An Historical Review of the Age Assignments

Applied To the Chalk Bluff Fossil Plants,

Central Sierra Nevada, California

Howard E. Schorn (2012)

You Bet or Chalk Bluff Diggings

Standing on the northwest lip of the hydraulic pit at~39.2100N, 120.8950W at ~2920 feet (890m) elevation. View looking NE between Chalk Bluff Hill (just right of center) and Chalk Bluff Ridge (larger hill left of center).

Chalk Bluff Hill is an outlier of Chalk Bluff Ridge to the north-northeast of the hill. In this photograph the Hill is about 3/4 mile (3960′, 1207m) distant from the point of view. Both Hill and Ridge are capped by ±150′ (45m) of andesitic rocks of the Miocene Mehrten Formation. In descending order below the Mehrten is ~250′ (75m) the light-colored Oligocene rhyolitic ash-flow tuffs and some ~150′ (45m) of light-colored biotite sands. These two light-colored units form Chalk Bluff. The biotite sands rest on the older channel deposits of the Auriferous Gravels. In this area the Auriferous Gravels is about 350′ (105m) thick. Fossil leaves, seeds, fruits, etc. occur in the upper ~150′ (45m) of the Auriferous Gravel unit. The lower horizontal light-colored strip

at mid-photograph, with trees on top that hide the Chalk Bluff Road, is the north wall of the hydraulic pit. Information estimated and modified from MacGinitie, 1941, p.19.

Introductory Statement

In my opinion, the 2005 paper by L.J. Garside, C.D. Henry, J.E. Faulds and N.H. Hinz is already, or certainly will become, a classic paper regarding the ancient river channels and their deposits in the Northern Sierra Nevada Mountains of California. These authors (p. 7), in what might almost seem as an understatement, but what is a very fundamental observation, state that "The paucity of modern age determinations on the Auriferous Gravels limits our present understanding of the unit." Their statement emphasizes the important need for a number of new dates derived from this complex of channel deposits. When we consider the histories of these long-lived, sinuous, once mobile ribbons of fluvial sediments and fossils, now often broken by subsequent erosion, or hidden by burial beneath younger deposits, it becomes clear that the continuous addition of new dates will greatly aid workers in viewing these ancient systems as a set of more dynamic, continually changing systems, each unique, but integrated into a whole because of their regional setting. An example of the lithologic associations and the length of time it took for their development is illustrated by a portion of the channel in the area centered at Oroville South Table Mountain. In the Oroville area, in ~2mi^2 (~5km^2) and some 300-400' (90-129m) of stratigraphic section, this area has basal sites with marine megainvertebrate localities of Eocene Capay Age, ~52-49Ma. A younger dated horizon is the ~25Ma old Oroville andesite tuffs. These earlier units are capped by the widespread, flat-topped tablelands of the ~16Ma Lovejoy Basalt. Also, within this same drainage channel, but at the more proximal location of Moonlight (~80mi 130k east of Oroville), Lovelock *et al*. (2010) record a detrital zircon date of ~35Ma. None of these Northern Sierra channels and their lithologic and/or fossil associations appears to be of only a single uniform age throughout. This attribute has been recognized since the earliest workers in the area, and yet, probably because of their complex nature, and surely because they are so sparsely dated, the channels are often treated more simplistically as if they were of uniform age throughout.

Early workers such as Lesquereux (1878), Knowlton (1911) assigned the fossil plants found in these channel deposits to the Neocene, that is, younger than the Eocene. Others, *i.e.*, Chaney (1933) recognized the plants were Eocene.

MacGinitie (1941) was the first to assign a specific Eocene age to the Chalk Bluff flora. He utilized the area in the vicinity of Oroville North and South Table mountains to determine the age of the fossils. In this fairly restricted area three significant geologic units are present in close proximity, 1) the basal marine beds ("Dry Creek" formation) bearing a megainvertebrate fauna of Capay Age, 2) the

continental leaf-bearing Auriferous Gravels, and 3) the Ione Formation in the sense of Allen (1929). Such favorable physical relationships make this area one of the better locations to determine both the geologic relations of the rock units, and to assign an age to the fossil plants that occur in the continental leaf-bearing Auriferous Gravels. These Oroville sites occur in the ancient Buckeye-Bear Hill Channel (Garside *et al.*, 2005). In discussing the age of the fossil plants, MacGinitie (p 23) first notes that "Although the relations are somewhat obscure, it appears certain the Capay Stage fauna from the vicinity of Oroville occurs in beds just underlying the Ione." That is, in the Dry Creek formation of Allen (1929).

MacGinitie (p. 82) continued his discussion regarding the age of the Chalk Bluff flora by directing his discussion away from the Oroville area to the Chalk Bluff area, a distance of some 45 air miles (70km) to the southeast, and into deposits of the ancestral Yuba River Drainage (Garside *et al*., 2005). From his work in the Oroville area MacGinitie incorrectly concluded that the Capay fauna occurs in beds equivalent to the Ione Formation. Then, because it was commonly accepted that the Ione in turn was equivalent to the plant-bearing Auriferous Gravels, it was valid for MacGinitie to conclude that (p.82) "… the Chalk Bluff flora is preserved in the continental facies of the Ione Formation. Its age is therefore lower Middle Eocene, on the basis of the Capay invertebrate fauna." MacGinitie clearly indicates his assignment of the Ione Formation and the Chalk Bluff flora to a Capay Age, as presented by their stratigraphic position in his Table 1, on p. 28.

Hence, the beginning of the use of the Capay age assignment for the Chalk Bluff plants. Note that at the date of MacGinitie's publication in 1941 the Capay Stage was correlated with the lower Claiborne of the Gulf Coast and the Ypresian Stage of the Paris Basin. In 1941 the Ypresian Stage was still considered middle, not lower, Eocene (see Wood, et *al.,* 1942).

Greely (1965) mapped the geology of the Oroville 1944 edition, 15' topographic quadrangle. He recognized that the name Dry Creek of Allen (1929) was preoccupied so he used it in a quotational sense. He also recognized that although the Capay marine fauna does come from the "Dry Creek" Formation that underlies the Ione, he specifically emphasized that (p. 47), "… the age of the strata at South Table Mountain are directly applicable to the "Dry Creek" beds, *but not to the Ione strata which overly them*." [italics mine] Greely's work, on geologic evidence, contradicts MacGinitie's age assignments.

Adherence to the Capay age for the Chalk Bluff flora and it equivalents, or purported equivalents, has resulted in some spurious conclusions. Such examples are briefly outlined here, beginning with MacGinitie (Mac), and

followed by Wolfe, (1961-1998); Wing and Greenwood, 1993; and Hren, Pagani, Erwin, and Brandon, 2010. Please note that I consider these people my mentors, teachers, colleagues and friends. Their contributions are used here to show how the lack of accurately dated floras, and the continued use of a Capay age for the plant-bearing beds, has resulted in misinterpretations of the timing of events.

Wolfe 1961-1998. Wolfe began study of the fossil plants from the Puget Group in 1960. He and others published a brief account the following year [**1961. Wolfe, J.A., Gower, H.D. and Vine, J.D. 1961**. Age and correlation of the Puget Group, King County, Washington. U.S.G.S. Professional Paper 224-C, p. C230-C232. [(Not seen).] This paper was followed by a more complete geologic/stratigraphic account by Vine, [**1962. Vine, J.D. 1962**. Stratigraphy of Eocene rocks in a part of King County, Washington. State of Washington, Department of Conservation, Division of Mines and Geology, Report of Investigations No. 21, 20 pp.

http://www.dnr.wa.gov/publications/ger_ri21_strat_eocene_king_co.pdf

In this study Vine recognized some 14,250 feet (4343.4m) of section in the Puget Group. Wolfe (1961) provided the preliminary identifications of the fossil leaves from the Raging River (3,000') and Tiger Mountain (2,000') formations. The leaves from these two formation are shown in tabular arrangement on pages 13 (Tiger Mountain) and 15 (Tukwila Formation) respectively.

Wolfe continued his study of the Puget Group fossil plants and set up formal time-stratigraphic units. **1968. Wolfe, J.A. 1968.** Paleogene biostratraphy of nonmarine rocks in King County, Washington. U.S.G.S. Professional Paper 571, 37 pp.

http://pubs.usgs.gov/pp/0571/report.pdf

Of primary concern for the present review is his recognition of a new unit that he designated as the Franklinian. Based on the plant species present, Wolfe correlated (pages 6 and 7) this newly established Franklinian Stage with the Chalk Bluff flora of MacGinitie, and as such, he considered Chalk Bluff flora to be equivalent to some part to the Capay Stage, presently considered approximately ~49-53 Ma (~Eocene Climatic Optimum).

The Franklinian age assignment was subsequently questioned by Turner *et al.*, 1983. **1983. Turner, D.L., Frizzell, V.A., Triplehorn, D.M. and Naeser, C.W. 1983.** Radiometric dating of ash partings coal of the Eocene Puget Group, Washington: Implications for paleobotanical stages. Geology 11(9):527-531.
http://geology.geoscienceworld.org/cgi/content/abstract/11/9/527

These authors provide KAr dates that are all younger than Capay Age.

