State of California
The Resources Agency
Department of Water Resources

PALEONTOLOGIC RESOURCES IN THE VICINITY OF FERC PROJECT 2100 (OROVILLE RESERVOIR AND LOWER FEATHER RIVER): LITERATURE-BASED INVENTORY AND SIGNIFICANCE ASSESSMENT

Oroville Facilities Relicensing
FERC Project No. 2100

JANUARY 2005

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1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

1.1.1 Statutory/Regulatory Requirements

The Oroville Facilities, a multipurpose water supply, flood control, power generation, recreation, fish and wildlife, and salinity control project (Federal Energy Regulatory Commission [FERC] Project 2100) is currently being relicensed under Alternative Licensing Procedures, by the California Department of Water Resources. The Oroville Facilities are located on the Feather River in the foothills of the Sierra Nevada in Butte County, California. The Oroville Facilities encompass 41,000 acres within the project boundary and include Lake Oroville, Oroville Dam, three powerplants (Edward Hyatt Powerplant, Thermalito Diversion Dam Powerplant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Thermalito Forebay and Forebay Dam, and the Thermalito Afterbay and Afterbay Dam, as well as a number of recreational facilities.

The present study is intended to provide baseline data for an Applicant Prepared Environmental Assessment (APEA), to meet the requirements of the National Environmental Policy Act (NEPA), FERC's relicensing regulations, and the California Environmental Quality Act. Known fossil localities within the boundaries of the study area (listed in confidential Appendix C) all fall within state lands owned by either the California Department of Parks and Recreation or the California Department of Fish and Game. California laws and statutes therefore apply to these localities.

Table 1.1–1. Ownership of land including known fossil localities within study area

Locality/Area	Formation	Ownership
Limesaddle boat ramp	"Calaveras" marble	Parks and Recreation
West Branch Bridge	"Calaveras" marble	Parks and Recreation
Other "Calaveras" limestone outcrops	"Calaveras" marble	Parks and Recreation
Thermalito Diversion Pool	Monte de Oro	Parks and Recreation
Thermalito Diversion Pool	Late Cenozoic gravels	Parks and Recreation
Thermalito Afterbay	Late Cenozoic gravels	Fish and Game

The California Environmental Quality Act (CEQA) includes references to paleontology in its Appendix G, which defines significant effects of projects on paleontological resources, and Appendix I, which asks the applicant if the proposal would affect such resources.

The California Public Resources Code, (Division 5, Parks and Monument, Chapter 1.7 entitled "Archeological, Paleontological, and Historic Sites". Section 5097 to 5097.6) is more explicit and broader in applicability than CEQA, imposing sanctions for "unauthorized excavation, removal, destruction, etc., of … paleontological …features on public lands…". Under this statute, "public lands" include "…lands owned by, or under the jurisdiction of, the state, or any city, county, district, authority, or public corporation, or any agency thereof".

As portions of the study area are owned by federal agencies (US Bureau of Land Management and US Forest Service), federal regulations apply to fossils found on these lands.

The Federal Land Policy and Management Act (FLPMA) authorizes inventories of paleontological resources on federal land managed by the Bureau of Land Management which now issues permits for collecting of fossils on those lands only for scientific purposes by recognized paleontologic institutions. The Bureau of Land Management has subsequently adopted explicit policies and criteria used in the management and assessment of paleontological resources within their purview (BLM 1969).

The Antiquities Act of 1906 has been cited in past efforts to protect paleontological resources on federal lands, and is currently recognized as the authorizing legislation for regulation of the collecting of vertebrate fossils on land managed by the National Park Service and Department of Energy.

A bill currently before the US Congress would expand and standardize the protection and collecting policy of fossils of all kinds on federal lands, and restrict commercial fossil collecting (S. 546, Senator Akaka 2003). If enacted, this measure may affect management policy relating to paleontological resources in at least some of the project area.
More extensive citations of existing laws are presented in Appendix A.

1.1.2 Study Area

1.1.2.1 Description

This study focuses on known or potential paleontological resources within and adjacent to the Oroville Reservoir, Oroville Dam and Diversion Pool, Thermalito Forebay, and Thermalito Afterbay as defined by the Oroville FERC 2001 Project Boundary (Department of Water Resources 2001, Figure 1-1). It also extends southward along both sides of the Feather River to its confluence with the Sacramento River, and laterally to and including the banks defining the margins of its modern floodplain. Information relevant to the probable distribution and composition of fossils within this area also derives from records of paleontological resources outside these boundaries, but within areas elsewhere in the Sacramento Valley and Sierra Foothills which are underlain by geologic units also identified within the stated boundaries.

1.1.2.2 History

The complex geologic history of the Oroville Reservoir/Feather River area, straddling the boundaries of the Sierra Nevada and Great Valley geological provinces, has fostered an unusually long local record of geologic and biologic events, which, in turn, have led to a rich history of paleontologic research in the vicinity.

Scientific investigation of fossils from within the present project area began well over a century ago with the formal description of previously unknown invertebrate species from

Permian rocks (type specimens of *Clisiophyllum gabbi* and *Spiriferina*), probably from the area of the present Limesaddle boat launch (Meek 1864). In his pioneering study of California fossils, Gabb described marine Cretaceous fossils from nearby localities that he included in his Chico Series (Gabb 1864, 1869). Near the end of the 19th century, Fontaine described fossil plants dating to the Jurassic Period found in rock outcrops adjacent to what is now the Thermalito Diversion Pool (Fontaine 1896, Fontaine 1900). Later discoveries from these sites as well as localities just outside the project boundaries have continued to reveal new species of plants and animals dating from the Cretaceous Period to the Pleistocene Epoch of the Quaternary Period (e.g. Fry 1963, Hanna 1929, Hilton and Antuzzi 1997, Hilton et al. 1999, Long et al. 1997, Watkins et al. 1987).

2.0 NEED FOR STUDY

The past three decades have seen a marked increase in the recognition of paleontological resources as significant and threatened components of our natural environment, offering the only direct evidence of the history and distribution of prehistoric organisms. Ongoing concern is reflected by the recent introduction of a bill in the US Senate (the Paleontological Resources Preservation Act) in which Section 2. FINDINGS states:

"The Congress finds the following:

(1) Paleontological resources are nonrenewable. Such resources on Federal lands are an accessible and irreplaceable part of the heritage of the United States and offer significant educational opportunities to all citizens.

(2) Existing Federal laws, statutes, and other provisions that manage paleontological resources are not articulated in a unified national policy for Federal land management agencies and the public. Such a policy is needed to improve scientific understanding, to promote responsible stewardship, and to facilitate the enhancement of responsible paleontological collecting activities on Federal lands.

(3) Consistent with the statutory provisions applicable to each Federal land management system, reasonable access to paleontological resources on Federal lands should be provided for scientific, educational, and recreational purposes."

Development of appropriate management policy, with respect to actions which directly affect paleontological resources as well as those resulting in indirect effects due to routine facilities operations and recreation, necessarily begins with an inventory and assessment of the distribution, significance, and sensitivity of local resources.

3.0 STUDY OBJECTIVES

3.1 APPLICATION OF STUDY INFORMATION

3.1.4 Environmental Documentation

The primary objectives of the present study are to provide a preliminary inventory and assessment of paleontological resources of the Oroville Reservoir and lower Feather River area. With the scope of the study limited to data assembled from written published and unpublished records and personal interviews, specific details of resource sensitivity (vulnerability) and impacts of operational and recreational activities would require supplemental field studies.

4.0 METHODOLOGY

4.1 MODELS AND STUDY DESIGN

The intent of this study is threefold: (1) to identify and generally describe fossil localities known to exist within the study area, (2) to identify subareas in which fossils are likely to be found, and (3) to classify all subareas according to their probable significance to paleontologic investigations.

4.1.1 Documentation of known localities

We approached the first objective by (1) investigating published literature bearing on the known paleontology and geology of the area, (2) examining museum collections and associated unpublished records documenting previous finds, and (3) interviewing persons familiar with the geology and/or paleontology of the area, who may know of additional unpublished fossil localities. It must be pointed out that the distribution of *known* fossil localities depends on many factors other than the intrinsic fossil content of the geologic units under consideration: Wide geographic variations exist in the degree of surface exposure (extent of vegetation and soil cover), intensity and history of construction-related excavation (undoubtedly correlated with population density), probability of reporting of discoveries by the general public, and distance from institutions maintaining paleontological records. Furthermore, a *locality* is defined only as a place where one or more fossils have been found: The areal size and number of specimens may vary greatly among localities. Nevertheless, the distribution of known localities, in conjunction with the distribution of enclosing rock units, provides basic constraints on the assessment of paleontologic significance of designated subareas. There have been no large-scale systematic field surveys to assess objectively the distribution of fossils in any major part of northern California.

4.1.2 Identification of Probable Fossiliferous Areas

The second objective requires additional interpretation. Fossils of all kinds are very unevenly but non-randomly distributed within the rocks comprising the earth's crust. Consequently, areas offering higher or lower probability of fossil access and discovery are defined by the geographic distribution of surface exposures of different rock units which have been variously produced, uplifted, distorted, altered, and eroded during the course of geologic history. Delineation of these patterns within a particular geographic area depends on the integration of information from geologic mapping, the distribution of previously discovered fossil sites, and interpretation of local environments, favorable or unfavorable to fossil preservation, which prevailed at and after the time each rock unit originated. In the absence of direct field investigation, this last information source depended on detailed published descriptions of rock composition and the authors' interpretations.

Most components of the earth's crust and surficial deposits originated in response to one of three categories of processes, leading to the basic classification of rocks as igneous, sedimentary, or metamorphic.

Igneous processes include both intrusive phenomena -- in which a molten mix of minerals (magma) from a deep source is injected into overlying crust -- and extrusive or volcanic processes in which the magma escapes to the earth's surface to form lava flows, domes, volcanic mudflows (lahars), or volcanic ash (tuff). Intrusive magma never comes in contact with organisms or their remains (except those already preserved as fossils in adjacent pre-existing rock) so could not include fossils. Extrusive lava flows may override plant or animal remains, but, with rare exceptions, any organic material is almost always incinerated or vaporized before the lava cools and hardens. Volcanic ash (also termed tuff, tephra, or ignimbrite) or lahar deposits may include fossils, sometimes well-preserved, if it is sufficiently fine-grained and cool enough when it was deposited on land, lake bed, or seafloor, and if organisms or their remains are already present in the area. Because volcanic ash is an accumulation of individual grains, it may also be classified as a sedimentary deposit. As with non-volcanic sediments, initially unconsolidated tuff may become hardened by groundwater deposition of cementing minerals to form rock.

