel spreadsheets (RauPaleo.xls). The following is a list and explanation of the fields or columns in the main spreadsheet, which is called "Records":

Record No. refers to the order in which each report was entered into the database file.

File No., sometimes referred to as lab number, is simply a consecutive number under which the report and slides were originally filed.

Field No. is an identification number given to a sample by the collector. Usually the first digit in a field number refers to the collector's name, for example, in W86-21, the "W" may signify that Ray Wells collected the material. The number following indicates the year it was collected and the final number "21" relates to the 21st note that the collector took that year.

Collector lists the last name of the collector(s) when known.

County indicates the county where the assemblage was collected.

State gives the state where the assemblage was collected.

30 x 60-Minute Quadrangle gives the name of the 1:100,000-scale quadrangle, when known.

Primary Quadrangle gives the 7½- or 15-minute quadrangle name(s), when known.

Scale is the map scale of the primary quadrangle.

Location is the specific location where the sample was collected, usually given by listing the distance from a corner of a specified section together with its township and range.

Sample Type and **Depth Interval** provide information on whether the assemblage is from a surface collection or drill hole and from what depth (in feet unless otherwise specified).

Rock Unit (Formation) gives the name assigned to the rock unit from which the assemblage was collected, if known.

Local Foraminiferal Zone, **Pacific Coast Foraminiferal Stage**, and **Geologic Age** are given when known.

Paleoecology/bathymetry and **Water Conditions** present suggested paleoecological conditions, such as water depth and temperature during deposition, for many of the assemblages.

Species List gives the names of species contained in an assemblage, when known.

Rock Lithology is the lithology of the rock from which the sample was taken.

Pub. No. is the number of the publication that resulted from the project for which the foraminiferal assemblage was collected.

Remarks usually refers to why the sample was collected.

Ref. No. lists all publications that are in some way related to the assemblage studied, including those already listed under Pub. No.

The references that go with the numbers under Pub. No. and Ref. No. are listed in a separate spreadsheet (called "References") in the same workbook.

Miscellaneous Materials Associated with the USGS Foraminiferal Collection

Alaska Slides and Reports

An undetermined number (probably hundreds) of slides and reports on assemblages from southeast Alaska Tertiary strata are interspersed throughout the latter part of the USGS collection between years 1972 and 1982, involving lab. numbers between 5826 and 9005. The reports for each assemblage identify them as Alaska materials. These were prepared, studied, and reported on largely for projects completed in association with George Plafker and Gary Winkler, mainly for the publication "Foraminiferal Biostratigraphy and Correlations in the Gulf of Alaska Tertiary Province" (Rau and others, 1983). Information on these materials, however, was not placed in the database.

Species Set

During the time the collection was accumulating, I maintained a set of slides containing representative specimens of each species encountered in the Pacific Northwest Tertiary sequence. I refer to these as species slides. There are over 200 in the collection and they are divided into four groups: Eocene, Oligocene, Miocene, and Pliocene. Each slide contains representatives of all species of a given genus that has been encountered in each series of the Northwest Tertiary. Trays containing these slides are color-coded blue. There is a corresponding card file containing a set of cards for each series. Each card bears a number corresponding to a number in a section on the slide containing a representative specimen of a species. Each card contains information about the name of each species, as well as where the specimen is from. A similar set of slides (37) together with a corresponding set of cards was set up for strata of Cretaceous age. These were assembled almost entirely from rocks in northern California during my brief studies in that area. Trays containing these slides are also color-coded blue and are found at the end of the Northwest Tertiary species set. An additional set of 49 slides with corresponding cards was set up for all species

encountered during my southeast Alaska studies. They are color-coded red.

Selected Assemblages from Various Formations

Although not at all complete, assemblages typical of various formations have been assembled: one for the Northwest Tertiary (27 slides), one from selected California formations (60 slides), and one from southeast Alaska formations (9 slides). Trays containing these slides are color-coded orange.

Also in this group are 57 slides labeled "Quinault Fig. Specimens". These materials were used in connection with the report "Foraminifera, Stratigraphy, and Paleoecology of the Quinault Formation" (Rau, 1970). They are color-coded orange. Another group of 36 slides is labeled "Nye Types" and color-coded pink. These were used in connection with studies in the Newport, Oregon, area.

Personal Slides

Miscellaneous Slides—Some 27 slides labeled "Miscellaneous Personal" are assemblages I collected prior to joining the USGS. Trays containing them are color-coded clear.

Willapa Thesis Slides—A set of 80 slides marked "Willapa Thesis Fauna" are assemblages from localities of my Willapa River Valley dissertation and 1951 publication. Trays containing these slides are color-coded green. Also from the Willapa studies are 78 slides, each containing representatives of a particular species found in the Willapa section. These trays are also color-coded green.

