Field Guide to the Geology of Black Diamond Mines Regional Preserve

NC GS
FIELD GUIDE TO THE GEOLOGY OF BLACK DIAMOND MINES REGIONAL PRESERVE

RAYMOND SULLIVAN, Dept. of Geosciences, San Francisco State University
JOHN WATERS, East Bay Regional Park District
MORGAN D. SULLIVAN, Exxon Production Research Company
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Location map of Tertiary Submarine Canyons</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Generalized Stratigraphic Section of the Tertiary Rocks</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Stratigraphic Units in Black Diamond</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Chronostratigraphic interpretation of the Tertiary</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Fining Upward Parasequences in Tide Dominated Settings</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>Stratigraphic Section of the Domengine Formation</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>W-E Stratigraphic relationships of the late Tertiary sections</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>Stop 1. Section exposed in Devil’s Mountain Ranch</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>West to East section of the Neroly Formation</td>
<td>16</td>
</tr>
<tr>
<td>10</td>
<td>Shell Ginochio #1</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>Trail guide map of Black Diamond Mines</td>
<td>22</td>
</tr>
<tr>
<td>12</td>
<td>Stop 2. Map of the underground workings at Somersville</td>
<td>23</td>
</tr>
<tr>
<td>13</td>
<td>Stop 2. Section in Hazel-Atlas Portal</td>
<td>29</td>
</tr>
<tr>
<td>14</td>
<td>Stop 2. Section in Greathouse Portal</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>Stops 2 and 4. Sections at Somersville and Nortonville</td>
<td>32</td>
</tr>
<tr>
<td>16</td>
<td>Stop 4. Section in Coal Canyon Nortonville</td>
<td>33</td>
</tr>
<tr>
<td>17</td>
<td>Stop 5. Section in west on Black Diamond Wåy</td>
<td>35</td>
</tr>
<tr>
<td>18</td>
<td>Stop 6. Section on Black Diamond Trail</td>
<td>36</td>
</tr>
<tr>
<td>19</td>
<td>Stops 1, 2 and 8. N-S Structural Section</td>
<td>37</td>
</tr>
<tr>
<td>20</td>
<td>Geological map of Black Diamond Mines</td>
<td>40</td>
</tr>
<tr>
<td>21</td>
<td>Stratal Patterns in a Typical Sequence</td>
<td>43</td>
</tr>
<tr>
<td>22</td>
<td>Typical Stacking Patterns of Parasequences</td>
<td>44</td>
</tr>
<tr>
<td>Plate</td>
<td>Stop</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>1 Upper</td>
<td>Stop 2</td>
<td>View looking southeast across Somersville</td>
</tr>
<tr>
<td>1 Lower</td>
<td>Stop 1</td>
<td>View looking northwest across Sidney Flat</td>
</tr>
<tr>
<td>2 Upper</td>
<td>Stop 1</td>
<td>Late Tertiary Section in Markley Canyon</td>
</tr>
<tr>
<td>2 Lower</td>
<td>Stop 1</td>
<td>Contact of Kirker and Cierbo formations</td>
</tr>
<tr>
<td>3 Upper</td>
<td>Stop 3</td>
<td>View looking west across Nortonville</td>
</tr>
<tr>
<td>3 Lower</td>
<td>Stop 1</td>
<td>View looking north from Markley Canyon</td>
</tr>
<tr>
<td>4 Upper</td>
<td>Stop 2</td>
<td>Upper “White Sandstone” Hazel-Atlas mine</td>
</tr>
<tr>
<td>4 Lower</td>
<td>Stop 2</td>
<td>Fault, Hazel-Atlas mine</td>
</tr>
</tbody>
</table>
AN OVERVIEW OF THE TERTIARY STRATIGRAPHIC SECTION IN BLACK DIAMOND MINES REGIONAL PRESERVE

INTRODUCTION

Black Diamond Mines Regional Preserve is located in the foothills on the northeast flanks of Mount Diablo. The central structure of Mount Diablo is a complex overturned duplex fold composed of ophiolite suites together with Franciscan and Knoxville rocks that were uplifted in late Cenozoic time (Crane 1994). The northeastern foothills that make up the Preserve are composed of steeply tilted Cretaceous and Cenozoic strata which overlie the wedge-backthrust of the Mount Diablo complex. In the Black Diamond area the formations strike northwest-southeast and dip northeast away from Mt. Diablo. Resistant sandstones in the succession produce prominent strike ridges covered by sandy soils. In contrast, softer shale units weather to adobe rich clay soil and erode to form intervening valleys. Numerous north-south high angled faults disrupt the prevailing structural trend and many of the narrow canyons that dissect the strike ridges are located in this fault system.

