LOCATION AND AGE OF FORAMINIFER SAMPLES COLLECTED BY CHEVRON PETROLEUM GEOLOGISTS IN CALIFORNIA

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1 INTRODUCTION AND BACKGROUND

1.1 Need for information

Most of the geologic maps published for parts of central California in the past century have been made without the benefit of ages from microfossils. The ages of Jurassic, Cretaceous and Tertiary rocks in the mostly poorly exposed and structurally complex sedimentary rocks represented in the Coast Ranges are critical in determining stratigraphic succession or lack of it, and in determining whether the juxtaposition of similar appearing but different age formations means that a fault is present. Since the 1940's, at least, oil company geologists have used microfossils to assist them in geologic mapping and in determining the environments of deposition of the sedimentary rocks containing them. This information had been so confidential that even the names of species were coded by some paleontologists to prevent disclosure. In the past 20 years, however, the attitude of petroleum companies about this information has changed, and many of the formerly confidential materials and reports are now available. We report here on an estimated 50,000 Chevron foraminifer samples from surface localities in more than 600 U.S. Geological Survey 7.5' quadrangles in California. Ages are provided for more than 27,000 of these samples which have been donated by Chevron, along with locality maps, paleontology reports, and other data, to the California Academy of Sciences. To our knowledge, this collection is the largest ever released to the public by a petroleum company for the West Coast. The information from the slides can be used to update geologic maps prepared without the benefit of microfossils, to study foraminifers of Jurassic, Cretaceous and Tertiary age collected from a variety of geologic environments, to analyze the depth and temperature of ocean water covering parts of California during these periods, and for solving nomenclature and other scientific problems.

1.2 Need for revision

Unfortunately, the first release of this information by Brabb and Parker (2003) had many errors and was restricted to Chevron foraminifer samples with slides donated to the California Academy of Sciences (CAS). Chevron had ages of thousands of additional samples and other information that were not included. Hundreds of samples with an obsolete numbering system were put in a separate database (#5) where they could be overlooked. Thousands of barren and non-diagnostic samples and samples without paleontologic (hereafter abbreviated to paleo) information were interspersed with dated samples, making the files exceedingly large and difficult to use. Finally, the ages provided by Chevron were not in accord with the North American Code of Stratigraphic Nomenclature, and modern correlation standards.

1.3 Revision of April 15, 2005

Nearly all of the errors, omissions, and problems mentioned above are solved in version 2.0. Specifically:

Samples that have no slides but do have a Chevron age have been added to revised databases #1 and #2. Barren and non-diagnostic samples and samples without paleo data have been removed from #1 and #2 and put in database #3, greatly reducing the size of #1 and #2 and making the files easier to use. Errors in databases #1 and #2 have been corrected, and database #2 is now simply a sort of #1 to provide access to the numbers by quadrangle name. The age of all samples has been revised to be more in accordance with the North American Stratigraphic Code and more modern correlations. Many Chevron ages from nannoplankton and some from mollusks, diatoms, pollen, and other fossils have been added. The location and age of samples with an obsolete numbering system and from obsolete quadrangles, formerly in database # 5, have been moved into #1 and # 2.

Database #3 now provides at least some information for every Chevron locality number in every quadrangle. This database was used extensively to find slides and paleo reports that have no definitive locality data. Note that any number might be found in as many as seven quadrangles, partly because

Chevron labs in different districts used the same (and therefore duplicate) numbering system, and partly because some lot numbers extended into several quadrangles. Note also that all sub-lot numbers have been eliminated in order to reduce the size of the database and increase its' usefulness.

Database #4 was changed to show the number of localities in a quadrangle if no slides had been prepared. Several errors were corrected and a few quadrangles were added to bring the total to 616.

Database # 5 now provides location data for the porosity, permeability, density, sorting, and magnetic susceptibility of 750 samples. A few potassium-argon dates are also included.

A separate report (Brabb and others, 2001) provides a database summary of thousands of Chevron slides from selected oil wells in northern California. Chevron slides for oil wells in southern California, and for surface samples and oil wells in Oregon, Washington, and offshore areas have not been arranged in a database.