Porter Thesis Material—There are 47 slides containing specimens of various species encountered in the Porter section that were studied for my masters thesis and 1948 publication. Also, the original type material from which photographs were made for the Porter study are contained in 76 slides marked "Porter Paper Types". Trays containing all Porter material are also color-coded green.

Preachers Slough Slides—During my graduate studies at Iowa in 1948, I published a short paper describing an Astoria Formation assemblage from Grays Harbor County known as the Preachers Slough fauna. There are 12 slides of type material and 10 of extra material of each species encountered. These too are color-coded green.

All type material for the Willapa, Porter, and Preachers Slough studies were originally deposited in the University of Iowa Geology Department's repository and therefore each contains a University of Iowa number that corresponds to the published number for each specimen. However, these type specimens were, in later years, transferred to my possession.

Sample Residue

Washed residue from which USGS assemblages were removed was kept and stored in individual glass vials. However, only those with lab numbers 4132–9098 have been preserved with the collection. Those with numbers 1–4131 were not transferred with the collection when I moved to Olympia in 1960. They may still be in Menlo Park, California, in USGS storage.

WASHINGTON STATE COLLECTION

History

The State of Washington's collection of Foraminifera began in 1960 when I was hired by the Division of Mines and Geology, a part of the now defunct Department of Conservation. At that

time, I began stratigraphic studies of southwest Washington, first in the upper drainage area of the Satsop River. This work resulted in Bulletin 53, "Stratigraphy and Foraminifera of the Satsop River Area, Southern Olympic Peninsula, Washington" (Rau, 1966). As time progressed, I continued geologic mapping of several quadrangles in southwest Washington and eventually the north coast of the Olympic Peninsula. This collection therefore contains many assemblages I collected and studied in connection with formal reports and geologic maps published by the Washington State Division of Geology and Earth Resources (DGER) and its predecessors. There are, however, some assemblages that I studied while working for the State that were in support of USGS geologists, projects that were a joint effort between Washington State and the USGS. These assemblages usually display USGS field numbers. In addition, dispersed throughout the collection are assemblages that were prepared from numerous oil and gas test wells of western Washington. Some of these assemblages I have studied and checklisted in connection with various geologic mapping projects; others I have not. The results of any study I might have conducted on various western Washington wells can be found in a file labeled "Biostratigraphic Data on Oil Wells, Oregon and Washington". Numerous checklists were made and conclusions drawn as to geologic age and paleoecologic conditions. Also, many surface sections were measured and sampled for Foraminifera. Information on this work can be found under the file "Measured Sections".

Records

Since those surface collections I made were for projects I was engaged in, formal reports were not generally prepared. However, records were kept on a series of file cards for each assemblage studied. There are two sets of these cards. One is filed in consecutive order and assigned lab numbers from S-1 to S-1208, the "S" referring to State rather than USGS. The duplicate set is filed alphabetically by counties. Contained on each card are the field number, lab number, location, quadrangle, field remarks, and lab determination (age and remarks).

Several systems of field numbering were employed, some with the standard USGS system (W62-4), previously discussed, and others with the old state system such as GH2108W24.15. The latter system actually supplies the location. First, the GH stands for Grays Harbor County. The 2108 represents the Township and Range, 24 is the section and .15 represents a position in the section. The "1" refers to .10 the distance to the right (east) and "5" indicates .50 of the distance up (north) from the southwest corner of the section.

Aside from field and lab numbers, a publication number appears on some slides. This number is usually preceded by an "F", indicating a foraminiferal collecting locality. Such numbers will appear on the geologic map that resulted from the mapping project for which the collection was made.

Sample Residue

As with the USGS collection, washed residue from which each state assemblage was removed, was kept and stored in individual glass vials. There should be representative material numbering from S-1 to S-1216.

MATERIALS ASSOCIATED WITH BOTH THE USGS AND DGER COLLECTIONS

The Files

There are eight drawers of files in two cabinets.

Drawer 1 contains a file on correlations and zones, with charts used by various workers. Most of the remainder of the drawer contains a file on stratigraphic and foraminiferal materials dealing with various wells drilled throughout the Pacific Northwest, including some offshore wells. These files are divided into the following groups: Oregon offshore wells, Oregon onshore wells, Washington offshore wells, and Washington onshore wells. Among these categories, the wells are arranged alphabetically by name. Each well folder contains all of the information I was able to glean from foraminiferal studies I either conducted or received from other workers. Some correlations may be suggested. These materials may well be the most valuable of all files, especially for those wishing to conduct stratigraphic studies of the Pacific Northwest. One or two small folders in the back of the drawer contain information on auger holes drilled by both Standard Oil Company of California and the Phillips Petroleum Company.