The present study of the Tertiary successions in the Black Diamond and surrounding area is still not complete but many individuals have been of assistance at this stage in the study. I wish to thank Chris Denison, Tom Dignes, Sharma Gapanoff and Bill Steinkraus of Chevron Overseas Petroleum Company, Kris McDougal of the USGS and Gerta Keller of Princeton University for providing most of the microfossil zonation used in this report. Scott Morgan, formerly of Exxon Production Research, and Chris Denison were very helpful in discussions on applying a sequence stratigraphy framework to the succession. Andre Sarna-Wojcicki of the USGS analyzed the volcanic tuffs in the Kirker Formation. Gary Palmer of San Francisco State University has contributed invaluable assistance in drafting of maps and assembling the field guides. John Waters and the staff of Black Diamond Mines Regional Preserve have been very supportive of my field work in the Preserve.

REGIONAL SETTING

Graham et al. (1984) has shown that during late Mesozoic and early Tertiary times a forearc basin existed over the Great Valley of California and it was bounded to the west by an active subduction-trench system. A change in plate motion from the Mesozoic to Tertiary was marked by a lower angle of plate subduction which resulted in a period of quiescence in the Sierran magmatic arc. As a result, the early Tertiary successions in the region lack the volcanic-clastic rich sediments which characterized some parts of the late Mesozoic and late Tertiary formations. For much of the early Tertiary, the shoreline was located along the present day foothills of the Sierra Nevada and a shelved forearc basin extended over the Sacramento-San Joaquin Valley. Several submarine canyons were periodically cut into the shelf during lowstands of sea level in the early Tertiary. One of these canyons, the Meganos Canyon, existed in the Black Diamond area in the late Paleocene (fig. 1).

The early Tertiary strata, total more than 2000 meters (6500 feet) in thickness, consist predominantly of alternating successions of shallow marine sandstones and bathyal marine mudstones. Almgren (1978) and others have shown that the early Tertiary succession is
composed of a series transgressive-regressive cycles (fig. 2). The cyclic pattern of sedimentation is interpreted as a series of depositional sequences which can be broadly correlated to global sea level events. Regional tectonism also influenced sediment accommodation and such structures as the ancestral Mt. Diablo uplift, Midland, Kirby Hills and Kirker Pass faults were thought to have been active in early Tertiary times. Lowstand systems tracts are marked by cutting of submarine canyons and development of incised valleys on the shelf. Lowstand deposits are dominated by fluvial and estuarine valley fill and prograding deltaic deposits. Transgressive to highstand systems tracts are composed of strand line sandstones, marine shales and distal sandy-rich turbidite deposits.

Graham et al. (1984) described another change that took place in late Tertiary times when a steeper angle of plate subduction tectonics was reestablished during a transition to the present day transform system of the San Andreas fault. This resulted in renewed volcanism in the Sierra Nevada and volcanic detritus was carried by streams westward across alluvial plains that covered the Great Valley. These rivers flowed into a large embayed coastline in the vicinity of Mount Diablo. The paleogeographic settings of the late Tertiary, therefore,
were very similar to the modern setting of San Francisco Bay with a well developed coastal estuaries system. These volcanic-rich sequences are represented in the succession by the Kirker Formation of Oligocene age, and the Cierbo and Neroly formations of Miocene age. Graham (1984) has described the volcanic-rich predominantly fluvial deposits of the Neroly Formation as representing the last pulse of Sierran arc volcanism.

Another major change in the paleogeographic setting of the region took place in Pliocene times when tectonic activity in the Coastal Ranges produced local sources of detritus. A major influx of rhyolitic ash and breccia in the Lawlor Tuff has been dated at 4.5 Ma. The overlying Wolfskill Formation, composed of non-marine sands, gravels and clay, is the youngest stratigraphic unit in the vicinity of the Preserve. Basaltic flows associated with tectonically active faults are also of this age.

**EOCENE STRATIGRAPHY**

The early Tertiary succession of the Black Diamond Mines Regional Preserve has been described by Almgren (1978), Bodden (1981), Cherven (1983a), Fischer (1979), Fulmer (1956), and Sullivan (1987). The oldest part of the Tertiary succession, which includes the Martinez Formation of Paleocene age, is poorly exposed in the southern most part of the Black Diamond Mines Regional Preserve and will not be discussed in the present account. Eocene strata, on the other hand, underlies most of Preserve and are well displayed in the canyons and hillsides (fig. 20). These rocks are also present in the underground mine workings.
Meganos Formation

The cutting of the Meganos Canyon was an important late Paleocene to early Eocene lowstand event. Almgren (1978) showed that the canyon can be traced for about 80 km (49 miles) in the subsurface across the southern part of the Sacramento Valley where it attained a width of between 2 to 13 kilometers (1.25 to 8 miles) and a maximum depth of about 800 meters (2625 feet). It underlies the southern part of the Preserve and trends east-west through Deer Valley (fig. 1).

