Geologic Map and Map Database of Northeastern San Francisco Bay Region, California

Most of Solano County and Parts of Napa, Marin, Contra Costa, San Joaquin, Sacramento, Yolo, and Sonoma Counties

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Geologic Explanation and Acknowledgements

Introduction

This report contains a new geologic map at 1:100,000 scale, a set of geologic map databases (Arc-Info coverages) containing information at a resolution associated with 1:62,500 scale, and a new description of geologic map units and structural relationships in the mapped area. The map database represents the integration of previously published reports and new geologic mapping and field checking by the authors (see Sources of Data index map on the map sheet or, for digital-data users, the Arc-Info coverage nesf-so and the textfile nesf-so.txt). The descriptive text (below) contains new ideas about the geologic structures in the area, including the active San Andreas fault system, as well as the geologic units and their relations.

Together, the map (or map database) and unit descriptions in this report describe the composition, distribution, and orientation of geologic materials and structures within the study area at regional scale. Regional geologic information (between about 1:50,000 and 1:100,000 scale) is important for analysis of earthquake shaking, liquifaction susceptibility, landslide susceptibility, engineering materials properties, mineral resources and hazards, and groundwater resources and hazards. It is also vital for answering questions about the geologic history and development of the California Coast Ranges.

The information, however, is not sufficiently detailed for site-specific investigations. Those seeking information for specific sites should consult the detailed work of the earthquake-hazards maps produced by the California Division of Mines and Geology or contact a licensed geologist or engineering geologist.

The digital nature of the geologic map information is important for three reasons. First, the geologic map data can be digitally combined with other map datasets (topography, groundwater information, landslide distribution) for rapid and complex analysis of geologic resources and hazards. Second, digital maps are much more easily updated than traditional printed maps. Third, digital publication provides an opportunity for regional planners, local, state, and federal agencies, teachers, consultants, and others who are interested in geologic data to have the new information long before a traditional paper map could be published.

The map area includes all but the eastern edge of Solano County, eastern Napa County, and surrounding small parts of Marin, Sonoma, Yolo, Sacramento, San Joaquin, and Contra Costa Counties. This area includes the Sacramento-San Joaquin River delta in the southeast, flat Central Valley in the east, rugged mountains of modest height (mostly less than 800 meters) in the northwest and western parts, and rolling hills surrounding San Pablo and Suisun Bays in the southwestern and southern parts. The northern and central mountains and delta areas are largely uninhabited, but the eastern valley lands and the areas surrounding the bays are undergoing rapid development.

The map in this report is modified from and supercedes U.S. Geological Survey Miscellaneous Field Studies Map MF-484 (Sims and others, 1973). Two factors led to the decision to remap the area. First, there has been almost 30 years of new geologic information gathered for the map area. Second, tectonic theories for the California Coast Ranges have changed since the publication of the earlier map, and the new tectonic models have a strong influence on the depiction of through-going active faults, volcanic fields, folds, and other mapped features. Changes in the map include the following:

1. An updated depiction of the active Concord-Green Valley and Rodgers Creek Fault Zones.
2. New Quaternary surficial deposits mapping throughout the map.
3. Mapping of areas in Sacramento and Yolo Counties left blank on the earlier map.
4. Extensive revisions based on new mapping in Sears Point, Cordelia, Benicia, Cuttings Wharf, Fairfield South, Denverton, and Lake Berryessa quadrangles.
5. Reinterpretation of the Early Cretaceous section in the northwestern part of the map.
6. Inclusion of major subsurface faults north and east of Suisun Bay.

This pamphlet also includes enhanced unit descriptions, as well as a discussion of the stratigraphy and structure not present in the earlier publication.

Stratigraphy

Mesozoic terrane complexes

The rock units in the San Francisco Bay region are made up of two components: an older set of rocks comprised of amalgamated, highly deformed tectonostratigraphic terranes that are displaced, at least in part, from hundreds to thousands of kilometers from their position of origin (allocthonous or parautochthonous); and a younger, less deformed set of rocks that overlie the amalgamated terranes and are only offset from their original sites of deposition by offsets of the San Andreas fault system. Throughout the map area, the older set of rocks are Mesozoic and the younger are Tertiary.

The amalgamated Mesozoic terranes can be grouped into three related rock complexes, two of which crop out in the map area. One of these, the Great Valley complex, is made up of the Jurassic Coast Range ophiolite, which in the map area consists mostly of serpentinite, gabbro, diabase, basalt, and keratophyre (altered silicic and intermediate volcanic rocks), and the Great Valley sequence, composed of sandstone, conglomerate, and shale of Jurassic and Cretaceous age. Although the sedimentary rocks and ophiolite are in fault contact almost everywhere in the map area, the Great Valley sequence was originally deposited on top of the ophiolite. This depositional relationship is preserved in the map area within the Capell Valley quadrangle. This complex represents the accreted and deformed remnants of arc-related Jurassic oceanic crust with a thick sequence of overlying turbidites, at least in part related to the North American forearc (parautochthonous).

The second set of amalgamated terranes composes the Franciscan Complex, consisting of weakly to strongly metamorphosed graywacke, argillite, basalt, serpentinite, chert, limestone, and other rocks. The Franciscan Complex also includes sedimentary-matrix mélange, sheared graywacke and argillite matrix containing small to hill-size blocks of sedimentary, volcanic, and metamorphic rocks. The rocks of the Franciscan Complex in the map area are mostly derived from Jurassic to Cretaceous oceanic crust and pelagic deposits overlain by Late Jurassic to Late Cretaceous turbidites. Although most Franciscan Complex rocks are little metamorphosed, high-pressure, low-temperature metamorphic minerals are common in rocks that crop out as mélange blocks (Bailey and others, 1964) and in several fault-bounded lenses within the map area. High-grade metamorphic blocks in sheared but relatively unmetamorphosed argillite matrix (Blake and Jones, 1974) reflect the complicated history of the Franciscan Complex. The parts of the complex that crop out in the map area were subducted beneath the Coast Range ophiolite, a process that continued into Late Cretaceous time, after the deposition of the Franciscan Complex sandstone containing Campanian (Late Cretaceous) fossils that crops out in the southwestern corner of the map area (Kfs, see also Blake and others, 2000). Because much of the Franciscan Complex was accreted under the Great Valley complex, which contains the Coast Range Ophiolite, the contact between the two Mesozoic complexes is everywhere faulted (Bailey and others, 1964), and the Franciscan Complex presumably underlies the entire San Francisco Bay area east of the San Andreas fault.

Both the Franciscan Complex and the Great Valley complex have been further divided into a number of fault-bounded tectonostratigraphic terranes (Blake and others, 1982, 1984, 2000, 2002). Within the map area, strata of three terranes of the Great Valley complex (Blake and others, 1984, 2002) crop out. The conglomerates at Black Point (Kgvn) are part of the Healdsburg terrane, which is distinguished by the presence of abundant quartz-porphyry and granitic clast conglomerate. The strata and underlying ophiolitic rocks in the Cordelia and Martinez areas are probably part of the Del Puerto terrane, based on the presence of large masses of keratophyre. The extensive outcrops of Great Valley complex strata north and west of Vacaville are laterally equivalent to the type area of the Elder Creek terrane, which is characterized by the near absence of keratophyre and the presence of ophiolite breccia in the basal sedimentary strata.

The Franciscan Complex in the map area comprises two terranes as well as mélange. The southwest corner of the map area is underlain by Late Cretaceous strata (Kfs) of the Novato Quarry terrane. Metagraywacke (KJfm) of the Yolla Bolly terrane crop out in Capell Valley and Sears Point quadrangles. Franciscan Complex mélange (fsr), which is not a true terrane but is formed by tectonic mixing of rocks of several terranes, crops out in the Sears Point and Cordelia quadrangles.

The various Mesozoic terranes are described in detail elsewhere. See Blake and others (2002) for a recent discussion of the origin of the Coast Range ophiolite and the Franciscan Complex mélange, as well as a more extensive description of the terranes listed above.

Tertiary Stratigraphy

In the San Francisco Bay area, Franciscan Complex detritus in the Paleocene strata overlying Great Valley complex rocks in Rice Valley and the eastern Diablo Range (Bartow, 1985), as well as unmetamorphosed early Eocene quartzofeldspathic strata overlying Franciscan Complex metamorphic rocks (Pampeyan, 1993), indicate that much of the tectonic activity that brought the two Mesozoic complexes together was complete by early Tertiary time.

In the map area, the Late Cretaceous rocks northwest of Vacaville and south of Martinez are conformably overlain by Paleocene strata, whereas in the Cordelia area they are unconformably overlain by Eocene strata. In the western part of the map area, Franciscan Complex and Great Valley complex rocks are unconformably overlain by Miocene sedimentary and volcanic rocks.

The Tertiary stratigraphic relationships in the area also reveal significant late Tertiary and Quaternary fault offset. As illustrated by the chart showing correlation of map units (see map sheet or database nesf-corr), Tertiary stratigraphic packages of variable age and lithology (assemblages) are juxtaposed along faults in the map area. For example, the assemblage in the Cordelia area lacks the Oligocene and early to middle Miocene strata found in the adjacent package near Martinez. These differences reflect fault offsets that have brought once separated depositional basins or parts of basins into their current juxtaposition. The faults that bound distinct stratigraphic packages include the active Concord-Green Valley and Hayward-Rodgers Creek Fault Zones, but also include the probably inactive Franklin Canyon and Lake Herman faults. The total amount of right-lateral offset on these faults through the map area since 12 Ma is about 175 km (Jones and Curtis, 1991; McLaughlin and others, 1996; Jachens and others, 1998).

Structure

The mapped structures fall into two general categories. The younger structures are north-northwest trending faults and associated north-northwest to west-northwest folds generated by the transpressional Pacific-North American plate margin. The faults have a predominate right-lateral strike-slip offset, but they also accommodate a component of fault-normal compression as shown by the uplift of fault-parallel ridges and formation of fault-parallel folds in addition to the more westerly trending folds more typical of strike-slip systems. These younger structures probably were initiated when the transpressional plate margin in this region was established following the northward migration of the Mendocino Triple Junction, which passed through the San Francisco Bay region between about 12 and 4 Ma. The structures therefore cut and deform late Miocene and younger rocks.