Drawer 2 contains files on measured sections, biostratigraphy of southeastern Alaska wells, general data acquired from various oil companies, California type sections and maps, and original plates for some of my early taxonomic papers on Foraminifera.

Under measured sections are folders on the Newport-Waldport, Oregon area, and miscellaneous sections of Washington and Canada. All of these folders contain information on various measured sections throughout western Oregon and Washington and a few in Canada. Most sections were sampled for Foraminifera and therefore usually include a checklist of Foraminifera. Some folders contain field notes and many contain columnar sections that have been constructed from field data.

The section on biostratigraphy of southeastern Alaska wells contains folders of material on all wells that I either obtained information on from other workers or generated myself during my southeast Alaska studies. Most of my contributions are checklists of Foraminifera.

The section on oil company data contains general information acquired from various oil companies on a number of areas in western Oregon and Washington. Included are geologic maps, paleogeographic maps, and the results from various geologic related studies. Also included is information on the Navarin Basin in the Arctic Ocean where I conducted biostratigraphic studies using Foraminifera on a well drilled in that area.

The section labeled "California Type Sections and Maps" contains materials, including field notes, that accumulated during my studies of some of the well-known type sections of California. During that study, I collected foraminiferal assemblages that are contained on slides in the collection marked "Type California Faunas".

The section labeled "Original Plates" contains plates used to produce some of my early taxonomic publications.

Drawer 3 contains mostly pollen slides submitted to the State by various oil companies after they had studied materials from the State's core repository. It was required by law that all slides made from State core material were to be deposited with the State geologic survey. Also in this drawer are two boxes of thin section slides, most of which I prepared and examined for

Foraminifera in connection with Tabor and Cady's studies in the Olympic Mountains.

Drawer 4 contains two major groups of reports: Standard Oil Company auger reports and a complete set of all paleontologic reports I prepared for USGS projects. The Standard Oil Company reports are probably not usable without the original maps. These reports were most likely made from borrowed company materials and therefore there are no slides or lab numbers with which to associate the reports.

The second group of reports are, for the most part, original copies of reports I prepared for various projects my studies supported (lab. numbers 1–9008). There is some confusion with the lab number arrangement in the first two folders of reports (starting from the back of the drawer). Early on, for a short time, I used a different system of reporting. Therefore, the first two folders may be intermixed with two different reporting systems. However, the lab numbers in each report correspond to lab numbers on slides in the collection. Starting with lab number 244 in the second folder, all reports should be found to be arranged in consecutive order with respect to lab numbers. This complete file has been copied and is in the possession of the Washington State Division of Geology and Earth Resources library. The originals of nearly all these reports were transmitted to whomsoever submitted a sample for study. It should also be pointed out that a report was prepared and a lab number was assigned to each sample submitted, regardless of whether it contained Foraminifera or not. Therefore, for those samples barren of Foraminifera, there will not be a corresponding numbered slide in the collection.

Drawer 5 contains four groups of files. Aside from one book of my 1953 and 1955 USGS notes, the first group in the front of the drawer consists of copies of USGS field notes made available to me by other geologists for inclusion in the spreadsheet discussed in this report. The second file in one folder labeled "USGS Computer Locs.—Data for Foram Locs." consists of materials Parke Snively assembled about foraminiferal collections made in the Port Angeles–Cape Flattery region. The foraminiferal stage and geologic age of many localities were plotted on quadrangle maps of the area. The third file, a single folder labeled "Maps with locations", contains copies of Oregon quadrangle maps with field localities. The fourth group of materials are my state field notes and a few personal field notes I made before I joining the USGS.

Drawer 6 contains quadrangle maps, many with field locations, some with lab numbers in reference to assemblages in the slide file collection, and a few are original field maps that were used to accumulate data from which published maps were made. The maps are in two groups, Washington and Oregon, and each group is alphabetically arranged according to quadrangle name.

Drawer 7 contains aerial photographs and photomaps. Field notes have been placed on the backs of many by pin-pointing each locality. In many cases, the only field note for a locality will be on the back of one of these photographs.

Drawer 8 contains five small folders with information variously on cross indexing of materials and general inventory on available slides for certain completed projects. The first folder is labeled "Cross Index for Published Reports—Lab., Field, and Map Numbers". It cross-indexes lab numbers, field numbers, and some map and manuscript numbers for a number of my reports. Folder 2 consists largely of cross-references on foraminiferal slides available from various wells drilled in Washington State. In many cases, the permit number assigned to the well by

DGER is given, as well as the company, well name, lab number for the slide, and the number of slides in the collection. Also, there is a list of various materials that DGER had at one time from various wells drilled in the state. Folder 3 consists of a general inventory of USGS foraminiferal slides in that collection from lab numbers 5 through 7238. Folder 4 is a cross-index from field numbers to lab numbers, together with remarks on geologic age (usually stage) of each assemblage from the Newport Embayment area of western Oregon. The information included on each list varies. An additional list is of slides that were donated to the collection by James Moore, formerly of Shell Oil Company. Folder 5 consists of several lists of information on slides in the Washington State collection from various wells drilled in the State. Also, there is a short list of measured surface sections in both Oregon and Washington for which there are slides, checklists, traverses, and columnar sections.

