



Geologic map and map database of the Palo Alto 30' X 60' quadrangle, California

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Geologic explanation, sources, and references

Introduction

This map database represents the integration of previously published and unpublished maps by several workers (see Sources of Data index map on Sheet 2 and the corresponding list below) and new geologic mapping and field checking by the authors with the previously published geologic maps of San Mateo County (Brabb and Pampeyan, 1983) and Santa Cruz County (Brabb, 1989, Brabb and others, 1997), and with various sources in a small part of Santa Clara County. These new data are released in digital form to provide an opportunity for regional planners, local, state, and federal agencies, teachers, consultants, and others interested in geologic data to have the new data long before a traditional paper map is published. The new data include a new depiction of Quaternary units in the San Francisco Bay plain that emphasizes depositional environment, important new observations between the San Andreas and Pilarcitos faults, and a new interpretation of structural and stratigraphic relationships of rock packages (Assemblages).

Scope and Purpose of this report

The purpose of this new map is to compile the best available data on the identity and distribution of bedrock units, surficial deposits, and geologic structures at a regional scale, and to integrate those data into a digital spatial database. The digital nature of the product is important because it allows the geologic data to be easily combined with other data to produce derivative products (some of which are discussed below), allows new information to be readily integrated into the map database, makes transfer of data to users easy via the Internet, and facilitates production of high-quality paper maps. Some of the benefits that can be derived from these geologic data are discussed below.

1. Materials properties and geologic maps.

The character of the materials beneath the ground

surface affect engineering use of the land. For example, expansivity of the materials may affect the stability of foundations, permeability determines the success of water wells and suitability of the ground for septic systems, and ease of excavation is related to hardness of the material and fracture spacing. Such material properties can be delineated in a regional way based on lithologic units shown on geologic maps. The characterization of several materials properties of geologic map units has been done in the San Francisco Bay region by Ellen and Wentworth (1995) for hillside materials, and Helley and others (1979) for flatland (Quaternary) materials. Our geologic map can be used in combination with the reports mentioned above to give the most up-to-date depiction of the distribution of materials properties that affect land use engineering.

2. **Earthquake shaking and geologic maps.** The intensity of earthquake shaking has been shown to depend strongly on the distribution of geologic units, the intensity increasing with decreasing firmness of ground materials. In the San Francisco Bay region, the relationship between intensity and geologic units was first calculated by Borcherdt and others (1975). More recently, earthquake shaking maps have been prepared for the region for a number of hypothetical earthquakes (Perkins and Boatwright, 1995) that integrate the effect of the geologic units on the calculated intensity. These intensity maps are based on the most detailed geologic maps that were available at that time, but could be improved by integration of the most up-to-date geologic mapping available, such as this report.

3. **Liquefaction potential and geologic maps.** Liquefaction during earthquakes happens in areas underlain by loose sand and silt that is saturated with water. The distribution of these areas can be delineated by geologic and hydrologic mapping. This mapping was first done for the San Francisco Bay region by Youd and others (1973), and later by Dupre and Tinsley (1980), and Tinsley and Holtzer (1990). Most recently, Sowers and others (1992) have developed a technique that combines geologic

mapping of surficial deposits with other mapped factors to produce a map of liquefaction potential. The method of that report is entirely compatible with the new mapping of surficial units in this report, and therefore this report could be used in combination with other factors to produce a liquefaction susceptibility map for the map area.

4. Ground water pollution and geologic maps.

In urban areas, such as the San Francisco Bay region, the contamination of ground water by introduction of pollution from the surface is a major problem (Howard, 1997). Because the flow of groundwater pollutants is governed by the porosity and permeability of materials shown on geologic maps, areas that are vulnerable to rapid contamination of groundwater can be identified. In the southern San Francisco Bay region, for example, Helley (1986) showed that pollutants tended to follow high-porosity Holocene stream channel and levee deposits, like those shown on our map.

5. Relating landslides to geologic maps. Although the distribution of mapped landslides is a good first order indicator of future landslide activity in the San Francisco Bay region (Nilsen and Turner, 1975), a better analysis of the landslide hazard is provided by a statistical approach that involves more than a single factor, and yields a quantitative prediction of landslide potential. Work by Brabb and others (1972) in San Mateo County provided the first such study using two factors, lithologic distribution, taken from a geologic map, and slope, in addition to landslide distribution. GIS capabilities now allow a much more sophisticated analysis, using many factors and a variety of statistical methods (see Soeters and van Westin, 1996, for a discussion of statistical methods). At least one of the factors required for any such analysis, lithologic distribution, is provided solely by a geologic map. In addition, some, but not all, of the additional factors, such as distance from an active fault or orientation of strata, may be derived from a geologic map. Clearly, accurate geologic maps are a prerequisite to sophisticated studies of landslides.

6. Location of mineral hazards and geologic maps. Certain naturally occurring minerals can pose a hazard to human health or to the environment when disturbed by human development. An example is the naturally occurring mercury deposits in the San Francisco Bay region (J. Rytuba, USGS, written commun., 1997). Because hazardous minerals are in many places associated with a specific geologic unit, such as mercury with silica-carbonate rock in serpentinite (Crittenden, 1951), geologic maps that show the distribution of those units can be used to regionally delineate the potential hazard.

7. Seismic velocity. Accurate seismic velocity

models are required to precisely locate earthquake epicenters, which can be used to map fault location, geometry, and activity. Seismic velocity is proportional to the density of the rock in the crust, which in turn is dependent on the rock type. However, most seismic velocity models are constructed by calculation based on travel times of seismic waves from various sources. Construction of a superior model may be possible by combining the regional distribution of geologic materials at the surface provided by a geologic map with data from well logs and aeromagnetic, gravity, and seismic data..

8. Earthquake faults and geologic maps.

Although regional geologic maps cannot take the place of large-scale fault-rupture hazard maps (Hart, 1988), they do show faults in their geologic context. Recent work by the authors along the Hayward fault in the east San Francisco Bay area has shown that studying active faults in their geologic context reveals a much more complex history of faulting and a wider zone of Holocene active faults than previously thought (Graymer, Jones, and Brabb, 1995). In addition, other recent work based on the geologic context of faults in the San Francisco Bay region (Jones and others, 1995; Jayko and Lewis, 1996) has shown that a component of stress in the area is perpendicular to known active faults, suggesting the possibility of active thrust and blind-thrust faults. The 1989 Loma Prieta earthquake may have occurred on such a fault. Blind-thrusts, in areas without intensive seismic reflection/refraction studies, such as most urban areas, must be mapped by studying the regional structure, as there is no surface rupture.

9. Education and scientific inquiry. In addition to applications related to engineering and geologic hazards, regional geology can be a subject of intellectual curiosity and academic inquiry. This map represents the state of knowledge of the geology of the area at the time of publication, and can be used by the academic community and by the public to understand the geology of the area at a regional scale.

NOTE

Uses of this map database are limited by compilation scale and content. The map is not intended for site specific studies of any sort. The fault maps of the California Division of Mines and Geology (see Hart, 1988, for an index) should be used for site specific studies of fault activity, whereas the work of Wentworth and others, 1997, provide a regional depiction of landslides, and Pike, 1997, provides an index of more detailed work.

Stratigraphy

Lithologic associations in the Palo Alto 30' X 60' quadrangle are divided into ten assemblages (see Index Map on Sheet 2). As defined in Graymer, Jones, and Brabb (1994), assemblages are large, fault-bounded blocks that contain a unique stratigraphic sequence. The stratigraphic sequence differs from that of neighboring assemblages by containing different rock units, or by different stratigraphic relationship among similar rock units. These stratigraphic differences represent changes in depositional conditions in one or more large depositional basins. The current adjacent location of the different assemblages reflects the juxtaposition of different basins or parts of basins by large offsets along the faults that bound the assemblages.

In general, the Tertiary strata in the map area rest with angular unconformity on three complexly deformed Mesozoic rock complexes. One of these Mesozoic complexes is made up of the Coast Range ophiolite, which includes serpentinite, gabbro, diabase, and basalt; keratophyre which is closely associated with the ophiolite; and overlying Great Valley sequence of Jurassic and Cretaceous age. This complex represents the accreted and deformed remnants of Jurassic oceanic crust, overlying arc volcanic rocks, and a thick sequence of turbidites. In the map area, rocks of this complex are only definitely present in small, fault-bounded slivers at the base of the Portola Valley Assemblage, although the large unit of diabase and gabbro (db) along the San Andreas fault in the Woodside Assemblage may also be part of the complex.