2 INITIAL ORGANIZATION OF THE CHEVRON MATERIAL

2.1 Separation of the slides

The first formidable task was to separate the estimated 80,000 foraminifer slides into piles organized by state, surface or subsurface sample, by slide number for surface sample, and by county for well sample. Unfortunately, the numbering system varies for many slides, from Roman numerals to Arabic numbers, and combinations of letters and numbers. The only consistent number on the back of nearly every slide indicated the drawer and cabinet numbers where the slide was stored in Houston; those cabinets have since been discarded. Many slides have no geographic information, and others have no numbers to indicate whether or not the slides are from surface localities or wells. A digital print was provided by Chevron to accompany the slides, but the information for most of the wells and surface localities was different from the information on the slides.

2.2 Putting the slides in numerical order

Once the apparent surface samples for California were segregated, the next task was to put them in numerical order. This task was made difficult by the fact that perhaps half the slides (and maps and paleo reports) have Roman numerals to identify the localities. The Roman numerals on every slide, map, and paleo report had to be converted to Arabic numerals. Another difficulty is that most of the slides have two numbers, a lot number that was assigned for an area, and a sub-lot number or letter that was assigned for a specific sample within the area. Identification of the principal number and the sub-lot number was not consistent on many slides. Some lots have hundreds of sub-lot samples. Other slides have numbers that correspond to number of feet along a seismic line. Still another, and almost devastating problem, is that at least two Chevron laboratories used the same numbering system, so that a locality number on a slide could be on Chevron maps from two or more areas within California. Chevron data file #3 was designed to cope with this problem by listing the alternatives for localities with the same number.

Another problem with arranging the surface locality slides in numerical order is that samples collected seemingly in the 1930's were assigned letters and numbers within a quadrangle, such as F-4 in the Whitaker Peak quadrangle. Nearly all of those quadrangles are obsolete; some are at 1:125,000-scale, some are 1:62,500-scale, and some are 1:31,250-scale. Locality A-4 in the old Dry Canyon quadrangle, for instance, is in the Canoga Park 7.5' modern quadrangle. Locality H-9 from the old Van Nuys quadrangle is in the Beverly Hills 7.5' modern quadrangle (and not the modern Van Nuys quadrangle). Because of this confusion, because letters are repeated in every quadrangle, and because the letters can also be confused with the lot system described above, these 807 surface localities that have obsolete quadrangle numbers and letters were originally described separately in Chevron data file #5. For revision

2.0, all of the samples with ages were moved into databases #1 and #2, and database 5 was used for other data in revision 2.0.

2.3 Putting the paleo reports in numerical order

The paleo reports, which are now arranged numerically in thirty-five 3-inch thick loose-leaf notebooks, came in a pile 17-feet high of brown folders arranged by topics with numbers from many different quadrangles in the same folder. Each folder had to be disassembled and the reports placed in numerical order so that they could be related to the slides and locality maps. The reports included notes by paleontologists, drafted stratigraphic columns, cross-sections, check lists, and maps with age notations next to locality numbers. Many reports and stratigraphic columns had widely separated locality numbers on the same page, requiring duplication so that copies could be placed in numerical order.

2.4 Putting the maps in alphabetical order

Most of the localities were plotted on obsolete USGS topographic quadrangles at 1:62,500-scale, some were plotted at 1:31,250-, 1:125,000-, and 1:250,000-scale, and others were plotted at 24,000-scale. In order to cope with four 7.5' quadrangles on the 15' maps, the maps were enlarged 200%, split into the four quadrangles, and put in alphabetical order along with the 7.5' maps. Localities from all of the original maps are present in 616 7.5' USGS quadrangles.

3. ADDITIONAL DATA

3.1 Card files

Two 3- x 5-inch card file boxes were among the materials received from Chevron. Each card is for a different locality and each card has on the back a list of the foraminifers identified by a Chevron paleontologist. Some of this information is duplicated in paleo reports, but many of the cards are for slides with no paleo reports. Some cards have a little locality information that was useful in determining where the sample was collected. Some cards have age information. Unfortunately, the card files are only for a limited number of localities in Southern California. One card file, for example, begins with Roman numeral I (1) and ends with DCCI (701). A second and similar card file begins with 1,992 and ends with 42,644, but there are major gaps and missing cards, especially from 10,132 to 42,644.