Library Materials

The library associated with the foraminiferal slide collections is probably one of the few major collections of foraminiferal literature on the West Coast and therefore should serve future students well, particularly in the fields of micropaleontology and biostratigraphy. It consists of several major formal volumes on the subjects, together with a number of categories of literature on Foraminifera and biostratigraphy dealing with Tertiary strata of the Pacific Northwest. Each is summarized below. Since the Burke is short of space, most of these materials will eventually be integrated into their divisional library and duplicates (or in some cases, triplicate copies) will not be kept.

The Catalog of Foraminifera

These volumes by Ellis and Messina are an important tool for students of Foraminifera, particularly when dealing with taxon unknown to the worker. They are a must for beginning students of micropaleontology. The original set consists of some forty volumes, each several inches thick. A species of Foraminifera is illustrated and described on each page, usually from the original report describing and illustrating the species. A second set, begun in 1960, consists of inserts of new species that were sent out periodically by the publisher to be included in the original volumes. Species listed in both sets are arranged under the genus in which they were originally placed. However, over the years, various workers have modified concepts on many genus–species relationships and therefore changes have been made as to which genus a given species is now assigned.

Contributions from the Cushman Foundation for Foraminiferal Research

These periodicals contain a series of articles by Cushman and his students describing various assemblages or simply a species of Foraminifera. Besides Contributions, the set also includes a few special publications volumes dealing comprehensively with certain aspects of foraminiferal micropaleontology.

The Journal of Foraminiferal Research

This publication was started by the Cushman Foundation after Cushman died. It is the official publication of the Cushman Foundation and continues the Contributions from the Cushman Laboratory for Foraminiferal Research, which were published from 1925 until 1950, and Contributions from the Cushman Foundation for Foraminiferal Research, which were published continuously from 1950 until 1970.

Most-Used Literature

These materials consists mostly of reports dealing with various foraminiferal assemblages described from numerous formations and localities throughout the West Coast Tertiary. They were used for comparison of assemblages I studied from Pacific Northwest formations with those of other West Coast formations, not only for correlation purposes but in some cases for identification of taxon. Most of these reports contain plates of Foraminifera that were used to identify taxon in question. As a matter of convenience, I divided this literature into the following groups: Eocene, Oligocene, Miocene, Pliocene, and Pleistocene–Recent. Each section contains literature on assemblages of a given geologic age. In addition, there is a section on correlation. This includes various correlation charts and information pertaining to zones, stages, and geologic age of certain assemblages, as well as concepts of various workers regarding correlations and ranges of various foraminiferal species. Another small section consists of reports in which several faunas of different ages are contained and thus could not be placed in a specific age category. Also included is a section on paleoecology. Another section consists of Alaskan literature that I used in connection with Southeast Alaska studies. Finally, several books on foraminiferal taxonomy are also included in this group, mainly Cushman's "Foraminifera" and Loeblich and Tappan's "Treatise on Foraminifera" in two volumes.

Stratigraphic Literature

These materials consist largely of an accumulation of geologic maps and reports that, for the most part, are the product of projects to which my foraminiferal studies were applied. These publications were used extensively in the preparation of the database discussed in this report. This literature is divided into areas of study in western Washington and Oregon listed below: southwest Oregon, Coos Bay (Oregon) area, Newport (Oregon) area, Willamette Valley (Oregon), northwest Oregon, lower Columbia Basin, Grays Harbor, Chehalis Valley, Olympic Mountains, Washington coastal, north and east flank of the Olympic Peninsula, Puget Basin, eastern Washington, offshore Oregon, offshore Washington and Vancouver Island, miscellaneous western Washington stratigraphy, and old miscellaneous reports and coastal. Also included is literature on northeast Russia, Japan, the North Pacific, and the Bering Sea. These latter reports were assembled while working on a well in the Naverin Basin of eastern Russia. Also included in this general category of literature are symposiums and theses dealing with stratigraphy of the Pacific Northwest that accumulated during the years of my studies on biostratigraphy.

Miscellaneous Foraminiferal Literature

These are reports, separates, and general foraminiferal literature that have accumulated over the years of my career. Some have been used from time to time for studies on various projects. Most of these reports are complimentary materials sent to me by various workers in the field of micropaleontology. There are two groups. One has been divided according to age and each age has been alphabetized according to author. The second group of "Miscellaneous Foraminifera Literature" is arranged alphabetically by author only. Most of the reports of the latter group deal with more than one age of fossils or a subject that is not particularly applicable to a geologic age division.