The second Mesozoic complex is the Franciscan complex, which is composed of weakly to strongly metamorphosed graywacke, argillite, limestone, basalt, serpentinite, chert, and other rocks. The rocks of the Franciscan complex in the area were probably Jurassic oceanic crust and pelagic deposits overlain by Upper Jurassic to Upper Cretaceous turbidites. Although Franciscan rocks are dominantly little metamorphosed, high-pressure, low-temperature metamorphic minerals are common within the complex (Bailey, Irwin, and Jones, 1964). High-grade metamorphic blocks in sheared but relatively unmetamorphosed argillite matrix (Blake and Jones, 1974) reflect the complicated history of the Franciscan. The complex was subducted beneath the Coast Range ophiolite, at least in part, during Late Cretaceous or early Tertiary time, after the deposition of the Franciscan sandstone containing Campanian (Late Cretaceous) fossils that crops out in Marin County. Because the Franciscan was subducted under the complex containing the Coast Range Ophiolite, the contact between the two Mesozoic complexes is

everywhere faulted (Bailey, Irwin, and Jones, 1964), and the Franciscan complex presumably underlies the entire area east of the Pilarcitos fault.

The third Mesozoic complex is the Salinian complex, which is composed of granitic plutonic rocks, and inferred gabbroic plutonic rocks at depth, overlain in places by Cretaceous strata. It is separated from the combined Franciscan, Coast Range ophiolite, and Great Valley sequence Mesozoic basement on the east by the Pilarcitos fault in the north part of the map area, and the San Andreas fault in the south part of the map area where the Pilarcitos and San Andreas faults join. In places, small outcrops of pre-plutonic (Paleozoic?) rocks are also preserved, such as unit KJV in the Pigeon Point Assemblage, marble and hornfels (m) in the Montara Mountain Assemblage, and schist (sch) in the Santa Cruz Assemblage. The plutonic rocks are part of a batholith that has been displaced northward by offset on the San Andreas fault system. Estimates of total offset vary, but all are more than a few hundred kilometers.

An angular unconformity at the base of the Tertiary strata has been preserved in all of the assemblages. The exception is the Portola Valley Assemblage, where the base of the Tertiary strata is everywhere faulted.

Paleontology

Hundreds of fossil collections from the Palo Alto 30' X 60' quadrangle are described in the references provided in this report, as well as in Brabb (1983).

Radiometric Ages

A compilation of the radiometric ages of rocks in the Palo Alto 30' X 60' quadrangle and other areas south of latitude 38 degrees is provided by Lindquist and Morganthaler (1991). Additional data are provided by Sarna-Wojcicki (1976, and written commun., 1990), Sarna-Wojcicki and others (1979), Turner (1970), Brabb and Hanna (1981), and Curtis (1989).

Structure

The faults of the map area are characterized by both strike-slip and dip-slip components of displacement. Three major fault systems display large late Tertiary right-lateral offsets--the San Andreas, the Pilarcitos, and the San Gregorio fault zones. These fault systems trend roughly N30°W, and most of them have many fault strands in a broad zone as much as 10 km wide. Offset is distributed on the various faults in the zones, and the locus of fault movement associated with a fault zone has changed through

geologic time (see Graymer, Jones, and Brabb, 1995, and Montgomery and Jones, 1992, for a description of fault zone evolution and distribution of offset on similar active faults in the East Bay region). Both the San Andreas and San Gregorio fault zones have strands that display Holocene offset. The land on either side of the San Andreas fault zone was displaced as much as several meters in the map area during the 1906 earthquake.

Current estimates of total offset since 8 Ma are about 35 km for the San Andreas fault zone in the map area, 120 km for the Pilarcitos fault zone, and 155 km for the San Gregorio fault zone (Clark and others, 1984; McLaughlin and others, 1996; Dickinson, 1997). However, ongoing work by the authors and others has correlated the Coast Range ophiolite (Jgb, Jsv, sp) and Great Valley Sequence (Ka, Ks) rocks at the base of the Portola Valley Assemblage with rocks in the Gualala area more than 150 km north of the map area, which might indicate even more offset on the Pilarcitos fault.

The three major right-lateral fault systems also form many of the boundaries of the assemblages. The juxtaposition of rocks with different stratigraphic histories across these faults probably resulted from the large offsets on the faults. The other assemblage-bounding faults probably had total offsets of tens of kilometers, as they also juxtapose rocks with different stratigraphic histories. However, the offset is undoubtedly less than the three major systems, because the stratigraphic differences are less.

In addition to strike-slip faults, some faults in the map area have a major component of reverse or thrust offset. These structures run generally subparallel to the strike-slip faults, and reflect a component of stress perpendicular to the trend of the faults. This fault-normal compression has generated faults that typically have juxtaposed older rocks above younger. Part of the offset on some of these reverse and thrust faults has taken place during Quaternary time, as shown by faulting of unit QTsc west of Crystal Springs Reservoir.

Apparent offset on the large, assemblage-bounding faults in the west-central part of the map area becomes progressively younger to the northeast. The Zayante fault completed most of its offset by late Miocene time, because the base of the Santa Margarita Sandstone (Tsm) unconformably overlaps the fault. The Butano fault appears to have completed the bulk of the offset along it by Pliocene or latest Miocene time, because it is overlapped by the Purisima Formation (Tp, Tpt), but truncates Tsm and Tsc. The La Honda fault cuts unit Tp, and so was active at least into the Pliocene, whereas the Pilarcitos fault cuts unit QTsc, so it was active into the Pleistocene, but both faults show little or no

evidence for Holocene offset. The San Andreas fault zone is the locus of Holocene activity, as shown by the large offset in 1906. The significance of this northeastward younging trend is not at present understood.

Folds in the map area can be divided into two categories based on axial trend and style of deformation. The first category includes tight folds and overturned folds with inclined axial planes whose axes trend obliquely to the major strike-slip fault zones (about N60°W). These folds were probably caused by the same component of regional stress that formed the strike-slip faults and the thrust and reverse faults discussed above.

The second category of fold is tight, upright folds whose axes strike roughly parallel to the major strike-slip faults (about N30°W). These folds must have been formed by a component of regional compression perpendicular to the strike-slip faults (Jones and others, 1995).

Preserved folds in the map area for the most part formed in Pliocene or later time, because Pliocene strata (Tp), where present, are involved in the folds. In the Portola Valley Assemblage, major pre-Pliocene Tertiary folding is not indicated, because Pliocene rocks are folded as much as pre-Pliocene Tertiary strata. However, in the Butano Ridge and Santa Cruz Assemblages, the major angular unconformity at the base of the late Miocene strata indicates a significant period of pre-late-Miocene folding. In addition, whereas all pre-late Miocene strata in the Butano Ridge Assemblage appear to have undergone the same amount of deformation, an additional major angular unconformity is present within the pre-late Miocene strata of the Santa Cruz Assemblage at the base of the middle Miocene Lompico Sandstone (Tlo). In the Montara Mountain Assemblage, a nonconformity at the base of the middle Miocene strata and an angular unconformity at the base of the Pliocene strata indicate two periods of pre-Pliocene Tertiary uplift and folding. In the Pigeon Point Assemblage, a similar angular unconformity at the base of the Pliocene is present, and unit Tuv rests unconformably on unit Kpp. In the Mindego Hill Assemblage, the base of the Pliocene unconformity is again present, but the middle Miocene strata there are folded as much as the pre-Miocene strata, indicating that only one period of pre-Pliocene Tertiary deformation occurred in that Assemblage. In the Woodside Assemblage, Pliocene rocks of the Merced Formation are folded as much as earlier Tertiary strata, indicating that Tertiary deformation in that Assemblage must be Pliocene or younger. The Tertiary deformation of the strata in the map area is, therefore, a complex amalgamation of independently deformed blocks that have been brought

into proximity only in late Tertiary time. Pre-Tertiary folding undoubtedly occurred, associated with subduction of the Franciscan complex beneath the Coast Range ophiolite and subsequent deformation associated with the unconformity at the base of the Tertiary sequence, as well as offset on strike-slip faults. These folds have for the most part been totally disrupted. The youngest folding must postdate the Pliocene and Pleistocene deposition of units QTsc and QTm, as those strata are folded in at least one area,

and are steeply inclined throughout the county. Pleistocene strata and marine terraces have not been observed to be folded, but are tilted and uplifted in several places, and locally faulted. Late Pleistocene and Holocene surficial deposits retain most of their original depositional shape and orientation, so are not tilted or folded, but late Pleistocene alluvium and marine terrace deposits have been uplifted as much as several meters in places throughout the county.