Sediments, whether unconsolidated or hardened by later geologic processes to form sedimentary rock, include nearly all potential sources of fossils, although not all sediments include fossils. The initial presence and continued preservation of organic remains depend on the physical and biological circumstances at the time and place of deposition, and on subsequent physical and chemical processes affecting the sediments after accumulation, some of which may still destroy the contained organic remains.

Metamorphism refers to the alteration of the chemistry and structure of pre-existing rocks (igneous, sedimentary, or lower-grade metamorphic) by physical and chemical processes within the earth, usually at considerable depth. These processes usually destroy any fossils that may have existed in the parent rock, but, if not exceedingly altered, metasediments (metamorphic rocks derived from sedimentary rocks) may include fossils.

Geologic maps provide a basic link between the geographic positions of known fossil localities and predicted likelihood of future finds in other areas. Development of a map of paleontologic significance begins with delineation of all subareas shown on a geologic map to be underlain by sediments, sedimentary rocks, or low-grade metamorphic rocks. Sediments deposited in post-Pleistocene ("Recent" or Holocene) time, less than about 9,000 or 10,000 years, are less likely to contain fossils of paleontologic interest, and can generally be excluded as non-sensitive. The remaining sediments and sedimentary rocks may vary considerably in fossil content, but the probability of finding fossils correlates closely with the areas of surface exposure of specific geologic units, and with the geographic concentration of previous finds in that unit.

Geologic maps are usually produced in pursuit of other goals and inevitably incorporate the authors' interpretations in areas where access to bedrock data is limited by vegetation, soil, or surficial deposits. The selection of rock units to be depicted and the level of both stratigraphic and geographic resolution therefore reflect each author's research intent and the extent of observable surface exposure of the mapped units.

Mappable geologic units are defined by their lithology -- distinctive characteristic details of their composition. For sedimentary units, these details are mostly products of the physical and chemical environment in which they were deposited. Many of the same factors, such as grain size, bedding features, and carbonate or silica content also relate to the probability of accumulation and preservation of remains of contemporary organisms as fossils. Levels of fossil abundance within subareas of a project site are therefore correlated with the geographic distribution of the different geologic units present. Because many existing geologic maps, each with different research goals and somewhat different lists of mapped units, overlap all or parts of the study area, estimates presented here of relative fossil abundance (a primary component of significance) are based on the distribution of previously mapped units whose stated characteristics most closely reflect depositional environments, sometimes at the expense of time-resolution.

The basic mapped unit of sedimentary rocks is the formation, and is usually assigned a formal name. In some cases, distinctive subunits of a formation may be mapped separately, and possibly assigned names as members of the formation. These mapped units define the practical resolution level for this report, although fossil abundance may vary considerably within named formations. Records of fossil finds, published or unpublished, usually include the name of the geologic formation in which it was found, leading to an initial estimate of the abundance and types of fossils expected in that unit. For purposes of this report, records of fossil localities anywhere in the central and southern Sacramento Valley and adjacent foothills were considered in assessment of the fossil potential for each geologic unit mapped within the project boundaries.

Sedimentary rocks can originate in a broad spectrum of depositional environments, which vary greatly in their potential for fossil preservation. To the extent that known features of a sedimentary rock body can be interpreted in terms of its depositional environment, expectation that it will yield fossils can often be at least qualitatively estimated.

4.1.3 Significance Assessment

4.1.3.1 Scientific Importance

The relative importance of a fossil locality to the science of paleontology depends on a large number of factors whose relative importance may be differently weighted by different investigators, depending on their research interests and subject matter. Research based on fossils may emphasize their use as indicators of geologic time, records of anatomical details of extinct organisms, evidence of the course of evolution, or samples of former ecosystems. However, three general attribute categories of a locality contribute to the decision as to whether the locality is "noteworthy": What combined levels of uniqueness, diversity, and quantity of information about past life may be available from the given resource?

4.1.3.2 BLM criteria

A set of explicit, broadly applicable, and relatively objective criteria for assessment of paleontological significance, compatible with the above considerations, has been developed by the US Bureau of Land Management. These criteria lead to a ranking of geographic areas according to the probability of occurrence and the level of importance of fossils:

> **"Condition 1**: Areas that are known to contain vertebrate fossils or noteworthy occurrences of invertebrate or plant fossils.
>
> **Condition 2:** Areas with exposures of geologic units or settings that have a high potential to contain vertebrate fossils or noteworthy occurrences of invertebrate or plant fossils. The presence of geologic units from which such fossils have been recovered elsewhere may require further assessment of these same units where they are exposed in the area of consideration.
>
> **Condition 3:** Areas that are very unlikely to produce vertebrate fossils or noteworthy occurrences of invertebrate or plant fossils based on their surficial geology, igneous or metamorphic rocks, extremely young alluvium, colluvium, aeolian deposits, or the presence of deep soils. Anticipated depth of bedrock will aid in determining if fossiliferous deposits will be potentially uncovered during surface-disturbing activities. " (BLM 1969)

These conditions will be abbreviated C1, C2, and C3 where appropriate in this report.

4.2 How and Where Studies were Conducted

To meet the stated goals, the study proceeded through four steps:

(1) Identify geologic units present within the study area or in close enough proximity that they might be directly or indirectly affected by reservoir and ancillary facilities operations or by associated recreational activities;

(2) Assemble geologic information about these units which may bear on their potential to include fossils, and on the significance of any fossils that may be found;

(3) Assemble information about previously discovered fossil localities in the identified geologic units and within, or in the region of, the study area;

(4) Integrate geologic and fossil locality data to identify areas with sensitive paleontologic resources, and to provide a preliminary assessment of the potential for and scientific significance of additional fossils that may occur or be found in the study area or nearby areas of possible facilities-related impacts.

We collected the data contributing to this report from three categories of sources: published records of previous work, unpublished museum locality and fossil data, and personal interviews. In addition, Dr. David White (Montgomery-Watson-Harza) passed along several documents produced by the Department of Water Resources but not available in public or institutional libraries. These included project site maps, geologic maps, reports, and excerpts of particular importance to this investigation.

Research for this project did not include personal field investigation within the project area or at nearby localities.

Relevant existing publications include geologic maps; descriptions, interpretations, and discussions of the geology and geologic units within and near the study area; and findings related to fossils from the study area and from geologic units existing within the study area but from other parts of the Sacramento Valley and adjacent foothills. We located geologic maps of the area through both hardcopy and online geologic map indices. Other sources led to published geological and paleontological literature (GeoRef and University of California Library reference databases MELVYL and GLADIS). The GeoRef search, using both geographic and formation name search keys, was conducted by Dr. Howard Schorn. Bibliographies in the located publications themselves led to further references. Libraries at the University of California, Berkeley, held most of the significant maps and literature. Specific sources are given in Section 5.1; also see Appendix B.

In April, 2003, I directly examined records of localities in the region of the study area at both the University of California Museum of Paleontology (UCMP) in Berkeley and the California Academy of Sciences (CAS) in San Francisco, with the helpful guidance of Dr. Patricia Holroyd (UCMP) and Dr. Jean DeMouthe (CAS). Contacted by telephone in March and April, 2003, personnel at other northern California institutions considered as possible sites of additional records (Dr. Richard Hilton, Sierra College, Rocklin; Dr. Matthew James, Sonoma State University, Rohnert Park; and Dr. Richard Flory, Chico State University, Chico) conveyed information about the extent, relevance, location, and content of their collections.
In a personal interview at his home in Oroville (Apr. 8, 2003), Mr. Eric Göhre provided location and content information of several fossil localities, of which he had personal knowledge, within and near the project study area. Mr. Göhre is an avocational paleontologist who has contributed important specimens and field information to several institutions. In collaboration with professional paleontologists, he has co-authored a number

of technical papers relating to his finds (e.g. Hilton, Göhre, Embree and Stidham 1999; Long, Lawler and Göhre 1997).

I assembled and integrated the information and prepared this report at my office in Richmond, California.

5.0 STUDY RESULTS

5.1 INFORMATION SOURCES

5.1.1 Geologic Data

Ten geologic maps and descriptive and interpretive information which accompanied five of them (Table 5.1-1; Appendix B) provided most of the geologic data incorporated into the paleontological assessment. These were found through a check of several indices of geologic maps in both hardcopy (Frasse and Kiessling 1983; Jennings 1985; Kiessling 1972; Kiessling and Peterson 1979; Kiessling, McMillan and Smith 1981; Koenig 1962; Koenig and Kiessling 1968; Saucedo and Wagner 1992; Strand, Koenig and Jennings 1958) and online formats (especially those of the Meriam Library, Maps Department, California State University, Chico; and California Geological Survey, Index to Geologic Mapping in California).

Geologic and geographic information associated with records of fossil localities usually allowed the identification of the geologic units that produced the fossils, although the level of resolution varied.

Table 5.1-1. Geologic maps consulted for this study

Reference*	Map scale	Associated text description
Creely 1965	1:62,500	General geology
Busacca et al.1989	1:150,000	Late Cenozoic units
Jennings 1977	1:750,000	Brief descriptions of grouped-formation map units
Cole and McJunkin 1978	1:48,000	Detailed lithologic detail, historical interpretation
Saucedo and Wagner 1992	1:250,000	Radiometric dates
DWR Map 2	1:30,000	None – Enlarged portion of Cole & McJunkin 1978
DWR Map 3	1:24,000	None
DWR Map 4	1:24,000	None
DWR Map 5	1:24,000	None
DWR Map 6	1:24,000	None

* See section 7.0 References for complete source information; see Appendix B for an index of areas covered by the various maps.