Older structures that are cut and deformed by late Miocene and younger structures are of two types. In the Capell Valley and Mount George quadrangles, Great Valley complex rocks are imbricated along northwest- to west-northwest-trending reverse faults. These faults and associated folds also involve Franciscan Complex rocks south of Lake Berryessa. These structures are possibly the remnants of deformation associated with Cretaceous accretion of Franciscan Complex rocks. They may be reactivated by ongoing deformation, but the lack of young strata in the area makes identification of young structures difficult.

The map area also includes a broad, regional deformation that is manifested as a somewhat disrupted east-dipping homocline east and southeast of Lake Berryessa, along with the northwest-trending faulted anticline in the Brooks quadrangle and the west-northwest-trending folds north of Suisun Bay. These older structures are largely pre-Miocene, as shown by the large angular unconformity at the base of the Putnam Peak Basalt (Tpb) and the overlap of the Sonoma Volcanics. However, the more modest deformation of the Pliocene Tehama Formation (Tpth), as well as the uplift of late to early Pleistocene alluvial deposits (Qoa), suggest that deformation on the older structures may continue into the Quaternary.

There are two known active fault zones in the map area (Hart and Bryant, 1999): the Hayward-Rodgers Creek Fault Zone near the western edge of the map and the Concord-Green Valley Fault Zone in the central part (see fig. 1 on the map sheet or database nesf-flt).

Description of Map Units

Unit descriptions are divided into three sections. The first describes Quaternary surficial deposits that are similar throughout the map area. The second describes early Pleistocene and older rocks, and is subdivided into nine sections based on areas which display a relatively consitant stratigraphy (assemblages, see the index map on the map sheet or GIS coverage nesf-as for distribution of assemblages). As noted above, fault offset within the map area has juxtaposed depositional basins or parts of depositional basins that were once kilometers or tens of kilometers apart, and therefore the stratigraphy in adjacent assemblages may be quite different. It is also important to note that units of similar stratigraphic position in various parts of the map area have been traditionally given the same unit name, despite differences in lithology. Therefore each stratigraphic unit is described in each assemblage, even if a unit has the same name as one already described for another assemblage. The third section describes rocks of the Franciscan Complex, which crop out at the surface in small fault bounded structural blocks in the western and northern part of the map area. Although little exposed at the surface in the map area, rocks of the Franciscan Complex probably underlie much of the map area at depth.

SURFICIAL DEPOSITS

[Descriptions of surficial deposits are modified from Helley and Barker (1979), Atwater (1982), Helley and Graymer (1997), and Knudsen and others (2000).]

ac **Artificial channel deposits (Historic)**—Modified stream channels, usually where streams have been straightened and realigned. Deposits in artificial channels range from concrete in lined channels to sand and gravel similar to natural stream channel deposits (Qhc)

ads **Dredge spoils (Historic)**—This unit, mapped and described by Atwater (1982), consists of sand, locally laminated, and subordinate silt, clay, and peat that have been deposited as hydraulic dredge spoils during attempts to widen, straighten, and (or) deepen the Sacramento and San Joaquin Rivers. The large body of sand near the Montezuma Hills was probably emplaced between 1908 and 1941 (Atwater, 1982). This unit is mapped only in a few quadrangles within the San Joaquin/Sacramento Delta

af **Artificial fill (Historic)**—Undifferentiated man-made deposit of various materials and ages, including some dredge spoils, levee fill, and fill over Bay mud and also road embankments, earthen dams, and railroad grades. Some are compacted and quite firm, but fills made before 1965 are nearly everywhere not compacted and consist simply of dumped materials. Much of this unit is mapped based on topographic expression on the most recent USGS 7.5 minute quadrangles of the map area

afbm **Artificial fill over bay mud (Historic)**—Artificial fill placed in the estuarine environment to create new land

alf **Artificial levee fill (Historic)**— Man made deposit of various materials and ages, forming artificial levees as much as 20 ft (6.5 m) high. Some are compacted and quite firm, but fills made before 1965 are almost everywhere not compacted and consist simply of dumped materials. Levees bordering waterways of the Sacramento/San Joaquin Delta, mudflats, and large streams were first emplaced as much as 150 years ago. The distribution of levee fill conforms to levees shown on the most recent U.S. Geological Survey 7.5-minute quadrangle maps

Qhay **Younger alluvium (late Holocene)**—Loose sand, gravel, silt, and clay deposited in active depositional environments and judged to be less than 1000 years old based on geomorphic expression or historic records of deposition

Qha **Alluvium (Holocene)**—Sand, silt, and gravel deposited in fan, valley fill, terrace, or basin environment. Mostly undissected by later erosion. Typically mapped in smooth, flat valley bottoms in medium-sized drainages and other areas where geomorphic expression is insufficient to allow differentiation of depositional environment

Qht **Terrace deposits (Holocene)**—Moderately well sorted sand, silt, gravel, and minor clay deposited in point bar and overbank settings. These deposits are as much as 10 m above the historic flood plain, but mostly undissected by later erosion

Qhf **Alluvial fan deposits (Holocene)**—Moderately to poorly sorted and moderately to poorly bedded sand, gravel, silt, and clay deposited where streams emanate from upland regions onto more gently sloping valley floors or plains. Holocene alluvial fan deposits are mostly undissected by later erosion. In places, Holocene deposits may only form a thin layer over Pleistocene and older deposits

Qhff **Fine-grained alluvial fan deposits (Holocene)**—Mostly silt and clay with interbedded lenses of sand and minor gravel deposited at the distal margin of large alluvial fan complexes

Qhc **Stream channel deposits (Holocene)**—Loose sand, gravel, and cobbles with minor clay and silt deposited within active, natural stream channels

Qhl **Natural levee deposits (Holocene)**—Moderately- to well-sorted sand with some silt and clay deposited by streams that overtop their banks during flooding. Natural levees are often identified by their low, channel-parallel ridge geomorphology

Qhfp **Floodplain deposits (Holocene)**—Medium- to dark-gray, dense, sandy to silty clay. Lenses of coarser material (silt, sand, and pebbles) may be locally present. Flood plain deposits usually occur between levee deposits (Qhl) and basin deposits (Qhb) and are prevalent in the Walnut Creek-Concord Valley, much of which is south of the map area

Qhfb **Floodbasin deposits (Holocene)**—Firm to stiff silty clay, clayey silt, and silt, commonly with carbonate nodules and locally with black spherules (Mn and (or) Fe oxides). The deposits laterally grade into peaty mud and mud of tidal wetlands (unit Qhdm). Locally, the deposits are veneered with silty, reddish-brown alluvium of historic age, some of which may have resulted from hydraulic mining in the Sierra Nevada during the late 1800s

Qhb **Basin deposits (Holocene)**—Very fine silty clay to clay deposits occupying flat-floored basins and flat areas in the Brentwood dune field east of Antioch, where the basin deposits bury older eroded sand dunes (Qds)

Qhbm **Bay mud deposits (Holocene)**—Water-saturated estuarine mud, predominantly gray, green, blue, and black clay and silty clay underlying marshlands and tidal mud flats of San Francisco Bay and Carquinez Strait. The mud also contains lenses of well-sorted, fine sand and silt, a few shelly layers (oysters), and peat. The mud interfingers with and grades into fine-grained fan deposits at the distal edge of Holocene fans. This unit is time-transgressive and generally occupies the area between the modern shoreline and the historical limits of tidal marsh

Qhdm **Delta mud deposits (Holocene)**—Mud and peat with minor silt and sand deposited at or near seal level in the Sacramento/San Joaquin River Delta. Much of the area underlain by this unit is now dry because of construction of dikes and levees and below sea level due to compaction and deflation of the now unsaturated delta sediments

Qa **Alluvium (Holocene and late Pleistocene)**—Sand, silt, and gravel deposited in fan, valley fill, terrace, or basin environments. Similar to unit Qha, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time. In Yolo County, this unit includes the Modesto and Riverbank Formations as mapped by Helley and Barker (1979)

Qt **Terrace deposits (Holocene and late Pleistocene)**—Moderately sorted to well-sorted, moderately bedded to well-bedded sand, gravel, silt, and minor clay deposited on relatively flat, undissected stream terraces. Similar to unit Qht, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time

Qf **Alluvial fan deposits (Holocene and late Pleistocene)**—Poorly sorted, moderately to poorly bedded sand, gravel, silt, and clay deposited in gently sloping alluvial fans. Similar to unit Qhf, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time

Qls **Landslide deposits (Holocene and Pleistocene)**—Chaotic deposits of sand, silt, clay, angular boulders, and blocks of bedrock up to hundreds of meters long deposited by gravity-driven sliding and flow. These deposits are mostly mapped based on their characteristic geomorphic expression. Only some of the larger landslide deposits are mapped, mostly where the deposits obscure the underlying bedrock. For more complete mapping of landslides see Sims and Nilsen (1972), Frizzell and others (1974), and Sims and Frizzell (1976)

Qds **Dune sands (early Holocene and latest Pleistocene)**—Very well sorted fine- to medium-grained eolian sand. They occur mainly in two large northwest-southeast trending sheets, as well as many small hills, most displaying Barchan morphology. Dunes display as much as 30 m of erosional relief and are presently being buried by basin deposits (Qhb) and delta mud (Qhdm). They probably began accumulating after the last interglacial high stand of sea-level began to recede about 79 ka (Imbrie and others, 1984; Martinson and others, 1987; Hendy and Kennett, 2000), continued to form when sea level dropped to its Wisconsin minimum about 18 ka, and probably ceased to accumulate after sea level reached its present elevation (about 6 ka). Atwater (1982) recognized buried paleosols in the dunes, indicating periods of nondeposition

Qpa **Alluvium (late Pleistocene)**—Poorly to moderately sorted sand, silt, and gravel in the Capay area (Esparto quadrangle). This unit is mapped on gently sloping to level alluvial fan or terrace surfaces where separate fan, terrace, and basin deposits could not be delineated. Late Pleistocene age is indicated by depth of stream incision, development of alfisols, and lack of historical flooding

Qpf **Alluvial fan deposits (late Pleistocene)**—Poorly sorted, moderately to poorly bedded sand, gravel, silt, and clay deposited in gently sloping alluvial fans. Late Pleistocene age is indicated by erosional dissection and development of alfisols. These deposits are about 10% denser and have 50% greater penetration resistance than unit Qhf (Clahan and others, 2000)

Qpb **Basin deposits (late Pleistocene)**—As mapped by Atwater (1982), older alluvium widely but sparsely exposed at the toe of the Putah Creek fan (Dozier quadrangle), most commonly in basins between stream-built ridges of younger alluvium