3.2 Chevron digital file

Some paleo information was provided by Chevron from a proprietary computer file. The fields printed for each locality would have provided virtually all of the information needed for the databases in revision 2.0, but, unfortunately, hardly any of this information was digitized. Perhaps a dozen or two plots provided a little useful information.

4. PROBLEMS WITH DATA SETS

4.1 Tasks to integrate the information

Once the slides and paleo reports were in numerical order and the maps were in alphabetical order, the task of preparing a database indicating the location and age of the samples should have been easy. It was not because many slides lacked geographic information, some had obsolete, incorrect, or misleading quadrangle names, and some localities were never plotted on the maps provided by Chevron. The following examples will illustrate some of the problems and alert the users of the databases that the information is probably as reliable as it can be under the circumstances, but the odds are very high that some data are erroneous!

4.2 Examples of slides with limited or misleading geographic information

Lot 684 with 45 localities illustrates some of the problems in locating slides with little geographic information on the slide or in the paleo report. The slides have “Deep Canyon” as a geographic location, but the USGS Geographic Names Information System (GNIS) for California lists 14 “Deep Canyons” in 12 counties. The mounting frame for the slides has a light tan color characteristic of Miocene and Pliocene slides for Southern California in contrast to slightly darker mounting frames for slides from other areas. Of the four candidates in the GNIS for a “Deep Canyon” in Southern California, only the Dana Point 7.5’ quadrangle has Chevron localities. However, the shortened inventory of locality numbers (Chevron database #3) indicates that locality 684 is also located in the Guinda and Simi Valley East quadrangles, but neither of these has a “Deep Canyon.” Moreover, Lot 684 in the Guinda quadrangle is a single sample, and Lot 684 in the Simi Valley East quadrangle has 8 localities, indicating that the slides are probably not from those areas either. The Dana Point quadrangle does not have Lot 684 but it does have Lot 634 with 45 localities in Deep Canyon. Apparently the Roman Numeral “L” was omitted by mistake from the locality number DCLXXXIV when the lot was plotted on the locality map.

4.4 Examples of slides with obsolete, incorrect, or misleading quadrangle names

Many slides have geographic names or even quadrangle names that are highly misleading. For example, slides for localities 3646 to 3653 have “Arroyo Grande quad” on each slide. The Arroyo Grande 15’ quadrangle consists of the Pismo Beach, Arroyo Grande NE, and Oceano 7.5’ quadrangles. None of the slides are in these quadrangles, but instead are in the Caldwell Mesa, Huasna Peak, and Chimney Canyon 7.5’ quadrangles within the Nipomo and Branch Mountain 15’ quadrangles. Similarly, the slide for locality 2031 is marked “Adelaida quad” but this locality is several miles from the Adelaida quadrangle and is in the Santa Margarita quadrangle.

4.5 Localities missing from maps

An unknown number of localities were never plotted on the Chevron locality maps. If the information in the paleo report or stratigraphic column suggests that the slide is probably in the same quadrangle as a locality with a number nearly in sequence, the quadrangle name on the spread sheet is followed with a question mark and a notation is made that the locality could not be found.

5. PREPARATION OF THE DATA SET

5.1 Determining the location of the samples

After the lessons of slides with obsolete, incorrect, or misleading quadrangle names or limited geographic information were learned, and particularly after the duplication of numbers was discovered, the task of assigning geographic and age information to the correct locality number in the database became overwhelming. Database #3 was made to provide the options for each number and to help to decide where the sample belongs. To prepare the database, every lot or principal number on every map had to be transferred from the map to the database. All of the clues from the slides, paleo reports, 3" x 5" cards, drawer numbers on the back of the slides, plots from Chevron digital files, cross-sections, stratigraphic columns and marginal data on the paleo reports locality maps were used to determine where the slides and paleo data probably belong. Difficulties when geologists from two different regional offices used the same numbers in the same quadrangle were particularly vexing. Some notes about these difficulties are provided in the miscellaneous columns in the databases, but, as noted above, some errors were probably made.