5.1.2 Paleontologic Data

Many existing publications include references to fossils from the vicinity of Oroville Reservoir and lower Feather River. Creely (1965) lists 11 invertebrate localities and three plant localities, all of which fall in the eastern half of the area he mapped, corresponding to the Cherokee and Oroville 7½‘ quadrangles. Other publications describing fossils from relevant individual localities or geologic units include Dundas and Cunningham (1993), Fontaine (1896, 1900), Fry (1964), Gabb (1869), Hanna (1929), Hilton and Antuzzi (1997), Hilton et al. (1999, 2000), Long et al. (1997), Parham and Stidham (1999), and Watkins et al. (1987).

Institutions holding the largest paleontological collections from the vicinity of the study area are UCMP and CAS. The UCMP collection includes materials formerly held by the US Geological Survey, Menlo Park. It has catalogued specimens from the Chico and New Era Formations and several Pleistocene units. Collections at CAS include specimens formerly held at Stanford University. Most localities recorded at CAS are from the Chico Formation with a smaller collection representing the Ione Formation. Sierra College collections include specimens from the Chico and Monte de Oro Formations, and the University of California at Chico holds specimens from the “Calaveras” limestone and the Chico and Tuscan Formations as well as small Pleistocene localities. No other northern California educational institutions are known to hold significant fossil collections from the region of the study.

5.2 GEOLOGIC UNITS AND THEIR FOSSIL CONTENT

Except for strictly anatomical studies, the significance of fossils is closely tied to the geologic and paleoenvironmental context in which they occur. Discussions of the environments of origin of the rocks found in the Oroville/Feather River area therefore accompany descriptions of the individual rock units. These discussions briefly summarize interpretations of the local geology, primarily those presented in Marlette et al. (1979).

Table 5.2-1. Geologic units considered in study

Series	Unit name or predominant rock types	Age	Marine/ Nonmarine
Bedrock			
Melange	marble (exotic; = "Calaveras" limestone)	Permian?	M
	metasediments, metavolcanics, serpentine	Late Jurassic ?	M
Arc rocks	volcanic, volcaniclastic rocks	Jurassic?	M
	Oregon City Fm. of Creely 1965	Late Jurassic	M
	Monte de Oro Fm.	Late Jurassic	M?
Ophiolite	Smartville ophiolite (mostly intrusive rocks)	Jurassic	M
Intrusive	(3 granitic plutons – large intrusive bodies)	Early Cretaceous	--
Superjacent			
	Chico Formation	Late Cretaceous	M
	Ione Formation (undifferentiated)	Middle Eocene	N
	"Oroville tuff" member	Middle Eocene	N
	"Auriferous Gravels" member	Middle Eocene	N
	Lovejoy Formation	Early Miocene	N
	New Era Formation	Middle Miocene	N
	Tuscan Formation	Late Pliocene	N
	Nomlaki Tuff Member	Late Pliocene	N
	Late Cenozoic gravels*	Plio-Pleistocene	N
	recent deposits (incl. dredge tailings)	Recent	N
	landslide	Quaternary	N

* Alluvial fan fcies of Laguna, Riverbank, and Modesto Formations.

Seven different lists of mapped geologic units accompany the ten maps consulted, depending on the authors' research goals, current theoretical framework of interpretation of geologic history, and the scale of mapping. With minor modifications, the units selected for individual consideration in this report most closely follow those recognized by Marlette et al. (1979) and in the accompanying geologic map by Cole and McJunkin (1978). This intermediate-scale map includes rock units that reflect current (post-1960s) concepts of rock origins in the framework of plate tectonics. These concepts have radically recast the meaning of fossils included in the older geologic units in the study area. Understanding of the significance of included fossils depends in part on recognition of their role in unraveling and refining the complex geologic history of the region.

Individual units are grouped into three large categories, which broadly reflect major modes, ages, and paleogeographic places of origin. The two groups composed mostly of stratified rocks, originally deposited on or near the earth's surface during two long stretches of geologic time are termed "series". The following sections present a brief geologic history of the area and the environments of formation, rock descriptions, distribution relative to the study area, and general fossil content of each of the units, from oldest to youngest.

5.2.1 Bedrock Series

The “Bedrock series” rocks of the Oroville area originated seaward from or adjacent to the continental margin of Jurassic and earlier times. Different suites of rock types, termed “melange”, “arc rocks”, and “ophiolite” in modern usage, originated in each of three subareas of this offshore realm.

Unlike the modern setting along much of the California coast, in which the Pacific Plate moves slowly northwest, subparallel to the western edge of the North American (continental) plate, conditions in Jurassic and earlier times caused the oceanic plate to move toward and under the edge of the continental plate (a process termed *subduction*), creating a deep offshore trench comparable to that now bordering most of the west coast of South America. Most of the lighter sediments and volcanic rocks which had accumulated on the surface of the oceanic plate and in the trench itself were essentially “scraped off” and accumulated chaotically in the trench as the heavier lower plate descended into the subduction zone. These heterogeneous, folded, and faulted surficial deposits accreted at the edge of the continental plate to form the suite of rocks grouped as *“melange”*.

(Geographic directions of plate movement used in this section refer to motion relative to an assumed “fixed” North American continental plate, although it has been proven that this plate also moved relative to the earth’s rotational poles and equator.)

Shoreward from the trench, combined minor uplift and volcanic activity created arcuate areas of shallow or emergent parts of the seafloor. Volcanic debris and flows as well as non-volcanic, continentally-derived sediments accumulated in the shallow basin between these island arcs and the coastline, eventually to form the suite termed *“arc rocks”.*

Seaward from the trench, perhaps thousands of kilometers, a spreading zone marked by a relatively shallow, segmented submarine volcanic ridge bounded the other side of the oceanic plate and continued to form new oceanic crust. Continuing plate movement brought seafloor crustal rocks, originally formed at the spreading ridge, in contact with the edge of the continental plate to preserve a characteristic suite of rocks: intrusive dikes, submarine-extrusive lavas, and capping marine sediments, collectively termed *“ophiolite”.*

Formed in the vicinity of the suboceanic spreading ridge, the ophiolite suite consists mostly of intrusive igneous rocks, submarine-extruded basalts (“pillow basalts”), and a veneer of oceanic sediments, all constituents of the seafloor portions of the earth’s crust. While the sedimentary part of this series carries the potential to include organic remains, most sediments eventually were incorporated in the trench deposits (melange suite) as the deeper igneous layers became subducted below adjacent crust.

5.2.1.1 Melange Suite

Metasediments, Metavolcanics, Serpentine

The prefix "meta-" applied to a rock name implies that it has undergone metamorphism – alteration of its internal structure, recrystallization, and often changes in mineral composition due to high temperature and/or pressure.

In the case of metasediments, these changes typically affect included fossils as well, usually to the extent that fossils become unrecognizable or at least severely distorted. Modern trench environments support a very low density of preservable organisms, and the same can be assumed to have been true of the ancient trench, although remains of organisms living in shallower water adjacent to the trench could have been swept into it by seafloor currents or submarine slides. Despite the unfavorable conditions, a very few fossils have been found in these metasediments, leading to differing interpretations of the timing of local geologic events.

A small fossil clam from melange metasediments just outside the study area was reported to be in the possession of Ralph Imlay of the US Geological Survey (Marlette et al. 1979, p. 34, citing Bob Treet pers. comm.1978). Interpreted to indicate a Jurassic age, the specimen may have contributed to the conclusion by Marlette et al. (1979) that the entire melange suite was also of Jurassic age. Later detailed investigations by Watkins et al. (1987) led to the discovery, in settings comparable to that of the clam, of several distorted fossils they state could be no younger than Permian, about 100 million years older.

Volcanic rocks deposited in the trench environment are even less likely to incorporate organic remains, and the metamorphosed volcanic rocks now present in the study area offer almost no probability of yielding fossils.

Serpentine is a rather unique, although relatively common, rock type which may have originated either as an extreme alteration product of submarine volcanic or intrusive rocks or emplaced as intrusive bodies in overlying rocks. In either case, the probability of incorporation of fossils is virtually zero. There appear to be no known examples of inclusion of fossils in primary serpentine bodies.

Rocks of the melange suite underlie nearly all of the North Fork and West Branch areas of the Oroville reservoir and adjacent study area.

Marble (= "Calaveras" Limestone)

Although included in the melange complex by virtue of geologic association and metamorphism, several relatively small areas along the southern part of the West Branch Canyon are underlain by a distinctive type of rock unique in its possible longer history and fossil content. These restricted areas contain large bodies or "pods" of calcium carbonate rock, which originated as limestone but have been partly recrystallized to form marble. Long thought to be essentially contemporaneous with the surrounding metasediments (e.g.

Creely 1965), these bodies were interpreted by Marlette et al. (1979) to have formed far from the trench some 100 million years earlier, during the Permian Period, then carried eastward with the oceanic plate and into the trench some time during the Jurassic Period. Here, one or more slab-shaped limestone units were broken into large fragments, incorporated with the more contemporary sediments and volcanics, and distorted, metamorphosed, and accreted to the edge of the adjacent plate.

An alternative interpretation was later published by Watkins et al. (1987). Based in part on the discovery of fossils no younger than Permian in the sediments surrounding the marble pods, this hypothesis envisions fragments from a carbonate platform formed near the trench breaking away and sliding downslope (perhaps tens of kilometers, but not hundreds or more) to become incorporated in the chaotic trench deposits. In this interpretation, the entire melange deposit, not just the marble units, are again ascribed a Permian age. Despite the extreme conditions encountered during their history, these marble pods still contain locally abundant and recognizable fossils, documentation of an ecosystem that existed not only long ago, but perhaps far away!

The white to bluish-gray marble pods within the study area are “restricted to a linear belt of exposures in West Branch Canyon” (Marlette et al. 1979). According to those authors, marble exposures in other areas of the melange are scarce and non-fossiliferous, and probably contemporaneous with the other metasediments of the melange suite. Several map figures in Watkins et al. (1987) illustrate in detail the distribution of the marble pods and other less fossiliferous units.

Records at UCMP and at CSU Chico include documentation of fossil localities within this unit.