Qop **Pediment deposits (late and early Pleistocene)**—Thin deposits of sand, silt, clay, and gravel on broad, planar erosional surfaces. These deposits are extremely dissected, have well-developed soils, and are mostly tens or hundreds of meters above the current depositional surface

Qoa **Alluvium (late and early Pleistocene)**—Sand, silt, clay, and gravel deposits with little or none of the original geomorphic expression preserved. Moderately to extremely dissected, in places tens or hundreds of meters above the current depositional surface, and capped by well-developed soils. In Yolo County, this unit includes the Red Bluff Formation as mapped by Helley and Barker (1979)

BLACK POINT ASSEMBLAGE

Great Valley Complex

Kgvn **Novato Conglomerate (Early Cretaceous)**—Pebble to boulder conglomerate with abundant rhyolite clasts and less abundant dark chert and granitic clasts. Minor coarse sandstone lenses and interbeds may contain more than 10% detrital potassium feldspar. The unit contains thin, vesicular basalt in outcrop west of the map area. Sandstone outcrops just west of the map area contain Early Cretaceous (Valanginian) *Buchia* (Berkland, 1969)

PINOLE POINT ASSEMBLAGE

Tor **Orinda Formation (late Miocene)**—Greenish-gray lithic sandstone, conglomeratic sandstone, and conglomerate and green and maroon siltstone and claystone. Contains angular to well-rounded clasts including varicolored chert, graywacke, metagraywacke, greenstone, and glaucophane schist predominantly derived from rocks of the Franciscan Complex. South of the map area this unit contains terrestrial mammal fossils of late Miocene (Clarendonian) age (Merriam, 1913)

HERCULES ASSEMBLAGE

Tcgl **Conglomerate (late Miocene)**—Conglomerate, sandstone, and siltstone. Contains moderately rounded to well-rounded pebbles and cobbles of laminated brown and gray chert and porcellanite probably derived from the Claremont chert which crops out south of the map area, as well as varicolored chert, andesite, greenstone, graywacke, blueschist, and pumice. Just south of the map area this unit includes a tuff bed correlated with the informally named Roblar tuff of Sarna-Wojcicki (1992), which has yielded radiometric ages around 6 Ma (Sarna-Wojckici, 1976). The lithology, clast composititon, and the presence of Roblar tuff suggest that this unit is, at least in part, correlative with the Petaluma Formation (Tps) in the Sears Point area. These two units have probably been offset about 35 km from their original contiguous depositional position in the past 6 m.y. by movement on the Hayward-Rodgers Creek-Healdsburg Fault Zone

Tut **Tuffaceous sandstone (late Miocene)**—Tuffaceous sandstone containing pumice fragments. Originally mapped as Pinole Tuff, this unit is now thought to underlie the Roblar tuff of Sarna-Wojcicki (1992), which is now known to be older than the Pinole Tuff (Tpt)

Tdi **Diatomite (middle to early Miocene)**—Light-gray to white diatomite with minor brown shale

Tsa **Sandstone (middle to early Miocene)**—Massive, light-gray, fine- to medium-grained sandstone

RODEO ASSEMBLAGE

Tpt **Pinole Tuff (Pliocene)**—White, fine ash to lapilli, rhyolite tuff and pumiceous to tuffaceous sandstone. Volcanic sandstone beds also include clasts of chert and schist derived from Franciscan Complex rocks. This tuff has yielded a K/Ar date of 5.2 ± 0.11 Ma (Evernden and others, 1964; Sarna-Wojcicki, 1971 1976)

Tn **Neroly Sandstone (late Miocene)**—Brown to blue, volcanic-rich, lithic to arkosic, shallow marine sandstone. Also includes minor shale, siltstone, and tuffaceous sandstone

Tc **Cierbo Sandstone (late Miocene)**—Brown, gray, white, and minor blue marine quartz and quartz-lithic sandstone, with minor tuffaceous sandstone, shale, and conglomerate

Briones Sandstone (late and middle Miocene)—Orange- to tan-weathering, white to gray quartz-lithic sandstone, shell breccia, conglomerate, siltstone, and shale. Shell-breccia beds are erosion resistant. In the Hercules area, the unit is divided into:

Tbu **Upper member**—Sandstone and siltstone

Tbh **Hercules Shale Member**—Gray shale, siliceous shale, sandy shale, and siltstone. Locally contains abundant muscovite

Tbl **Lower member**—Sandstone and siltstone

Tr **Rodeo Shale (middle Miocene)**—Light-brown siltstone, silty shale, shale, siliceous shale, and chert. Foraminifers are locally abundant, as are yellow-orange dolomitic concretions

Th **Hambre Sandstone (middle Miocene)**—Light-brown to gray, massive, medium- to fine-grained sandstone and siltstone

Tt **Tice Shale (middle Miocene)**—Brown to light-gray siliceous shale, argillaceous chert, and yellow-orange dolomitic lenses and concretions

MARTINEZ ASSEMBLAGE

Tbr **Briones Sandstone (late and middle Miocene)**—Orange- to tan-weathering, white to gray quartz-lithic sandstone, shell breccia, conglomerate, siltstone, and shale

Ts **Sobrante Sandstone (early Miocene)**—Massive, white, medium-grained, calcareous quartz sandstone

Tsr **San Ramon Sandstone (early Miocene and (or) Oligocene)**—Bluish-gray to brown, medium-grained sandstone with conglomerate locally present in basal part. The accepted age for this unit was early Miocene, based on Addicott (1970) who noted that Weaver and others (1944) had reclassified the molluscan zone of the San Ramon Sandstone fauna (*Echinophoria apta*) from late Oligocene to early Miocene. However, Kleinpell (1938) reported early Zemorrian foraminifers from the San Ramon Sandstone. Weaver and others (1944) classified the Zemorrian as early Miocene (probably based on the relationships in this unit), but more recent work on foraminiferal zonation by McDougall (1983) has shown the Zemorrian zone to be entirely Oligocene. In addition, the San Ramon Sandstone south of the map area underlies tuffaceous sandstone and tuff correlated with the Kirker Tuff, which is considered to be Oligocene. The contradiction in accepted ages of the two units and the contradiction of foraminiferal and molluscan zonation has caused Graymer (2000) to use the less restricted age indicated

The Tertiary units below were mapped by Sims and others (1973) as Markley Sandstone, Nortonville Shale, Domengine Sandstone, Paleocene unnamed formation, and Martinez Formation. We, however, reverted to the earlier, local, names of Weaver (1953) because of differences in the lithologic and paleontologic character of the rocks at Martinez from rocks also designated Markley, Nortonville, Domengine, and Martinez elsewhere, especially on the north flank of Mount Diablo (Graymer and others, 1994), and because of the confusion of stratigraphic ranking associated with those terms, especially the Martinez. Of course, this leads to the unfortunate result that the Martinez Formation is mapped in several areas, none of which are near Martinez. Eventually another name will have to be defined for the Paleocene strata outside of Martinez, but that effort is beyond the limits of this report.

Tes **Escobar Sandstone of Weaver (1953) (Eocene)**—Massive, medium- to coarse-grained, brown sandstone and gritty sandstone with interstratified silty shale. Also includes:

Teh **Basal shale member**—Thinly laminated, light-brown to white shale

Tmr **Muir Sandstone of Weaver (1953) (Eocene)**—Massive, yellow-weathering, brownish-gray, fine- to medium-grained silty arkose and silty shale. Foraminifers are common in the shales, and fossil molluscs and corals are present in the sandstone. Locally, divided into:

Tmru **Upper member**—Massive arkose and silty sandstone with minor shale

Tmrl **Lower member**—Brown silty shale and claystone with thin sandstone beds in the basal part of the member

Tlj **Las Juntas Shale of Weaver (1953) (Eocene and Paleocene)**—Gray clay shale and silty shale with minor interbeds of siltstone and sandstone. The Las Juntas Shale was considered Eocene by Weaver (1953) but is now known to contain both Eocene and Paleocene foraminifers. The unit is locally divided into:

Tlju **Upper member**—Brownish-gray silty shale

Tljl **Lower member**—Fine- to medium-grained silty sandstone and silty shale

Tvh **Vine Hill Sandstone of Weaver (1953) (Paleocene)**—Massive, medium- to coarse-grained, brown, glauconitic sandstone and silty shale

Tvhu **Upper member**—Gray, brown, and white, massive sandstone, with minor pebbly sandstone in the upper part of the member and thin-bedded brown sandstone and silty shale in the lower part of the member

Tvhl **Lower member**—Brown and gray, locally gritty, sandstone and silty to sandy shale. A five-foot-thick bed of pebble conglomerate may mark the base of the member in places

Great Valley complex

Ku **Undivided sandstone, siltstone, and shale (Late Cretaceous)**—Brownish-gray, fine- to coarse-grained, thin bedded to massive sandstone and greenish-gray to black shale and silty shale. Also includes minor pebbly sandstone and conglomerate. This unit has yielded foraminifers of Cenomanian to Maastrichtian age. The unit is locally divided into:

Kcs **Massive sandstone**—Gray, massive quartz arenite

Kus **Sandstone, siltstone, and shale**—Similar to Ku

Kuh **Massive sandstone**—Also includes minor siltstone

KJgv **Massive sandstone and shale (Early Cretaceous and Late Jurassic)**—Gray and greenish-gray clay shale, siltstone, lithic wacke, and gritstone. Shale has dolomite and calcite concretions in many places. This unit has yielded *Buchia* of Tithonian to Valanginian age

SEARS POINT ASSEMBLAGE

QThg **Huichica and Glen Ellen Formations, undivided (early Pleistocene and Pliocene)**—Siltstone, sandstone, and gravel equivalent to the Glen Ellen Formation found north of the map area (Fox, 1983) and (or) Huichica Formation of the Sonoma assemblage

Tsv **Sonoma Volcanics (Pliocene and late Miocene)**—The Sonoma Volcanic complex includes tuff, obsidian, flow rock, pyroclasitic breccia, and intrusives which range in composition from rhyolite to basalt and were probably derived from several eruptive centers, along with interbedded volcaniclastic sedimentary rocks. In part equivalent to Sonoma Volcanics in the Sonoma, Cordelia, and Vacaville assemblages; radiometric ages from the Sonoma Volcanics in the Sears Point assemblage range from about 4.2 to about 8.5 Ma (Fox, 1983; Fox and others, 1985a; Youngman, 1989). The Sonoma Volcanics are thought to have formed, along with the Clear Lake Volcanics, Donall Ranch volcanics of Youngman (1989), and andesite of Burdell Mountain of Blake and others (2000), as part of the northward younging series of volcanic centers related to initiation of the San Andreas Fault system (Fox and others, 1985b). For more about the Sonoma Volcanics, see Fox (1983) and Sarna-Wojcicki (1976). In the Sears Point assemblage, the Sonoma Volcanics in the map area include only:

Tsva **Andesite to basalt flows**

Tsvr **Rhyolite flows**—Includes intercalated rhyolite tuff in places

Tsvt **Ash-flow tuff**—Pumiceous tuff, aglomeratic tuff. Also contains minor flow rocks

Tsvs **Volcanic sand and gravel**

Petaluma Formation (early Pliocene and late Miocene)—Crops out mostly west and northwest of the map area. Gray weathering, brown and green pebble- and cobble-conglomerate, gritstone, lithic and quartz-lithic arenite, and mudstone. Coarse clasts include varicolored chert, quartz- and plagioclase-porphyry rhyolite and andesite, vesicular andesite, laminated rhyolite, white tuff, basalt, quartz, graywacke, greenstone, and laminated chert. Locally present within the sandstone and conglomerate are land-mammal fossils, and lacustrine and estuarine ostracods, fish remains, and thin-shelled mollusks (Liniecki-Laporte and Anderson, 1988) have been found in the mudstone. Mammal fossils originally described as late Pliocene (Stirton, 1939) are now known to be late Miocene (late Hemphilian; McFadden, 1998). Early Pliocene mammal fossils have been found elsewhere within the unit, however (early Blancan; Bartow and others, 1973; Davies, 1986). In the map area, the Petaluma Formation also includes a tuff bed correlated with the informally named Roblar tuff of Sarna-Wojcicki (1992), which has yielded radiometric ages around 6 Ma (Sarna-Wojckici, 1976). West of the map area the Petaluma Formation contains a layer of basalt flow rock (8.52 ± 0.18 Ma; Fox and others, 1985a) probably equivalent to the mafic member of the Donall Ranch volcanics of Youngman (1989; Tdm, Tdr). Therefore, the Petaluma Formation overlies and interfingers with the Donall Ranch volcanics at its base. It is also coeval with (and may interfinger with) the lower part of the Sonoma Volcanics at its top. It is probably equivalent to the similar unit Tcgl in the Hercules area, which also contains tuff correlated with the Roblar tuff. These two units have probably been offset about 35 km by movement on the Hayward-Rodgers Creek-Healdsburg Fault Zone from their original contiguous depositional position in the past 6 Ma. In the map area, the Petaluma Formation is divided into:

Tps **Mudrock, sandstone, and conglomerate**

Tpc **Claystone**—Massive to laminated gray claystone

Donall Ranch volcanics of Youngman (1989) (late Miocene)—Originally mapped as Sonoma Volcanics (Weaver, 1949), later assigned to the Tolay Volcanics (Fox, 1983), the Donall Ranch volcanics were separated by Youngman (1989) based on lithology, age, chemical composition, and stratigraphic position. The Donall Ranch volcanics have yielded radiometric ages of 8.65 ± 0.02 to 10.64 ± 0.27 Ma (K/Ar; Fox and others, 1985a; Youngman, 1989). Youngman also showed that the Donall Ranch volcanics are equivalent to the volcanic rocks in the Berkeley Hills south of the map area. These two units have been separated by as much as 45 km of offset on the Hayward-Rodgers Creek-Healdsburg Fault Zone in the past 9 Ma (Fox and others, 1985b). In the map area, the Donall Ranch volcanics are divided into:

Tdm **Mafic member**—Medium-gray to black basalt and olivine basalt and brown-gray to dark-gray basaltic andesite. The volcanics are phaneritic to porphyritic, locally vesicular. Phenocrysts include plagioclase and lesser olivine and pyroxene

Tdr **Rhyolite member**—Pink to gray rhyolite and dacite flow rock and breccia. The volcanics are mostly phaneritic and vesicular or amygduloidal. This unit also includes minor rhyolite tuff

SONOMA ASSEMBLAGE

QTh **Huichica Formation (early Pleistocene and Pliocene)**—Massive, yellow siltstone, well-sorted quartz-lithic sandstone, and poorly consolidated gravel. Detritus includes varicolored chert, quartz-lithic sandstone, biotite wacke, rhyolite, metachert, and tuff reflecting derivation from Franciscan Complex, Great Valley complex, and older Tertiary rocks. The Huichica Formation also includes a tuff bed near the base that has been correlated with the Lawlor Tuff (Tl; Sarna-Wojcicki, 1976)

Sonoma Volcanics (Pliocene and late Miocene)—In part equivalent to Sonoma Volcanics in the Sears Point, Cordelia, and Vacaville assemblages; radiometric ages from the Sonoma Volcanics in the Sonoma assemblage range from about 3.8 to about 8.5 Ma (Fox, 1983; Fox and others, 1985a; Youngman, 1989). In the Sonoma assemblage in the map area, the Sonoma Volcanics are divided into:

Tsvt **Ash-flow tuff**—Pumiceous tuff, agglomeratic tuff. Also contains minor flow rocks

CORDELIA ASSEMBLAGE

QTh **Huichica Formation (early Pleistocene and Pliocene)**—Siltstone, sandstone, and gravel, probably equivalent to the Huichica Formation of the Sonoma assemblage

Tsv **Sonoma Volcanics (Pliocene and late Miocene)**—Equivalent to the Sonoma Volcanics in the Sears Point, Sonoma, and Vacaville assemblages, although in the Cordelia assemblage the volcanic field has not yielded radiometric ages older than about 5.35 ± 0.37 Ma (Fox and others, 1985a) and has a wider variety of lithologies than in other assemblages, including perlite, welded tuff, and lithic tuff. In this area, the Sonoma Volcanics are divided into:

Tsva **Andesite to basalt flows**

Tsvi **Andesite to dacite plugs and dikes**

Tsvr **Rhyolite flows**—Includes interbedded rhyolite tuff in places

Tsvri **Rhyolite plugs and dikes**

Tsvp **Rhyolite and perlitic flows and plugs**

Tsvt **Ash-flow tuff**—Pumiceous tuff, agglomeratic tuff. Also contains minor flow rocks

Tsvw **Welded ash-flow tuff**—Similar to unit Tsvt, but partly welded

Tsvl **Lithic tuff**—Also includes agglomerate, agglomeratic tuff

Tsvs **Volcanic sandstone, siltstone, and conglomerate**—Tuffaceous mudstone, crossbedded, coarse-grained volcanic sandstone, and cobble conglomerate with well-rounded to angular andesite and basalt clasts

Tsvd **Diatomite**—Includes interbedded sand, gravel, and tuff

Tc **Cierbo Sandstone (late Miocene)**—Orange-weathering, clean, white quartz-biotite and quartz-lithic sandstone and pebble conglomerate. This unit includes shelly conglomerate in several places. Conglomerate pebbles are well rounded and include varicolored chert, quartz, andesite, and rhyolite. It also includes, locally:

Tv **Intercalated basalt**—Black basalt. Crops out only in one hill north of Napa Junction, in the westernmost part of the Cordelia quadrangle

Tcc **Claremont Shale (Miocene)**—White-weathering, light-brown, laminated siliceous shale and mudstone. This unit crops out in only two small exposures in the Cuttings Wharf quadrangle

Tmk **Markley Sandstone (Eocene)**—Mainly buff-weathering, white to light-gray, quartz-mica sandstone. Characterized in many places by small to large plates of white mica (up to several mm across). In places, the sandstone also includes carbonized plant debris and other carbonaceous material. This unit also includes white- or brown-weathering, brown or dark-gray, foraminifer- and diatom-bearing, mudstone and sandy mudstone. In some outcrops the mudstone is laminated and siliceous and has a slabby parting. The mudstone has been previously mapped in places as Nortonville Shale (for example Sims and others, 1973), but it is distinguished by younger fossils and by being more siliceous. In the mapped area this formation also includes, mapped locally:

Tmkj **Jameson Shale Member**—Laminated and siliceous, foraminifer-, diatom-, and radiolarian-bearing brown mudstone with slabby parting. This unit is similar to the Nortonville Shale but contains younger fossils and is more siliceous

Tnv **Nortonville Shale Member of Kreyenhagen Formation (Eocene)**—Gray-weathering, brown shale. Also contains thin beds of fine-grained, dark-gray, quartz-lithic-glauconitic sandstone. In the Cordelia area, this unit pinches out in the northern part of the Cordelia quadrangle

Td **Domengine Sandstone (Eocene)**—Gray-weathering, white, clean, quartz, quartz-lithic, and quartz-biotite sandstone, locally crossbedded. In one outcrop in the northern part of the Cordelia quadrangle, the sandstone contains abundant invertebrate fossils (shells). Also in the area, this unit contains near the base a prominent ridge-forming boulder to pebble conglomerate containing clasts of serpentinite, gabbro, pyroxenite, crinoidal limestone, black argillite, and diorite

Tm **Meganos Formation (Eocene and (or) Paleocene)**—Brown-weathering gray shale and quartz-biotite lithic sandstone. This unit, which crops out only in a small area in the northeastern part of the Cuttings Wharf quadrangle, contains foraminifers of early Eocene and (or) late Paleocene age (probably planktic foraminiferal zone P6 or early early Eocene according to K. McDougall, written commun., 2002)

Great Valley complex

Ku **Sandstone and shale (Late Cretaceous)**—Interbedded carbonaceous biotite wacke, carbonaceous white-mica sandstone, greenish-gray mudstone and shale, laminated fine-grained sandstone and gray shale, carbonaceous siltstone, black shale, and fine-grained mica wacke. Locally includes hard laminated clean white quartz-lithic-biotite sandstone and fossil-hash gritstone

KJgv **Sandstone and shale (Early Cretaceous and Late Jurassic)**—Gray shale with concretions. Locally contains pebbly gritstone with green shale chips and probable glauconite. This unit is differentiated from Ku by the presence of fossil *Buchia*, including both *Buchia piochii* and *Buchia pacifica*, and by the absence of thick beds of sandstone

Jsv **Keratophyre (Jurassic)**—Orange-weathering, white, altered silicic (quartz keratophyre) and intermediate (keratophyre) volcanic rocks. Locally contains red jasper, rhyolite, and rhyolite tuff

Jb **Massive and pillow basalt (Jurassic)**—Black basalt and pillow basalt, locally amygduloidal