5.2 Determining the age of the samples

The paleo files, which include notes made by paleontologists, check lists, and stratigraphic columns were the main age source for the databases. The ages of the foraminifers follows the zonation of Goudkoff (1942) for the Cretaceous, modified by Berry (1974) for the Early Cretaceous and Jurassic; Laiming (1940) and Schenck and Kleinpell (1936) for the Eocene; and Kleinpell (1938, 1980) for the Oligocene and Miocene (see figs. 1 and 2). All ages are from foraminifers unless stated otherwise. The term "barren" refers only to foraminifers because most barren samples commonly contain diatoms, radiolarians, and other microfossils. The general character of the fauna on some of the slides was checked with the paleo report to help make certain that the slide was correctly located and dated. A notation of abundant planktic foraminifers on the paleo report was especially helpful because these are easily identified on a slide.

Some of the foraminifers used to determine the age of a sample may be in a paleo report but not on the slide. These age determinations may come from casts that did not survive washing. Rubber molds were made of some casts, and some of these are included on the slides and may be mentioned in the paleo data.

5.3 Supplemental sources

A list of species but not an age was provided for several samples in paleo reports, on file cards, on check-lists, and on stratigraphic columns. The range charts of Kleinpell (1938) and Mallory (1959) were consulted to determine the probable age of the sample. If only the formation name was provided, the correlation chart of Weaver and others (1944) was used to determine the possible age.

5.4 Discarded and missing slides

Slides that have no paleo information and could not be found on a locality map were either discarded or given to the Earth Sciences Department at California State University at Long Beach to be used for teaching purposes. Many of these were barren or contained poor faunas.

Sample records and paleo reports indicate that slides were prepared for many samples that were not in the Chevron collection given to the California Academy of Sciences. Presumably these slides are