Description Of Map Units

- af **Artificial fill (Historic)**--Loose to very well consolidated gravel, sand, silt, clay, rock fragments, organic matter, and man-made debris in various combinations. Thickness is variable and may exceed 30 m in places. Some is compacted and quite firm, but fill made before 1965 is nearly everywhere not compacted and consists simply of dumped materials
- alf **Artificial levee fill (Historic)**--Man-made deposits of various materials and ages, forming artificial levees as much as 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. The distribution of levee fill conforms to levees shown on the most recent U.S. Geological Survey 7.5-minute quadrangle maps
- Qhasc **Artificial stream channels (Historic)**--Modified stream channels; in most places where streams have been straightened and realigned
- Qhsc **Stream channel deposits (Holocene)**--Poorly to well-sorted sand, silt, silty sand, or sandy gravel with minor cobbles. Cobbles are more common in the mountainous valleys. Many stream channels are presently lined with concrete or rip rap. Engineering works such as diversion dams, drop structures, energy dissipaters and percolation ponds also modify the original channel. Many stream channels have been straightened, and these are labeled Qhasc. This straightening is especially prevalent in the lower reaches of streams entering the estuary. The mapped distribution of stream channel deposits is controlled by the depiction of major creeks on the most recent U.S. Geological Survey 7.5-minute quadrangles. Only those deposits related to major creeks are mapped. In some places these deposits are under shallow water for some or all of the year, as a result of reservoir release and annual variation in rainfall
- Qbs **Beach sand (Holocene)**--Unconsolidated, well-sorted sand. Local layers of pebbles and cobbles. Thin discontinuous lenses of silt relatively common in back-beach areas. Thickness variable, in part due to seasonal changes in wave energy; commonly less than 10 m thick. May interfinger with either well-sorted dune sand or, where adjacent to coastal cliff, poorly-sorted colluvial deposits. Iron- and magnesium-rich heavy minerals locally form placers as much as 0.7 m thick
- Qhbm **Bay mud (Holocene)**--Water-saturated estuarine mud, predominantly gray, green and blue clay and silty clay underlying marshlands and tidal mud flats of San Francisco Bay, Pescadero, and Pacifica. The upper surface is covered with cordgrass (*Spartina* sp.) and pickleweed (*Salicornia* sp.). The mud also contains a few lenses of well-sorted, fine sand and silt, a few shelly layers (oysters), and peat. The mud interfingers with and grades into fine-grained deposits at the distal edge of Holocene fans, and was deposited during the post-Wisconsin rise in sea-level, about 12 ka to present (Imbrie and others, 1984). Mud varies in thickness from zero, at landward edge, to as much as 40 m near north County line
- Qhb **Basin deposits (Holocene)**--Very fine silty clay to clay deposits occupying flat-floored basins at the distal edge of alluvial fans adjacent to the bay mud (Qhbm). Also contains unconsolidated, locally organic, plastic silt and silty clay deposited in very flat valley floors
- Qhbs **Basin deposits, salt-affected (Holocene)**--Clay to very fine silty-clay deposits similar to Qhb deposits except that they contain carbonate nodules and iron-stained mottles (U.S. Soil Conservation Service, 1958). These deposits may have been formed by the interaction of bicarbonate-rich upland water and saline water of the San Francisco Bay estuary. With minor exceptions, salt-affected basin deposits are in contact with estuary deposits.
- Qhfp **Flood-plain 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)

- Qhl **Natural levee deposits (Holocene)**--Loose, moderately to well-sorted sandy or clayey silt grading to sandy or silty clay. These deposits are porous and permeable and provide conduits for transport of ground water. Levee deposits border stream channels, usually both banks, and slope away to flatter flood plains and basins. Abandoned levee systems, no longer bordering stream channels, have also been mapped
- Qhaf1 **Younger alluvial fan deposits (Holocene)**--Brown, poorly sorted, dense, sandy or gravelly clay. May represent the modern loci of deposition for Qhaf, although small fans at mountain fronts may have a debris-flow origin
- Qhaf **Alluvial fan and fluvial deposits (Holocene)**--Alluvial fan deposits are brown or tan, medium-dense to dense, gravelly sand or sandy gravel that generally grades upward to sandy or silty clay. Near the distal fan edges, the fluvial deposits are typically brown, never reddish, medium-dense sand that fines upward to sandy or silty clay
- Qyf **Younger (inner) alluvial fan deposits (Holocene)**--Unconsolidated fine- to coarse-grained sand, silt, and gravel, coarser grained at heads of fans and in narrow canyons
- Qyf0 **Younger (outer) alluvial fan deposits (Holocene)**--Unconsolidated fine sand, silt, and clayey silt
- Qcl **Colluvium (Holocene)**--Loose to firm, friable, unsorted sand, silt, clay, gravel, rock debris, and organic material in varying proportions
- Qs **Sand dune and beach deposits (Holocene)**--Predominantly loose, medium- to coarse-grained, well-sorted sand but also includes pebbles, cobbles, and silt. Thickness less than 6 m in most places, but in other places may exceed 30 m
- Qal **Alluvium (Holocene)**--Unconsolidated gravel, sand, silt, and clay along streams. Less than a few meters thick in most places
- Qls **Landslide deposits (Pleistocene and/or Holocene)**--Poorly sorted clay, silt, sand, and gravel. Only a few very large landslides have been mapped. For a more complete map of landslide deposits, see Nilsen and others (1979)
- Qpaf **Alluvial fan and fluvial deposits (Pleistocene)**--Brown, dense, gravelly and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display variable sorting and are located along most stream channels in the county. All unit Qpaf deposits can be related to modern stream courses. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger soil profile development. They are less permeable than Holocene deposits, and locally contain fresh-water mollusks and extinct late Pleistocene vertebrate fossils. They are overlain by Holocene deposits on lower parts of the alluvial plain, and incised by channels that are partly filled with Holocene alluvium on higher parts of the alluvial plain. Maximum thickness is unknown but at least 50 m
- Qpaf1 **Alluvial terrace deposits (Pleistocene)**--Deposits consist of crudely - bedded, clast-supported, gravel, cobbles, and boulders with a sandy matrix. Clasts are as much as 35 cm in intermediate diameter. Coarse sand lenses may be locally present. Pleistocene terrace deposits are cut into Pleistocene alluvial fan deposits (Qpaf) a few meters and are as much as several meters above Holocene deposits
- Qpoaf **Older alluvial fan deposits (Pleistocene)**--Brown, dense, gravelly and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display various sorting qualities. All Qpoaf deposits can be related to modern stream courses. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger profile development. They are less permeable than younger deposits, and locally contain fresh-water mollusks and extinct Pleistocene vertebrate fossils
- Qof **Coarse-grained older alluvial fan and stream terrace deposits (Pleistocene)**--Poorly consolidated gravel, sand, and silt, coarser grained at heads of old fans and in narrow canyons
- Qmt **Marine terrace deposits (Pleistocene)**--Poorly consolidated and poorly indurated well to poorly sorted sand and gravel. Thickness variable but probably less than 30 m
- QTsc **Santa Clara Formation (lower Pleistocene and upper Pliocene)**--Gray to red-brown poorly indurated conglomerate, sandstone, and mudstone in irregular and lenticular beds. Conglomerate consists mainly of subangular to subrounded cobbles in a sandy matrix but locally includes pebbles and boulders. Cobbles and pebbles are mainly chert, greenstone, and graywacke with some schist, serpentinite, and limestone. On Coal Mine Ridge, south of Portola Valley, conglomerate contains boulders of an older conglomerate as long as one meter. Gray to buff claystone and siltstone beds on Coal Mine Ridge contain carbonized wood fragments as large as 60 cm in diameter. Included in Santa Clara Formation are similar coarse-grained clastic deposits near Burlingame. Sarna-Wojcicki (1976) found a tuff bed in Santa Clara Formation near Woodside, and correlated it with a similar tuff in the Merced Formation. Later

work indicated that the tuff correlates with the 435 ka Rockland ash (Sarna-Wojcicki, oral commun., 1997). Thickness of Santa Clara Formation is variable but reaches a maximum of about 500 m along Coal Mine Ridge