Miscellaneous General Literature

This is a small assortment of literature (one box) that was assembled while I was conducting studies on various projects. These materials are divided into several general categories:

1. **Tectonics and sea-floor spreading section.** Includes papers on mélange, diapirs, and various aspects of plate tectonics. Many of these papers represent some of the early thoughts on plate tectonics and concepts on the formation of mélange rocks.
2. **Turbidites and sedimentation section.** Contains papers that were used during my coastal studies. Many of the strata of that area are turbidites or related strata.
3. **Coastal history section.** Contains papers and reports dealing with the historical background of various coastal areas in which I conducted geologic studies.
4. **Coastal Pleistocene section.** Contains papers and reports on Pleistocene concepts developed by various workers in that field of geology along the coast.

Also included in the box with the above materials are several Oregon theses or dissertations that were significant to my studies in micropaleontology and stratigraphy.

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REFERENCES

- Armentrout, J. M.; Hull, D. A.; Beaulieu, J. D.; Rau, W. W., 1983, Correlation of Cenozoic stratigraphic units of western Oregon and Washington: Oregon Department of Geology and Mineral Industries Oil and Gas Investigation 7, 90 p., 1 plate.
- Armentrout, J. M.; Hull, D. A.; Beaulieu, J. D.; Rau, W. W., coordinators, 1983, Correlation of Cenozoic stratigraphic units of western Oregon and Washington; Draft: Oregon Department of Geology and Mineral Industries Open-File Report O-83-5, 268 p., 1 plate.
- Beikman, H. M.; Rau, W. W.; Wagner, H. C., 1967, The Lincoln Creek Formation, Grays Harbor basin, southwestern Washington: U.S. Geological Survey Bulletin 1244-I, 14 p.
- Deacon, R. J.; Butler, Ann; Rau, W. W., 1986, ARCO field trip, northwest Oregon—southwest Washington, June 2-3-4, 1986—Nehalem basin, Astoria basin, Chehalis basin, coastal Olympic Peninsula: [Privately published by the authors], 14 p.
- Hull, D. A.; Armentrout, J. M.; Hintze, L. F.; Beaulieu, J. D.; Rau, W. W., coordinators, 1988, Correlation of stratigraphic units of North America (COSUNA) project—Northwest region: American Association of Petroleum Geologists [Correlation Chart Series], 1 sheet.
- Niem, A. R.; Van Atta, R. O.; Livingston, V. E., Jr.; Rau, W. W., 1973, Cenozoic stratigraphy, Oregon—Washington—Road log. In Beaulieu, J. D., field trip chairman, Geologic field trips in northern Oregon and southern Washington: Oregon Department of Geology and Mineral Industries Bulletin 77, p. 93-132.
- Rau, W. W., 1946, Foraminifera from the Oligocene Lincoln Formation in the Porter area, Washington: University of Iowa Master of Science thesis, 104 p.
- Rau, W. W., 1948, Foraminifera from the Miocene Astoria Formation in southwestern Washington: Journal of Paleontology, v. 22, no. 6, p. 774-782.