Jgb **Gabbro (Jurassic)**—Locally also contains plagioclase-porphyry diabase, pyroxenite, and serpentinite

sp **Serpentinite (Jurassic)**—Locally also contains pyroxenite and silica-carbonate rock

sc **Silica-carbonate rock**—Red and yellow masses of quartz, opal, and carbonate formed by hydrothermal alteration of serpentinite. This unit also locally includes minor remnants of serpentinite, and, in rare localities, concentrations of cinnabar

ls **Limestone (age unknown)**—Gray algal limestone. In the mapped area, this unit only crops out as a small fault-bounded sliver associated with silica-carbonate rock (altered serpentinite) in the northern part of the Cordelia quadrangle

PITTSBURG ASSEMBLAGE

QTu **Sandstone, siltstone, and gravel (early Pleistocene and late Pliocene)**—Semi-consolidated to unconsolidated poorly sorted gravel, sand, silt, and clay distributed in isolated patches. Outcrops are distinguished from younger alluvial deposits (such as unit Qoa) by lack of relation to modern or Pleistocene drainage. Thickness varies but most outcrop areas exceed 50 m. At most localities, soil profiles are absent due to erosion

Tpth **Tehama Formation (Pliocene)**—Poorly consolidated, nonmarine, gray to maroon siltstone, sandstone, tuff, and conglomerate. This unit was correlated with the Tehama Formation in the Vacaville Assemblage based on the presence of tuff correlated with the Putah Tuff member (Sims and Sarna-Wojcicki, 1975)

Tl **Lawlor Tuff (Pliocene)**—Nonmarine, pumiceous, andesitic ash-flow tuff. Redating of the tuff in this area has yielded an Ar/Ar age of 4.83 ± 0.04 Ma. (Sarna-Wojcicki, written communication, 2002)

Tn **Neroly Sandstone (late Miocene)**—Dark-red-brown or brown-gray weathering, blue to dark-blue-gray, volcanic-rich, crossbedded sandstone, conglomerate, and minor siltstone. In places this unit contains nonmarine fossils. In some places the base of the unit is marked by a 3-m-thick section of green and brown sandstone and tuffaceous mudstone. Conglomerate clasts include black, white, and gray chert, quartzite, andesite, and greenstone. The Neroly Sandstone in this area contains tuffs with K/Ar ages of about 9.8 Ma (Black Diamond Park Tuff) and about 11.1 Ma (Alves Tuff) (Sarna-Wojcicki and Walker, 1999)

Tc **Cierbo Sandstone (late Miocene)**—Light-gray, light-blue, and black, massive to distinctly bedded quartz-mica-lithic arenite, conglomerate, siltstone, and tuff. Sandstone beds are crossbedded in places. Conglomerate clasts include black and gray chert and argillite, sandstone, greenstone, and much andesite. A tuff bed in this unit has been correlated with tuff in Idaho that has yielded an Ar/Ar age of about 10.5 Ma (Walker and others, 1996)

Markley Sandstone (Eocene)

Tmku **Upper member**—White- to light-gray-weathering, brown and light-gray, plant-debris rich, thin-bedded mudstone, siliceous mudstone, siltstone, and quartz-muscovite sandstone

Tmkl **Lower member**—Thin-bedded to massive quartz-muscovite sandstone with minor siltstone and conglomerate

VACAVILLE ASSEMBLAGE

Qmz **Montezuma Formation (early Pleistocene)**—Orange-weathering, soft, brown, poorly sorted quartz-lithic sand, silt, and pebble gravel. Pebbles include red chert and volcanics

Tpth **Tehama Formation (Pliocene)**—White quartz arenite, tuffaceous sandstone, siltstone, and pebble to cobble conglomerate. This unit also contains beds of white ash tuff and pink tuff breccia. In the northern part of the map area, the Tehama Formation includes near the base:

Tptt **Putah Tuff member**—Water-lain tuff and tuffaceous and volcaniclastic sedimentary rocks. This unit has yielded a radiometric age of 3.3 ± 0.1 Ma (K/Ar, Miller, 1966). This member was correlated with the Nomlaki Tuff Member of the Tehama Formation north of the map area, which is similar in age, but chemical analysis has shown the tuffs to be distinct (Miller, 1966; Sarna-Wojcicki, 1976)

Tsv **Sonoma Volcanics (Pliocene and late Miocene)**—Equivalent to the Sonoma Volcanics in the Sears Point, Sonoma, and Cordelia assemblages, although in the Vacaville assemblage the volcanic field has not yielded radiometric ages older than about 4.2 Ma (Fox and others, 1985a). In this area, the Sonoma Volcanics are divided into:

Tsva **Andesite to basalt flows**

Tsvad **Andesite to dacite flows**

Tsvr **Rhyolite flows**—Includes interbedded rhyolite tuff in places

Tsvt **Ash-flow tuff**—Pumiceous tuff, agglomeratic tuff, also contains minor flow rocks

Tsvs **Volcanic sandstone, siltstone, and conglomerate**—Tuffaceous mudstone, crossbedded, coarse-grained volcanic sandstone, and cobble conglomerate with well-rounded to angular andesite and basalt clasts

Tn **Neroly Sandstone (late Miocene)**—Blue-gray, fine- to coarse-grained lithic sandstone. In places in the Vacaville area, this unit also includes tuffaceous sandstone, white-weathering, tan tuffaceous mudstone, and pebble to boulder conglomerate. Conglomerate clasts include porphyry andesite and basalt, black hornfels argillite, quartz, white tuff, quartzite, granitic rocks, serpentinite, greenstone, siliceous shale, and minor red chert

Tpb **Putnam Peak Basalt (Miocene)**—Olivine basalt flow rock. Columnar jointing locally developed. Correlated with the Lovejoy Basalt of the Sierra Nevada foothills (Durrell, 1959; Gromme, 1963; Siegel, 1988) based on geochemical similarities, suggesting that the Putnam Peak Basalt is the remnant of extensive flood basalts that extended from the Sierra Nevada to the Coast Ranges. The age of the Lovejoy Basalt has been controversial, having been reported variously from Eocene to Miocene, but recent Ar/Ar analysis has yielded an age of about 16 Ma (Page and others, 1995; Wagner and others, 2000), suggesting the revised provisional assignment of Miocene age to the Putnam Peak Basalt

Tmk **Markley Sandstone (Eocene)**—Yellow- and tan-weathering, light-gray and white, fine- to coarse-grained quartz-muscovite and quartz-lithic sandstone and siltstone. The Markley Sandstone unit in the Vacaville area also includes light-gray and brown foraminiferal mudstone in places. Plant debris is locally abundant

Tnv **Nortonville Shale Member of Kreyenhagen Formation (Eocene)**—Brownish-gray concretionary shale and thin-bedded white to dark-gray quartz-muscovite-lithic sandstone. Sandstone contains echinoid spines in at least one area. In the Vacaville area, this unit is locally divided into:

Tnvu **Upper member**—Brownish-gray shale with thin sandstone beds

Tnvm **Middle member**—Argillaceous arkose

Tnvl **Lower member**—Brownish-gray silty shale

Td **Domengine Sandstone (Eocene)**—White, fine- to coarse-grained quartz and quartz-lithic sandstone and very light brown siltstone. Locally includes conglomerate with pebbles of quartz, chert, and andesite, as well as thin beds of gray shale

Tsh **Shale (Eocene)**—Brown, thin-bedded and laminated, foraminiferal mudstone and gray micaceous shale. Previously mapped as Vacaville shale (Merriam and Turner, 1937) and Capay Formation (for example, Weaver, 1949). This unit contains foraminifers and nannoplankton of middle and early Eocene age (Prothero and Brabb, 2001)

Tpu **Shale and sandstone (Paleocene)**—Brown, glauconitic, mica-lithic wacke and gritstone; gray, fine-grained quartz-biotite-lithic wacke; and gray foraminiferal shale and mudstone. Locally, also contains gray glauconitic shale, red and olive shale, and brown biotite-feldspar-lithic sandstone. This unit contains Paleocene foraminifers (Lachenbruch, 1962; Emerson and Roberts, 1962; Sonneman and Switzer, unpub. data, 1961-1962; Almgren, unpub. data, 2002). In the Vaca Valley area, this unit also includes:

Tpus **Basal sandstone member**—White, clean, mica-quartz-lithic sandstone. Crossbedded in places

Tmz **Martinez Formation (Paleocene)**—Very light brown and light-gray, fine-grained mica-lithic and mica-quartz-lithic sandstone and micaceous mudstone with plant debris. This unit includes a shelly sandstone containing Paleocene *Turitella* (C. Powell, written commun., 2002) in the Fairfield North quadrangle. Only mapped south of Vacaville

Great Valley complex

Kuhs **Sandstone and shale (Late Cretaceous)**—Biotite-quartz-lithic sandstone, gray-weathering brown siliceous shale, and gray siliceous shale and mudstone. Locally divided into:

Kuss **Sandstone**

Ksh **Siliceous shale**—Contains radiolarians and foraminifers of Late Cretaceous (Campanian) age (Emerson and Roberts, 1962; Sonneman and Switzer, unpub. data, 1961-1962; Almgren, unpub. data, 2002)

Kfo **Forbes Formation (Late Cretaceous)**—Thick beds of massive, fine- to coarse-grained biotite-muscovite-quartz-lithic wacke with shell fragments grading up into interbedded siltstone and shale. This unit contains foraminifers of Late Cretaceous (Campanian to Santonian) age (Goudkoff, 1945; Lachenbruch, 1962; Emerson and Roberts, 1962; Sonneman and Switzer, unpub. data, 1961-1962; Almgren, unpub. data, 2002)

Kg **Guinda Formation (Late Cretaceous)**—Thick-bedded to massive, coarse- to fine-grained, biotite-quartz-feldspar-lithic wacke. Grades up into gray siltstone and shale bearing radiolarians and foraminifers of Late Cretaceous (Santonian) age (Goudkoff, 1945; Lachenbruch, 1962; Emerson and Roberts, 1962; Sonneman and Switzer, unpub. data, 1961-1962; Almgren, unpub. data, 2002)

Kf **Funks Formation (Late Cretaceous)**—Tan weathering, greenish-gray and gray, carbonaceous, biotite siltstone and mudstone. This unit also includes thin beds of biotite-quartz-feldspar-lithic wacke. The shale beds have foraminifers of Late Cretaceous (Santonian) age (Goudkoff, 1945; Lachenbruch, 1962; Emerson and Roberts, 1962; Sonneman and Switzer, unpub. data, 1961-1962; Almgren, unpub. data, 2002)