- QTsl **Lake beds (upper Pliocene)**--Fine-grained sandstone, calcareous mudstone, and marl. Locally contains vertebrate fossils of late Pliocene (Blancan) age. Fossiliferous marl is best exposed near Stevens Creek Reservoir, where it is about 30 m thick
- QTm **Merced Formation (lower Pleistocene and upper Pliocene)**--Medium-gray to yellowish-gray and yellowish-orange, medium- to very fine grained, poorly indurated to friable sandstone, siltstone, and claystone, with some conglomerate lenses and a few friable beds of white volcanic ash. In many places sandstone is silty, clayey, or conglomeratic. Some of the conglomerate, especially where fossiliferous, is well cemented. Volcanic ash is in beds as much as 2 m thick and consists largely of glass shards. In type section of Merced Formation north of the map area, the ash was originally reported by Sarna-Wojcicki (1976) to be 1.5 ± 0.8 m.y. old, but more recent work by Sarna-Wojcicki and others (1991) indicates that the formation contains both the 738 ± 3 ka Bishop ash and the 435 ka Rockland ash (Sarna-Wojcicki, oral commun., 1997). Merced Formation is about 1,525 m thick in the sea cliffs north of Mussel Rock
- Tp **Purisima Formation (Pliocene and upper Miocene)**--Predominantly gray and greenish-gray to buff, fine-grained sandstone, siltstone, and mudstone, but also includes some porcelaneous shale and mudstone, chert, silty mudstone, and volcanic ash. West of Portola Valley, this unit consists of fine- to medium-grained silty sandstone. Locally divided into:
- Tptu **Tunitas Sandstone Member (Pliocene)**--Greenish-gray to light-gray, pale-orange, or greenish-brown, very fine- to medium-grained sandstone with clay matrix. Concretions generally less than 30 cm across are present locally. Tunitas ranges in thickness from 76 m at type section to 122 m elsewhere
- Tpl **Lobitos Mudstone Member (Pliocene)**--Dark-gray to light-gray and shades of brown, unbedded, silty mudstone. Lobitos has a maximum thickness of 140 m
- Tpsg **San Gregorio Sandstone Member (Pliocene)**--Greenish-gray to light-brown, fine- to coarse-grained sandstone containing calcareous concretions less than 30 cm across. San Gregorio Member ranges in thickness from 45 m at type section to about 140 m elsewhere
- Tpp **Pomponio Mudstone Member (Pliocene)**--Gray to white porcelaneous shale and mudstone, in places rhythmically bedded with alternating layers of nonsiliceous mudstone. This unit resembles Monterey Shale, Santa Cruz Mudstone, and Lambert Shale. At its type section in Pomponio Creek the member is 700 m thick
- Tpt **Tahana Member (Pliocene and upper Miocene)**--Greenish-gray to white or buff, medium- to very fine grained sandstone and siltstone, with some silty mudstone. Locally, such as at San Gregorio State Beach, sandstone is tuffaceous and weathers white. Near Memorial Park, this member includes dark-gray porcelaneous mudstone. Pebble conglomerate crops out near base from Memorial Park eastward. Maximum thickness is 655 m. A tuff bed in this member west of the San Gregorio fault has been tentatively correlated with the 2.6 Ma Ishi Tuff (Sarna-Wojcicki and others, 1991)
- Tsc **Santa Cruz Mudstone (upper Miocene)**--Brown and gray to light-gray, buff, and light-yellow siliceous mudstone with nonsiliceous mudstone and siltstone and minor amounts of sandstone. Santa Cruz Mudstone is more than 1,000 m thick
- Tsm **Santa Margarita Sandstone (upper Miocene)**--Light-gray to grayish-orange to white, friable, very fine to very coarse grained arkosic sandstone. Fine-grained sandstone commonly contains glauconite. A quartz and feldspar pebble conglomerate crops out locally at the base of section. Santa Margarita Sandstone is as thick as 60 m
- Tms **Unnamed marine sandstone and shale (upper Miocene)** -Light-gray, grayish-orange, and white, soft, friable, very fine to medium-grained, well-sorted, poorly cemented quartzose sandstone with minor interbeds of siliceous mudstone and semi-siliceous shale. Contains late Miocene, shallow-water marine fossils (Sorg and McLaughlin, 1975)
- Tlad **Ladera Sandstone (upper(?) and middle Miocene)**--Medium- to light-gray to yellowish-gray and buff, fine-grained, poorly cemented sandstone and siltstone, with minor amounts of coarse-grained sandstone, yellow-brown dolomitic claystone, and white to light-gray porcelaneous shale and porcelanite. Fine-grained sandstone and siltstone comprise more than 90 percent of formation. Coarse-grained sandstone crops out in beds less than a few meters thick in lower half of section; dolomitic claystone and porcelaneous shale beds are less than a meter thick and outcrop through the upper half of the section; porcelanite crops out in thin-bedded lenses less than a few meters thick in the lower part of the section.