1994. Burnham, R.J. 1994. Paleoecological and floristic heterogeneity in the plant-fossil record---An analysis based on the Eocene of Washington. U.S. Geological Survey Bulletin 2085-B.

http://pubs.usgs.gov/bul/2085b/report.pdf

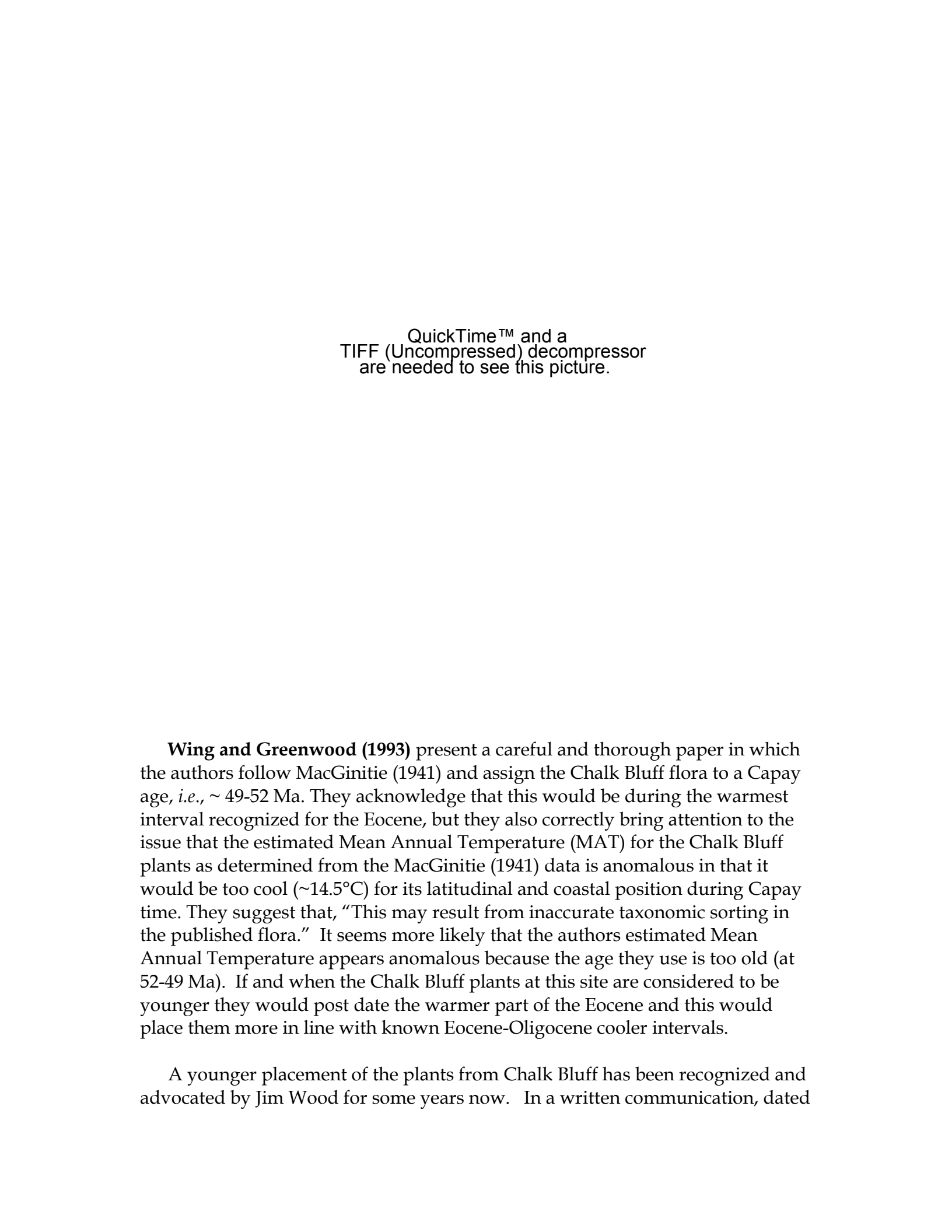
Burnham provides a through review of the consequences of the Turner *et al*, radiometric dates of the Franklinian.

1998. Wolfe, *et al*., 1998; GSA Bull. 110(5):667 fig. 5
http://www.colorado.edu/GeolSci/faculty/molnarpdf/1998GSAB.Wolfe.Palo-elevations.pdf

The authors suggest that the discrepancy between their and Turner *et al*. age assignment is because the dates by Turner *et al*. had been thermally reset at ~43 Ma. As far as I can determine, this review presents the current status of the Puget Group plants referred to the Franklinian Stage. With the death of Jack Wolfe in 2005 much of the activity on the Puget Group plants has declined.

The following figures are Figure 5 and Figure 6 from Wolfe *et al*., 1998.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.



Wing and Greenwood (1993) present a careful and thorough paper in which the authors follow MacGinitie (1941) and assign the Chalk Bluff flora to a Capay age, *i.e.*, ~ 49-52 Ma. They acknowledge that this would be during the warmest interval recognized for the Eocene, but they also correctly bring attention to the issue that the estimated Mean Annual Temperature (MAT) for the Chalk Bluff plants as determined from the MacGinitie (1941) data is anomalous in that it would be too cool (~14.5°C) for its latitudinal and coastal position during Capay time. They suggest that, "This may result from inaccurate taxonomic sorting in the published flora." It seems more likely that the authors estimated Mean Annual Temperature appears anomalous because the age they use is too old (at 52-49 Ma). If and when the Chalk Bluff plants at this site are considered to be younger they would post date the warmer part of the Eocene and this would place them more in line with known Eocene-Oligocene cooler intervals.

A younger placement of the plants from Chalk Bluff has been recognized and advocated by Jim Wood for some years now. In a written communication, dated

2 May 2011, he discusses plant fossils from the You Bet /Chalk Bluff Diggings (~39.21N, 120.88W) and states: "The implications of this important leaf horizon, ie., Chalk Bluff Flora, is that it lies within the smectitic Upper Gravel or Unit stratigraphy; therefore, the leaf horizon is not in the kaolinitic Ione Lower Unit (50 Ma) as some of the proponents of Eocene Sierran uplift assume; but is actually 31 to 32 Ma based on the Ar/Ar age dates of the tuff beds embedded in this smectitic Upper Unit section per Chris [Chris D. Henry, Nevada Bureau of Mines]. So, the "paratropical" climatic regimen that the floral assemblage denotes was that of the prevailing Late Eocene to Early Oligocene climate at 35Ma to 30Ma and not because it was at a higher elevation at 50Ma."

As Wood indicates in his letter, the fossil site is stratigraphically closer to, or part of, the Upper Unit's smectitic 'biotite sands', and not the older kaolinitic Ione (see the diagram on page 19 of MacGinitie). The apparent anomalous Mean Annual Temperature (~14.5°C) is too cool for a 49-52 Ma flora, but fits better in to the Late Eocene/Early Oligocene. Once again, as cautioned by Garside *et al*., 2005, we see the results of the lack of adequate dates for so much of the Auriferous Gravels.

Hren et al. (2010) use the time interval from 52-49 Ma in their discussion. The time interval used by these authors corresponds to the Capay Age. Following Ogg *et al.* (2008), this is the later half of the Ypresian, or early Eocene. The interval would be approximately equivalent to the marine planktonic foraminifera zones P7-P9, part of calcareous nannoplankton zones CP9, CP10-CP11, and ~the first half of zone CP12. The time interval used by Hren *et al.* is based on the Chalk Bluff plants. They assert that the "Plant fossils are classified as Chalk Bluff Flora after their best-preserved occurrence, *and are dated at 52-49 Ma by faunal and floral correlation* (MacGinitie 1941; Wing and Greenwood, 1993)." Italics mine. Based on these conclusions, Hren. *et al*. asserted they had obtained "… well-constrained early Eocene (52-49 Ma) organic geochemical data that record range-scale and channel paleoelevations and provide an indication of early Sierra Nevada relief." This example, once again, illustrates the problem created by the lack of adequate age control in these channel deposits (see Garside *et al*. p. 7, 2005). By accepting MacGinitie's, 1941 Capay Age, which is incorrect, and by further inferring that all the samples they used are contemporaneous, which is considered suspect, their conclusions are questionable. Their appended data, (Table 1), is also somewhat confusing. For example: their use of the You Bet 2 and Chalk Buff E localities. Their data indicates that these two sites plot within <1/2 mi apart, and are separated topographically by ~400 ft. They list the You Bet 2 locality as having an Eocene elevation of 1634 and an Eocene temperature of 15.1°C, and the Chalk Bluff E site as Eocene elevation 1246 and Eocene temperature as 20.1. When it is considered that a difference of approximately 400 ft in elevation of two closely (< 1/2mi) situated floras would not result in a difference of 5°C; but that a difference in both age and

global/regional climatic temperature would.

The purpose of the present review is to provide information that shows that the Capay invertebrate fauna as referenced by MacGinitie (1941) is from the areas of Sutter Buttes and South Table Mountain, California. In those two areas the Capay fossils occur in the "Dry Creek" formation of Allen (1929) that disconformably underlies the plant-bearing beds of the Ione Formation (Greely, 1965), and that the Ione is considered to be equivalent to the Auriferous Gravels. We need to discontinue assigning the fossil plants at Chalk Bluff to a Capay age, and recognize their age is younger. How much of an age difference is present in each specific location, needs to be verified by further radioisotopic dating.

This review is an outline of the historical development of the ideas that have led to our present understanding regarding the age of the Chalk Bluff fossil flora.

Each direct and related topic is linked to an electronic publication, where available. If not, each reference is bibliographically complete.