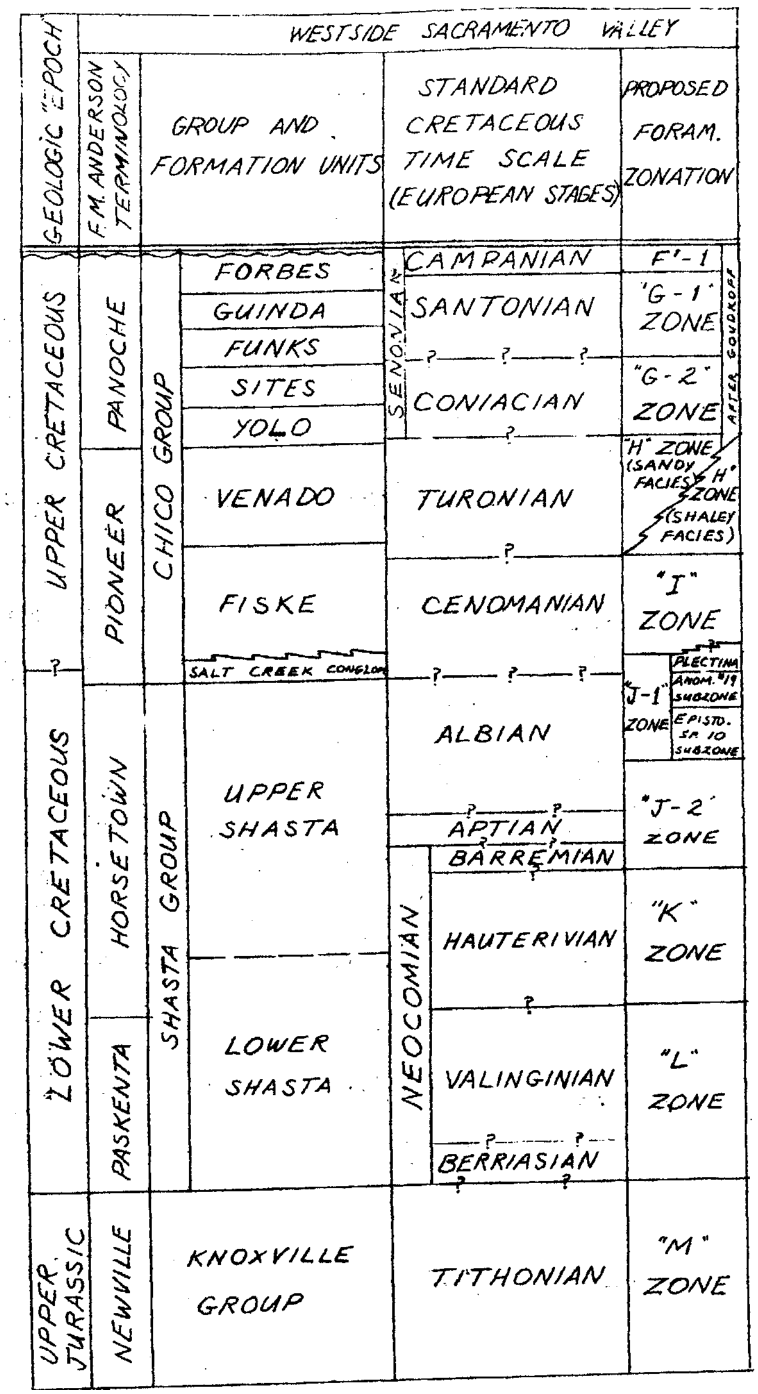

Figure 1. Stratigraphic terminology used by Chevron paleontologists for the Late Jurassic and Cretaceous. Zones F, G, and H are from Goudkoff (1945) and Zones I, J, K, L, and M were defined by Berry (1974). Zones A through E proposed by Goudkoff (1945) are not shown on this chart but were used in Chevron paleontologic reports for the Late Cretaceous.