- Rau, W. W., 1948, Foraminifera from the Porter shale (Lincoln Formation), Grays Harbor County, Washington: *Journal of Paleontology*, v. 22, no. 2, p. 152-174.
- Rau, W. W., 1950, Tertiary Foraminifera from the Willapa River valley of southwest Washington: State University of Iowa Doctor of Philosophy thesis, 137 p.
- Rau, W. W., 1951, Tertiary Foraminifera from the Willapa River valley of southwest Washington: *Journal of Paleontology*, v. 25, no. 4, p. 417-453.
- Rau, W. W., 1956, Foraminifera from the McIntosh Formation (Eocene) at McIntosh Lake, Washington: *Cushman Foundation for Foraminiferal Research Contributions*, v. 7, part 3, no. 155, p. 69-78.
- Rau, W. W., 1958, Stratigraphy and foraminiferal zonation in some of the Tertiary rocks of southwestern Washington: U.S. Geological Survey Oil and Gas Investigations Chart OC-57, 2 sheets.
- Rau, W. W., 1963, Foraminifera from the upper part of the Poul Creek Formation of southeastern Alaska: *Cushman Foundation for Foraminiferal Research Contributions*, v. 14, part 4, p. 135-145.
- Rau, W. W., 1964, Foraminifera from the northern Olympic Peninsula, Washington: U.S. Geological Survey Professional Paper 374-G, 33 p., 7 plates.
- Rau, W. W., 1965, Biostratigraphy of "Oligocene" strata, southern Olympic Peninsula, Washington [abstract]: *American Association of Petroleum Geologists Bulletin*, v. 49, no. 7, p. 1089.
- Rau, W. W., 1966, Stratigraphy and Foraminifera of the Satsop River area, southern Olympic Peninsula, Washington: *Washington Division of Mines and Geology Bulletin* 53, 66 p., 8 plates.
- Rau, W. W., 1967, Geology of the Wynoochee Valley quadrangle, Grays Harbor County, Washington: *Washington Division of Mines and Geology Bulletin* 56, 51 p., 1 plate.
- Rau, W. W., 1968, Correlation chart of coastal wells (in Washington): *Washington Division of Mines and Geology Open File Report* 68-1, 1 sheet.
- Rau, W. W., 1970, Foraminifera, stratigraphy, and paleoecology of the Quinault Formation, Point Grenville–Raft River coastal area, Washington: *Washington Division of Mines and Geology Bulletin* 62, 41 p.
- Rau, W. W., 1973, Geology of the Washington coast between Point Grenville and the Hoh River: *Washington Division of Geology and Earth Resources Bulletin* 66, 58 p.
- Rau, W. W., 1973, Preliminary identifications of Foraminifera from E. M. Warren Coos County No. 1-7 Well, Oregon: *Oregon Department of Geology and Mineral Industries Oil and Gas Investigations No. 4*, 2 p., 2 sheets.
- Rau, W. W., 1973, Preliminary identifications of Foraminifera from General Petroleum Corporation Long Bell No. 1 Well, Oregon: *Oregon Department of Geology and Mineral Industries Oil and Gas Investigations No. 3*, 2 p., 2 sheets.
- Rau, W. W., 1973, The Olympic Peninsula report: *Washington Geologic Newsletter*, v. 1, no. 1, p. 5.
- Rau, W. W., 1974, Stratigraphic and biostratigraphic relationships of the Tyee and Yamhill Formations—Comments: *The Ore Bin*, v. 36, no. 7, p. 120-122.
- Rau, W. W., 1975, Foraminifera and biostratigraphy of the Alsea Formation of western Oregon. In Weaver, D. W.; Hornaday, G. R.; Tipton, Anne, editors, *Paleogene symposium and selected technical papers; conference on future energy horizons of the Pacific Coast*: American Association of Petroleum Geologists Pacific Section, p. 409-416.
- Rau, W. W., 1975, Geologic map of the Destruction Island and Taholah quadrangles, Washington: *Washington Division of Geology and Earth Resources Geologic Map* GM-13, 1 sheet, scale 1:63,360.
- Rau, W. W., 1975, Oil and gas in Washington: *Washington Geologic Newsletter*, v. 3, no. 3, p. 5-7.
- Rau, W. W., 1976, The Oil City story: *Washington Geologic Newsletter*, v. 4, no. 2, p. 1-3.
- Rau, W. W., 1977, General geology of the southern Olympic Coast. In Brown, E. H.; Ellis, R. C., editors, *Geological excursions in the Pacific Northwest*: Geological Society of America, 1977 annual meeting, Seattle: Western Washington University, p. 63-83.
- Rau, W. W., 1979, Geologic map in the vicinity of the lower Bogachiel and Hoh River valleys, and the Washington coast: *Washington Division of Geology and Earth Resources Geologic Map* GM-24, 1 sheet, scale 1:62,500.
- Rau, W. W., 1979, Unusually well preserved and diverse Eocene foraminifers in dredge samples from the eastern Gulf of Alaska continental slope: *U.S. Geological Survey Circular* 804-B, p. B139-B141.
- Rau, W. W., 1980, Pacific Northwest Tertiary benthonic foraminiferal biostratigraphic framework—An overview: *Washington Division of Geology and Earth Resources Open File Report* 80-5, 50 p.
- Rau, W. W., 1980, Washington coastal geology between the Hoh and Quillayute Rivers: *Washington Division of Geology and Earth Resources Bulletin* 72, 57 p.
- Rau, W. W., 1981, Eocene correlations—A comment: *Washington Geologic Newsletter*, v. 9, no. 1, p. 15-16.
- Rau, W. W., 1981, Pacific Northwest Tertiary benthic foraminiferal biostratigraphic framework—An overview. In Armentrout, J. M., editor, *Pacific Northwest Cenozoic biostratigraphy*: Geological Society of America Special Paper 184, p. 67-84.
- Rau, W. W., 1981, Unusually diverse and well preserved Eocene foraminifers in dredge samples from the eastern Gulf of Alaska continental slope. In Albert, N. R.; Hudson, Travis, editors, *The United States Geological Survey in Alaska—Accomplishments during 1979*: U.S. Geological Survey Circular 823-B, p. 131-135.
- Rau, W. W., 1984, The Humptulips Formation—A new Eocene formation of southwest Washington: *Washington Geologic Newsletter*, v. 12, no. 4, p. 1-5.
- Rau, W. W., 1986, Geologic map of the Humptulips quadrangle and adjacent areas, Grays Harbor County, Washington: *Washington Division of Geology and Earth Resources Geologic Map* GM-33, 1 sheet, scale 1:62,500.
- Rau, W. W., 1987, Mélange rocks of Washington's Olympic coast. In Hill, M. L., editor, *Cordilleran section of the Geological Society of America: Geological Society of America DNAG Centennial Field Guide* 1, p. 373-376.
- Rau, W. W., 1998, Appendix 2—Foraminifera from the Sequim–Gardiner area, Washington. In Schasse, H. W.; Logan, R. L., *Geologic map of the Sequim 7.5-minute quadrangle, Clallam County, Washington*: *Washington Division of Geology and Earth Resources Open File Report* 98-7, p. 18-19.
- Rau, W. W., 2000, Appendix 4—Foraminifera from the Carlsborg 7.5-minute quadrangle, Washington. In Schasse, H. W.; Wegmann, K. W., *Geologic map of the Carlsborg 7.5-minute quadrangle, Clallam County, Washington*: *Washington Division of Geology and Earth Resources Open File Report* 2000-7, p. 24-26.
- Rau, W. W., 2002, Appendix 3—Foraminifera from the Morse Creek quadrangle. In Schasse, H. W.; Polenz, Michael, *Geologic map of the Morse Creek 7.5-minute quadrangle, Clallam County, Washington*: *Washington Division of Geology and Earth Resources Open File Report* 2002-8, p. 16-17.