I wish to acknowledge all the people who over these many, many years have taken part in this aspect of West Coast geology/paleobotany, but the list is very, very long, so I will just deeply thank all these people, and restrict my sincere thanks to two people who have continually helped me by keeping my interest alive, by sharing ideas, presenting questions, or just generally kept pushing me into getting something down on paper that relates to the paleobotanical age calls for the Chalk Bluff fossil plants; to that end I wish to extend my sincerest thanks to Richard (Dick) Hilton of Sierra College, Rocklin, California and Jim Wood of Colfax. California.

A chronological arrangement of resources used in this review.

***Note: if** a link does not function properly, copy and paste the link into your web browser, and click.*

USGS Photographic Library. http://libraryphoto.cr.usgs.gov/cgi-bin/search.cgi?free_form=geological;search_mode=noPunct;start=6494

USGS Geologic Folios

A very nice collection of these folios is maintained at Texas A & M University.

Bidwell Bar Folio
http://repository.tamu.edu/handle/1969.1/3041?show=full

Colfax Folio
http://repository.tamu.edu/handle/1969.1/3391

Downieville Folio
http://repository.tamu.edu/handle/1969.1/2947

Jackson Folio
http://repository.tamu.edu/handle/1969.1/3012

Marysville Folio
http://repository.tamu.edu/handle/1969.1/3017

Sacramento Folio
http://repository.tamu.edu/handle/1969.1/3006

Smartsville Folio
http://repository.tamu.edu/handle/1969.1/3018

Sonora Folio
http://repository.tamu.edu/handle/1969.1/2813

USGS Topographic Map Collection, California State University Chico
http://cricket.csuchico.edu/maps/topo_search.html
[An excellent collection of California topographic maps. *E.*g., Search for Oroville and select number 4. This is the 1944 Edition of the 15' topographic map that plots the Butte County Hospital, and it is the edition that Creedly (1955) used as the base map for his geologic map.]

California Gold Mines, A Sesquicentennial Photograph Collection. 1998. Compiled By R. Guerin-Place, L. Roefs, and K. Twomey. California Division of Mines and Geology, DMG CD 98-001.
{A rich and interesting collection of photographs in a CD format.]

REFERENCES ARRANGED CHRONOLOGICALLY.

1864.USE THIS LINK,: **Palæontology (Volume 1)** - Geological Survey of California

I. Carboniferous and Jurassic fossils, by F. B. Meek. Triassic and Cretaceous fossils, by W. M. Gabb.
II. **II. Cretaceous and Tertiary fossils**, by W. M. Gabb.

http://www.archive.org/search.php?query=creator%3A%22Meek%2C%20F.%20B.%20(Fielding%20Bradford)%2C%201817-1876%22

[Strata now known to be Eocene were originally assigned to the Cretaceous by Gabb (1864). Later (1869) he revised his Division B and named it the Tejon group, but he still placed it in the Cretaceous. Stanton (1896, p. 1013) recognized that, "The first determination of the age of any part of the Chico-Tejon series was made by Conrad[1] in 1855, when he described a few species of fossils from the neighborhood of Fort Tejon, in southern California, and referred them to the Eocene. He especially mentions the occurrence of *Cardita* [i.e.,*Venericardia*] *planicostata* and two other species that he regards as identical to forms from the Claiborne beds of the Alabama Eocene." See also Dickerson (1913, 1915, 1916), Anderson and Hanna (1925), Nilsen (1979, 1987), and Prothero, 2003 for further discussion.]

footnote [1]. From Pacific Railroad Survey Reports, 1853-1854, Vol. V, Part 2, page 318, quote by Conrad:

http://quod.lib.umich.edu/m/moa/afk4383.0005.002/372?page=root;rgn=full+text;size=100;view=image

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

1878. Lesquereux, L. 1878. Report on the fossil plants of the auriferous gravel deposits of the Sierra Nevada. Memoirs of the Harvard Museum of Comparative Zoölogy, vol. 6, no. 2.

[Fossil plants from various localities within auriferous gravels were first described in this report. Lesquereux assigned the fossils to the Neocene, *i.e.*, more recent than Eocene, essentially the Miocene-Pliocene of present-day terminology.]

1882. Butte County Hospital and Infirmary, location of
In: The History of Butte County, California Volume 1-2 by Harry Laurenz Wells Frank T. Gilbert and W. L. Chambers (1882.
http://books.google.com/books?id=9BYVAAAAYAAJ&pg=PA149&lpg=PA149&dq=history+butte+hospital+ca&source=bl&ots=e1Eux7Q6m-&sig=pFyp65P2LJ9VhOsWGiKPbmArDQE&hl=en&ei=EZaOTMPIM4e8sQOW3dSLBA&sa=X&oi=book_result&ct=result&resnum=5&ved=0CCMQ6AEwBA#v=onepage&q&f=false
[The Butte County Hospital is used as a physical reference point in some of the older literature. This 1882 reference presents a direct account of the County Hospital and Infirmary, it discusses the choice and purchase of the land, and the construction of the structure in the southern part of Section 6, T. 19 N., R. 4 E. MDBM. The Hospital is plotted on the 1944 edition of the Oroville 15' topographic quadrangle. It is also illustrated as the frontispiece in Volume I of Wells *et al*.]

1883. Lesquereux, L. 1883. Species of plants from the Chalk Bluff of California. Contributions to the fossil flora of the western territories. III. The Cretaceous and Tertiary floras. *In*, F.V. Hayden (ed.), Report of the United States Geological Survey of the Territories. Vol. 8. Government Printing Office, Washington, D.C., pp.1-283.
http://www.archive.org/stream/contributionstof03lesq#page/n6/mode/1up
[See pp. 265, and Plate XLVb for small additions to the Chalk Bluff and other California and Oregon fossil plants.]

1896. You Bet (i.e., Chalk Bluff) Hydraulic Mine, area
California journal of mines and geology, Volumes 12-13. California. State Mining Bureau, California. Division of Mines and Geology, p. 236
http://books.google.com/books?id=v3LOAAAAMAAJ&pg=RA1-PA236&lpg=RA1-PA236&dq=you+bet+hydraulic+mine.+ca&source=bl&ots=kHDR0ffNel&sig=pDzlgqmgDOwH4JNl5bGIt-JDacg&hl=en&ei=rfuETLjlK4j2tgORgZ33Bw&sa=X&oi=book_result&ct=result&resnum=4&ved=0CCUQ6AEwAw#v=onepage&q&f=false
[The Chalk Bluff area, equivalent in part to what was later referred to as the Birdseye Creek Gold Mining Co.'s Mine (Hydraulic), is "…1/2 mile E. of You Bet, at 2,910' elevation, and comprised 700 acres. Twenty-five men were employed. C. Goodwin, of You Bet, was the owner in 1898."

One half mile east of You Bet places the site in the main Chalk Bluff (You Bet) diggings, as illustrated in the frontispiece.]

1896. Lindgren, W. and Knowlton, F.H. 1896. Age of the auriferous gravels of the Sierra Nevada. Journal of Geology, 4:881-906. [not seen]

1896. Stanton, T. W. 1896. The faunal relations of the Eocene and Upper Cretaceous on the Pacific coast. U.S. Geological Survey Annual Report, 17 (part 1):1005-1048.
[See the 1864 Gabb reference above]

1910. Cockerell, T.D.A. 1910. The Miocene trees of the Rocky Mountains. American Naturalist, 44:31-47.
[Cockerell notes that the collections of Lesquereux are of mixed ages, and that the Chalk Bluff is Eocene.]

1911. Lindgren, W. 1911. The Tertiary gravels of the Sierra Nevada of California. U.S.G.S. Professional Paper 73.
http://books.google.com/books?id=cpYNAAAAYAAJ&pg=PA23&lpg=PA23&dq=lindgren,+chico+folio&source=bl&ots=2zc8AZ0RBj&sig=dJK8m5DtboMlc20nNoNLF0p14tI&hl=en&ei=Z0hPTI60G5G6sQOj1tW0Bw&sa=X&oi=book_result&ct=result&resnum=5&ved=0CB8Q6AEwBA#v=onepage&q&f=false
[The classic report of the Geology of the Auriferous gravels. Lindgren, based his age calls on the works of Lesquereux, and also Knowlton (see immediately below), and thus he considered the plant-bearing gravels to be Neocene, *i.e.*, more recent than the Eocene, essentially Miocene-Pliocene.]

1911. Knowlton, F.H. 1911. Flora of the auriferous gravels of California. *In*, W. Lindgren, The Tertiary gravels of the Sierra Nevada of California. U.S.G.S. Professional Paper, 73, pp. 57-64.
[p. 63 Knowlton states: "The oldest or so-called deep gravels of Lindgren have not been found fossiliferous, the lowest apparent point at which plants occur being the upper portion of the bench gravels. To this horizon belongs the localities of Chalk Bluff, Nevada County (32 species); Independence Hill, Placer County (54 species); and Volcano Hill, Placer County (5 doubtfully determined species)." Knowlton, with the exception of a site near Taylorsville which he considered Eocene, assigned the Auriferous Gravel plants to the Neocene.]

1913. Dickerson, R.E. 1913. Fauna of the Eocene at Marysville Buttes, California. University of California Publications, Bulletin of the Department of Geology, 7(12):257-298. plates. 11-14.
http://www.google.com/books?id=ZX4OAQAAIAAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

[The conclusions presented in this report, and modified by subsequent reports (see e.g., Anderson and Hanna, 1925; Williams, 1929; Merriam and Turner, 1937), figure directly into MacGinitie's assignment of a Capay age to the fossils from the Chalk Bluff area.
See Dickerson's Table of Contents, page 257.]