Ks **Sites Formation (Late Cretaceous)**—Distinctly and moderately thick bedded, laminated, gray-brown or greenish-gray, fine- to medium-grained biotite wacke, quartz wacke, and lithic wacke and moderately thick (up to 2 meters) beds of dark gray carbonaceous siltstone. This unit contains foraminifers of Late Cretaceous (Coniacian) age (Goudkoff, 1945; Lachenbruch, 1962; Emerson and Roberts, 1962; Sonneman and Switzer, unpub. data, 1961-1962; Almgren, unpub. data, 2002)

Ky **Yolo Formation (Late Cretaceous)**—Distinctly and moderately thick bedded, fine- to coarse-grained, laminated quartz-biotite-lithic sandstone and greenish-gray mudstone and micaceous siltstone. Carbonaceous debris is common in places. Mudstone beds contain radiolarians and foraminifers of Late Cretaceous (Coniacian) age (Goudkoff, 1945; Lachenbruch, 1962; Emerson and Roberts, 1962; Sonneman and Switzer, unpub. data, 1961-1962; Almgren, unpub. data, 2002)

Kv **Venado Formation (Late Cretaceous)**—Massive and thick-bedded, brown-weathering, greenish-gray, shale-chip bearing, biotite-lithic wacke. The unit also includes minor siltstone, more common near the top, and conglomerate near the base. In Monticello Dam quadrangle, the basal part also includes a layer of megabreccia, angular blocks of sandstone and siltstone up to 3.5 m in length in a conglomeratic mudstone matrix (see

Peterson, 1965; Lowe, 1972). This unit contains sparse foraminifers of Late Cretaceous (Turonian) age (Goudkoff, 1945; Lachenbruch, 1962; Emerson and Roberts, 1962; Sonneman and Switzer, unpub. data, 1961-1962; Almgren, unpub. data, 2002)

KJgv **Sandstone and shale (Early Cretaceous and Late Jurassic)**—Mostly rhythmically thin bedded, fine-grained quarz-lithic wacke and greenish-gray to black mudstone and shale. Locally, this unit contains beds of massive sandstone or conglomerate that can be tracked for several kilometers before pinching out. The southern part of the unit (northwest of Fairfield) is coarser grained, being composed mostly of light-gray, fine- to coarse-grained quartz-biotite-lithic wacke, gritstone, and pebble conglomerate with minor siltstone, shale, and shell hash. The shelly layers contain rudistid fossils. This unit was divided by Sims and others (1973) into three distinct stratigraphic units, but Weaver (1949) recorded the presence of Late Jurassic and Early Cretaceous *Buchia* in both the structurally lower and upper parts of the unit. In addition, Boyd (1956) reported Early Cretaceous (Albian) ammonites from an area now covered by the southeasternmost part of Lake Berryessa. Because the fossils in the structurally upper parts of the unit are reported from concretions in shale beds, it is unlikely that the fossils have been redeposited as clasts. It is more likely that there are unmapped structures present that have disrupted the original stratigraphic sequence. These structures are not recognized, probably because of the similar lithology throughout most of this unit, and will probably only be mappable through the application of thorough paleontological studies. In one part of the unit, a relatively continuous marker bed is mapped:

KJu **Sandstone member**—Ridge-forming section as much as 350 m thick of massive to thick-bedded lithic wacke

KJgvm **Mélange**—Southwest of Lake Berryessa lies a fault-bounded zone of highly to moderately sheared and disrupted sandstone and shale identical to unit KJgv. The deformation ranges from small scale isoclinal folds to formation of slaty cleavage in the shale and complete disruption of the sandstone. Quartz and calcite veins are common. Large lenses of basalt breccia (Jv) are intercalated into the unit. This unit has either undergone repeated imbrication along reverse or thrust faults that have tectonically interleaved the sedimentary rocks with the previously underlying volcanics or formed as an olistostrome from volcanic-bearing submarine debris flows and has undergone considerable later deformation

Jk **Knoxville Formation (Late Jurassic)**—Only differentiated in the Mt. George quadrangle, this unit is made up of distinctly bedded black shale and thin beds of biotite-lithic wacke and contains only Late Jurassic fossils

Jv **Basalt and keratophyre (Jurassic)**—Mostly massive black basalt, also includes amygdaloidal and plagioclase-porphyry basalt, pillow basalt, basalt breccia, diabase, and keratophyre. Coast Range ophiolite volcanic rocks are distinguished from Franciscan complex volcanic rocks by lack of metamorphism and alteration, by association with intrusive rocks, and by lack of associated ribbon chert

sp **Serpentinite (Jurassic)**—Mainly sheared serpentinite, but also includes massive serpentinized harzburgite. In places, pervasively altered to silica carbonate rock

Franciscan Complex

Kfs **Sandstone (Late Cretaceous)**—Sandstone and interbedded shale, with minor conglomerate. This unit crops out in alternating sequences of largely medium thick to very thick sandstone beds with generally minor interbedded shale and predominantly shale with interbedded thin to medium-thick sandstone beds. The rock is locally severely sheared or brecciated but lacks tectonic inclusions of other rock types such as greenstone and chert which are common in unit fsr. The sandstone is light gray where fresh, weathering to buff colors, and shale is commonly dark gray. Laumontite veins, calcite veins, and microscopic secondary prehnite and (or) pumpellyite are common in sandstone. Rocks of this unit typically form resistant topography

KJfm **Metagraywacke (Early Cretaceous and Late Jurassic)**—Brown-weathering, gray, foliated (textural zone 2A of Jayko and others, 1986), jadeite-bearing metagraywacke. Similar jadeite-bearing metagraywacke elsewhere in the Coast Ranges has yielded radiometric metamorphic ages of 90-110 Ma (Wakabayashi, 1999; Mattinson and Echevarria, 1980) and has yielded Late Jurassic (Tithonian) fossils (Crawford, 1976)

fsr **Mélange**—Sheared argillite and graywacke matrix enclosing blocks and lenses of graywacke, chert, metachert, greenstone, serpentinite, silica-carbonate rock, blueschist (metasediment and metabasalt), eclogite, amphibolite, limestone, and quartz-mica schist. Enclosed blocks and lenses range in size from pebbles to slabs several hundred meters across. The matrix graywacke has yielded Late Jurassic (Tithonian) fossils northwest of the map area (Bailey and others, 1964). High-grade blocks northwest of the map area have yielded metamorphic ages of about 138-150 Ma (K/Ar, Kelley, 1982; Lee and others, 1964). Chert blocks in Marin County west of the map area almost all similar to coherent chert of the Marin Headlands terrane (Murchey and Jones, 1984). Mélange blocks are probably derived from tectonic detachment of pieces of surrounding coherent Franciscan Complex and Great Valley complex terranes

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Digital Publication and Database Description

Introduction

This publication includes, in addition to cartographic and text products, geospatial (GIS) databases and other digital files. These files are published on the Internet through the U.S. Geological Survey (USGS) Publications Group web sites. The database files are particularly useful because they can be combined with any type of other geospatial data for purposes of display and analysis. The other files include digital files that support the databases and digital plot files that can be used to display and print the cartographic and text products included in this publication.

Following is the digital publication and database description. It contains information about the content and format of the digital geospatial databases used to create this digital geologic map publication. **This information is not necessary to use or understand the geologic information in the map and preceding geologic description.** The digital map and database description contains information primarily useful for those who intend to use the geospatial databases. However, it also contains information about how to get digital plot files of the map and geologic pamphlet via the Internet or on magnetic tape, as well as information about how the map sheet and pamphlet were created, and information about getting copies of the map sheet and text from the USGS.

In addition, in 1999, the USGS adopted policies regarding revision of publications, introducing the concept of version numbers similar to those used in the computer industry. See the section “Revisions and version numbers” for information about the version system and about how to access a revision list explaining changes from version 1.0, if any have been made.

The digital map database, compiled from previously published and unpublished data and new mapping by the authors, represents the general distribution and orientation of bedrock and surficial deposits in the mapped area. Together with the accompanying text file (nesfmf.txt, nesfmf.pdf, or nesfmf.ps), it provides current information on the geologic structure and stratigraphy of the map area. The database delineates map units that are identified by general age and lithology following the stratigraphic nomenclature of the USGS. The scale of the source maps limits the spatial resolution (scale) of the database to 1:62,500 or smaller. The content and character of the database, as well as two methods of obtaining the database, are described below.

For those who don't use digital geologic map databases

For those interested in the geology of the mapped area who do not use an ARC/INFO compatible Geographic Information System (GIS), we have provided two sets of plotfiles containing images of much of the information in the database. Each set contains an image of a geologic map sheet and explanation and an explanatory pamphlet. There is a set of images in PostScript format and another in Adobe Acrobat PDF format (see the sections “PostScript plot files” and “PDF plot files” below).

Those interested who have computer capability can access the plot file packages in either of the two ways described below (see the section “Obtaining the digital database and plotfile packages”). However, it should be noted the plot file packages do require gzip and tar utilities to access the plot files. Therefore additional software, available free on the Internet, may be required to use the plot files (see section “Tar files”).

Those without computer capability can obtain plots of the map files through USGS plot-on-demand service for digital geologic maps (see section “Obtaining plots from USGS Map On Demand Services”) or from a commercial vendor (see section “Obtaining plots from a commercial vendor”).

MF-2403 Digital Contents

This report includes three digital packages. The first is the PostScript Plotfile Package, which consists of PostScript plot files of a map sheet containing a geologic map and explanation and a pamphlet containing a geologic description. The second is the PDF Plotfile Package, which contains the same plotfiles as the first package but in Portable Document Format (PDF). The third is the Digital Database Package, which contains the geologic map database itself and the supporting data, including base maps, map explanation, geologic description, and references.