- Rau, W. W.; Grocock, G. R., 1974, Piercement structure outcrops along the Washington coast: Washington Division of Geology and Earth Resources Information Circular 51, 7 p.
- Rau, W. W.; Johnson, S. Y., 1999, Well stratigraphy and correlations, western Washington and northwestern Oregon: U.S. Geological Survey Geologic Investigations Series Map I-2621, 3 sheets, with 31 p. text.
- Rau, W. W.; McFarland, C. R., 1982, Coastal wells of Washington: Washington Division of Geology and Earth Resources Report of Investigations 26, 4 sheets.
- Rau, W. W.; Plafker, George; Winkler, G. R., 1977, Preliminary foraminiferal biostratigraphy and correlation of selected stratigraphic sections and wells in the Gulf of Alaska Tertiary province: U.S. Geological Survey Open-File Report OF-77-747, 54 p., 3 plates, scale 1:4,400,000.
- Rau, W. W.; Plafker, George; Winkler, G. R., 1978, Foraminiferal biostratigraphy in Gulf of Alaska Tertiary province: American Association of Petroleum Geologists Bulletin, v. 62, no. 11, Part 1, p. 2360.
- Rau, W. W.; Plafker, George; Winkler, G. R., 1978, Foraminiferal biostratigraphy in the Gulf of Alaska Tertiary province. In Hill, F. L.; Wilkinson, E. R.; Schneider, R. H., coordinators, Energy exploration and politics; Pre-prints: California Division of Oil and Gas, 2 p.
- Rau, W. W.; Plafker, George; Winkler, G. R., 1978, Foraminiferal biostratigraphy in Gulf of Alaska Tertiary province. In Ikebe, N., chairperson, Correlation of tropical through high latitude marine Neogene deposits of the Pacific Basin: Stanford University Publications Geological Sciences 14, p. 45-46.
- Rau, W. W.; Plafker, George; Winkler, G. R., 1983, Foraminiferal biostratigraphy and correlations in the Gulf of Alaska Tertiary province: U.S. Geological Survey Oil and Gas Investigations Chart OC-120, 1 sheet, scale 1:4,224,000, 11 p. text.
- Rau, W. W.; Wagner, H. C., 1974, Oil and gas in Washington. In Washington Division of Geology and Earth Resources, Energy resources of Washington: Washington Division of Geology and Earth Resources Information Circular 50, p. 63-81.
- Snively, P. D., Jr.; Brown, R. D., Jr.; Roberts, A. E.; Rau, W. W., 1958, Geology and coal resources of the Centralia-Chehalis district, Washington, with a section on Microscopical character of Centralia-Chehalis coal, by J. M. Schopf: U.S. Geological Survey Bulletin 1053, 159 p., 6 plates.
- Snively, P. D., Jr.; Brown, R. D., Jr.; Roberts, A. E.; Rau, W. W.; Hoover, Linn, Jr.; Pease, M. H., Jr., 1954, Geology and coal resources of the Centralia-Chehalis district, Lewis and Thurston Counties, Washington: Science, v. 119, no. 3091, p. 419-420.
- Snively, P. D., Jr.; MacLeod, N. S.; Niem, A. R.; with Minasian, D. L.; Pearl, J. E.; Rau, W. W., 1993, Geologic map of the Cape Flattery, Clallam Bay, Ozette Lake, and Lake Pleasant quadrangles, northwestern Olympic Peninsula, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1946, 1 sheet, scale 1:48,000.
- Snively, P. D., Jr.; MacLeod, N. S.; Rau, W. W., 1969, Geology of the Newport area, Oregon; Part 1, field trip guidebook—Geological Society of America, Cordilleran Section, 65th Annual Meeting: The Ore Bin, v. 31, no. 2, p. 25-48.