1915. Dickerson, R.E. 1915. Fauna of the Type Tejon: Its relation to the Cowlitz Phase of the Tejon Group of Washington. California Academy of Sciences, Fourth Series, 5(3):33-98, pls. 1-11.
http://books.google.com/books?id=jmsbAAAAMAAJ&pg=PA46&dq=dickerson,+r.e.+fauna+type+tejon&hl=en&ei=bmCjTILSL4K8sQPOyNGzAQ&sa=X&oi=book_result&ct=result&resnum=1&ved=0CCkQ6AEwAA#v=onepage&q=dickerson%2C%20r.e.%20fauna%20type%20tejon&f=false
[This and the next referenced publication were available, but not referenced by MacGinitie , 1941, although they are directly applicable to his assignment of a Capay age to the Chalk Bluff fossil plants.]

1916. Dickerson, R.E. 1916. Stratigraphy and fauna of the Tejon Eocene of California. University of California Publications Bulletin of the Department of Geology, 9(17):363-524, plates 36-46.
http://books.google.com/books?id=938OAQAAIAAJ&pg=PA387&lpg=PA387&dq=dickerson,+r.e.,+eocene+Tejon+sutter&source=bl&ots=ZeHtlqcIy-&sig=ZOe2S6PFRWpZqQ4jVYHnHj6iXBw&hl=en&ei=1FejTMyzJoG6sAOLwOH6Bg&sa=X&oi=book_result&ct=result&resnum=2&ved=0CBcQ6AEwAQ#v=onepage&q=dickerson%2C%20r.e.%2C%20eocene%20Tejon%20sutter&f=false
[On p. 496 under the discussion of the new species, *Nyctilochus thunani*, Dickerson gives the most clearly defined location of the UCMP locality 2225 (Dyer Shaft) that I have been able to find in the literature. Copied as follows:

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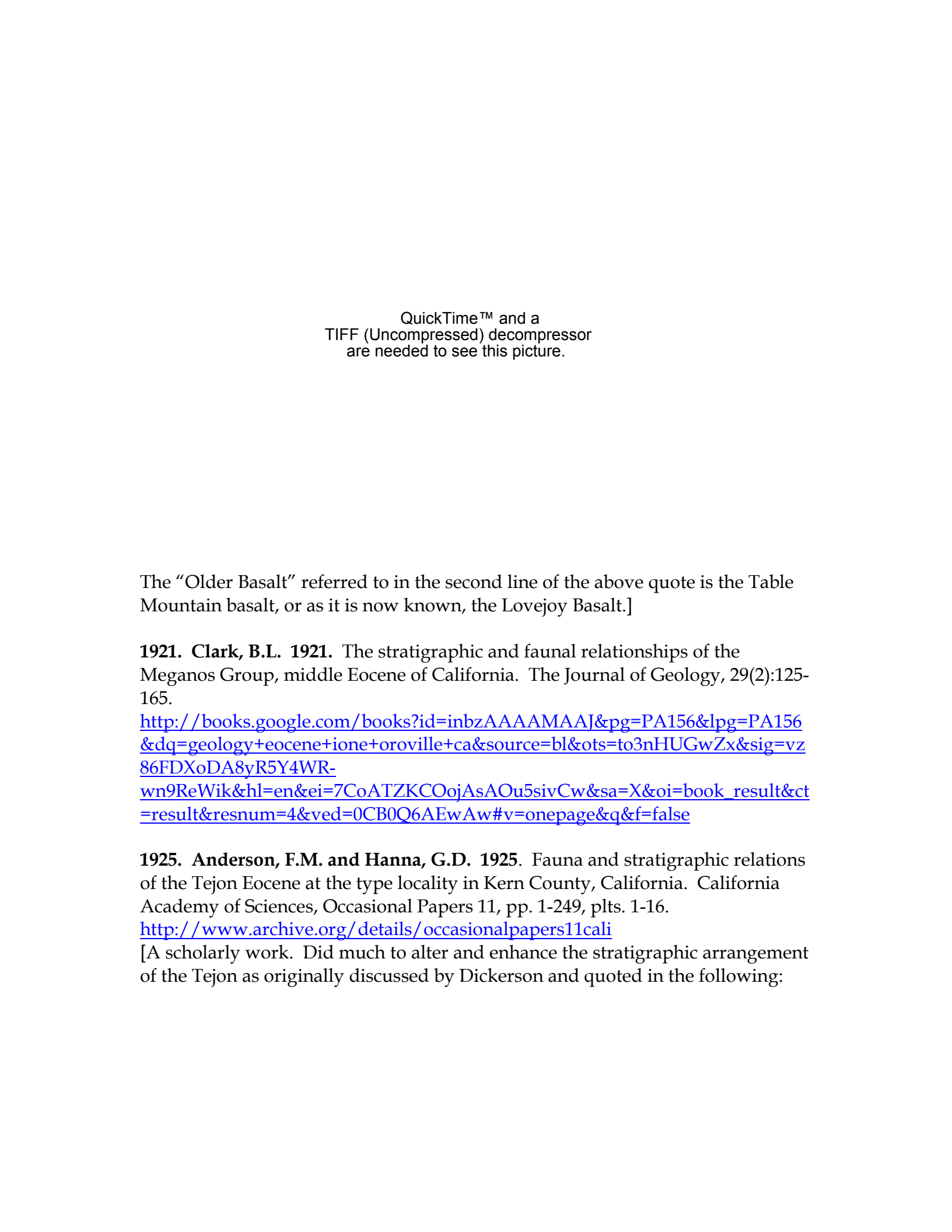
TIFF (Uncompressed) decompressor
are needed to see this picture.

Tejon refers to a Tejon age (*i.e., Siphonalia sutterensis* fauna) as Dickerson used it at that time, not the presently recognized Tejon Age;]

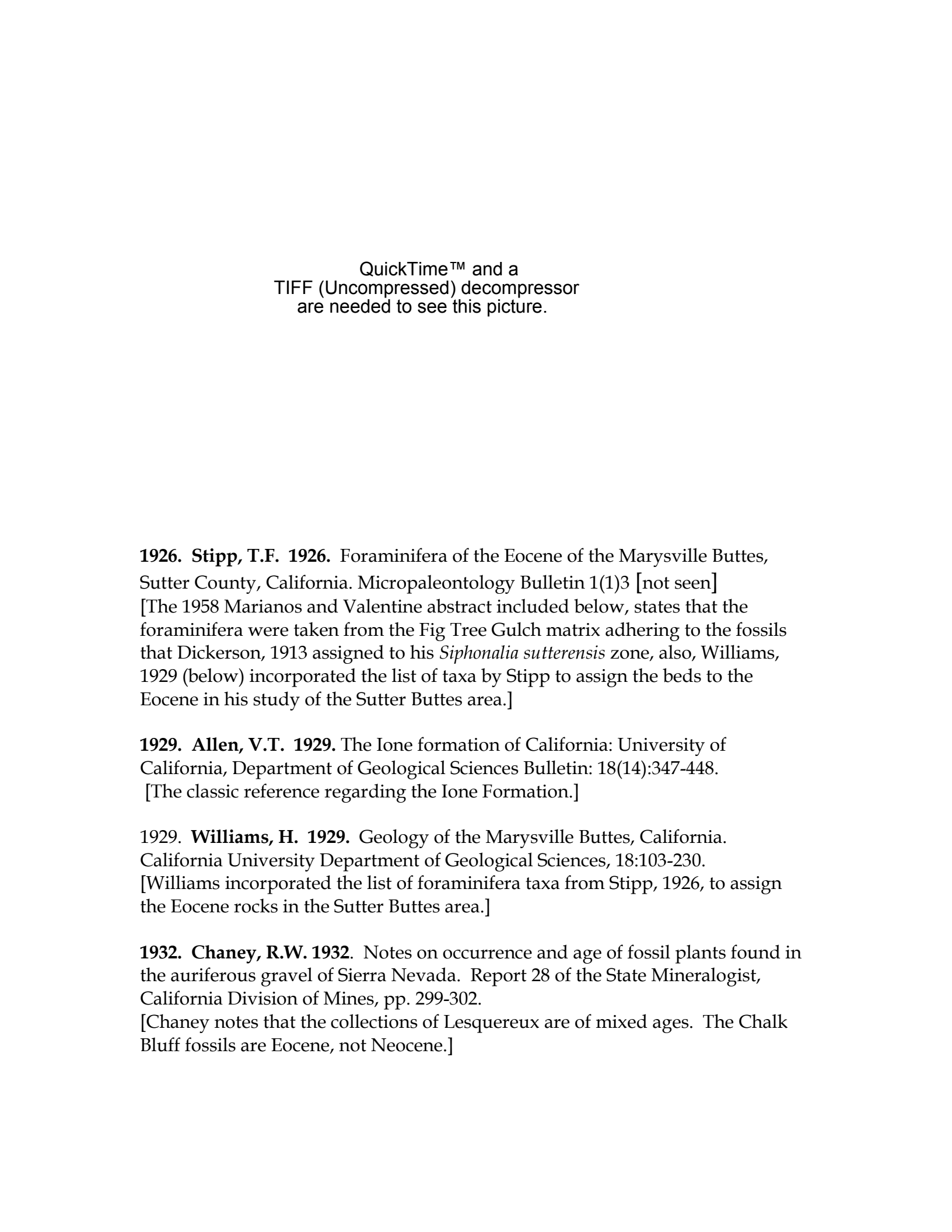
On p. 389, Dickerson 1916 records the 'information *re* Dyer Shaft'



The "Older Basalt" referred to in the second line of the above quote is the Table Mountain basalt, or as it is now known, the Lovejoy Basalt.]