- At and near base of Ladera Sandstone are medium to thick lenticular beds of well-cemented, fossiliferous, chert-granule sandstone which interfingers with fine-grained sandstone. About 450 m thick
- Tm **Monterey Formation (middle Miocene)**--Grayish-brown and brownish-black to very pale orange and white, porcelaneous shale with chert, porcelaneous mudstone, impure diatomite, calcareous claystone, and with small amounts of siltstone and sandstone near base. Monterey is generally thinner bedded than the Santa Cruz Mudstone but closely resembles parts of Purisima Formation, especially Pomponio Mudstone Member. Thickness ranges from 120 to more than 600 m
- Tlo **Lompico Sandstone (middle Miocene)**--Very pale orange, fine- to coarse-grained, mostly well cemented and hard arkosic sandstone. Maximum thickness about 300 m
- Tpm **Page Mill Basalt (middle Miocene)**--Interlayered, columnar-jointed basaltic flows and agglomerate. Flows are dark greenish gray to light gray, dense to vesicular, and finely crystalline; agglomerate is light gray to reddish brown. Volcanic rocks are pyritiferous in part. Ranges in thickness from 0 to 15 m. The Page Mill Basalt has yielded a K/Ar age of 14.8 ± 2.4 Ma (Turner, 1970; recalculated by Fox and others, 1985)
- Tuv **Unnamed Sedimentary and Volcanic Rocks (Miocene and Oligocene)**--Mainly dark-gray, hard mudstone in Año Nuevo area and thick-bedded, coarse-grained and pebbly, crossbedded, hard sandstone in Pescadero Point area. Mapped as Vaqueros(?) Formation by Hall and others (1959), but rocks do not resemble those of Vaqueros Sandstone in Santa Cruz Mountains. Includes andesite breccia. Intrusive rocks associated with the andesite have yielded a K/Ar age of 22.0 ± 0.7 Ma (Taylor, 1990). Contains foraminifers and mollusks of Zemorrian (Oligocene) and Saucesian (Miocene) age according to Clark and Brabb (1978). About 135 m thick near Pescadero Point and at least 85 m thick near Año Nuevo
- Tls **Lambert Shale and San Lorenzo Formation, undivided (lower Miocene, Oligocene, and middle and upper Eocene)**--Brown and dark-gray to gray, brown, and red mudstone, siltstone, and shale. Includes some beds of fine- to coarse-grained sandstone. Lambert Shale is generally more siliceous than San Lorenzo Formation, but the two units cannot be distinguished where out of stratigraphic sequence and without fossils
- Tla **Lambert Shale (Oligocene and lower Miocene)**--Dark-gray to pinkish-brown, moderately well cemented mudstone, siltstone, and claystone. Chert crops out in a few places in upper part of section, and sandstone bodies as much as 30 m thick, glauconitic sandstone beds, and microcrystalline dolomite are present in places. Lambert Shale is generally more siliceous than San Lorenzo Formation and less siliceous than the Monterey Shale. It resembles Santa Cruz Mudstone and parts of Purisima Formation. Lambert Shale is about 1,460 m thick
- Tmb **Mindego Basalt and related volcanic rocks (Miocene and/or Oligocene)**--Basaltic volcanic rocks, both extrusive and intrusive. Extrusive rock is primarily dark-gray to orange-brown to greenish-gray flow breccia, but includes lesser amounts of tuff, pillow lavas, and flows. Extrusive rocks have a maximum thickness of 120 m. Intrusive rock is dark greenish gray to orange brown and medium to coarsely crystalline. It commonly weathers spheroidally, and crops out as roughly tabular bodies as much as 180 m thick intruding older sedimentary rocks. Minor amounts of sandstone and mudstone are locally included. The Mindego Basalt has yielded a K/Ar minimum age of 20.2 ± 1.2 Ma (Turner, 1970; recalculated by Fox and others, 1985)
- Tvq **Vaqueros Sandstone (lower Miocene and Oligocene)**--Light-gray to buff, fine- to medium-grained, locally coarse-grained, arkosic sandstone interbedded with olive- and dark-gray to red and brown mudstone and shale. Sandstone beds are commonly from 0.3 to 3 m thick and mudstone and shale beds are as much as 3 m thick. Vaqueros varies from a few meters to as much as 700 m in thickness
- Tz **Zayante Sandstone (Oligocene)**--Thick- to very thick bedded, yellowish-orange arkosic non-marine sandstone containing thin interbeds of greenish and reddish siltstone and lenses and thick interbeds of pebble and cobble conglomerate. Thickness 550 m along Lompico Creek.
- Tsl **San Lorenzo Formation (Oligocene and upper and middle Eocene)**--Dark-gray to red and brown shale, mudstone, and siltstone with local interbeds of sandstone. About 550 m thick. Locally divided into:
- Tsr **Rices Mudstone Member (Oligocene and upper Eocene)**--Olive-gray to red and brown unbedded mudstone and siltstone with some laminated shale. Spheroidal weathering is common, as are elongate carbonate concretions. About 300 m thick
- Tst **Twobar Shale Member (middle and upper Eocene)**--Olive-gray to red and brown laminated shale with some mudstone. Includes a few thin interbeds of very fine grained sandstone which thicken to as much as 30 m near Big Basin. About 240 m thick

- Tb **Butano Sandstone (middle and lower Eocene)**--Light-gray to buff, very fine to very coarse grained arkosic sandstone in thin to very thick beds interbedded with dark-gray to brown mudstone and shale. Conglomerate, containing boulders of granitic and metamorphic rocks and well-rounded cobbles and pebbles of quartzite and porphyry, is present locally in lower part of section. Amount of mudstone and shale varies from 10 to 40 percent of volume of formation. About 3,000 m thick
- Tbu **Upper sandstone member**--Thin-bedded to very thick bedded medium-gray, fine- to medium-grained arkosic sandstone containing thin interbeds of medium-gray siltstone. Thickness about 215 m
- Tbm **Middle siltstone member**--Thin- to medium-bedded, nodular, olive-gray pyritic siltstone. Thickness about 215 m
- Tbl **Lower conglomerate and sandstone member**--Thick to very thick interbeds of sandy pebble conglomerate and very thick bedded to massive, yellowish-gray, granular, medium- to coarse-grained arkosic sandstone. Thickness as much as 1,500 m
- Tblc **Conglomerate**--Thick to very thick interbeds of sandy pebble conglomerate mapped locally in the lower member
- Tbs **Shale in Butano Sandstone (lower Eocene)**--Greenish-gray, light-gray, red, and reddish-brown clay shale, mudstone, siltstone, and a few thin interbeds of light-gray sandstone. Exposed near the head of Corte Madera Creek. Total thickness is unknown, but at least 200 m of this material is exposed
- Tw **Whiskey Hill Formation (middle and lower Eocene)**--Light-gray to buff, coarse-grained arkosic sandstone, with light-gray to buff silty claystone, glauconitic sandstone, and tuffaceous siltstone. Sandstone beds constitute about 30 percent of map unit. Tuffaceous and silty claystone beds are expansive. Locally, sandstone beds are well cemented with calcite. At apparent base of section on north side of Jasper Ridge, just east of Searsville Lake, a thin greenstone-pebble conglomerate is present. In places within this map unit, sandstone and claystone beds are chaotically disturbed. This formation is as much as 900 m thick
- Tws **Shale in Whiskey Hill Formation (lower Eocene)**--Brown and reddish-brown claystone, mudstone, siltstone, and shale. Locally contains lenses of sandstone as much as 50 m thick. Exposed along Highway 84 and along Highway 92, east of Half Moon Bay, where a small patch of red mudstone can be seen in a drainage ditch. Total thickness is unknown, but at least 200 m of this material is exposed along Highway 84
- Tu **Unnamed sedimentary rocks (Eocene?)**--Mudstone, shale, and argillite with minor sandstone
- Tl **Locatelli Formation (Paleocene)**--Nodular, olive-gray to pale-yellowish-brown micaceous siltstone. Thickness 245-275 m. Locally near base includes:
- Tlss **Sandstone**--Massive, medium-gray, fine- to medium-grained arkosic sandstone. Maximum thickness 25 m
- Kpp **Pigeon Point Formation (Upper Cretaceous)**--Sandstone and conglomerate, interbedded with siltstone and mudstone and pebbly mudstone. Sandstone is fine- to coarse-grained, arkosic, and gray to greenish gray; mudstone and siltstone are gray or black to buff. Conglomerate contains well-rounded pebbles, cobbles, and boulders of red and gray fine-grained and porphyritic felsic volcanic rocks, granitic rocks, chert, quartzite, dark metamorphic rock, limestone, and clastic sedimentary rocks. Pigeon Point Formation is estimated to be more than 2,600 m thick
- Ksh **Unnamed shale (Upper Cretaceous)**--Dark-gray, thin-bedded, nodular shale and silty shale. Unit is exposed only in the bed of San Francisquito Creek, in Menlo Park, where about 15 m of section is visible
- Ka **Conglomerate of strata of Anchor Bay (Wentworth, 1968) (Cretaceous)**--Massive sandstone and conglomerate with pebbles and cobbles of diabase, gabbro, and minor granitic rocks; contains abundant shell fragments of a rudistid bivalve similar to *Coraliochama orcutti* of Late Cretaceous (Campanian) age
- Ks **Unnamed sandstone and shale (Cretaceous?)**-- Rhythmically interbedded, indurated micaceous sandstone and greenish-gray argillite; age uncertain, but probably Cretaceous based on lithologic similarity to other Cretaceous strata in the Santa Cruz Mountains
- Kgr **Granitic rocks of Montara Mountain (Cretaceous)**--Very light gray to light-brown, medium- to coarsely crystalline foliated granitic rock, largely quartz diorite with some granite. These rocks are highly fractured and deeply weathered. Foliation is marked by an alignment of dark minerals and dark dioritic inclusions. Tabular bodies of aplite and pegmatite generally parallel foliation. Rocks from this unit have yielded K/Ar ages of 91.6 Ma (Curtis, Everndon, and Lipson, 1958) and 86.2 ± 3.4 Ma (Calif. Div. Mines and Geol., 1965), fission track ages of 84.1 ± 7.8 Ma and 81.7 ± 6.3 Ma (Naeser and Ross,

1976), and most recently Rb/Sr and Ar/Ar ages of 93 ± 2.5 Ma (Kistler and Champion, 1997)