Postscript plotfile package

This package contains the images described here in PostScript format (see below for more information on PostScript plot files):

nesfmap.ps	A PostScript plotfile containing an image of the geologic map and base maps at a scale of 1:100,000 along with a map explanation including terrane map, index maps, and correlation chart
nesfmf.ps	A PostScript plotfile that contains an image of the pamphlet containing detailed unit descriptions and geological information, a description of the digital files associated with the publication, plus references cited

PDF plotfile package

This package contains the images described here in PDF format (see below for more information on PDF plot files):

nesfmap.pdf	A PDF file containing an image of the geologic map and base maps at a scale of 1:100,000, along with a map explanation including terrane map, index maps, and correlation chart
nesfmf.pdf	A PDF file that contains an image of the pamphlet containing detailed unit descriptions and geological information, a description of the digital files associated with the publication, plus references cited

Digital database package

The database package includes geologic map database files for the map area. The digital maps, or coverages, along with their associated INFO directory have been converted to uncompressed ARC/INFO export files. ARC export files promote ease of data handling and are usable by some Geographic Information Systems in addition to ARC/INFO (see below for a discussion of working with export files). The ARC export files and the associated ARC/INFO coverages and directories, as well as the additional digital material included in the database, are described below:

ARC/INFO export file	Resultant Coverage	Description of Coverage
nesf2-geol.e00	nesf2-geol/	Polygon and line coverage showing faults, depositional contacts, and rock units in the southwestern part of the map area
nesf3-geol.e00	nesf3-geol/	Polygon and line coverage showing faults, depositional contacts, and rock units in the central part of the map area
nesf4-geol.e00	nesf4-geol/	Polygon and line coverage showing faults, depositional contacts, and rock units in the northern part of the map area
nesf5-geol.e00	nesf5-geol/	Polygon and line coverage showing faults, depositional contacts, and rock units in the southeastern part of the map area
nesf-strc.e00	nesf-strc/	Point, line, and annotation coverage showing strike and dip information and fold axes in the map area

The database package also includes the following ARC coverages and files:

ARC Coverages, which have been converted to uncompressed ARC/INFO export files

ARC/INFO export file	Resultant Coverage	Description of Coverage
nesf-flt.e00	nesf-flt/	Line coverage showing index map of faults in the map area. Lines and annotation only

nesf-corr.e00	nesf-corr/	Polygon and line coverage of the Correlation of Map Units for this map database. This coverage is not geospatial
nesf-so.e00	nesf-so/	Polygon and line coverage showing sources of data index map for this map database
nesf-quad.e00	nesf-quad/	Polygon, line, and annotation coverage showing 7.5’ quadrangles in the map area
nesf-as.e00	nesf-as/	Polygon, line, and annotation coverage of the index map of Tertiary stratigraphic assemblages in the map area (stratigraphic assemblages are described in the geologic explanation)

ASCII text files, including explanatory text, ARC/INFO key files, PostScript plot files, and an ARC Macro Language file for conversion of ARC export files into ARC coverages

nesfmf.ps	A PostScript plotfile that contains an image of the pamphlet containing detailed unit descriptions and geological information, a description of the digital files associated with the publication, plus references cited
nesfmf.pdf	A PDF version of nesfmf.ps
nesfmf.txt	A text-only file containing an unformatted version of nesfmf.ps without figures
nesfso.txt	ASCII text-only file containing sources of data related to coverage nesf-so
import.aml	ASCII text file in ARC Macro Language to convert ARC export files to ARC coverages in ARC/INFO
mf2403d.met	A parsable text-only file of publication level FGDC metadata for this report
mf2403e.rev	A text-only file describing revisions, if any, to this publication

The following supporting directory is not included in the database package but is produced in the process of reconverting the export files into ARC coverages:

info/	INFO directory containing files supporting the databases

Tar files

The three data packages described above are stored in tar (UNIX tape archive) files. A tar utility is required to extract the database from the tar file. This utility is included in most UNIX systems and can be obtained free of charge over the Internet from Internet Literacy's Common Internet File Formats Webpage (http://www.matisse.net/files/formats.html). Both tar files have been compressed and may be uncompressed with **gzip**, which is available free of charge over the Internet via links from the USGS Public Domain Software page (http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/public.html). In addition, several common proprietary freeware programs such as Stuffit Expander (http://www.aladdinsys.com/expander/index.html) and shareware programs such as WinZip (http://www.winzip.com) can handle both tar file extraction and gzip uncompression. When the tar file is uncompressed and the data is extracted from the tar file, a directory is produced that contains the data in the package as described above. The specifics of the tar files are listed below:

Name of compressed tar file	Size of compressed tar file (uncompressed)	Directory produced when extracted from tar file	Data package contained
mf2403a.tgz	9.2 MB (41.2 MB)	nesfps	PostScript Plotfile Package
mf2403b.tgz	8.6 MB (8.6 MB)	nesfpdf	PDF Plotfile Package
mf2403c.tgz	6.3 MB (24.7 MB)	nesfgeo	Digital Database Package

PostScript plot files

For those interested in the geology of the map area who don't use an ARC/INFO compatible GIS system we have included a separate data package with two PostScript plot files. One contains a color plot of the geologic map at 1:100,000 scale, along with index maps, correlation chart, and map explanation (nesfmap.ps). A second PostScript file (nesfmf.ps) containing the geologic and digital publication description and discussion (this pamphlet) is provided.

The PostScript images of the geologic maps and map explanation are 36 inches high by 43 inches wide, so it requires a large plotter to produce paper copies at the intended scale. In addition, some plotters, such as those with continual paper feed from a roll, are oriented with the long axis in the horizontal direction, so the PostScript image will have to be rotated 90 degrees to fit entirely onto the page. Some plotters and plotter drivers, as well as many graphics software packages, can perform this rotation. The geologic description is on 8.5- by 11-inch pages.

The PostScript plotfiles for maps were produced by the 'postscript' command with compression set to zero in ARC/INFO version 7.1.1. The PostScript plotfiles for pamphlets were produced in Microsoft Word 6.0 using the Destination PostScript File option from the Print command.

PDF plot files

We have also included a second digital package containing PDF versions of the PostScript map sheet and pamphlet described above. Adobe Acrobat PDF (Portable Document Format) files are similar to PostScript plot files in that they contain all the information needed to produce a paper copy of a map or pamphlet and they are platform independent. Their principal advantage is that they require less memory to store and are therefore quicker to download from the Internet. In addition, PDF files allow for printing of portions of a map image on a printer smaller than that required to print the entire map without the purchase of expensive additional software. All PDF files in this report have been created from PostScript plot files using Adobe Acrobat Distiller. In test plots we have found that paper maps created with PDF files contain almost all the detail of maps created with PostScript plot files. We would, however, recommend that those users with the capability to print the large PostScript plot files use them in preference to the PDF files.

To use PDF files, the user must get and install a copy of Adobe Acrobat Reader. This software is available **free** from the Adobe website (http://www.adobe.com). Please follow the instructions given at the website to download and install this software. Once installed, the Acrobat Reader software contains an on-line manual and tutorial.

There are two ways to use Acrobat Reader in conjunction with the Internet. One is to use the PDF reader plug-in with your Internet browser. This allows for interactive viewing of PDF file images within your browser. This is a very handy way to quickly look at PDF files without downloading them to your hard disk. The second way is to download the PDF file to your local hard disk and then view the file with Acrobat Reader. **We strongly recommend that large map images be handled by downloading to your hard disk**, because viewing them within an Internet browser tends to be very slow.

To print a smaller portion of a PDF map image using Acrobat Reader, it is necessary to cut out the portion desired using Acrobat Reader and the standard cut and paste tools for your platform and then to paste the portion of the image into a file generated by another software program that can handle images. Most word processors (such as Microsoft Word) will suffice. The new file can then be printed. Image conversion in the cut and paste process, as well as changes in the scale of the map image, may result in loss of image quality. However, test plots have proven adequate.

Obtaining the Digital Database and Plotfile Packages

The digital data can be obtained in either of two ways:

a. Western Region Geologic Publication Web Page.
b. Anonymous ftp over the Internet

To obtain tar files of database or plotfile packages from the USGS web pages

The USGS now supports a set of graphical pages on the World Wide Web. Digital publications (including this one) can be accessed via these pages. The location of the main Web page for the entire USGS is:

http://www.usgs.gov

The Web server for digital publications from the Western Region follows:

http://geopubs.wr.usgs.gov

Go to the following address to access this publication:

http://geopubs.wr.usgs.gov/map-mf/mf2403

Besides providing easy access to the entire digital database, the Western Region Web page also affords easy access to the PostScript and PDF plot files for those who do not use digital databases (see below).

To obtain tar files of database or plotfile packages by ftp:

The files in this report are stored on the USGS Western Region FTP server. The Internet ftp address of this server is:

ftp://geopubs.wr.usgs.gov

The user should log in with the user name 'anonymous' and then input their e-mail address as the password. This will give the user access to all the publications available via ftp from this server.

The files in this report are stored in the subdirectory:

pub/map-mf/mf2403

Obtaining plots from a commercial vendor

Those interested in the geologic map, but who use neither a computer nor the Internet, can still obtain the information. Many vendors can download the plotfiles via the Internet. Important information regarding file formats is included in the sections "Tar files," "PostScript plot files," and "PDF plot files" above, so be certain to provide a copy of this document to your vendor.

Obtaining plots from USGS Map On Demand Services

The USGS provides a plot-on-demand service for map files, such as those described in this report, through Map On Demand Services. In order to obtain plots, contact Map On Demand Services:

U.S. Geological Survey
Information Services
Box 25286
Federal Center
Denver, CO 80225-0046

(303) 202-4200
1-800-ASK-USGS

FAX: (303) 202-4695

e-mail: infoservices@usgs.gov

Be sure to include with your request the MF Report number.

Revisions and version numbers

From time to time, new information and mapping, or other improvements, will be integrated into this publication. Rather than releasing an entirely new publication, the USGS has adopted a policy of using version numbers similar to those used in the computer industry. The original version will be labeled Version 1.0. Subsequent small revisions will be denoted by the increase of the numeral after the decimal, while large changes will be denoted by increasing the numeral before the decimal. Information about the changes, if any, that have been made since the release of Version 1.0 will be listed in the publication revision file. This file will be available at the publication web site (see above) and will also be included in the digital database package. A simplified version of the revision list will be included in the publication metadata.

Digital database format

The databases in this report were compiled in ARC/INFO, a commercial Geographic Information System (Environmental Systems Research Institute, [ESRI] Redlands, California), with version 3.0 of the menu interface ALACARTE (Fitzgibbon and Wentworth, 1991; Fitzgibbon, 1991; Wentworth and Fitzgibbon, 1991). The files are in either GRID (ARC/INFO raster data) format or COVERAGE (ARC/INFO vector data) format. Coverages are stored in uncompressed ARC export format (ARC/INFO version 7.x). ARC/INFO export files (files with the .e00 extension) can be converted into ARC/INFO coverages in ARC/INFO (see below) and can be read by some other Geographic Information Systems, such as MapInfo via ArcLink and ESRI's ArcView (version 1.0 for Windows 3.1 to 3.11 is available for free from ESRI's web site: http://www.esri.com). The digital compilation was done in version 7.1.2 of ARC/INFO with version 3.0 of the menu interface ALACARTE (Fitzgibbon and Wentworth, 1991; Fitzgibbon, 1991; Wentworth and Fitzgibbon, 1991).