1921. Clark, B.L. 1921. The stratigraphic and faunal relationships of the Meganos Group, middle Eocene of California. The Journal of Geology, 29(2):125-165.
http://books.google.com/books?id=inbzAAAAMAAJ&pg=PA156&lpg=PA156&dq=geology+eocene+ione+oroville+ca&source=bl&ots=to3nHUGwZx&sig=vz86FDXoDA8yR5Y4WR-wn9ReWik&hl=en&ei=7CoATZKCOojAsAOu5sivCw&sa=X&oi=book_result&ct=result&resnum=4&ved=0CB0Q6AEwAw#v=onepage&q&f=false

1925. Anderson, F.M. and Hanna, G.D. 1925. Fauna and stratigraphic relations of the Tejon Eocene at the type locality in Kern County, California. California Academy of Sciences, Occasional Papers 11, pp. 1-249, plts. 1-16.
http://www.archive.org/details/occasionalpapers11cali
[A scholarly work. Did much to alter and enhance the stratigraphic arrangement of the Tejon as originally discussed by Dickerson and quoted in the following:



1926. Stipp, T.F. 1926. Foraminifera of the Eocene of the Marysville Buttes, Sutter County, California. Micropaleontology Bulletin 1(1)3 [not seen]
[The 1958 Marianos and Valentine abstract included below, states that the foraminifera were taken from the Fig Tree Gulch matrix adhering to the fossils that Dickerson, 1913 assigned to his *Siphonalia sutterensis* zone, also, Williams, 1929 (below) incorporated the list of taxa by Stipp to assign the beds to the Eocene in his study of the Sutter Buttes area.]

1929. Allen, V.T. 1929. The Ione formation of California: University of California, Department of Geological Sciences Bulletin: 18(14):347-448.
[The classic reference regarding the Ione Formation.]

1929. **Williams, H. 1929.** Geology of the Marysville Buttes, California. California University Department of Geological Sciences, 18:103-230.
[Williams incorporated the list of foraminifera taxa from Stipp, 1926, to assign the Eocene rocks in the Sutter Buttes area.]

1932. Chaney, R.W. 1932. Notes on occurrence and age of fossil plants found in the auriferous gravel of Sierra Nevada. Report 28 of the State Mineralogist, California Division of Mines, pp. 299-302.
[Chaney notes that the collections of Lesquereux are of mixed ages. The Chalk Bluff fossils are Eocene, not Neocene.]

1934. MacGinitie, H.D. 1934. Ecological aspects of the floras of the auriferous gravels. Proceedings of the Geological Society of America, p. 356. [not seen recently}

1935. Crook, T.H. and Kirby, J.M., 1935. Capay Formation. (Abs.) Geological Society of America Annual Meeting Proceedings for 1935, p. 334-335. [not seen]

1937. Merriam, C. W. and Turner, F. E. 1937. The Capay Middle Eocene of northern California. University of California Publications in Geological Sciences 24(6):91–114.
[on p. 91 the authors introduce the Capay stage: "Existence of a well-characterized faunal and depositional stage between the Meganos and the Domengine (…) is forcibly indicated by evidence developing out of recent investigation." And p. 92, "At the type section of the Meganos, on the north side of Mount Diablo, the Capay stage is either missing or represented by the well-known coal beds, which have offered little or no fossil evidence of their immediate age. The newly recognized stage, herein termed Capay, is believed to include certain deposits which have previously been regarded as correlatives of the Meganos." Continuing (p. 94) "The locality which has yielded most of the fossils lies on the west side of Capay Valley, Yolo County, and west of Tancred Station, in the south central part of Sec. 28, T. 11 N., R. 3 W., Mt. Diablo B. & M. According to Mr. Crook, the fossils occur between 450 and 500 feet stratigraphically above the contact of the Eocene and Cretaceous." See also the following reference by 1943 Bentson]

1941. MacGinitie, H.D. 1941. A Middle Eocene Flora from the Central Sierra Nevada. Carnegie Institution of Washington Publications 534. [Issued November 1941.]
MacGinitie began his study of the Chalk Bluff geology and fossils during the summer of 1933. Subsequent collecting was continued during the summers of 1934-1936, and 1938. The Colfax topographic quadrangle, edition 1898, scale 1/250,000 was the only topographic map MacGinitie had available during his field work. The Colfax, scale 1/125,000 edition, was not published until 1938. So far as I am aware, none of the fossil plant sites that follow is plotted by MacGinitie on any of these maps.
On Page 4 MacGinitie lists the University of California Museum of Paleontology (UCMP) plant locality numbers and their corresponding site names as follows:
<u>42 (or P3319)</u> – Iowa Hill and Independence Hill, respectively 8 and 9 miles east of Colfax.
<u>P3318, P3324, P3325, P3345</u> – Chalk Bluff proper, 2 miles east of the town of You Bet. (The town site of You Bet is located at ~39.200844N, 120.900llW, this would be only approximately 1/2 mile, not 2 miles, from the Chalk Bluff main diggings.)
<u>104 and P3320</u> – Buckeye Flat.

P3346 – Quaker Flat and its northward extension, Scotts Flat ~8 miles east of Nevada City.
P3347 – Sailor Flat, is part of the Blue Tent Mine, and lies about 4 miles northeast of Nevada City and 1 mile northwest of Quaker Flat.
206 – Cherokee Mine, given as about 8 miles north of Oroville.

MacGinitie utilized the area in the vicinity of Oroville North and South Table Mountain to determine the age of the Chalk Bluff Flora. In this fairly restricted area are 1) marine beds, the ("Dry Creek formation"), bearing a marine megainvertebrate fauna of Capay Age, 2) the Ione Formation in the strict sense, and 3) the continental leaf-bearing Auriferous Gravels, these three rock units are essentially contiguous, therefore making the area an ideal location to both determine the geologic relations of the rock units, and to assign an age to the fossil plants that occur in the continental leaf-bearing Auriferous Gravels. These sites are in the ancient Buckeye-Bear Hill Channel (Garside *et al.*, 2005). MacGinitie (p 23) first notes that "Although the relations are somewhat obscure, it appears certain the Capay Stage fauna from the vicinity of Oroville occurs in beds just underlying the Ione." The marine beds just underlying the Ione were called the Dry Creek formation by Allen, 1929. Greely 1965 notes that the name Dry Creek was preoccupied so he uses it in a quotational sense, and he further notes that although the Capay fauna does come from the "Dry Creek" formation he specifically emphasizes that (Greely 1965, p. 47), "… the age of the strata at South Table Mountain are directly applicable to the "Dry Creek" beds, *but not to the Ione strata which overly them*." (Italics mine).

Mac (p. 82) continues his discussion regarding the age of the Chalk Bluff flora by directing attention away from the Oroville area, directly to Chalk Bluff area, southeast some ~45 air miles (72k), and into deposits of the ancestral Yuba Drainage (Garside *et al.*, 2005). MacGinitie states that "… the Chalk Bluff flora is preserved in the continental facies of the Ione formation [*i.e.*, the Auriferous Gravels]. Its age is therefore lower Middle Eocene, on the basis of the Capay invertebrate fauna." Hence, the beginning of the use of the Capay age for the Chalk Bluff plants. At the date of Mac's publication in 1941 the Capay Stage was correlated with the lower Claiborne of the Gulf Coast and the Ypresian Stage of the Paris Basin. In 1941 the Ypresian Stage was still considered middle Eocene, not lower Eocene.

The purpose of the present review is to point out that the Capay invertebrate fauna as referenced by MacGinitie is from the areas of Sutter Buttes and South Table Mountain just north of Oroville. In these two areas the fossil invertebrates occur in a formation that disconformably underlies the Ione Formation, which was considered to be equivalent to the plant-bearing Auriferous Gravels (see Allen, 1929, and Creely, 1965). Until these plants are specifically dated,

especially by non plant correlations, we need to discontinue assigning the fossil plants at Chalk Bluff to a Capay age, and recognize they are younger. How much younger remains to be determined.

POST 1941 MACGINITIE

1941. Wood, H.E., Chaney, R.W., Clark, J., Colbert, E.H., Jepsen, G.L., Reeside, J.B., and Stock, C., 1941. Nomenclature and correlation of the North American Continental Tertiary: Geological Society of America Bulletin, 52:(1-48).

1943. Johnson, H.R., 1943. Marysville Buttes (Sutter Buttes) gas field. *In*. O.P. Jenkins, (*Ed*.), Geologic Formations and Economic Development of Oil and Gas Fields of California. State of California Department of Natural Resources, Bulletin 118, pp. 610-615.
http://books.google.com/books?id=IHMtHxJ58fkC&pg=PA11&lpg=PA11&dq=kione+formation,+ca&source=bl&ots=RnySrVzzPt&sig=FnPyAzwu1sx7rUmcdkGTI5FM1s0&hl=en#v=onepage&q&f=false
[Submitted June 1941. On paleontological evidence, Johnson restricts the thickness of the Eocene at Marysville (Sutter) Buttes to ~350-400 feet by placing ~1,000 feet of the previously included basal beds into the Cretaceous, assigned to the Cretaceous (K)+Ione, or Kione Formation.]