- Kqd **Granitic rocks of Ben Lomond Mountain (Cretaceous)** -- Predominantly dark-weathering, white to light-gray, fine- to coarse-grained hornblende-biotite quartz diorite. Also includes stocks and plugs of medium- to coarse-grained, light-gray alaskite and granite, and dark, fine- to coarse-grained, hornblende-cummingtonite gabbro. Alaskite dikes similar to the larger alaskite body, locally intrude the quartz diorite. The gabbro body appears in map view to intrude the quartz diorite as well, but contact relations have not been observed because of poor exposure of the gabbro. The quartz diorite is very similar to that of Montara Mountain, but is distinguished by having fewer dark minerals and virtually lacking metallic opaque minerals (Ross, 1972), as well as by association with other types of plutonic rocks. Rocks from this unit have yielded fission track ages of 86.9 ± 6.6 Ma (Naeser and Ross, 1976) and K/Ar ages of 71.0 ± 0.9 Ma (Calif. Div. Mines and Geol., 1965) and 86.9 ± 6.6 Ma (Leo, 1967). This unit includes, mapped locally:
- ga **Granite and alaskite**
- hcg **Hornblende-cummingtonite gabbro**
- KJv **Unnamed volcanic rocks (Cretaceous or older)**--Dark-gray, dense, finely-crystalline felsic volcanic rock, with quartz and albite phenocrysts. Exposed only west of Pescadero. Thickness unknown
- KJf **Franciscan Complex, undivided (Cretaceous and Jurassic)**--Mostly graywacke and shale (fs). May be variably sheared. Partly coeval with Pigeon Point Formation (Kpp), granitic rocks of Montara Mountain (Kgr) and Ben Lomond Mountain (Kqd), unnamed shale (Ksh), and unnamed volcanic rocks (KJv). Locally divided into:
- fs **Sandstone**--Greenish-gray to buff, fine- to coarse-grained sandstone (graywacke), with interbedded siltstone and shale. Siltstone and shale interbeds constitute less than 20 percent of unit, but in places form sequences as much as several tens of meters thick. In many places, shearing has obscured bedding relations; rock in which shale has been sheared to gouge constitutes about 10 percent of unit. Gouge is concentrated in zones that are commonly less than 30 m wide but in places may be as much as 150 m wide. Total thickness of unit is unknown but is probably at least many hundreds of meters
- fg **Greenstone**--Dark-green to red, altered basaltic rocks, including flows, pillow lavas, breccias, tuff breccias, tuffs, and minor related intrusive rocks, in unknown proportions. Unit includes some Franciscan chert and limestone bodies that are too small to show on map. Greenstone crops out in lenticular bodies varying in thickness from a few meters to many hundreds of meters
- fc **Chert**--White, green, red, and orange chert, in places interbedded with reddish-brown shale. Chert and shale commonly are rhythmically banded in thin layers, but chert also crops out in very thick layers. In San Carlos, chert has been altered along faults to tan- to buff-colored clay. Chert and shale crop out in lenticular bodies as much as 75 m thick; chert bodies are commonly associated with Franciscan greenstone
- fl **Limestone**--Light-gray, finely to coarsely crystalline limestone. In places limestone is unbedded, in other places it is distinctly bedded between beds of black chert. Limestone crops out in lenticular bodies as much as 120 m thick, in most places surrounded by Franciscan greenstone
- fm **Metamorphic rocks**--Dusky-blue to brownish-gray blocks of metamorphic rock, commonly glaucophane schist, but some quartz-mica granulite. These rocks are finely to coarsely crystalline and commonly foliated. They almost always crop out as tectonic inclusions in sheared Franciscan rocks (fsr) and serpentinite (sp), and they reach maximum dimensions of several tens of meters though many are too small to show on map
- fh **Argillite**--Dark-gray to grayish-black argillite and shale with minor beds of sandstone
- fsr **Sheared rock (melange)**--Predominantly graywacke, siltstone, and shale, substantial portions of which have been sheared, but includes hard blocks of all other Franciscan rock types. Total thickness of unit is unknown, but is probably at least several tens of meters
- sp **Serpentinite (Cretaceous and/or Jurassic)**--Greenish-gray to bluish-green sheared serpentinite, enclosing variably abundant blocks of unshaped rock. Blocks are commonly less than 3 m in diameter, but range in size from several centimeters to several meters; they consist of greenish-black serpentinite, schist, rodingite, ultramafic rock, and silica-carbonate rock, nearly all of which are too small to be shown on the map
- Jsv **Siliceous volcanic rocks and keratophyre (Jurassic?)**-- Highly altered intermediate and silicic volcanic and hypabyssal rocks. Feldspars are almost all replaced by albite. Recent biostratigraphic and isotopic analyses yielded a Jurassic age for similar rocks in Alameda and Contra Costa Counties (Jones and Curtis, 1991)

Jgb	Gabbro (Jurassic?) --Light greenish-gray, dark-gray weathering, mafic intrusive rock, mostly gabbro but also includes some diabase locally. The age of this unit is unknown, but the unit is probably part of the Jurassic Coast Range Ophiolite
db	Diabase and gabbro (Jurassic?)
gd	Gneissic granodiorite (Mesozoic or Paleozoic) --Strongly foliated, black and white gneiss. Foliation due to alignment of lenses of dark minerals in a light-colored matrix
sch	Metasedimentary rocks (Mesozoic or Paleozoic) --Mainly pelitic schist and quartzite
m	Marble (Mesozoic or Paleozoic) --White to gray finely crystalline marble and graphitic marble, in places distinctly bedded, in places foliated. Near Montara Mountain, this unit also includes quartz-mica hornfels and crops out as rare isolated bodies as much as 75 m long in granitic rocks. Near Ben Lomond Mountain, the unit locally includes schist and calc-silicate rocks

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Sources Of Data

Data for Quaternary deposits in Santa Cruz County are nearly entirely from Dupré (1975). Quaternary deposits in the west half of San Mateo County are mostly from Lajoie and others (1974), and in the east half are modified from Helley and Graymer (1997), Pampeyan (1993), and Lajoie and others (1974). Lines for San Andreas fault in San Mateo County are from Brown (1972). Numbers below refer to the "Index Map Showing Sources of Data," which is on Sheet 2 (or the equivalent Arc/Info coverage pa-so).

1. Pampeyan (1993) and Helley and others (1994). See also Helley and Lajoie (1979), and Pampeyan (1970). Faults inferred from geophysical investigations by Brabb and Hanna (1981) and Carle and others (1990).
2. Pampeyan (1993 and 1970); some data from Dibblee (1966), Brown (1972), Dickinson (1970), Rodine (1973), and Fleck (1967). See also Brabb and others (1991), and Beaulieu (1970).
3. Dibblee (1966).
4. Cummings (1960) and Dibblee (1966). See also Cummings and others (1962).
5. McLaughlin (1969); some field checking by E.E. Brabb, 1969, and E.H. Pampeyan, 1971.
6. Rogers and Armstrong (1973), some data from Dibblee (1966).
7. Unpublished geologic mapping by S.A. Brooks, K.F. Oles, and Eugene Borax, Union Oil Company of California, 1956, scale 1:24,000; some data from Classen (1959). Additional field work by T.W. Dibblee, Jr., 1947-49, and by E.E. Brabb, 1968-69.
8. New mapping by authors.
9. Thomas (1951) and field reconnaissance by E.E. Brabb, 1969, and E.H. Pampeyan, 1963.