Converting ARC export files

ARC export files are converted to ARC coverages using the ARC command IMPORT with the option COVER. To ease conversion and maintain naming conventions, we have included an ASCII text file in ARC Macro Language that will convert all of the export files in the database into coverages and create the associated INFO directory. From the ARC command line type:

Arc: &run import.aml

ARC export files can also be read by some other Geographic Information Systems. Please consult your GIS documentation to see if you can use ARC export files and the procedure to import them.

Digital compilation

The geologic map information was digitized from stable originals of the geologic maps at 1:62,500 and 1:24,000 scale. The author manuscripts (pen on mylar) were scanned using a Altek monochrome scanner with a resolution of 800 dots per inch. The scanned images were vectorized and transformed from scanner coordinates to projection coordinates with digital tics placed by hand at quadrangle corners. The scanned lines were edited interactively by hand using ALACARTE, color boundaries were tagged as appropriate, and scanning artifacts visible at 1:24,000 were removed.

Base maps

Base map layers were derived from published digital maps (Aitken, 1997) obtained from the USGS Geologic Division Website for the Western Region (http://geopubs.wr.usgs.gov). Please see the website for more detailed information about the original databases. Because the base map digital files are already available at the website mentioned above, they are not included in the digital database package.

Faults and landslides

This map is intended to be of general use to engineers and land-use planners. However, its small scale does not provide sufficient detail for site development purposes. In addition, this map does not take the place of fault-rupture hazard zones designated by the California State Geologist (Hart and Bryant, 1999). Similarly, because only some of the landslides in the mapped area are shown, the database cannot be used to completely identify or delineate landslides in the region. For a more complete depiction of landslide distribution, see Nilsen and others (1979), Ellen and others (1997), and Wentworth and others (1997).

Spatial resolution

Uses of this digital geologic map should not violate the spatial resolution of the data. Although the digital form of the data removes the constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. The fact that this database was edited for a scale of 1:62,500 means that higher resolution information is not present in the dataset. Plotting at scales larger than 1:62,500 will not yield greater real detail, although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of these data.

Database specifics

What follows is a brief and simple description of the databases included in this report and the data in them. For a comprehensive look at the database structure and content, please see the FGDC Metadata file, mf2403d.met, included in the database package and available separately at the publication web page.

The map databases consist of ARC coverages and supporting INFO files, which are stored in a California coordinate system (Stateplane) projection (table 1). Digital tics define a 2.5 minute grid of latitude and longitude in the geologic coverages corresponding with quadrangle corners and internal tics.

Table 1. Map Projection File

[The maps are stored in California Coordinate System projection. The following is a projection file of the type used in Arc/Info.]

```
PROJECTION STATEPLANE
UNITS METERS
ZONE 3326
SPHEROID CLARKE1866
DATUM NAD27
PARAMETERS
END
```

The content of the geologic database can be described in terms of the lines, points, and areas that compose the map. Each line, point, or area in a map layer or index map database (coverage) is associated with a database entry stored in a feature attribute table. Each database entry contains both a number of items generated by Arc/Info to describe the geometry of the line, point, or area and one or more items defined by the authors to describe the geologic information associated with that entry. Each item is defined as to the amount and type of information that can be recorded. Descriptions of the database items use the terms explained in table 2.

Table 2. Field Definition Terms

ITEM NAME	name of the database field (item)
WIDTH	maximum number of digits or characters stored
OUTPUT	output width
TYPE	B-binary integer, F-binary floating point number, I-ASCII integer, C-ASCII character string
N. DEC.	number of decimal places maintained for floating point numbers

Because some of the database structure is similar for all coverages, some descriptions apply to all coverages in the publication. In that case, the notation <coverage> has been used to indicate the description is valid for any included coverage. The precise description for a particular coverage can be made by substituting the name of the coverage for <coverage>. For example, <coverage>-ID means that the description is the same for every coverage. The specific notation for a single coverage can be derived by replacing <coverage> with the coverage name (for example, NESF-GEOL-ID for the coverage nesf-geol).

The specifics of the various attribute tables are described below, along with a listing of the line, polygon, and point labels associated with the geologic and structure coverages. For a more complete description of databases associated with all the coverages, please see the accompanying FGDC compliant metadata (mf2403d.met)

Lines

The lines (arcs) are recorded as strings of vectors and are described in the arc attribute table (the format of the arc attribute table is shown in table 3). They define the boundaries of the map units, the boundaries of open bodies of water, and the map boundaries. These distinctions, including the geologic identities of the unit boundaries, are recorded in the LTYPE field according to the line types listed in table 4.

The geologic linetypes are ALACARTE line types that correlate with the geologic line symbols in the ALACARTE line set GEOL.LIN according to the ALACARTE lines lookup table (GEOL.LUT). For more information on ALACARTE and its linesets, see Wentworth and Fitzgibbon (1991).

Table 3. Content of the Arc Attribute Tables

Item Name	Width	Output	Type	N. Dec	
FNODE#	4	5	B		starting node of arc (from node)
TNODE#	4	5	B		ending node of arc (to node)
LPOLY#	4	5	B		polygon to the left of the arc
RPOLY#	4	5	B		polygon to the right of the arc
LENGTH	4	12	F	3	length of arc in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
LTYPE	35	35	C		line type (see table 4)

Table 4. Line Types Recorded in the LTYPE Field
[Note, not every line type listed is present in every coverage. For example, nesf-as only has some of the fault types listed.]

nesf2-geol, nesf3-geol, nesf4-geol, nesf5-geol, nesf-flt, and nesf-as	nesf-strc	nesf-so, nesf-corr, and nesf-quad
contact, approx. located	f.a., anticline, approx. located	box
contact, certain	f.a., anticline, certain	box, approx. located
contact, concealed	f.a., anticline, concealed	bracket
contact, concealed, queried	f.a., syncline, approx. located	contact, certain
contact, gradational	f.a., syncline, certain	leader
contact, inferred	f.a., syncline, concealed	map boundary
county line	map boundary	scratch boundary
fault, approx. located		
fault, certain		
fault, concealed		
fault, concealed, queried		
fault, inferred		
fault, uncertain		
map boundary		
marker bed		
reverse fault, approx. located		
reverse fault, certain		
reverse fault, concealed		
scratch boundary		
thrust fault, approx. located		
thrust fault, certain		
thrust fault, concealed		
thrust fault, inferred		
water boundary		

Areas

Map unit labels and other area labels (polygon tags) are recorded in the polygon attribute table (the format of the polygon attribute table is shown in table 5). In the geologic coverages and the correlation coverage (nesf-corr), the identities of the map units from compilation sources are recorded in the PTYPE field by map label (table 6). Map units are described more fully above. In other coverages, various types of areal information is recorded in the PTYPE field (data source region number, assemblage number, terrane label, quadrangle name). Note that ARC/INFO coverages cannot contain both point and polygon information, so only coverages with polygon information will have a polygon attribute table, and these coverages will not have a point attribute table.

Table 5. Content of the Polygon Attribute Tables

Item Name	Width	Output	Type	N. Dec	
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
PTYPE	35	35	C		unit label or other area label

Table 6. Unit labels

[See the Description of Map units section in the pamphlet. Note, not every unit label listed is present in every coverage. For example, queried units are not present in the Correlation of Map Units coverage.]

H2O	Qhfb	Tmru
Jb	Qhff	Tmz
Jgb	Qhfp	Tmz?
Jk	Qhl	Tn
Jsp	Qhl?	Tn?
Jsv	Qht	Tnv
Jv	Qls	Tnvl
KJfm	Qmz	Tnvm
KJfm?	Qoa	Tnvu
KJgv	Qoa?	Tor
KJgvm	Qof	Tpb
KJu	Qop	Tpc
Kcs	Qpa	Tps
Kf	Qpb	Tpt
Kfo	Qpf	Tpth
Kfs	Qt	Tptt
Kg	Tbe	Tpu
Kgvn	Tbh	Tpus
Ks	Tbl	Tr
Ksh	Tbr	Ts
Ku	Tb	Tsa
Ku?	Tc	Tsh
Kuh	Tcc	Tsr
Kuhs	Tcc?	Tsv
Kuhs?	Tcgl	Tsva
Kus	Td	Tsva?
Kuss	Td?	Tsvad
Kuss?	Tdi	Tsvd
Kv	Tdm	Tsvl
Ky	Tdr	Tsvp
QTh	Teh	Tsvr
QTh?	Tes	Tsvr?
QThg	Th	Tsvri
QTu	Tl	Tsvs
Qa	Tlj	Tsvs?
Qcl	Tljl	Tsvt
Qds	Tlju	Tsvt?
Qds?	Tm	Tsvw
Qf	Tmk	Tsvw?
Qha	Tmk?	Tt
Qhay	Tmkj	Tut
Qhb	Tmkl	Tv
Qhbm	Tmku	Tvh
Qhc	Tmr	Tvh?
Qhdm	Tmr?	Tvhl
Qhf	Tmrl	Tvhu

ac	alf	sp
ads	fsr	sp?
af	ls	
afbm	sc	

Points

Data gathered at a single locality (points) are described in the point attribute table (the format of the point attribute table is shown in table 7). The identities of the points from compilation sources are recorded in the PTTYPE field by map label (table 8). Note that ARC/INFO coverages cannot contain both point and polygon information, so only coverages with point information will have a point attribute table, and these coverages will not have a polygon attribute table.

The geologic point types in the structure coverage are ALACARTE point types that correlate with the geologic point symbols in the ALACARTE point set ALCGEOL.MRK according to the ALACARTE point lookup table. For more information on ALACARTE and its pointsets, see Wentworth and Fitzgibbon (1991).

Table 7. Content of the Point Attribute Tables

Item Name	Width	Output	Type	N. Dec	
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
<coverage>#	4	5	B		unique internal control number
<coverage>-ID	4	5	B		unique identification number
PTTYPE	35	35	C		unit label
DIP	3	3	I		dip of bedding or foliation (structure coverages only)
STRIKE	3	3	I		strike of bedding or foliation (structure coverages only)

Table 8. Point Types Recorded in the PTTYPE Field for structure coverage (nesf-struc)

nesf-struc
approx bedding
bedding
bedding w/tops
foliation
horz joint
joint
ot bedding
ot bedding w/ tops
vert bedding

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