1943. Bentson, H. 1943. Eocene (Capay) corals from California. Journal of Paleontology, 17(3):289-297. http://www.jstor.org/pss/1299111 [Abstract.]
[The author gives precise locality information regarding the location of the type Capay fauna, stating that the corals are found (p. 289) "in the gritty sandstones and conglomerates in Smith Canyon, type locality of the Capay formation, west of Capay Valley, Yolo County;". The author gives the exact locality as UCMP locality "A-1313. Gritty sandstone locality on south bank of Smith Canyon west of Tancred Station (now abandoned) in Capay Valley, in south central part of sec, 28, T. 11 N., R. 3 W., Yolo County."]

1949. Stewart, R.E. 1949. Lower Tertiary Stratigraphy of Mount Diablo, Marysville Buttes and west border of lower Central Valley of California. Oil and Gas Investigation Chart 34**.** [not seen.]

1953. Verastegui, P. 1953. The pelecypod genus Venericardia in the Paleocene and Eocene of Western North America. Paleontographica Americana, 3(25):395-506.
http://www.archive.org/stream/palaeontographic1325pale#page/n534/mode/1up

1958. Marianos, A.W. and Valentine, J.W. 1958. Eocene ostracod fauna from Marysville Buttes, California. Micropaleontology 4(4):363-372. http://www.jstor.org/pss/1484266 [Abstract.]
[The authors point out that the foraminifera studied by Stipp, 1926 come from the matrix of the fossils studied by Dickerson, 1914.]

1961. Wolfe, J.A., Gower, H.D. and Vine, J.D. 1961. Age and correlation of the Puget Group, King County, Washington. U.S.G.S. Professional Paper 224-C, p. C230-C232. [(Not seen). The original work by Wolfe *et al*. on the fossil plants from the Puget Group: A brief account of their work in progress based on their early collecting in 1960-61. See Vine (1962) and Wolfe (1968) for a discussion of work in this area in 1960-61.]

1962. Lachenbruch, M.C. 1962. Geology of the west side of the Sacramento Valley. California. *In*, O.E. , Bowen, (*Ed*.) 1962. Geologic guide to the gas and oil fields of northern California. California Division of Mines and Geology Bulletin 181 pp. 53-66. and Map 4, Geologic Map. Capay – Wilbur Springs. Sacramento Geological Society, Bruce D. Brooks.
http://www.archive.org/stream/gasoilncgeologic00bowerich#page/n6/mode/1up

[An error exists here where it states that the Type Capay occurs in Sections 10 and 11, T. 12 N., R. 3 W. These sections are located on the Cretaceous Forbes Formation. The statement should be disregarded, and be replaced with, 'At its type locality in sec. 28, T. 11 N., R. 3 W.'

From the same volume, listed as Field Trip 1. [Sacramento Valley, by Bruce D. Brooks, Donald Rogers, Paul Day, and Tom Wootton, *In*, Bowen, O.E. (*Ed*.) 1962. Geologic guide to the gas and oil fields of northern California. California Division of Mines and Geology Bulletin 181, pp. 369-380, See especially p. 375, where these authors place the Type Capay Formation relative to the "Junction, road 70 and Highway 16, Smith Canyon, 1 1/2 miles west of this intersection, is the type locality of the lower Eocene Capay formation." Road 70 joins from the west side with Highway 16 immediately south of the site of Tancred].

1962. Vine, J.D. 1962. Stratigraphy of Eocene rocks in a part of King County, Washington. State of Washington, Department of Conservation, Division of Mines and Geology, Report of Investigations No. 21, 20 p.
http://www.dnr.wa.gov/Publications/ger_ri21_strat_eocene_king_co.pdf
[An early study of the thick (some 14,250 feet, 4343.4m) section of the Puget Group from which Wolfe (1961) provided the preliminary identifications of the fossil leaves from the Raging River (3,000') and Tiger Mountain (2,000') formations. The leaves from these two formation are shown in tabular arrangement on pages 13 (Tiger Mountain) and 15 (Tukwila Formation) respectively.]

1962. Garrison, L.E. 1962. The Marysville (Sutter) Buttes, Sutter County, California. *In*, O.E., Bowen, (*Ed*.) 1962. Geologic guide to the gas and oil fields of northern California. California Division of Mines and Geology Bulletin 181. pp. 69-72.
http://openlibrary.org/books/OL255839M/Geologic_guide_to_the_gas_and_oil fields_of_northern_California .
[See Plate 4, generalized geologic map of Sutter Buttes on p. 427. Greater detail is shown in the Fig Tree Gulch area where the Eocene Capay is differentiated from the narrow band of overlying Ione sands.]

1962. Arkley, R.J. 1962. The geology, geomorphology, and soils of the San Joaquin Valley in the vicinity of the Merced River California. In: Geologic guide to the Merced Canyon and Yosemite Valley, California, California Division of Mines and Geology Bulletin 182, pp. 25-31.
http://www.nps.gov/history/history/online_books/geology/publications/state/ca/cdmg-bul-182/sec3.htm
[Arkley's Photo #1 is of Planicosta Butte, which Arkley states is an outlier of the Ione Formation …"sandstone capping kaolinitic clays." The hill was informally? named for the fossil clam *Venericardia planicosta*, referred to as the "finger post of the Eocene" by Conrad in 1855 (see 1953 P. Verastegui, p. 401). The Butte is shown on Arkley's accompanying geologic map. It is also shown on the contemporary Merced Falls topographic map as Table Top Mtn., highest point at 669 feet (~204m). This site has been known since the 1860s.
See the excellent photographs of *Venericardia spp.* in the reference below by McClure, 2009]

1964. Dalrymple, G.B. 1964. Cenozoic chronology of the Sierra Nevada, California. University of California Publications in Geological Sciences, v. 47, 41p.
[Included is a KAr date of 23.8 ±0.6 (recalculated 24.4±0.6) on the andesitic rocks from Oroville South Table Mountain (area at ~39°33'02"N, 121°33'02"W). These rocks are interbedded within the auriferous gravels. Creely (1965) referred to these andesitic rocks as questionably the Mehrten Formation-?, whereas Marlette *et al*., (1979) assigned them to a new unit, the Oroville Tuff.]

1965. Creely, R.S. 1965. Geology of the Oroville (15') quadrangle, Butte County, California. California Division of Mines and Geology Bulletin 184, 86 p.
http://www.archive.org/stream/geologyoforovill00creerich#page/n1/mode/2up
[Invaluable to the present review. From the many helpful sources of information in this study, one that is primary to the present review is the recognition that Creely specifically points out that the "Dry Creek formation" of Allen, 1929 is the

glauconitic unit that lies disconformably below the Ione sands, and *it is the unit that bears the Capay megainvertebrates from Dickerson's Dyer Shaft locality, UCMP locality 2225, which is the fossil fauna that Mac used to assign a Capay age to the Chalk Bluff fossil plants*. Therefore, the Capay fauna and age does not directly apply to the Ione Formation at South Table Mountain, and it is equally not proven to apply to a Capay age for the fossil plants at Chalk Bluff.]

1966. Hackel, O. 1966. Summary of the geology of the Great Valley. *In*, Bailey, E.H. (*Ed.*), The geology of Northern California. California Division of Mines and Geology Bulletin 190, pp. 217-238.
http://www.archive.org/stream/northecalifornia00bailrich#page/n7/mode/2up

1966. Keroher, G.C. and others. 1966. A compilation of the geologic names of the United States, its possessions, the Trust Territory of the Pacific Islands, and the Panama Canal Zone. U.S. Geological Survey Bulletin 1200.
http://books.google.com/books?id=KssJAQAAIAAJ&pg=PA619&lpg=PA619&dq=eocene+capay+yolo+county,+ca&source=bl&ots=uCGUCI4zDC&sig=XVARPrbHNbug3IKhCW5kJC0qvbA&hl=en&ei=7nKjTbG3D5G6sQPx_fH5DA&sa=X&oi=book_result&ct=result&resnum=7&ved=0CCwQ6AEwBjgK#v=onepage&q&f=false
[The Capay figures so importantly in the discussion of the age of the Chalk Bluff plants, the following information is appended. See especially pp. 619-620 where the following is presented, quote.]

["Capay Formation
Capay Stage

Eocene, lower: Northern California.
Original reference: T.H. Crook and J.M. Kirby, 1935, Geol. Soc. America Proc. 1924, p. 334-335.

B.L. Clark and H.E. Vokes, 1936. Geol Soc. America Bull., v. 47, no. 6., p. 853 (fig.1), 858-861. Referred to as a stage based on faunal assemblages. Spans interval between Meganos stage below and Domengine stage above. Strata referable to this stage have been incorrectly correlated by Clark (1921, Jour, Geology, v, 29, no. 2) with those containing fauna of Division D of Meganos group.

C.W. Merriam and F.E. Turner, 1937, University of California Publications Bulletin of the Department of Geological Sciences v. 24, no. 6, p. 91-113. Discussion of middle Eocene Capay Stage of northern California. Check list of species of stage in Capay Valley and Vacaville areas is given. Deposits of stage

represent in several areas a discrete transgressive overlapping of marine conditions as shown by fact that beds rest both upon the Meganos and other earlier formations. At type section of Meganos, on north side of Mount Diablo, the Capay stage is either missing or represented by coal beds which have offered little or no fossil evidence of their immediate age. *Locality which has yielded most of the fossils lies on west side of Capay Valley. Yolo County, and west of Tancred Station, in south-central part of sec. 28, T. 11 N., R. 3 W., Mount Diablo base and meridian."* [Italics mine]

1968. Wolfe, J.A. 1968. Paleogene biostratraphy of nonmarine rocks in King County, Washington. U.S.G.S. Professional Paper 571, 37 pp, 7 plts.
http://pubs.usgs.gov/pp/0571/report.pdf
[pp. 6 and 7, Wolfe correlates his newly established Franklinian Stage with the Chalk Bluff flora, and as such, equivalent to some part of the Capay Stage. See this discussion of the Franklinian Stage in the Introduction of the present Review.]