5.2.1.2 Arc Rocks

<u>Volcanic and Volcaniclastic Rocks (=Oregon City Fm. of Creely 1965)</u>

Igneous activity along the island arc shoreward from the trench produced lava flows and airborne ash and coarse fragments (volcaniclastic rocks, or “tuffs”) which accumulated in the basin between the arc and the shoreline. Subsequent metamorphism altered most of these rocks to form “greenstone”.

Most of the volcanic and volcaniclastic arc rocks in the vicinity of the study area occupy a two- to four-kilometer-wide north-south trending band extending from near the lower West Branch Canyon southward to and beyond the Thermalito Diversion Pool. These rocks also underlie the peninsula now formed by the reservoir at the bend in the North Fork, across the reservoir from the Goat Ranch Recreational Area.

Volcaniclastic rocks, and especially the less-common flow rocks, rarely preserve fossils. Subsequent metamorphism has further reduced the probability of finding fossils. Nevertheless, a single important find by Creely (1965) provided rare information placing the age of these rocks in the Late Jurassic. This specimen, an ammonite, was in the Stanford

University Museum of Paleontology (Locality No. 9063) at the time of Creely's publication, and was presumably later transferred to CAS.

Monte de Oro Formation

A localized subarea of the arc rocks within and near the study area presents limited exposures of slightly metamorphosed sedimentary rock whose composition suggests a more near-shore or possibly estuarine depositional environment. This unit, separately named the Monte de Oro Formation, includes clasts (particles) of quartz and chert, minerals rarely associated with the andesitic volcanics of the other arc rocks, but common in continental rocks, implying transport to the site of deposition by streams heading on the continental block (Marlette et al. 1979).

The entire known extent of the Monte de Oro Formation lies within about two miles (three kilometers) of the study area, mostly in a narrow north-south band within the volcaniclastic unit, and crossing the Thermalito Diversion Pool. The Monte de Oro rocks are sharply folded into a tight syncline (much like a hard taco shell) so that the youngest parts fall along a central line, and the originally horizontal bedding planes are now nearly vertical (Creely 1965, Marlette et al. 1979). Part of this band is overlain by younger subhorizontal rock formations, and is not accessible at the surface. Cole and McJunkin (1978) map three other small areas of man-made exposures of the Monte de Oro: one within the study area along a short stretch of the Thermalito Power Canal, just west of the diversion dam, and two smaller exposures along the railroad cut ¼ and ½ mile north of the canal.

Despite the low-grade metamorphism and folding, the Monte de Oro has yielded a remarkably well-preserved flora with at least ten genera, including ferns, cycads, and ginkgoes, which indicate a middle Late Jurassic age (Fry 1963). Specimens from this area are housed in collections at UCMP and Sierra College. This flora has not yet been studied in detail (Schorn pers. comm. 13 May, 2003).

5.2.1.3 Ophiolite Suite

Smartville Ophiolite

The suite of rock types now collectively called ophiolite represent former oceanic crust, and consist primarily of intrusive and extrusive basalts and the crystallized products of deep-seated magmas. Sedimentary deposits, such as cherts, which thinly cap some ophiolites and could contain fossils, are rare in the Smartville Ophiolite (Marlette et al. 1979).

In the vicinity of the study area, the Smartville Ophiolite occupies a broad north-south band, up to 10 kilometers wide to the east of the arc rocks. It underlies most of the main body of the reservoir, the dam, and part of the Thermalito Diversion Pool.

Given the igneous mode of origin of the volumetric majority of ophiolites, and the particular rarity of sedimentary components in the Smartville ophiolite, fossils would be expected to be very rare or absent in the local ophiolite suite, and none have been reported.

5.2.2 Intrusive Rocks

In the earliest part of the Cretaceous Period, magmas invaded the “Bedrock series” in the southeastern part of the study area, and cooled to form the granitic rocks that now underlie most of the Middle Fork and South Fork canyons. These intrusive igneous rocks expectably lack fossils of any kind.

5.2.3 Superjacent Series

During most of the Cretaceous Period, following the emplacement of the arc rocks, any deposition of sediments that may have occurred in the area appears to have been outstripped by erosion.

Renewed deposition along the western flank of the ancestral Sierras began in the Late Cretaceous but was followed by repeated cycles of deposition and erosion continuing to the present. Several of the depositional intervals left local sedimentary or volcanic records, most of which include fossils. These deposits are collectively termed the Superjacent Series (Creely 1965, Marlette 1979).

5.2.3.1 Chico Formation

By late Cretaceous time, the Sierras, Central Valley, and Coast Ranges had begun to develop, but only the Sierras rose above sea level. Late Cretaceous sedimentary rocks in the vicinity of the study area, all assigned to the Chico Formation, record only marine environments, but probably not far offshore. “The Chico Formation is characterized by light-colored, massive fossiliferous sandstone” (Creely 1965, p. 35). This unit has been a focus of paleontological interest since the 1860s (Gabb 1869), and continues to yield new species as work continues (Hilton and Antuzzi 1997, Hilton et al. 1999, Göhre pers. comm. 2003).

Although the Chico Formation is not known to exist within the study area, the nearest outcrops are less than 2.5 kilometers from it, near the West Branch Canyon. The unit is considered here because of its vulnerability and possible impacts related to recreational activities centered on the reservoir.

The Chico Formation in the region north and west of Oroville contains an unusually high concentration of fossils. Vertebrate and invertebrate specimens from many localities along Big Chico Creek, Butte Creek, Dry Creek and nearby areas are now in collections at UCMP (some of which are listed in Creely 1965 Append. A), CAS (extensive collections), and Sierra College, and undoubtedly in many private collections.

5.2.3.2 Ione Formation

By middle Eocene time, the shoreline of the Central Valley seaway had retreated westward to the vicinity of the study area or just beyond it. The middle Eocene Ione Formation extends far south along the western Sierra foothills and records marine delta to upstream fluvial environments, although in the vicinity of the study area, only fluvial and possibly lacustrine

facies have been recognized. Included in the Ione formation of the Oroville area is a subunit, the Oroville Tuff Member, of varying thickness and consisting of varied volcanic sediments including altered fine-grained tuffs and volcanic mudflow deposits (Marlette 1979). This contrasts with the predominance of well-rounded quartz and chert clasts in other parts of the Ione. A second distinctive member, the “Auriferous Gravel”, documents the presence of high-gradient streams originating in non-volcanic terrain. Local concentrations of placer gold in this widespread unit give the unit its name and led to extensive mining excavations, incidentally exposing locally abundant fossil wood and leaves.

Portions of the study area underlain by Ione Formation are restricted to the vicinity of the Thermalito Diversion Pool and the Thermalito Forebay. Landslides on the south flank of South Table Mountain have brought fossiliferous parts of the Ione Formation to within 5000 feet (1500 meters) of the Thermalito Power Canal (CAS records). Fossils found here include several genera of invertebrates.

Elsewhere in the Sierra foothills, the Ione has yielded a rich floral record (leaves and wood), but invertebrate fossils are uncommon and vertebrate fossils are unknown. Trace fossils, the preserved burrows or trackways of contemporary organisms, have also been reported in the Ione Formation (Merrill 1984).

5.2.3.3 Lovejoy Formation

Capping local deposits of the Ione Formation are the eroded remnants of a once-extensive basalt lava flow, now named the Lovejoy Formation. This resistant unit also forms the caprocks of both North and South Table Mountains north of Oroville.

The age of the Lovejoy has been the subject of debate since it was described as a separate formation by Durrell 1959, who thought it to be Eocene. Marlette et al. (1979) cite Dalrymple (1964) who concluded from radiometric dates that the maximum age of the Lovejoy was 23.8 million years, or early Miocene, based on tuffs below the basalt. Wagner and Saucedo (1990) obtained a potassium-argon date on a volcanic mudflow above this tuff but below the Lovejoy basalt, and concluded that the Lovejoy is less than 14.8 million years in age, placing it in the mid-Miocene.

In rare cases, fine-grained, rapidly-cooled basalt flows have been known to preserve molds of burned tree trunks that the lava surrounded, but the probability of the occurrence of fossils in the coarse-grained Lovejoy Basalt is negligibly small.

5.2.3.4 New Era Formation

Creely (1965) described a restricted formation composed mainly of coarse fluviatile sediments above what is now recognized as the Lovejoy Formation and below the Tuscan Formation in the vicinity of the New Era mine. The mine is near the north end of Dry Creek, west of the West Branch reservoir area. This falls less than one mile (1.6 kilometers) outside the study area.

Although Creely reported finding no fossils from the unit at the time of his investigation, UCMP collections include a single specimen of a land mammal from the New Era Formation at the New Era mine. The locality number, UCMP loc. V6309, indicates that the specimen was found during or before 1963. An assigned storage age of Clarendonian suggests that the specimen probably dates from the Late Miocene Epoch.

5.2.3.5 Tuscan Formation

Renewed volcanic activity in the late Pliocene, centered several tens of kilometers north of Oroville, produced a blanket of diverse tuffs, lava flows, and debris flows across part of the western Sierra foothills, including at least the northwest portion of the study area. A basal subunit, the Nomlaki Tuff, has been dated at 3.4 million years (ma) (Busacca et al. 1979, recalculated from 3.3 ma reported by Evernden et al.1964, using new constants).

Remnants of the Tuscan Formation now form the western rim of West Branch Canyon and extend downslope to reservoir level at the westernmost parts of this reach. Tuscan volcanics also cap Johnson Hill and a smaller ridge to its south, both east of the West Branch and near the north end of the reservoir in this area.

Fossil leaves, cones, and possibly fossil vertebrates have been found in the Tuscan Formation north of the reservoir area exposures (Flory, pers. comm., 2003). The uncertainty regarding the vertebrate finds arises from the possibility that some or all of the reported camel and mammoth specimens may have been preserved in later (Pleistocene) deposits present in valleys carved into the Tuscan. Time-equivalent rocks (the Tehama Formation on the west side of the Sacramento Valley and the Laguna Formation farther south on the east side) are both known to yield locally abundant vertebrate fossils.

UCMP collections include a land mammal specimen found 110 feet (33 meters) below the surface in cutting from a 16” bore about five miles west of the Feather River near Pennington. Associated records assign it to the Tehama Formation, although it may be more properly referred to the Laguna Formation, a temporally equivalent unit found on the east side of the Sacramento Valley and included in this report with the Late Cenozoic gravels.