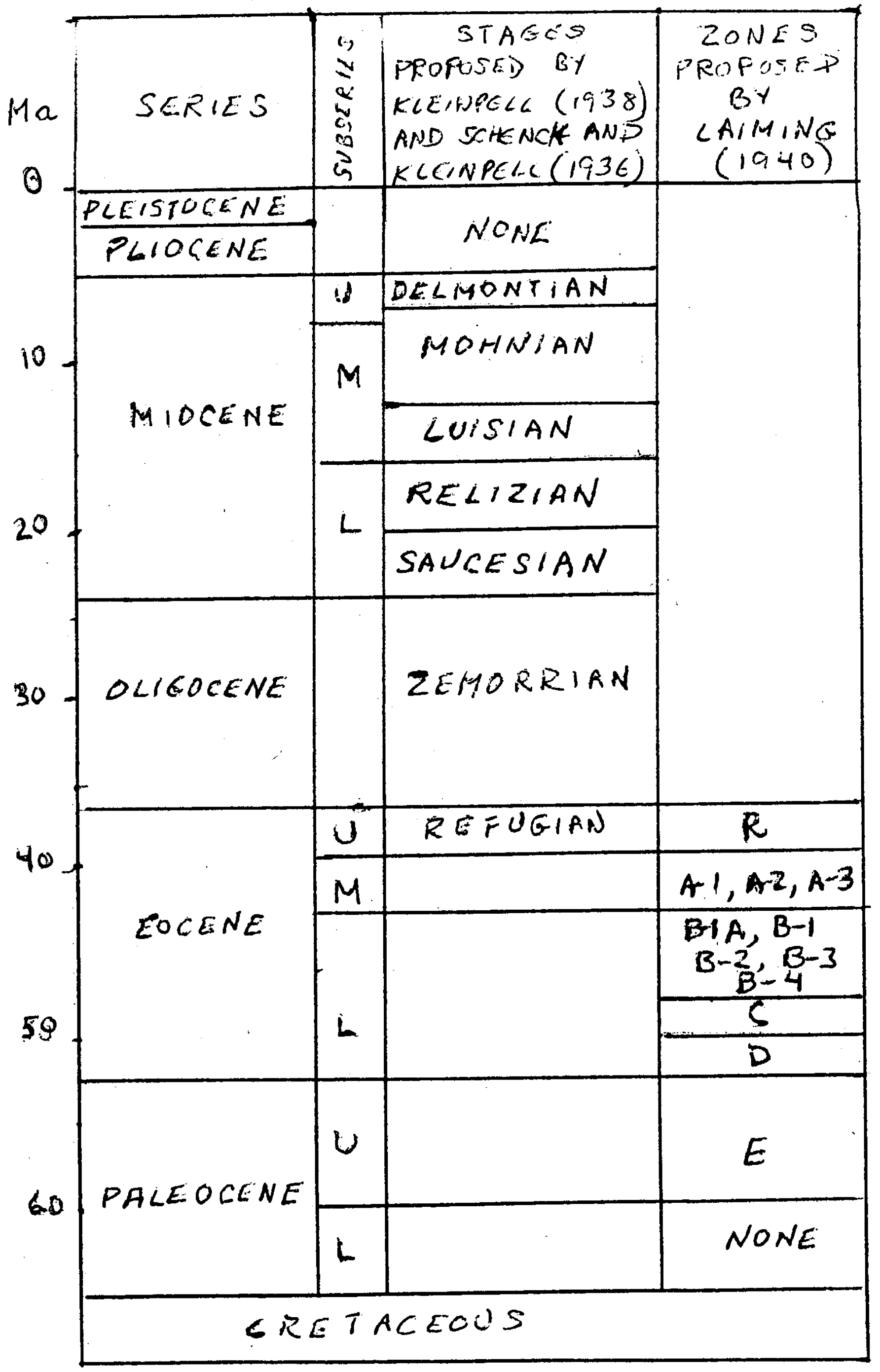

Figure 2. Stratigraphic terminology used in this report for the Cenozoic Era. Stages were defined by Kleinpell (1938) and Schenck and Kleinpell (1936). Zones were defined by Laiming (1940). Series and subseries used for the correlations are arbitrary and are used only to update somewhat the stratigraphic terminology used by Chevron paleontologists. Poore (1980) has pointed out that almost all the Paleogene stages are diachronous with respect to planktic standards. References consulted for this update include Almgren and others (1988), Kleinpell (1980), Prothero (2001), and Brabb (1983).

in regional field offices or have been lost. In general, however, most of the sample numbers on maps that do not have slides were barren, as determined from information in the paleo reports.

6 DESCRIPTION OF THE DATABASES

6.1 Chevron database file # 1 revised

This Excel file contains information for 27,135 Chevron surface localities in California that contain paleo information suitable for the assignment of an age. The database is arranged numerically by locality number. Most of the samples in this file have a slide with foraminifers that has the same number as the one on a locality map.

Column A - The name of the current USGS 7.5' quadrangle where the locality occurs. The original locality map is probably obsolete and may have a different name or a different scale or both.

Column B - Chevron surface locality or lot number. Numbers less than 1100 are generally shown as Roman Numerals on the slides, in the paleo reports, and on the locality maps. Those numerals were converted into Arabic numbers for this report. Many of the numbers are used for lots in a general area, with as many as 600 sub-lot numbers or several letters.

Column C - Sub-lot number or letter or both.

Column D - General geographic location within a quadrangle.

Column E - Number on back of each slide indicating original Chevron cabinet and drawer number.

Columns F and G - Miscellaneous information. May indicate which obsolete USGS map was used by Chevron paleontologists to plot the locality, the name of the geologic unit from which the sample was obtained, fossils that might be of interest to paleo specialists, or whether the paleo file contains a stratigraphic column.

Column H - Zone, stage, series, or age of the foraminifers in the slide. Information may have come from the slide, a separate paleo report, a stratigraphic column, the locality map, or may have been inferred from a list of species on an index card.

6.2 Chevron database #2 revised

This Excel file is the same as for database #1, except that it is sorted by USGS 7.5' quadrangle. This file will be useful to anyone wanting to get information about all of the dated localities in any particular quadrangle.

Column A - The name of the current USGS 7.5' quadrangle where the locality occurs. The original locality map is probably obsolete and may have a different name or a different scale or both.

Column B - Chevron surface locality or lot number. Numbers less than 1100 are generally shown as Roman Numerals on the slides, in the paleo reports, and on the locality maps. Those numerals were converted into Arabic numbers for this report. Many of the numbers are used for lots in a general area, with as many as 600 sub-lot numbers or several letters.

Column C - Sub-lot number or letter or both.

Column D - General geographic location within a quadrangle.