1968. Peterson, D.W., Yeend, W.E., Oliver, H.W. and Mattick, R.E. 1968. Tertiary gold-bearing channel gravel in Northern Nevada County, California. U.S. G. S. Circular 566, 22 pp.

1974. Yeend, W.E. 1974. Gold-bearing gravel of the ancestral Yuba River, Sierra Nevada, California. U.S. Geological Survey Professional Paper 772, 44 pp. [Pg. 15, Pl. 2, records a KAr date of 38.9 ±1 (adjusted) on a biotite-rich tuff from a drill hole located in the area just south of North Columbia, California.]

1975. Baker, P. 1975. A re-interpretation of the Eocene Capay Formation, Yolo County, California. Unpublished Masters Thesis, Stanford University, Palo Alto, California.
http://sul-derivatives.stanford.edu/derivative?CSNID=00016972&mediaType=application/pdf
[This report considers the Capay Formation to be an exposed portion of the Princeton or Capay Submarine Gulch]

1977. Williams, H. and Curtis, G.H. 1977. The Sutter Buttes of California. University of California Publications in Geological Sciences, 116, 56 pp.
http://books.google.com/books?id=IHMtHxJ58fkC&pg=PA46&lpg=PA46&dq=howell+williams+1929&source=bl&ots=RmFKtQEwMp&sig=OM5qnNVvMvjzLvSlZsH74sMl4q0&hl=en&ei=-9ddTODpEY3EsAOm8uipCw&sa=X&oi=book_result&ct=result&resnum=4&ved=0CCEQ6AEwAw#v=onepage&q&f=false [See pp. 11-13.]

1979. Marlette, J.W., R.J. Akers, K.A. Cole, and R.D. McJunkin. 1979. The August 1, 1975 Oroville Earthquake Investigations: Chapter II. Geologic Investigations. Department of Water Resources, Bulletin 203-78, pp. 15-121.
http://www.archive.org/details/august11975orovi20378cali
or read on line at
http://www.archive.org/stream/august11975orovi20378cali#page/n7/mode/2up
[Andesitic tuffs are interbedded in the Auriferous Gravels in the area of South Table Mountain. Dalrymple, 1964, reported a KAr date on these tuffs of 23.8 ±0.6 (recalculated 24.4±0.6). See Marlette, *et al*., Figure 37, page 52 for a picture of the tuffs interbedded in the Gravels.]

1979. Nilsen, T.H. l979. Early Cenozoic stratigraphy, tectonics and sedimentation of the central Diablo Range between Hollister and New Idria, *In* , T.H. , Nilsen and T.W., Dibblee, Jr., (*Eds*.)., Geology of the central Cordilleran Section, Geological Society of American Field Trip Guidebook, p. 31-55.
http://www.pmc.ucsc.edu/~crowe/ES109/readings/Nilsen81.pdf
[This publication presents a very careful and detailed tie-in between the stratigraphic relations of the northern and southern portions of the Sacramento Valley.]

1979. Bartow, J. A., and Marchand, D. E., 1979. Preliminary geologic map of Cenozoic deposits of the Sutter Creek and Valley Springs quadrangles, California. U. S. Geological Survey Open file Report 79-436.
http://pubs.er.usgs.gov/publication/ofr79436

1979. Dalrymple, G.B. 1979. Critical tables for conversion of K-Ar ages from old to new constants. Geology 7(11):558-560.

1980. Okada, H. and Bukry, D., 1980. Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973; 1975). Marine Micropaleontology *5*:321–325. [not seen.]

1981. Bodden, R.W., III 1981. Depositional environments of the Eocene Domengine Formation in the Mount Diablo Coal Field, Contra Costa County, California. Unpublished MS thesis, Stanford University, Palo Alto, California.
http://sul-derivatives.stanford.edu/derivative?CSNID=00017421&mediaType=application/pdf

1983. Bodden, W.R., III. 1983. Depositional environments of the Eocene Domingine Formation outcrop on the north side of Mount Diablo, California. *In*,

Cherven, V.B. and Graham, S.A. (*eds.*), Geology and Sedimentology of the Southwestern Sacramento Basin and East Bay Hills. Pacific Section, Society of Economic Paleontologists and Mineralogists, 29:43-57.

1983. Cherven, V.B. 1983. Stratigraphy, facies, and depositional provinces of the middle Eocene Domengine Formation, southern Sacramento Basin. *In*, Cherven, V.B. and Graham, S.A. (*eds.*), Geology and Sedimentology of the Southwestern Sacramento Basin and East Bay Hills. Pacific Section, Society of Economic Paleontologists and Mineralogists, 29:59-72.

1983. Turner, D.L., Frizzell, V.A., Triplehorn, D.M. and Naeser, C.W. 1983. Radiometric dating of ash partings in coal of the Eocene Puget Group, Washington: Implications for paleobotanical stages. Geology 11(9):527-531.
http://geology.geoscienceworld.org/cgi/content/abstract/11/9/527
[See abstract]

1984. Merrill, R.D. 1984. *Ophiomorpha* and other nonmarine trace fossils from the Eocene Ione Formation, California. Journal of Paleontology, 58(2):542-549.
http://jpaleontol.geoscienceworld.org/cgi/content/abstract/58/2/542
[An account of a common trace fossil in the Ione. See also Creely. S. and Force, E.R, 2007 for additional discussion and illustrations.]

1985. Helley, E.J. and Harwood, D.S. 1985. Geologic map of the Late Cenozoic deposits of the Sacramento Valley and Northern Sierran Foothills, California. U.S. Geological Survey Miscellaneous Field Studies Map MF-1790, 5 Plates and Pamphlet.
http://pubs.usgs.gov/mf/1985/1790/
[See especially Plate 2, the far southwest corner of the map, see the area of Tte, secs. 27-28, T. 11 N., R. 3 W. This is the type locality of the Capay fauna.]

1987. Smith, G.A. 1987. A palynological investigation of Eocene localities in Northern California. Unpublished Master Thesis, University of California Davis, 116 pp., 13 pls.
[Smith studied the palynofloras from a number of northern Sierra Nevada Eocene sites, his work suggests that the relative temporal placement of these sites is: 1) the Montgomery Creek Formation is oldest, 2) the Chalk Bluff is intermediate in age, and 3) the Cherokee Pit palynoflora from Oroville North Table Mountain as the youngest.]

1987. Nilsen, T.H. 1987. Stratigraphy and sedimentology of the Eocene Tejon Formation, western Tehachapi and San Emigdio Mountains, California. U.S.G.S. Professional Paper 1268.
http://pubs.usgs.gov/pp/1268/report.pdf

Geologic map, plate
http://pubs.usgs.gov/pp/1268/plate-1.pdf
[A very careful and well presented study of the geology and paleontology of the type Tejon Formation. The map scale is 1/62,500.]

1988. Almgren, A.A., Filewicz, M.V. and Heitman, H.L. 1988. Lower Tertiary foraminiferal and calcareous nannofossil zonation of California: An overview and recommendation. Pacific Section Society of economic Paleontogists and Mineralogists 58:83-105.
[Pages 88-89 present a detailed account of the problems, and suggested corrections, associated with the then existing Ulatisian Stage.]

1990. Wagner, D.L. and G.J. Saucedo. 1990. Age and stratigraphic relationships of Miocene volcanic rocks along the eastern margin of the Sacramento Valley, California. *In*, R.V. Ingersoll and T.H. Nilsen, (*eds*.) Sacramento Valley Symposium and Guidebook: Pacific Section S.E.P.M., Vol. 65, p. 143-151.]

1991. Burky, D. 1991. Coccolith correlations of California Cenozoic geologic formations. U.S.G.S. Open-File Report 91-574, 30 pp.
http://pubs.usgs.gov/of/1991/0574/report.pdf

1992. Saucedo. G.J. and Wagner, D.L. 1992. Geologic map of the Chico Quadrangle. Regional Geologic Map Series, Chico Quadrangle, Map No. 7A.
http://www.quake.ca.gov/gmaps/RGM/chico/chico.html Scale 1:250,000.

1992. Saucedo, R.J., Fulford, M.M., Mata-Sol, A.R. and Lindquist, T.A. 1992. Radiometric age of rocks in the Chico Quadrangle, California, Scale 1:250,000. California Department of Conservation, Division of Mines and Geology. To accompany the Regional Geologic Map Series, Chico Quadrangle, Map No. 7A.
[Page 9, records a KAr age of 24.4 ±0.6 (recalculated), and p. 21 records KA 24.69 ±0.71 and whole rock 14.38 ±0.29 for the andesitic material below the Lovejoy Basalt just north of South Table Mountain in the vicinity of the divide between Morris and Schirmer ravines. Creely (1965) referred to these as Mehrten Formation-?, and Marlette *et al.* (1979) assigned them to a new unit, the Oroville Tuff.]

1993. Wing, S.L. and Greenwood, D.R. 1993. Fossils and fossil climate: The case for equable continental interiors in the Eocene. Philosophical Transactions: Biological Sciences, 341(1297):243-252.
http://si-pddr.si.edu/dspace/bitstream/10088/8826/1/paleo_Wing__Greenwood_1993_equable_climates.pdf

[See the discussion in the Introduction to the present Review.]