5.2.3.6 Late Cenozoic Gravels

Plio-Pleistocene deposits, other than the lithologically distinctive Tuscan Formation, present a stratigraphically complex series of cross-cutting channel, alluvial fan and terrace, and minor floodplain sediments in the vicinity of the study area. Sediments composed of gravel-sized particles predominate in this series, especially near its higher, eastern limits, and all non-volcanic Pliocene and Pleistocene deposits have been grouped as a single map unit, “Late Cenozioc gravels”, by Marlette et al. (1979). These authors recognized that various parts are time-correlative with either Laguna, Riverbank, or Modesto Formations (listed oldest to youngest). These three units, and bi- or tripartite subdivisions of each, have been individually mapped in the central part of the study area, from the immediate vicinity of the Oroville Dam south to latitude 35°15’, by Busacca et al. (1989). Creely (1965) mapped these

deposits as “Red Bluff Formation” which they generally resemble, but Marlette (1979) cites evidence that they are not time equivalents of the Red Bluff Formation in its type area (near the city of Red Bluff, California) and extensive exposures in parts of the northern and western Sacramento Valley.

I have adopted the grouped designation here for the following reasons: 1) For purposes of assessment of paleontological significance, lithologic composition of the sediments has proven to be better correlated with fossil potential than is absolute age, 2) while the three named formations extend across the Sacramento Valley floor, sediments included in each range from coarse alluvial fan gravels near both valley margins through a variety of floodplain and channel deposits nearer the valley axis, and 3) most museum records do not designate a formation name for Pleistocene finds as these names were established rather late in the history of paleontological collecting. The scientific value of fossil specimens older than about 9,000 years is not appreciably influenced by age.

The base of the Laguna Formation in this area is marked by the 3.3 million-year-old Nomlaki Tuff, the same unit that is found at the base of the Tuscan Formation, indicating that the Laguna and the Tuscan are, at least in part, time-equivalent. According to Busacca et al. (1989), the upper member of the Laguna Formation includes the Plio-Pleistocene boundary. The Riverbank and Modesto, and their equivalents within the “Late Cenozoic gravels”, are Pleistocene in age. Dates on the younger Modesto range to as little as 9,000 years (Busacca et al. 1989).

Although grouped under the term “gravels”, the Plio-Pleistocene units near the study area also include sand, silt, and clay subunits, “most common away from upland terrains” and probably represent floodplain deposits (Marlette et al. 1979). Personal experience has suggested that a diversity of sediment types, reflecting changing local conditions and breaks between depositional episodes, often correlates with a higher probability of inclusion of fossils.

All of the geologic maps of the area depict extensive deposits of these units, locally extending to elevations as high as 700 feet (215 meters) along foothill flanks. Most of these deposits occur within and south of the Thermalito Forebay and the city of Oroville along both sides of the modern Feather River floodplain. Creely’s 1965 map also records them within the area of the future forebay. Late Cenozoic gravels not covered by Holocene (Recent) floodplain sediments appear as low as 125 feet (38 meters) in the vicinity of the town of Oak Grove, and probably at lower elevations farther south along the flanks of the Feather River. Because of repeated alternating episodes of erosion and aggradation, superimposed on a longer-term net drop in the elevation of the Sacramento Valley floor during the Pleistocene, progressively younger parts of the Late Cenozoic gravels form successively lower-elevation terraces with irregular margins from the lowest foothills to the modern floodplain limits.

Small deposits of Pleistocene sediments also appear in and near smaller drainages, sometimes at elevations well above those reached by the contiguous large-valley deposits. Many of these are too restricted to be mapped at the scales usually employed, so do not appear on geologic maps. The only documented example of a vertebrate fossil within the

strict limits of the study area (with the possible exception of the New Era specimen discussed above) was found in an unmapped Pleistocene remnant near the Thermalito Diversion Pool (UCMP V3739). Vertebrate fossils found a few miles north of the study area (discussed above under Tuscan Formation) may, in fact, have occurred in isolated later Pleistocene deposits as well.

Hanna (1929) published a report of a pair of large mammoth tusks that had been discovered in gravels below a clay layer about 11 miles south of Oroville. Although photographs in the publication leave no doubt of the discovery, research at the California Academy of Sciences (Hanna's institution at the time) and UCMP revealed no records or specimens corresponding to the discovery. The find was about seven miles east of the Feather River segment of the study area, but it demonstrates that the Late Cenozoic gravels hold the potential to yield important fossils.

Dr. Richard Flory (pers. comm. 2003) and Eric Göhre (pers. comm. 2003) both reported rumors of discovery of a large vertebrate fossil in the Thermalito Afterbay. The reports carried enough weight that Dr. Flory, accompanied by Koll Buer, Chief, Geologic Investigations Section of the Red Bluff office of the DWR undertook to verify them. Recent correspondence from Mr. Buer (pers. corr. 8, 9 May, 2003) has confirmed that mineralized vertebrae of a moderately large mammal (smaller than a mastodon) were exposed near the south shore of the afterbay in the late 1980s, but were left in place. No records of this reported specimen have been found among archives of the institutions consulted for this study. According to the map of Busacca et al. (1989), this area is underlain by the Riverside Formation, included here within the Late Cenozoic gravels. The area falls outside the coverage of the Cole and McJunkin (1978) map.

UCMP collections include two additional land mammal specimens from different localities within Late Cenozoic gravels in the Gilsizer Slough 7½' quadrangle, about three and five miles west of the Feather River. One specimen from UCMP locality V6426, estimated to be of Early Pleistocene age, appeared in drill tailings from the 140 foot level of a well. The other (from UCMP V3915) was found 4.5 feet (1.4 meters) below the surface near Oswald Road, and dates from the Late Pleistocene.

The larger central and southern Sacramento Valley region also includes at least three significant Pleistocene vertebrate fossil localities. To the south, excavations in preparation for construction of the Arco Arena near Sacramento revealed a rich assemblage of Pleistocene vertebrates from the Riverside Formation (Hilton et al. 2000). Across the valley, along the drainage of Putah Creek, late Pleistocene deposits (UCMP Locality V76199) yielded remains of a giant ground sloth and a mammoth (Dundas and Cunningham 1993). The same authors report "several late Pleistocene sites along Putah Creek". More directly across the valley from the study area and at comparable elevation, Dr. Hugh Wagner discovered nearly complete remains of another ground sloth in a surprisingly coarse gravel deposit during excavation for the PGE/PGT pipeline in 1993 (Wagner pers. comm. 1999). The gravels at this locality resemble those of the Late Cenozoic gravels in the study area and occur at comparable elevations.

5.2.3.7 Recent Deposits (including Dredge Tailings)

In the geologic-time context, the term “Recent” (capitalized) refers to the interval from the end of the Pleistocene, about 9,000 years ago, until today. This interval is more formally termed the Holocene Epoch. As discussed above, organic remains from this interval generally fall outside the realm of paleontology, although specimens from near the Pleistocene/Holocene boundary could improve understanding of the local faunal and floral changes associated with widespread terminal Pleistocene extinctions. Sedimentary deposits dating from historical times, such as dredge tailings, seldom contain information of paleontological interest unless they include fossils reworked from older units and their unit of origin is clear from characteristics of attached rock. None of the exceptions are known to apply to local sediments mapped as Recent.

5.2.3.8 Landslides

Gravitational transport of large masses of bedrock does not appreciably alter their original fossil content, especially if the internal structure of the rock is maintained in coherent slump blocks. Inferences regarding fossil potential in landslides therefore reflect those applicable to the parent formation(s).

Many landslides appear on the map of Cole and McJunkin (1978), and most are concentrated on the flanks of North and South Table Mountains. The known underlying geology of the Table Mountains area leads to the inference that the rocks transported by these slides include sediments of the Ione Formation including its Oroville Tuff member, and the basalt of the Lovejoy Formation (the caprock supporting the nearly flat upper surfaces of these large hills). The topography of these slides suggests that slump blocks are common. Although the Lovejoy is unfossiliferous, the Ione formation has yielded locally abundant fossils, especially plants (discussed above).

Five closely-spaced fossil localities recorded at CAS fall within the mapped landslide area north of Thermalito Power Canal and near the base of South Table Mountain. This is less than 2/3 mile (about 1 kilometer) north of the Thermalito Power Canal, and just outside the study area limits. These are recorded as Ione Formation localities and have yielded several well-preserved taxa of Eocene snails, animals otherwise uncommon in the formation. The records do not state whether the fossils were preserved in the “Oroville Tuff” member of the Ione, or in its undifferentiated main body: Attached sediments are too fine-grained for inclusion in the “Auriferous Gravels” member.

Northeast of North Table Mountain, other mapped landslides involve granitic and ophiolite series rocks which offer no fossil potential, or arc and melange rocks in which fossils are very rare. The slides apparently do not include any of the unique fossiliferous marble “pods” discussed above (see section 5.2.1.1, Melange Suite), or the Monte de Oro Formation (see 5.2.1.2, Arc Rocks).

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

6.1.1 Definition of Significant Paleontologic Resources

The criteria used in assignment of paleontologic significance have been presented in Section 4.1.3. The criteria are based on the presence or probable presence of fossils representing three major categories of organisms: plants, invertebrates, and vertebrates. Vertebrate fossils are given priority because of their relative rarity, and because of the large number of (usually) fragmental specimens required for acceptable reconstructions.

Very small specimens representing any of the three categories of organisms are sometimes referred to as “microfossils”. The significance of a particular microfossil assemblage depends on the category(s) of organisms it represents and on the probability that equivalent information could be obtained elsewhere. Within those sedimentary units in which they are found, both plant and invertebrate microfossils tend to occur in very large numbers and in laterally extensive beds. This tendency contributes to their usefulness in dating drill core samples, but reduces the scientific significance of individual microfossil-bearing rock outcrops: Removal of a surficial portion of the outcrop, either by human or natural agents, will probably expose equally informative samples behind it. Vertebrate microfossils, typically teeth and/or bones of rodent-sized mammals or similarly small fish or reptiles, tend to be much less common and much more restricted in their distribution where they do occur. Small size *per se* in no way reduces their scientific importance. Vertebrate microfossil localities therefore merit the same significance as their large-fossil counterparts, and are usually found in the same geologic units.