Column E - Number on back of each slide indicating original Chevron cabinet and drawer number.

Columns F and G - Miscellaneous information. May indicate which obsolete USGS map was used by Chevron paleontologists to plot the locality, the name of the geologic unit from which the sample was obtained, fossils that might be of interest to paleo specialists, or whether the paleo file contains a stratigraphic column.

Column H - Zone, stage, series, or age of the foraminifers in the slide. Information may have come from the slide, a separate paleo report, a stratigraphic column, the locality map, or may have been inferred from a list of species on an index card.

6.3 Chevron database #3 revised

This Excel file was made from all of the numbers shown on more than 600 Chevron locality maps primarily to determine which numbers are duplicated

Column A - The California county in which the samples were collected.

Column B - The name of the current USGS 7.5' quadrangle where the locality occurs. The original locality map is probably obsolete and may have a different name or a different scale or both.

Column C - Chevron surface locality and/or lot number.

Column D - Sub-lot number or letter or both within a lot. Only the maximum number of sub-lot samples is provided in order to reduce the size of the database. Blank spaces indicate that only a primary locality number was used.

Column E - General geographic location within a quadrangle.

Column F – A number with a hyphen and a letter is from the back of each slide and indicates the original Chevron cabinet and drawer number. If no slides were prepared for any samples in a quadrangle, the term “no slide” is provided.

Column G – Indicates the status of paleontologic information for each locality. If the sample is barren or not diagnostic, or if no paleontologic information is available, the sample is not listed in databases #1 and #2. If the sample can be dated, the date is provided in databases #1 and #2.

Columns H and I – Provide miscellaneous notes on the availability of a stratigraphic column or check list, samples with abundant planktic foraminifers, nannoplankton, and diatoms, the presence of fossils of particular stratigraphic interest, such as Discocyclina, Globotruncana, and Turritella, the availablility of physical or chemical information (see database #5 for specific information), a cross-reference with a locality number where data can be found if the number is quite different, area designations used by Chevron (E-2, K-1 etc.), and notes relevant to how the sample was collected, such as in a trench or by auger.

6.4 Chevron database # 4 revised

This Excel file is greatly abbreviated from database #2 and is intended to show which USGS quadrangles have locality numbers, which ones have foraminifer slides, the number of samples in a quadrangle if no slide has been prepared, and the name of obsolete USGS quadrangles on which the localities may have originally been plotted.

Column A - The county in which the samples were collected.

Column B - The name of the current USGS quadrangle where the locality occurs. The original locality map may have a different name or a different scale or both.

Column C - Number on back of each slide indicates original Chevron cabinet and drawer number. A number with a hyphen and letter in this column indicates that at least one foraminifer slide was received from Chevron. A number without a letter and hyphen indicates the total number of localities in the quadrangle

Column D - Name of at least one of the obsolete maps on which localities were originally plotted. If no name is provided, the localities were plotted on USGS 7.5' quadrangles.

6.5 Chevron database #5 revised

This Excel file indicates which localities have information on the porosity, permeability and density of the rocks at that locality, plus other chemical and physical information stored among the notes on paleo provided to the California Academy of Sciences.

Column A - The California county in which the sample was collected.

Column B - The name of the current USGS 7.5' quadrangle where the locality occurs. The original Chevron locality map may have a different name or a different scale or both.

Column C - Chevron surface locality or lot number.

Column D – Sub-lot number or letter.

Column E – General location of the locality within the quadrangle.

Column F – Notes indicating the physical or chemical information available in the paleo file provided to the California Academy of Sciences.

Column G - Miscellaneous information, including the lithology of the sample, if provided by Chevron, and where the information about a locality is stored if the number is significantly different.

7. HOW TO USE THE INFORMATION

Two scenarios are provided to speculate about how various users might most efficiently use the databases:

7.1 Scenario for geologist making or revising a geologic map

The geologist should go first to database #4 to determine if Chevron has localities in the map of interest. If localities are present, the quadrangle should be located alphabetically in database #2. All of the information about the localities is summarized. If slides were provided, the slides could be borrowed from the California Academy of Sciences to determine if a modern interpretation of the age would be different from the one inferred by Chevron.