10. Schlocker and others (1965) and Brown (1972).
11. Esser (1958) and Mack (1959), modified by field checking by E.E. Brabb, 1968-69.
12. Pampeyan (1970 and 1993). Some data from Dibblee (1966).
13. Helley and Graymer (1997).
14. Touring (1959). See also Cummings and others (1962). Bedrock geology modified from unpublished maps, scale 1:24,000, by F.J. Noble, S.A. Brooks, Eugene Borax, K.F. Oles, R.S. Fiske, H.L. Fothergill, R.N. Hacker, and J.H. van Amringe, Union Oil Company of California, 1951-57. Additional field work by T.W. Dibblee, Jr., 1947-49, and E.E. Brabb, 1958, 1968-69.
15. Dibblee (1966) and Johnson and Ellen (1968).
16. Dibblee (1966). Some data from Cummings (1960) and Cummings and others (1962).
17. Unpublished geologic mapping, scale 1:24,000, by S.A. Brooks, and R.S. Fiske, Union Oil Company of California, 1956. Additional field work by T.W. Dibblee, Jr., 1947-49, J.C. Clark and E.E. Brabb, 1969-70, and T.R. Simoni, 1971. Some San Gregorio fault lines from Weber and Lajoie (1980) and Roberta Smith (written commun., 1993). See also Hall and others (1959).
18. Brabb (1960). See also Cummings and others (1962) and Brabb (1964).
19. Cummings (1960). See also Cummings and others (1962).
20. Clark (1970), Clark and Brabb (1978), and Brabb, Clark, and Throckmorton (1977). More recently Clark (1981).
21. Miller-Hoare (1980).
22. Sorg and McLaughlin (1975). Some data from Dibblee (1966), Cotton and Associates (1978), W. McCormick (written commun., 1991), Cotton and Associates (written commun., 1991), and Helley and others (1994).
23. Helley and others (1994). See also Helley and Lajoie (1979). Faults inferred from geophysical investigations by Brabb and Hanna (1981) and Carle and others (1990).
24. Rogers (1972), supplemented with data from Sorg and McLaughlin (1975), Cotton and Associates (1977), Helley (written commun., 1991), and Brabb and Dibblee (1979).
25. Dibblee (1966).
26. Unpublished geologic mapping, scale 1:24,000, by S.A. Brooks and Richard Fiske, Union Oil Company of California, 1956.
27. Brabb (1960) and Cummings and others (1962). See also report by McJunken (1984).
28. Cotton and Associates (1978). Some data from Dibblee (1966), D. Sorg and R. McLaughlin (written commun., 1991), and Cotton and Associates (written commun., 1991).
29. Brabb and Dibblee (1979), Burchfiel (1958), and Hector (1976).
30. Clark (1981), Leo (1961, 1967). Ben Lomond fault extended from Stanley and McCaffrey (1983).

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Appendix One

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 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 map and database description pamphlet. 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, explanation sheet, and preceding geologic description pamphlet.** The digital map and database description pamphlet 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, explanation sheet, and geologic pamphlet via the Internet or on magnetic tape, as well as information about how the map sheets and pamphlets were created, and therefore is included here.

In addition, the USGS has adopted new policies regarding revision of publications, introducing the concept of version numbers similar to those used in the computer industry. The following pamphlet contains information about the version system and about how to access a revision list explaining changes from version 1.0, if any have been made.

Digital Geologic Map of the Palo Alto 30' X 60' Quadrangle, California

By E.E. Brabb, R.W. Graymer, and D.L. Jones

Digital publication and database description

Introduction

This pamphlet serves to introduce and describe the digital geologic map database and accompanying data, which are available for downloading at <http://greenwood.cr.usgs.gov>. These data include both a set of Arc/Info geospatial databases containing the geologic information and Adobe Acrobat PDF and PostScript plot files containing images of a geologic map sheet and an explanation sheet, as well as the accompanying text describing the geology of the area. For those interested in a paper plot of the map and explanation sheets or in obtaining the plot files, please see the section entitled "For Those Who Don't Use Digital Geologic Map Databases" below.

This digital map database, compiled from previously published and unpublished data, and new mapping by the authors, represents the general distribution of bedrock and surficial deposits in the Palo Alto 30' X 60' quadrangle. Together with the accompanying geologic explanation pamphlet (available as `pamf.txt`, `pamf.pdf`, or `pamf.ps`), it provides current information on the geologic structure and stratigraphy of the area covered. The database delineates map units that are identified by general age and lithology following the stratigraphic nomenclature of the U.S. Geological Survey. 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 digital publication, as well as methods of obtaining the digital files, are described below.

For those who don't use digital geologic map databases

For those interested in the geology of the Palo Alto 30' X 60' quadrangle 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, an explanation sheet, 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"). In addition, the map and explanation sheets are large, and require large-format color plotters to produce a plot of the entire image, although smaller plotters can be used to plot portions of the images using the PDF plot files (see the sections "PostScript plot files" and "PDF plot files" below).

Those without computer capability can obtain plots of the map files through USGS Map-On-Demand service for digital geologic maps (see section "Obtaining plots from USGS Information Services") or from an outside vendor (see section "Obtaining plots from an outside vendor").

Also, USGS has adopted version numbers for publications, similar to that used in the computer industry. See the section "Revisions and version numbers" for details on this new policy.

MF-2332 digital contents

This publication includes three digital packages. The first is the PostScript Plotfile Package, which consists of PostScript plot files of a geologic map, explanation sheet, and geologic description. The second is the PDF Plotfile Package, and contains the same plotfiles as the first package, but in Portable Document Format (PDF). The third is the Digital Database Package, and 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):

pamap.ps	A PostScript plottable file containing an image of the geologic map and base map of the Palo Alto 30' X 60' quadrangle at a scale of 1:100,000 (Sheet 1).
paexpl.ps	A PostScript plottable file containing an image of the map keys, and index maps for the Palo Alto 30' X 60' quadrangle (Sheet 2).
pamf.ps	A PostScript plot file of a report containing detailed unit descriptions and geological information, plus sources of data, references cited, and an appendix describing the digital content of the publication (this pamphlet).

PDF plotfile package

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

pamap.pdf	A PDF file containing an image of the geologic map and base maps of the Palo Alto 30' X 60' quadrangle at a scale of 1:100,000 (Sheet 1).
paexpl.pdf	A PDF file containing an image of the map keys, and index maps for the Palo Alto 30' X 60' quadrangle (Sheet 2).
pamf.pdf	A PDF file of a report containing detailed unit descriptions and geological information, plus sources of data, references cited, and an appendix describing the digital content of the publication (this pamphlet).

Digital database package

The database package includes geologic map database files for The Palo Alto 30' X 60' quadrangle. 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
pa_um-py.e00	pa_um-py/	Faults, depositional contacts, and rock units in the Palo Alto 30' X 60' quadrangle. This coverage includes arcs, polygons, and annotation.
pa_um-sr.e00	pa_um-sr/	Strike and dip information and fold axes in the Palo Alto 30' X 60' quadrangle. This coverage includes arcs, points, and annotation. Note: The structure coverage (pa_um-sr) includes additional point data that is not plotted in the map sheet (Sheet 1, plotfiles pamap.ps or pamap.pdf) because of space constraints at the map scale.

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 -----
pa_quad.e00	pa_quad/	Index map of quadrangles in the Palo Alto 30' X 60' quadrangle. This coverage includes arcs, polygons, and annotation.
pa_um-flt.e00	pa_um-flt/	Index map of faults in the Palo Alto 30' X 60' quadrangle with annotation showing the names of major faults. This coverage includes arcs and annotation only.
pa_corr.e00	pa_corr/	Correlation table for the units in this map database. This coverage includes arcs, polygons, and annotation.
pa_so.e00	pa_so/	Sources of data index map for this map database. This coverage includes arcs, polygons, and annotation.
pa_as.e00	pa_as/	Index map of Assemblages in the Palo Alto 30' X 60' quadrangle (Assemblages are described in pamf.txt or pamf.ps). This coverage includes arcs, polygons, and annotation.
pa_um-dr.e00	pa_um-dr/	Drainage base map (from 1:100,000 scale original). This coverage includes arcs with no attribute table only.
pa_um-cu.e00	pa_um-cu/	Cultural base map (from 1:100,000 scale original). This coverage includes arcs with no attribute table only.
pa_um-topo.e00	pa_um-topo/	Topographic contours base map (from 1:100,000 scale original). This coverage includes arcs with no attribute table only.

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

pamf.ps	A PostScript plot file of a report containing detailed unit descriptions and geological information, plus sources of data, references cited, and an appendix describing the digital content of the publication (this pamphlet).
pamf.pdf	A PDF version of pamf.ps.
pamf.txt	A text-only file containing an unformatted version of pamf.ps.
import.aml	ASCII text file in ARC Macro Language to convert ARC export files to ARC coverages in ARC/INFO.
mf2332.rev	A text-only file containing the revisions list for this report.
mf2332.met	A parsable text-only file of publication level FGDC metadata for this report.