6.1.2 Geographic Distribution of Significant Resources

All of the known fossil localities and potentially fossiliferous geologic units within the study area exist west of longitude 121° 30’. The only portion of the reservoir itself that includes paleontologically significant areas is the vicinity of West Branch Canyon. Except for a very significant area near the central Thermalito Diversion Canal, other significant subareas of the study area fall near the Thermalito Power Canal, Thermalito Afterbay, and the Feather River.

6.1.3 Significance Assessment of Geologic Units

When viewed in the context of the significance criteria presented in section 4.1.3.2, the combined data relating to each recognized geologic unit leads to an assessment of paleontologic significance which can be applied to that unit in bulk or to surface areas underlain by that unit, as depicted on geologic maps. Figure 6.1-1 illustrates the geographic distribution of rock units of different significance in the vicinity of the project area. Table 6.1-1 lists the geologic units considered here, first by assessed significance, then by age: Order of listing within each significance group is not intended to imply subranking.

Table 6.1-1. Geologic Units Arranged by Paleontologic Significance

BLM Significance Condition	Unit name or predominant rock types	Age	Within project area	Near Project Area
C1	"Calaveras" limestone; (exotic marble)	Permian?	**X**	
C1	Monte de Oro Fm.	Late Jurassic	**X**	**X**
C1	Chico Formation	Late Cretaceous		**X**
C1	New Era Formation	Middle Miocene		**X**
C1	Late Cenozoic gravels	Plio-Pleistocene	**X**	**X**
C2	Ione Formation (undifferentiated)	Middle Eocene	**X**	**X**
C2	Ione Formation ("Oroville tuff" member)	Middle Eocene	**X**	**X**
C2	Tuscan Formation	Late Pliocene	**X**	**X**
C2	landslide (predominantly Ione Formation)	Quaternary [1]	**X**	**X**
C3	metasediments, metavolcan., serpentine	Late Jurassic ?	**X**	**X**
C3	volcanic, volcaniclastic rocks[2]	Jurassic?	**X**	**X**
C3	Smartville ophiolite (mostly intrusive rocks)	Jurassic	**X**	**X**
C3	granitic plutons – (large intrusive bodies)	Early Cretaceous	**X**	**X**
C3	Ione Formation "Auriferous Gravels" m.	Middle Eocene		**X**
C3	Lovejoy Formation	Early Miocene		**X**
C3	Recent deposits (incl. dredge tailings)	Recent	**X**	**X**

[1] Quaternary landslides contain older rocks and fossils.
[2] Equals Oregon City Fm. of Creely (1965)

6.1.3.1 Condition 1 Units (most significant)

<u>"Calaveras" Limestone (Exotic Marble in Melange Deposits)</u>

The scattered bodies or "pods" of altered limestone in the West Branch area of the reservoir, variously referred to as "Calaveras" limestone or marble bodies within the melange suite of rocks, include locally abundant remains of marine invertebrates. These pods are, in effect, time capsules that include records of a faunal assemblage roughly 100 million years older than the enclosing rocks of the rest of the melange suite, and apparently formed thousands of kilometers west of the enclosing rocks. The very long, unique history of these rock units and their included fossil fauna raises their significance to a very high level, with implications for fields of the earth sciences beyond those usually associated with paleontology: No other currently available sources can provide the constraints of age and oceanic depth implied by this assemblage, constraints which must be considered in reconstruction of the plate tectonic history of the ancestral Pacific Ocean and western North America.

All known examples of these rock bodies in the region fall within the study area and several probably exist between the high and low water levels of the reservoir.

Areas underlain by the limestone bodies within the melange suite are consistent with the criterion of "notable invertebrate localities", hence assigned Condition 1 areas.

Monte de Oro Formation

The flora exquisitely preserved within this unit appears to be unequalled among late Jurassic assemblages of at least the western coastal states. Its unusual geological setting and associated sediment suggests it represents a coastal flora, either coastal lagoon or estuary. Research based on these fossil ferns, cycads, and gingkoes began over a century ago and continues to recent time.

Known exposures of this unit are also very restricted, mapped in a narrow belt measuring no more than six kilometers long and 0.8 kilometers wide. The belt crosses the study area through the Thermalito Diversion Pool, and also appears in three very small, man-made exposures in and near the Thermalito Power Canal. Overlying rocks, colluvial debris, and vegetation render much of even this small area inaccessible to detailed examination. Accessible exposures may exist only within the study area.

As this is clearly an area of notable plant localities, it ranks as a Condition 1 area according to the criteria adopted here.

Chico Formation

Despite the very long history of paleontological study of Chico Formation exposures near the reservoir, new discoveries continue. The relatively recent addition of vertebrate fossils to the assemblages from these sites further enhances their significance.

None of the areas mapped as Chico Formation (Cole and McJunkin 1978) fall within the delineated study area, but at least two areas underlain by the Chico appear along roads accessing the Limesaddle Recreational area, Vinton Gulch, and the West Branch Bridge.

Most areas underlain by the Chico Formation include known or potential localities likely to produce both notable invertebrate and vertebrate fossils, and are classified as Condition 1.

New Era Formation

This geographically restricted formation is the only one in the vicinity that is known to yield vertebrate fossils of Miocene age, though rare. With known exposures only in the old Cherokee Mine, the unit does not fall within the study area, but is less than one mile (1.5 kilometer) outside of the West Branch portion of it.

The known content of vertebrate fossils in the New Era Formation indicates assignment of Condition 1 significance.

Late Cenozoic Gravels

As used in this report, following Cole and McJunkin (1978), the Late Cenozoic gravels include three formations (the Plio-Pleistocene Laguna, Pleistocene Riverbank, and Modesto) that are individually mapped by some workers (Busacca et al. 1989, Helley and

Harwood 1985, Saucedo and Wagner 1992, Wagner et al. 1981). The combined unit underlies, at depth, nearly all of the project area from the Thermalito Afterbay and Thermalito Power Canal southward on the west side of the Feather River, and from Oroville southward on the east side, but natural and man-made Holocene deposits cover the Late Cenozoic gravels in the modern floodplain and most of the channel of the Feather River itself. The artificial Thermalito Afterbay occupies an area of pre-existing terrain developed on the Late Cenozoic sediments, and wave erosion sustains unvegetated exposures along much of its periphery and islands. Exposures may also exist along the banks of the Feather River channel where its meanders extend to the edge of the modern floodplain, although this has not been verified.

The appearance of at least a partial skeleton of a large Pleistocene mammal within the Thermalito Afterbay, and records of numerous vertebrate fossils from equivalent units elsewhere in the Sacramento Valley, document a potential for vertebrate fossils throughout most or all of the extent of these units, consistent with assignment of Condition 1.

Isolated Pleistocene sediment deposits, too small to appear on geologic maps, undoubtedly exist at higher elevations in the foothills, and at least one of these unmapped deposits has yielded a vertebrate fossil near the Thermalito Diversion Pool. These deposits are also assigned Condition 1, although their distribution remains unknown in the absence of directed field investigation.

6.1.3.2 Condition 2 Units (Potentially Significant)

<u>Ione Formation (Undifferentiated)</u>

Numerous exposures of the Ione Formation along the western flank of the Sierras present records of a broad range of local depositional environments, ranging from subcoastal to fluvial, though contemporary climatic conditions apparently favored preservation of plants rather than animals. The occurrence of well-preserved fossil snails very close to the study area appears to be exceptional, and indicate a potential for “noteworthy occurrences of invertebrate fossils” in Ione exposures within the study area. As the snail localities happen to occur in landslide deposits, there remains some uncertainty as to which subunit of the Ione is likely to yield additional specimens, although the fine sediment associated with the specimens held at CAS indicates they did not come from the “Auriferous Gravels” member.

The Ione Formation borders the northwest side of the Thermalito Afterbay, and extends to within 1.5 miles from the known localities.

<u>Ione Formation (“Oroville Tuff” Member)</u>

The upper portion of the Ione Formation near the Thermalito Afterbay includes the “Oroville Tuff”, a varied deposit ranging in composition from clays to coarse volcanic breccias. The invertebrate localities discussed in the above section may have been in lateral equivalents to this subunit. The same arguments for fossil potential therefore apply to this subunit as well as to the undifferentiated Ione, pending additional field confirmation.

Tuscan Formation

Fluvial and volcanic mudflow deposits within the Tuscan Formation north of the reservoir include fossil leaves and cones of Pliocene plants, and possibly mammals. Extensive exposures of the formation exist north and west of the study area and form the west rim of the canyon along the West Branch area, though only two small areas underlain by the Tuscan fall within the study area.

The Nomlaki Tuff Member of the Tuscan is not known to yield vertebrate fossils on the east side of the Sacramento Valley, but its lateral equivalent on the west side (where it occurs at the base of the Tehama Formation) includes several vertebrate localities.

The possible existence of vertebrate fossils localities in the unit requires a tentative assignment of Condition 2.

6.1.3.3 Condition 3 Units (Not Significant)

Metasediments, Metavolcanics, Serpentine

These rocks are all constituents of the melange suite, underlying nearly all of the West Branch of the reservoir as well as the portion of the North Branch upstream from its confluence with the West Branch (Cole and McJunkin 1978). Specifically excluded in this section are the older bodies of carbonate rocks discussed in section 6.1.3.1.

The remaining metasediments represent deposition in the deep trench that existed offshore in the Jurassic Period. Combined factors of low populations of organisms in this original environment and the subsequent destructive effects of low-grade metamorphism severely limit the abundance of fossils in the non-carbonate metasediments now exposed, although a single fossil clam has been collected from rocks of this category. Any additional fossils from these rocks would be very significant, as it could improve the accuracy of age estimates for the suite, but the probability of additional finds appears to be so low that assignment of a higher level condition is not justified at present.

The metavolcanics and serpentine subunits were formed under conditions that preclude the possibility of original inclusion of fossils.

Volcanic, Volcaniclastic Rocks

These rock types comprise all of the arc suite except the Monte de Oro Formation, a subunit discussed in section 6.1.3.1. They underlie a two- to three-mile segment of the North Branch, south of its confluence with the West Branch, and appear mostly above reservoir fill level along the south side of part of the West Branch. The volcanic and volcaniclastic arc rocks of the area correspond to the Oregon City Formation of Creely (1965).