1994. Burnham, R,J, 1994. Paleoecological and floristic heterogeneity in the plant-fossil record---An analysis based on the Eocene of Washington. U.S. Geological Survey Bulletin 2085-B.
http://pubs.usgs.gov/bul/2085b/report.pdf
[A thorough review. See the discussion under Wolfe in the Introduction to the present Review.]

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[This and the abstract above appear identical]
["Magnetic samples were taken from the 75 m of exposed section, and yielded a stable remanence held mainly in magnetite which passed a reversal test. The section showed two normal zones and three reversed magnetozones. Based on calcareous nannofossils and planktonic foraminifera, we correlate the type Ulatisian with Chron C20r-C22r, which is latest early Eocene to early middle Eocene on the global time scale. Our data calibrate what has been previously suggested by micropaleontologists: the base of the Ulatisian in the Vacaville Shale is 2 million years older than it is in Media Agua Creek in the Temblor Range, and that the top of the Ulatisian is a million years younger in the Vacaville section then it is at Media Agua Creek. Outcrops of the type Point of Rocks Sandstone near Devil's Den are the type section for Mallory's Narizian benthic foraminiferal stage, and Mallory's two zones of the Ulatisian Stage were defined in the Point of Rocks Sandstone in Media Agua Creek in the Temblor

Range. Magnetic samples from both sections yielded a stable remanence held mostly in magnetite which passes a reversal test. Based on calcareous nannofossil calibrations of the magnetic sections, the base of the Ulatisian falls in Chron C22r. The lower Ulatisian Vaginulinopsis mexicana/upper Ulatisian Amphimorphina californica zonal boundary lies in Chron C22n. Of particular significance to this study are the more than 1,100 meters of Upper Eocene strata belonging to the Point of Rocks Sandstone and the highly fossiliferous shales and siltstones of the overlying Welcome Member of the Kreyenhagen Formation. The oldest of these strata in the lower Point of Rocks Sandstone are referred to the Middle Eocene Ulatisian Stage, and the uppermost strata of the Welcome Member of the Kreyenhagen to the Upper Eocene Refugian Stage. Between strata of these stages are sediments containing the type area of the Narizian Stage and its two zones, the Bulimina corrugata and Amphimorphina jenkinsi zones. More than 240 distinct species or varieties of foraminifers have been identified from the Narizian strata here as well as radiolarians, diatoms, sponge spicules, and fish teeth. Four faunules are recognized. Of these, one characterizes a single zonule during the Point of Rocks deposition, and three other zonules occur in the Welcome Member. Tropical to subtropical surface temperatures are postulated for the times of deposition of both formational entities. The more coarsely clastic sediments of the Point of Rocks apparently were deposited at lower stratigraphic levels at neritic depths and at higher levels at bathyal or abyssal depths, perhaps as a submarine fan or turbidite. The Welcome Member of the Kreyenhagen appears to have been deposited at bathyal or abyssal depths, but turbidity currents had ceased their activity and only finely clastic and organic material contributed to the sedimentation. Forty-two species that are important both to correlations and to ecologic interpretations are illustrated and systematically discussed. The Foraminifera indicate that some of the rocks may be as old as early Eocene. The oldest rocks are tentatively referred to the Penutian Stage of Mallory. Other parts of the sequence are referred to the Ulatisian and Narizian stages of Mallory, the Refugian Stage of Schenck and Kleinpell, and the Zemorrian and Saucesian stages of Kleinpell. Several short periods of shallow, sheltered sea conditions are suggested by the Foraminifera from several parts of the stratigraphic sequence, but Foraminifera from most of the rocks suggest relatively deep, open-sea conditions.

In both areas, basal shallow-marine conglomerate of Penutian age grades upward into shale of Ulatisian and Narizian age that was deposited at bathyal water depths in a basin with access to open ocean. Additional similarities in the upper Eocene and Oligocene stratigraphic units suggest original contiguity of the depositional basins. The inferred offset indicates that the Salinian Block was attached to western California by at least early Eocene time. Forty-two species that are important both to correlations and to ecologic interpretations are illustrated and systematically discussed. The Foraminifera indicate that some of the rocks may be as old as early Eocene. The oldest rocks are tentatively referred

to the Penutian Stage of Mallory. Other parts of the sequence are referred to the Ulatisian and Narizian stages of Mallory, the Refugian Stage of Schenck and Kleinpell, and the Zemorrian and Saucesian stages of Kleinpell. Several short periods of shallow, sheltered sea conditions are suggested by the Foraminifera from several parts of the stratigraphic sequence, but Foraminifera from most of the rocks suggest relatively deep, open-sea conditions.

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[An excellent comprehensive review. The bibliography lists a number of Prothero papers related to west coast magnetic stratigraphy. If I were an instructor of a strat class I would list this and the following paper by Garside *et al.*, as, *Required Reading*.]

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[This reference illustrates and discusses the regional unconformable relationship between the Ione equivalent beds and the overlying Domengine transgressive sands.]

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[The Boston Mine was part of the Red Dog hydraulic mining area, approximately one half mile north of You Bet. The Mine is illustrated as the Endpiece. The report attached there indicates the amount of work necessary to remediate these old mine sites. See Endpiece reference also for complete report.]

2008. Ogg, J.G., Ogg, G. and Gradstein, F.M. 2008. Paleogene (22-66 Ma time – slice. The Concise Geologic Time Scale. Update of SEPM Special Publication 60, under the auspices of **ICS** and IUGS, Purdue University, Chart 2.
https://engineering.purdue.edu/Stratigraphy/charts/Timeslices/2_Paleogene.pdf
[I use this chart because it is continually updated and it is generally cited by most current workers. See also the Time Scale Creator at:
https://engineering.purdue.edu/Stratigraphy/tscreator/index/index.php]
see book also: [http://books.google.com/books?id=rse4v1P-f9kC&pg=PA455&lpg=PA455&dq=GRADSTEIN,+F.+M.,+J.+G.+OGG,+AND+A.+SMITH.+2004.+Geologic+Time+Scale&source=bl&ots=AxHQtgjFDA&sig=EVDO-UyHpcSgHxD-VJnIfh81p0U&hl=en&ei=qg4VTZqWCI74sAOZ4p3RAg&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBMQ6AEwAA#v=onepage&q=GRADSTEIN%2C%20F.%20M.%2C%20J.%20G.%20OGG%2C%20AND%20A.%20SMITH.%202004.%20Geologic%20Time%20Scale&f=false]
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[An excellent contemporary study, with very fine photographs of fossil *Venericardia*.]

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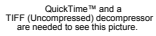
http://earth.geology.yale.edu/~markb/Eprints/Hren_etal2010_SierraNevada.pdf
[The authors use the time interval from 52-49 Ma in their discussion. As they state, this essentially corresponds to the Capay Age, as now understood. Following Ogg *et al.* (2008), this is the later half of the Ypresian, or early Eocene. The interval is approximately equivalent to the marine plantonic foraminifera zones P7-P9, part of calcareous nannoplankton zones CP9, CP10-CP11, and ~the first half of zone CP12. They determined this time interval based on the Chalk Bluff plants, asserting that the "Plant fossils are classified as Chalk Bluff Flora after their best-preserved occurrence*, and are dated at 52-49 Ma by faunal and floral correlation* (MacGinitie 1941; Wing and Greenwood, 1993)." [Italics mine]. Based on these conclusions, Hren. *et al*. asserted they had obtained "…well-constrained early Eocene (52-49 Ma) organic geochemical data that record range-scale and channel paleoelevations and provide an indication of early Sierra Nevada relief." This example illustrates the problem created by the lack of adequate age control in these channel deposits (see Garside *et al.* p. 7, 2005). By accepting MacGinitie's, 1941 Capay Age, which is incorrect, and by further inferring that all the samples they used are contemporaneous, which is considered suspect, their conclusions are questionable. Their appended data, (Table 1), is confusing and appears to need closer scrutiny. Example: the You Bet 2 and Chalk Buff E localities. These two sites plot within <1/2 mi apart and are separated by ~400 ft topographically. They list the You Bet 2 locality as Eocene elevation 1634 and Eocene temperature as 15.1, and the Chalk Bluff E as Eocene elevation 1246 and Eocene temperature as 20.1]

2010. Lovelock, E.C., Tiffney, B.H. and Kylander-Clark, A. 2010. Detrital zircons as a method for constraining the age of Eocene fossil floras, northern Sierra Nevada, California, USA. Geologic Society of America Abstracts with Programs, 42(5):672.
http://gsa.confex.com/gsa/2010AM/finalprogram/abstract_180543.htm
[The authors present a zircon date for the channel at the site of ~35Ma. This and other isolated dates indicate the age of the channel deposits over the northern Sierras range considerably in age. See introduction to this review.]

ENDPIECE

The Boston Hydraulic Mine, Red Dog area, California. Approximately one mile North Northwest of You Bet.



[The 'chemical cleanup' involved with this mine can be reviewed in the following publication: http://pubs.usgs.gov/sir/2004/5251/sir_2004-5251.pdf [Alpers, C.N., Hunerlach, M.P., May, J.T., Hothem, R.L., Taylor, H.E., Antweiler, R.C., De Wild, J.F. and Lawler, D.A. 2004. Geochemical characterization of water, sediment, and biota affected by mercury contamination and acidic drainage from historical gold mining, Greenhorn Creek, Nevada County, California, 1999–2001. USGS Scientific Investigations Report 2004-5251.]