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 data from the tar file. This utility is included in most UNIX systems, and can be obtained for a variety of platforms free of charge over the Internet from Internet Literacy's Common Internet File Formats Webpage:

(<http://www.matisse.net/files/formats.html>)

The 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>)

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
m2332ps.tgz	11.7 MB (531 MB)	paps	PostScript Plotfile Package
m2332pdf.tgz	7.2 MB (7.3 MB)	papdf	PDF Plotfile Package
m2332db.tgz	6.3 MB (31 MB)	pageo	Digital Database Package

PostScript plot files

For those interested in the geology of the Palo Alto 30' X 60' quadrangle who don't use an ARC/INFO compatible GIS system we have included a separate data package with three PostScript plot files. One contains a color plot of the geologic map database at 1:100,000 scale (Sheet 1, pamap.ps). The second contains a color plot of the map keys and index map (Sheet 2, paexpl.ps). Because this release is primarily a digital database, the plot files (and plots derived therefrom) have not been edited to conform to U.S. Geological Survey standards. Small units have not been labeled with leaders and in some instances map features or annotation overlap. Sample plots by the authors have proven to be quite legible and useful, however. In addition, a third PostScript file containing the geologic description and discussion is provided (pamf.ps).

The PostScript image of the geologic maps (Sheet 1) and map explanation (Sheet 2) are 44 inches wide by 34 inches high, 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 vertical 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 7.0.4. 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 sheets 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. From the Publications Group Web Page.
- b. Sending a tape with request

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

The U.S. Geological Survey 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 Central Region is

<http://greenwood.cr.usgs.gov>

Go to

<http://greenwood.cr.usgs.gov/mf/mf2332>

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

To obtain tar files of database or plotfile packages on tape:

The digital database package, including database files, PostScript plotfiles, and related files can be obtained by sending a tape with request and return address to:

Palo Alto 30' X 60' quadrangle Geologic Database
c/o Database Coordinator
U.S. Geological Survey

345 Middlefield Road, M/S 975
Menlo Park, CA 94025

Do not omit any part of this address!

Copies of either the PostScript or PDF plot-file packages can also be obtained by sending a tape with request and return address to:

Palo Alto 30' X 60' quadrangle Geologic Map Plotfiles
c/o Database Coordinator
U.S. Geological Survey
345 Middlefield Road, M/S 975
Menlo Park, CA 94025

Do not omit any part of this address!

NOTE: Be sure to include with your request the exact names, as listed above, of the tar files you require. A report number is not sufficient.

The compressed tar file will be returned on the tape. The acceptable tape types are:

2.3 or 5.0 GB, 8 mm Exabyte tape.

Obtaining plots from a commercial vendor

Those interested in the geologic map of the Palo Alto 30' X 60' quadrangle, but who use neither a computer nor the Internet, can still obtain the information. We will provide the PostScript or PDF plot files on digital tape for use by commercial vendors who can make large-format plots. Make sure your vendor is capable of reading Exabyte tape types and PostScript or PDF plot files. Important information regarding tape file format 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

U.S. Geological Survey provides a map-on-demand service for certain map plot-files, such as those described in this report. In order to obtain plots of the Geologic map of the Palo Alto 30' X 60' quadrangle, the accompanying explanation sheet, and this pamphlet, contact:

USGS Information Services
Box 25286
Denver Federal Center
Denver, CO 80225-0046

(303) 202-4200
1-888-ASK-USGS

FAX: (303) 202-4695
e-mail: infoservices@usgs.gov

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 that used in the computer industry. The original version of all publications 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. Pamphlets and map products will be clearly marked with the appropriate version number. 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, 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 7.0.4 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 1:24,000 and 1:62,500 scale. The author manuscripts (pencil on mylar) were scanned using a Altek monochrome scanner with a resolution of 800 pixels per inch. The scanned images were vectorized and transformed from scanner coordinates to projection coordinates with digital ties 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 included in the database package were prepared from scale-stable printing negatives of the U.S. Geological Survey Palo Alto (1982 edition) 1:100,000 topographic map, which has a 50 meter contour interval. Scanned and vectorized images were transformed from scanner coordinates to projection coordinates with digital ties placed by hand at map corners. The images were then trimmed interactively by hand using ALACARTE to conform to the area of the geologic coverages. Small mismatches at the boundaries caused by slight differences in the original scans remain in the three base map coverages. These base map layers are digital images but no information other than location is attached to the lines. The base map coverages are provided for reference only. The map images contain a monochromatic raster version of the base map.

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, 1997). Similarly, the database cannot be used to identify or delineate landslides in the region. For a depiction of landslide distribution, see Brabb and Pampeyan (1972), Brabb and others (1978), Cooper-Clark and Associates (1975), Mark (1992), Wieczorek and others (1985), and Wieczorek and others (1988).

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 at a scale of 1:24,000 means that higher resolution information is not present in the dataset. Plotting at scales larger than 1:24,000 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 lowest resolution of these data. Note that in contrast to the geologic coverages, the base map layers have a resolution of 1:100,000, so significant discrepancies with the geologic coverages are possible. The base map layers are provided for reference only.

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, mf2332.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 UTM (Universal Transverse Mercator) 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. In the base map layers, the tics define a 7.5-minute grid, corresponding with quadrangle corners.

Table 1. Map Projection

The maps are stored in UTM projection. The following is an annotated projection file of the type used in Arc/Info.

```
PROJECTION UTM
UNITS METERS (on the ground)
ZONE 10 (UTM zone)
SPHEROID CLARKE1866 (Arc/Info default)
PARAMETERS
END
```

The content of the geologic database can be described in terms of the lines and the areas that compose the map. Descriptions of the database fields 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

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.

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

pa_um-py -----	pa_um-sr -----
contact, certain	f.a., anticline, certain
contact, concealed	f.a., anticline, concealed
contact, approx. located	f.a., anticline, approx. located
fault, certain	f.a., syncline, certain
fault, concealed	f.a., syncline, concealed
fault, concealed, queried	f.a., syncline, approx. located
fault, approx. located	f.a., syncline, inferred, queried
fault, inferred	
reverse fault, certain	
reverse fault, concealed	
scratch boundary	
water boundary	
map boundary	

The geologic line types are ALACARTE line types that correlate with the geologic line symbols in the ALACARTE line set

according to the ALACARTE lines lookup table. For more information about these line types, as well as information about the line types in the supporting coverages, please see the publication metadata.

Areas

Map units (polygons) are described in the polygon attribute table (the format of the polygon attribute table is shown in Table 5). 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 in the accompanying text file pamf.txt or pamf.ps. 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. For more information about these polygon types, as well as information about the polygon types in the supporting coverages, please see the publication metadata.

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

Table 6. Map unit labels recorded in the PTYPE field in coverage pa_um-py (See the geologic explanation pamphlet for complete descriptions of units).

	Qhl	Tpsg
H2O	Qhsc	Tpt
Jgb	Qm	Tptu
Jsv	Qmt	Tsc
KJf	Qof	Tsl
KJs	Qpaf	Tsm
KJv	Qpaf1	Tsr
Ka	Qpoaf	Tss
Kgr	Qs	Tst
Kpp	Qyf	Tus
Ks	Qyfo	Tuv
Ksh	Tb	Tvq
QTm	Tbs	Tw
QTsc	Tbs?	af
Qal	Tl	alf
Qb	Tla	fc
Qc	Tlo	fcg
Qcl	Tls	fg
Qhaf	Tm	fl
Qhasc	Tmb	fm
Qhb	Tp	fs
Qhbd	Tpl	fsr
Qhbm	Tpm	m
Qhfp	Tpp	sp

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 PTTYPER field (Table 8). Additional information about the points is stored in additional attribute fields as described below and in Table 9. 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. For more information about these point types, as well as information about the point types in the supporting coverages, please see the publication metadata.

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 coverage only)
STRIKE	3	3	I		strike of bedding or foliation (structure coverage only)

Table 8. Point types recorded in the PTTYPE field in coverage pa_um-sr

approx bedding
bedding
bedding w/tops
flat bedding
foliation
ot bedding
vert bedding

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).

Note: The structure coverage (pa_um-sr) includes additional point data that is not plotted in the map sheet (Sheet 1, plotfiles pamap.ps or pamap.pdf) because of space constraints at the map scale.

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