The volcaniclastic rocks can include fossils, as documented by the single important ammonite specimen reported in Creely (1965), but they are deemed to be so rare in the study area that a “not significant” rating is assigned to this subunit.

The volcanic arc rocks, as with terrestrial lava flows, very rarely preserve fossil remains because of the extremely high temperatures associated with their origin.

Smartville Ophiolite

Rocks assigned to this suite underlie the Oroville Dam, upper portion of the Thermalito Diversion Pool, and most of the reservoir except the West Fork, the North Fork above its confluence with the West Fork and about three miles south of the confluence, and the Middle and South Forks east of their confluence.

Of the constituents of the Smartville ophiolite suite, only the metasediments formed under conditions in which organic remains might have been preserved, but most of these reflect more intense metamorphism than metasediments of the arc series, and offer a very small probability of preservation of fossils today. Other components of the suite formed from intrusive or extrusive magmas that could not have incorporated organic remains.

Granitic Plutons

These large intrusive bodies have been exposed as erosion stripped away formerly overlying rocks, and now form the surface terrain around the East Fork and South Fork except near their confluence. Their origin, through cooling and crystallization of magma far below the surface, precludes the presence of fossils.

Ione Formation, “Auriferous Gravels” Member

Compared with the rest of the Ione, this subunit is made up of much coarser clasts, deposited in the channels of pre-existing mountain stream and river valleys, much like the modern Feather River. Such high-energy environments do not favor the preservation of fragile organic remains, and fossils are nearly unknown from this subunit.

The “Auriferous Gravels” member approaches the study area only at a point about ¼ mile north of the sharp bend of the Thermalito Diversion Pool, near the east end of South Table Mountain.

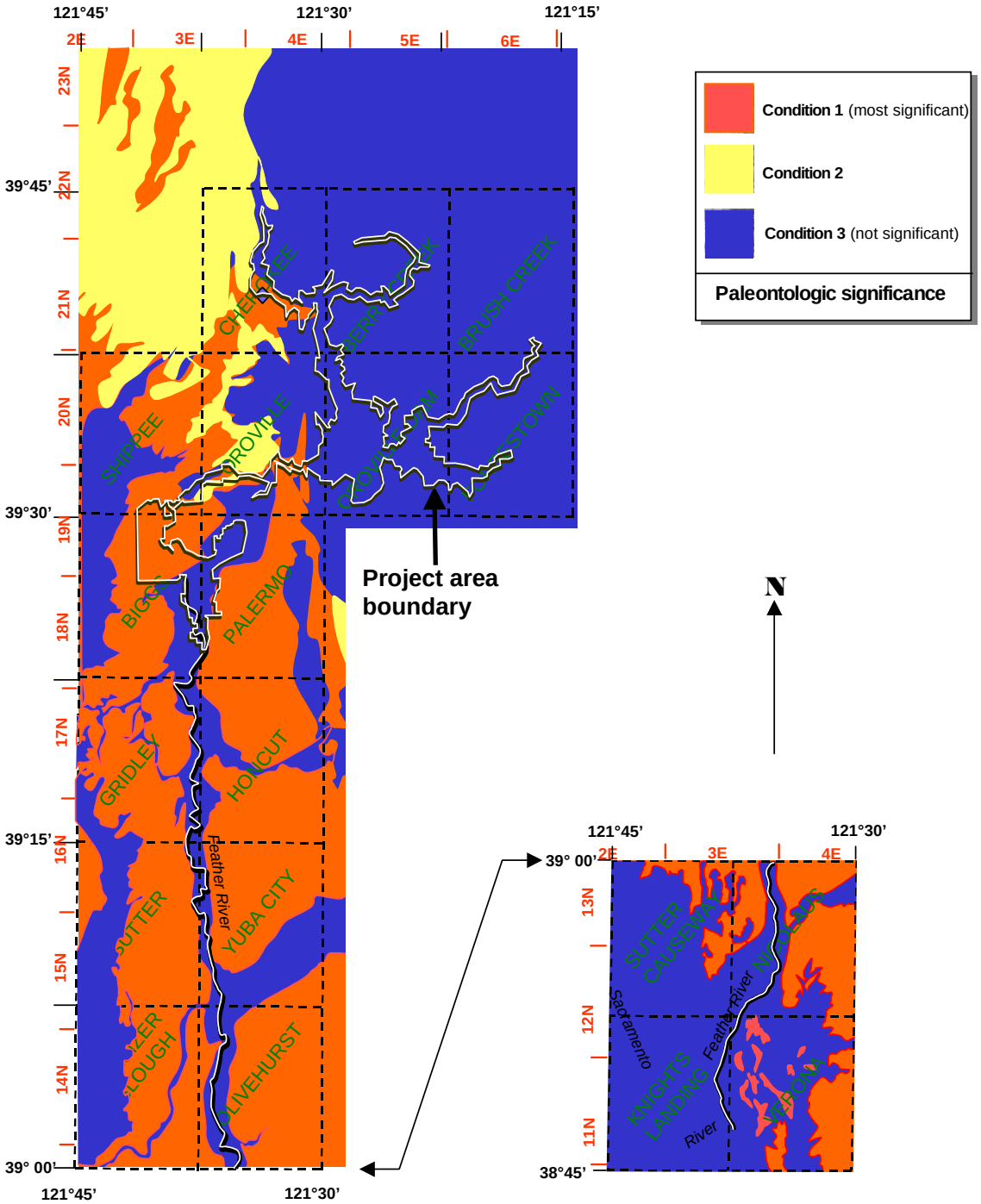
Lovejoy Formation

This basalt caprock of both of the Table Mountains formed by cooling of a lava flow, and offers virtually no probability of fossil preservation.

This unit also caps the hills and upper slope along the northwest side of Thermalito Afterbay, and approaches the study area at the eastern end of South Table Mountain.

Recent Deposits (including Dredge Tailings)

Natural sediments deposited in river channels and on floodplains since the end of the Pleistocene ("Recent" by definition) may well include remains of plants or animals, but these are generally of little or no scientific value to the field of paleontology. Sediments moved and redeposited through human activities hold even less value because the original geologic context has been lost. Within the study area recent natural deposits and dredge tailings cover most older sediments and rocks south of Oroville within the floodplain limits of the Feather River.



0 Scale (miles) 10 BIGGS USGS 7 ½' quadrangles	Geologic base from Jennings et al. 1977 with supplemental data from Wagner et al. 1981 and Saucedo and Wagner 1992.	**Figure 6.1-1 Paleontologic significance of areas in the vicinity of Oroville Reservoir and the lower Feather River**

6.2 Project-Related Effects

The construction and operation of reservoirs and attendant increase of human access through peripheral road construction, tourism, and recreation typically produce both positive and negative effects on paleontological resources. As this study did not include field investigations or review of operations and recreational activities at Oroville Reservoir, effects specific to the resources in the study area cannot be presented in detail. The following comments are restricted to effects generalized from personal observations at other California reservoirs, especially Black Butte Reservoir (Glenn and Tehama Counties, California) and New Melones Reservoir (Calaveras and Tuolumne Counties), and to logical effects at Oroville Reservoir in light of factors known, from published and verbal information, to exist there.

Effects of Reservoir Construction

The most immediate and obvious effect of reservoir development is the reduction of access to fossil-producing localities existing at elevations below reservoir fill level. As long-term submergence lead to algal growth and siltation, and may facilitate subaqueous landslides, formerly accessible localities may be permanently obscured even if the water level were to be restored to pre-reservoir levels in the future. This has occurred with at least one paleontologically significant area within the Oroville Reservoir study area: River-level outcrops of the restricted Monte de Oro Formation, formerly the site of many finds, are now made inaccessible by the presence of the Thermalito Diversion Pool (H. Schorn pers. comm. 2003). Reservoir filling also may have reduced access to some of the “Calaveras” limestone localities, and has apparently drowned the site of the single known Jurassic fossil from the melange suite (Creely 1965). Both of these areas are along the West Branch of the former Feather River course.

Reservoir-related reduction of non-aqueous vegetation, through tree removal prior to initial filling, and drowning of shrubs and herbs as the water level rises, may greatly increase accessibility of new exposures during subsequent periods of low water. This effect is typically enhanced in the zone between high and low stands by removal of soil and unconsolidated sediment cover through wave action. This has probably occurred, to an unknown extent, at both of the locales mentioned above.

Physical accessibility itself has both positive and negative effects on paleontologic resources. While it can improve the efficiency and thoroughness of scientific collecting, it also increases the vulnerability of the resources to unauthorized and possibly commercial fossil collecting, generally to the detriment of the resource.

Effects of Reservoir Operation

Long- and short-term water level regimes, dictated by a combination of reservoir operation practices and uncontrollable climatic factors, can influence the magnitude of most of the effects discussed in the above section. For instance, a rapid drop in water level may subaerially expose large areas, but rock exposures may be covered by algae and silt,

obscuring small or low-relief fossils until decomposition and rainfall removes the coating. A slower decrease in water level, or wind and power craft wakes, would allow or promote wave action and repeated wetting and drying, accelerating exposure of new rock surfaces.

Wave erosion, inevitable along shorelines of standing water bodies, produces mixed effects on paleontologic resources. Highly indurated rocks, such as those underlying most of the reservoir itself, may become more easily accessible as obscuring sediments are removed. However, continued wave action tends to degrade exposed fossils, even in hard bedrock. In areas where less indurated sediments or sedimentary rocks are exposed at the shoreline, this dual effect becomes greatly exaggerated: Repeated wetting and drying (or freeze/thaw cycles) promote the disaggregation of moderately- to poorly-consolidated sediment, allowing accompanying wave action to winnow away the finer clasts. This may expose a series of previously hidden fossils at a much higher rate than would have been obtained in the absence of waves. The fossils themselves, however, are typically little more resistant than the enclosing sediment, and may deteriorate quickly after exposure. These effects particularly apply to fossil resources in and along the Thermalito Afterbay, underlain by semiconsolidated Late Cenozoic sediments.