7.2 Scenario for a micropaleontologist specializing in foraminifers

Database #1 could be sorted to provide the ages of foraminifers of interest. Notes in the database provide clues about the quality of the faunas. Arenaceous faunas are probably of little interest to those who work with calcareous faunas, and the samples with planktic assemblages probably have the most complete faunas. The presence of slides generally indicates that the faunas were good enough to date. Slides could be borrowed from the California Academy of Science (CAS)s to determine if additional field sampling might be of value. The locality maps could be consulted in the USGS Library, Menlo Park, or at the CAS to determine exactly where the microfossils were collected. Paleo notes at CAS could also be examined to determine if additional and useful information is contained in the notes but not reported in the databases.

8. SUMMARY

The age of more than 6000 surface samples collected by Chevron geologists has been added to the original database file #1, and information for many of the original samples has been added or corrected. The total number of dated samples now exceeds 27,000. The status of paleo information for every Chevron surface locality sample shown on more than 600 USGS 7.5' quadrangle maps has been added to database file #3, along with new information on porosity, permeability, density, magnetic susceptibility, K-Ar age, and other physical and chemical data in database #5. An estimated 10,000 foraminifer slides, including many reference slides for foraminifer species, are available from the California Academy of Sciences for additional study. This amount of new and previously confidential information is unprecedented, and will hopefully stimulate new interest in correcting geologic map information for much of California.

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10. REFERENCES

Almgren, A. A., Filewicz, M. V., and Heitman, H. L., 1988, Lower Tertiary foraminiferal and calcareous nannoplankton zonation of California – an overview and recommendations *in* Filewicz, M. V., and Squires, R. L., eds., Paleogene stratigraphy, West Coast of North America, Society of Economic Paleontologists, Pacific Section, v. 58, p. 83-105.

Berry, K. D., 1974, Mesozoic foraminiferal zonation, Turonian to Tithonian stages, Pacific Coast Province: Society of Economic Paleontologists, Pacific Section, Proceedings, p. 1-24.

Brabb, E. E., ed., 1983, Studies in Tertiary stratigraphy of the California Coast Ranges: U. S. Geological Survey Professional Paper 1213, 93p.

Brabb, E. E., Powell, Charles II, and Brocher, T. M., 2001, Preliminary compilation of data for selected oil test wells in Northern California: U. S. Geological Survey Open File Report 01-152, 310 p.
Brabb, E. E., and Parker, J. M., 2003, Location and age of foraminifer samples collected by Chevron petroleum geologists in California: U. S. Geological Survey Open File Report 03-167.
Goudkoff, O. S., 1945, Stratigraphic relations of the Upper Cretaceous in the Great Valley of California: American Association of Petroleum Geologists Bulletin, v. 29, pp. 956-1007.
Kleinpell, R. M., 1938, Miocene stratigraphy of California: Tulsa, OK, American Association of Petroleum Geologists, 450 p.
Kleinpell, R. M., 1980, The Miocene stratigraphy of California revisited: Tulsa, OK, American Association of Petroleum Geologists, 349 p.
Laiming, Boris, 1940, Some foraminiferal correlations in the Eocene of San Joaquin Valley, California: Sixth Pacific Science Congress Proceedings, p. 535-568.
Mallory, V. S., 1959, Lower Tertiary stratigraphy of the California Coast Ranges: Tulsa, OK, American Association of Petroleum Geologists, 416 p.
Poore, R. Z., 1980, Age and correlation of California Paleogene benthic foraminiferal stages: U. S. Geological Survey Professional Paper 1162-C, 8p.
Prothero, D. R., ed., 2001, Magnetic stratigraphy of the Pacific Coast Cenozoic: Pacific Section Society of Economic Paleontologists, Pacific Section, Book 91, 394p.
Schenck, H. G., and Kleinpell, R. M., 1936, Refugian State of the West Coast Tertiary: American Association of Petroleum Geologists Bulletin, v. 30, no. 2, p. 215-225.
Weaver, C. E., and others, 1944, Correlation of the marine Cenozoic formations of western North America: Geological Society of America Bulletin, v. 55, pp. 569-598.