- Snively, P. D., Jr.; MacLeod, N. S.; Rau, W. W., 1969, Geology of the Newport area, Oregon; Part 2, field trip guidebook—Geological Society of America, Cordilleran Section, 65th Annual Meeting: The Ore Bin, v. 31, no. 3, p. 49-71.
- Snively, P. D., Jr.; MacLeod, N. S.; Rau, W. W., 1975, Alsea Formation—An Oligocene marine sedimentary sequence in the Oregon Coast Range: U.S. Geological Survey Bulletin 1395-F, 21 p.
- Snively, P. D., Jr.; MacLeod, N. S.; Wagner, H. C.; Rau, W. W., 1976, Geologic map of the Cape Foulweather and Euchre Mountain quadrangles, Lincoln County, Oregon: U.S. Geological Survey Miscellaneous Investigations Series I-868, 1 sheet, scale 1:62,500.
- Snively, P. D., Jr.; MacLeod, N. S.; Wagner, H. C.; Rau, W. W., 1976, Geologic map of the Waldport and Tidewater quadrangles, Lincoln, Lane, and Benton Counties, Oregon: U.S. Geological Survey Miscellaneous Investigations Series I-866, 1 sheet, scale 1:62,500.
- Snively, P. D., Jr.; MacLeod, N. S.; Wagner, H. C.; Rau, W. W., 1976, Geologic map of the Yaquina and Toledo quadrangles, Lincoln County, Oregon: U.S. Geological Survey Miscellaneous Investigations Series I-867, 1 sheet, scale 1:62,500.
- Snively, P. D., Jr.; Niem, A. R.; MacLeod, N. S.; Pearl, J. E.; Rau, W. W., 1979, Makah Formation—A deep marginal basin sedimentary sequence of late Eocene and Oligocene age in the northwestern Olympic Peninsula, Washington: U.S. Geological Survey Open-File Report 79-581, 75 p.
- Snively, P. D., Jr.; Niem, A. R.; MacLeod, N. S.; Pearl, J. E.; Rau, W. W., 1980, Makah Formation—A deep-marginal-basin sequence of late Eocene and Oligocene age in the northwestern Olympic Peninsula, Washington: U.S. Geological Survey Professional Paper 1162-B, 28 p.
- Snively, P. D., Jr.; Rau, W. W.; Hafley, D. J., 1986, Tertiary foraminiferal localities in the Cape Flattery area, northwestern Olympic Peninsula, Washington: U.S. Geological Survey Open-File Report 86344A, 18 p.
- Snively, P. D., Jr.; Rau, W. W.; Hoover, Linn, Jr.; Roberts, A. E., 1951, McIntosh Formation, Centralia-Chehalis coal district, Washington: American Association of Petroleum Geologists Bulletin, v. 35, no. 5, p. 1052-1061.
- Snively, P. D., Jr.; Rau, W. W.; Hoover, Linn, Jr.; Roberts, A. E., 1959, McIntosh Formation, Centralia-Chehalis coal district, Washington. In Washington Division of Mines and Geology, Tertiary stratigraphic papers, southwestern Washington: Washington Division of Mines and Geology Reprint 3, 10 p.
- Snively, P. D., Jr.; Rau, W. W.; Wagner, H. C., 1964, Miocene stratigraphy of the Yaquina Bay area, Newport, Oregon: The Ore Bin, v. 26, no. 8, p. 133-151.
- Snively, P. D., Jr.; Wagner, H. C.; Rau, W. W., 1982, Sections showing biostratigraphy and correlation of Tertiary rocks penetrated in wells drilled on the southern Oregon continental margin: U.S. Geological Survey Miscellaneous Field Studies Map MF-1482, 1 sheet.
- Snively, P. D., Jr.; Wagner, H. C.; Rau, W. W.; Bukry, David, 1981, Correlation of Tertiary rocks penetrated in wells drilled on the southern Oregon continental margin: U.S. Geological Survey Open-File Report 81-1351, 21 p.
- Snively, P. D., Jr.; Wagner, H. C.; Rau, W. W.; Bukry, David, 1981, Geology cross section of southern Oregon Coast Range and adjacent continental shelf: U.S. Geological Survey Open-File Report 81-957, 1 sheet. ■