In relatively narrow channels, such as the Thermalito Diversion Pool and Thermalito Power Canal, currents induced by reservoir releases may inhibit siltation while increasing displacement and loss of specimen-bearing rock fragments. Outcrops of the Monte de Oro Formation occur in both these areas.

Effects Related to Recreation

Reservoir filling, boat launch development, and associated construction of access roads have created new routes and more practical access for collecting, both by authorized and unauthorized individuals or groups. The presence of the reservoir and its recreational facilities has undoubtedly increased visitation to the surrounding area as well as the reservoir itself. Both improved accessibility and increased visitor population carry potential positive and negative effects. The net impacts may vary among specific sites, and cannot be assessed without field investigation of resource vulnerability and better understanding of actual effects (if any) of higher visitor frequency.

The occurrence of the “Calaveras” limestone at the Limesaddle Recreational Area appears to be particularly vulnerable to the effects of increased visitation. In this case, parts of the resource may be inadvertently degraded by foot or vehicle traffic, in addition to possible losses through intentional collecting.

Although less accessible, outcrop areas of the Monte de Oro Formation may be especially subject to amateur or commercial collecting because of the attractiveness of specimens available there. A commercial market for fossils of all types has become a growing threat to paleontologic resources worldwide.

7.0 RECOMMENDATIONS

Fossils constitute a non-renewable resource whose primary value rests in their unique documentation of past life. As new questions arise, and recovery and research techniques evolve, even long-known fossil localities continue to yield new information. Ideally, fossils should remain undisturbed until qualified researchers with specific goals can do the collecting, unless there are immediate threats to all or part of the resource.

7.1 FIELD SURVEY

1) All known existing fossil localities and Condition 1 geologic formations within the area subject to direct or indirect impacts of reservoir facilities construction, operation, or management policy should be subjected to a detailed field survey and assessment by paleontologists specializing in the kinds of fossils found in specific subareas.

2) The paleontologists' assessments of the significance, sensitivity, and vulnerability of each known locality and significant formation should be taken into account in the establishment of management policy and the planning of any new construction.

7.2 MANAGEMENT POLICY

1) None of the identified paleontologic resources within the study area are known to exist in sufficient abundance that recreational collecting can be recommended. This assessment is subject to modification in light of results and recommendations of a field survey.

2) Fossil collecting should be discouraged or preferably prohibited without written permission of appropriate authorities. Authorization criteria and permitting procedures might be modeled after US Bureau of Land Management policies.

3) Signs notifying visitors of policy and sanctions relating to paleontologic resources should be located at major recreational entry points, not near actual localities. Literature distributed to recreation area visitors should include a statement of restrictions on fossil collecting.

4) Commercial collecting – the collecting of fossils with the intent of sale or barter – should be strictly prohibited.

5) Enforcement officials should be educated in the value and geographic distribution of significant paleontologic resources and authorized to enforce current policy and sanctions governing fossil collecting or disturbance.

7.3 FACILITIES CONSTRUCTION

1) Any construction planning in the vicinity of identified fossil localities or Condition 1 geologic formations should provide for measures to avoid resource degradation or creation of barriers to authorized collecting. Construction is defined here to include any excavation, paving, building construction, or landscaping.

2) Any excavation in areas underlain by Condition 1 geologic formations should be preceded by detailed field survey by an appropriately qualified paleontologist prior to excavation and, if determined appropriate by the paleontologist, the excavation process should be directly monitored by an appropriately qualified paleontologist.

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http://www.scotese.com/sfsanim.htm

APPENDIX A

Paleontologic Resources – Statutory Protection

APPENDIX A

Paleontologic Resources – Statutory Protection

California statutes

Legal protection of paleontologic resources in California explicitly or implicitly extends to projects on state lands or projects conducted by state agencies, and some of these statutes apply to the current project. **Bold type** in the citations below has been added for emphasis in this report and is not part of the cited statutes.

The California Environmental Quality Act (CEQA) and its guidelines include references to paleontology in the appendices. Appendix G of the guidelines, defining significant effects for the purposes of the act, states:

> "A project will have significant effect on the environment if it will… (j) Disrupt or adversely affect a prehistoric or historic archeological site or a property of historic or cultural significance to a community or ethnic or social group; or a **paleontological** site except as part of a scientific study".

Appendix I of CEQA, the environmental checklist form, asks the applicant if the proposal would affect paleontological resources.

More explicit is the California Public Resources Code, Division 5, Parks and Monument, Chapter 1.7 entitled "Archeological, **Paleontological**, and Historic Sites". Section 5097 to 5097.6. states:

> "As used in this chapter, 'state lands' include lands owned by, or under the jurisdiction of, the state or any state agency".

Subsequent sections address pre-construction plans, surveys, and excavations relating to paleontological as well as archeological and historic sites threatened by proposed projects. Section 5097.5 details sanctions:

> "Unauthorized excavation, removal, destruction, etc., of archaeological, **paleontological**, or historical features on "public lands" as misdemeanor…"
>
> "No person shall knowingly and willfully excavate upon, or remove, destroy, injure or deface any historic or prehistoric ruins, burial grounds, archaeological or **vertebrate paleontological site**, including fossilized footprints, inscriptions made by human agency, or any other archaeological, **paleontological**, or historical feature, situated on public lands, except with the express permission of the public agency having jurisdiction over such lands. Violation of this section is a misdemeanor."
>
> "As used in this section, 'public lands' means lands owned by, or under the jurisdiction of, the state, or any city, county, district, authority, or public corporation, or any agency thereof".

Federal regulations

Certain federal laws apply to paleontological resources located on public lands.

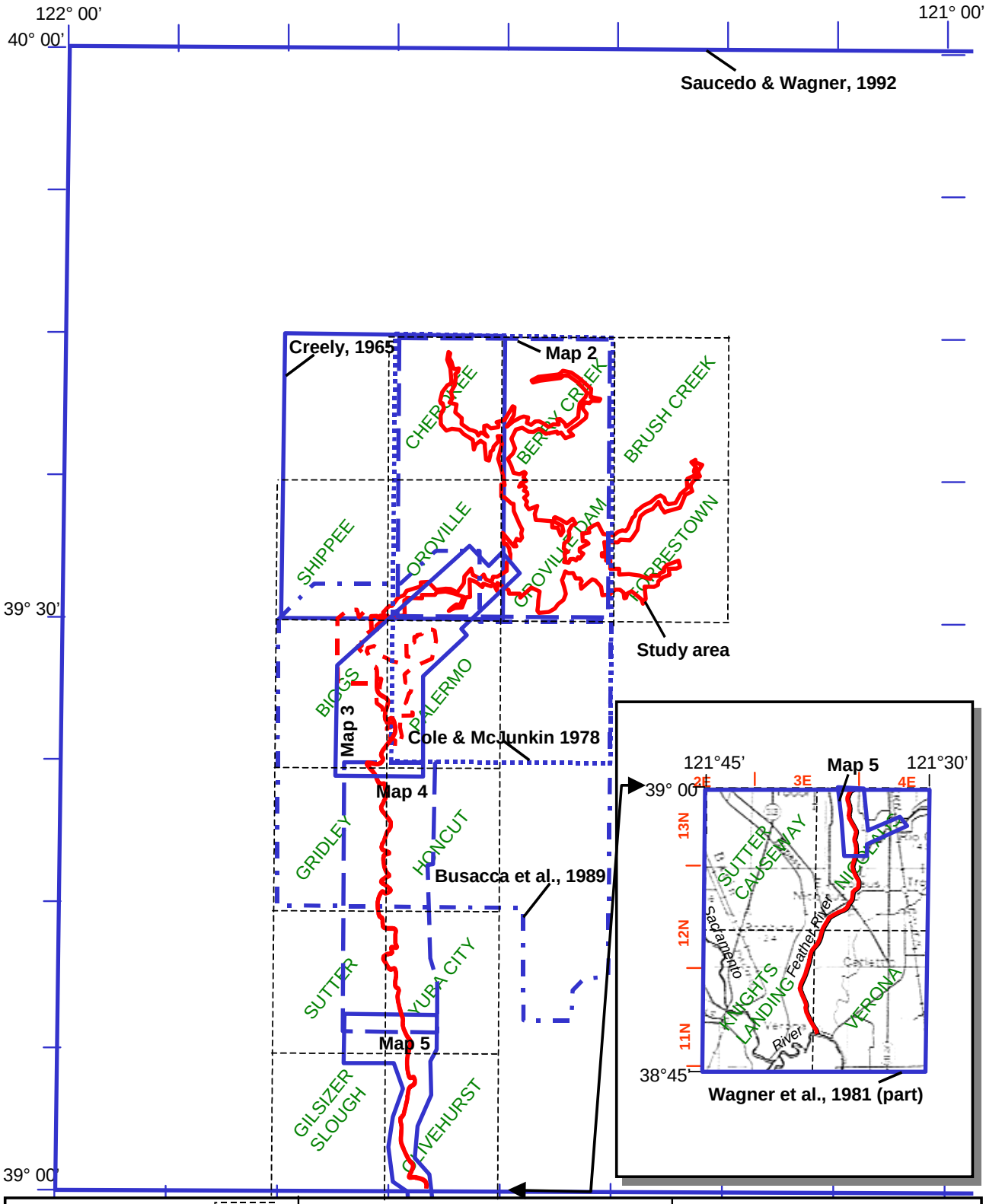
The Federal Land Policy and Management Act (FLPMA) authorizes inventories of paleontological resources on federal land managed by the Bureau of Land Management which now issues permits for collecting of fossils on those lands only for scientific purposes by recognized paleontologic institutions.

The Antiquities Act of 1906 has been cited in past efforts to protect paleontological resources on federal lands, and is currently recognized as the authorizing legislation for regulation of the collecting of vertebrate fossils on land managed by the National Park Service and Department of Energy.

Neither the state nor federal measures include criteria for assessment of sensitivity of these resources or threshholds of value for which mitigative measures may be required if the resources are threatened.

APPENDIX B

Index to Geologic Maps Covering Project Area



Maps 2 through 5 refer to geologic maps provided by the Department of Water Resources.

Appendix B

Figure B-1. Coverage of geologic maps consulted for this report