The Meganos Formation of early Eocene age has been subdivided into five subdivisions, designated units A to E from base to top (fig.3). Meganos “A” and “B” members are thought to be submarine lowstand fan and associated lowstand wedge deposits that total about 450 meters (1500 feet) in thickness. Meganos “C” is 250 to 675 meters (625 to 2225 feet) thick and is composed of laminated mudstones and poorly graded sandstones. The unit contains a rich planktic and benthic foraminiferal assemblage of early Eocene, P6 age (Keller 1988, pers. comm.) and CP9b-CP10 age based on nanofossils (Steinkraus 1991, pers. comm.).

The Hamilton Sandstone or Meganos “D” Member and Capay Shale or Meganos “E” record the next sequence (fig. 2 and 3). The Hamilton Sandstone is a shallow marine deposit which is about 0 to 110 meters (350 feet) in thickness. The overlying Capay Shale is only thinly represented in exposures south of Stewartville. Both units are cut out of the section by erosion below the regional unconformity at the base of the Domengine Formation. The age of the Capay Shale has been determined to be early Eocene, CP10-CP11 age (fig. 4) based on nanofossils (Denison 1991, pers. comm.).

Domengine Formation

The Domengine Formation of mid Eocene age forms a prominent northwest-southeast escarpment overlooking the sites of the old mining towns of Nortonville, Somersville and Stewartville. The formation is separated from the underlying strata by a regional unconformity which, when traced westwards, progressively truncates older units. In the Stewartville area, along the eastern margins of the Preserve, there is little evidence of a major hiatus since Domengine Formation rests directly on Capay Shales (Meganos "E"). In the western end of the Preserve, however, the Domengine rests on bathyal shales of Meganos “C” age and, further west it eventually rests on Cretaceous rocks. The unconformity is an erosional surface cut by fluvial incision during a relative fall in sea level. The incised valleys were subsequently back-filled with estuarine sandstones of the Domengine Formation associated with the relative rise of sea level during the late lowstand systems tract. This mid -Eocene sequence boundary can be identified in many other early Tertiary successions on the West Coast including the San Diego area (Lohmar et al. 1991), and Transverse Ranges (Champion et al. 1994).

Cheveron (1983b) has shown that only the upper part of the Domengine Formation, present in the subsurface in the southern Sacramento Basin, is represented in the outcrops in the Preserve. In these surface exposures, the formation is about 230 meters (750 feet) thick and can be divided into two members based on the correlation of a regional flooding surface that separates the formation into a lower aggradational member and an upper retrogradational member.
### Fig. 3 TERTIARY SUCCESSION IN BLACK DIAMOND AREA

<table>
<thead>
<tr>
<th>Era</th>
<th>Formation/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pliocene</td>
<td>Lawlor Tuff</td>
</tr>
<tr>
<td></td>
<td>Neroly Formation</td>
</tr>
<tr>
<td>Miocene</td>
<td>Cierbo Formation</td>
</tr>
<tr>
<td>Oligocene</td>
<td>Kirker Formation</td>
</tr>
<tr>
<td></td>
<td>Tuff Unit</td>
</tr>
<tr>
<td></td>
<td>Sandstone Unit</td>
</tr>
<tr>
<td></td>
<td>Upper Markley Member</td>
</tr>
<tr>
<td></td>
<td>Sidney Flat Shale</td>
</tr>
<tr>
<td></td>
<td>Upper Markley Member</td>
</tr>
<tr>
<td></td>
<td>Lower Markley Member</td>
</tr>
<tr>
<td>Middle Eocene</td>
<td>Nortonville Shale</td>
</tr>
<tr>
<td></td>
<td>Upper Shale Unit</td>
</tr>
<tr>
<td></td>
<td>Middle Sandstone Unit</td>
</tr>
<tr>
<td></td>
<td>Lower Shale Unit</td>
</tr>
<tr>
<td></td>
<td>Domengine Formation</td>
</tr>
<tr>
<td></td>
<td>Upper “Brown Ss” or Somersville Mbr</td>
</tr>
<tr>
<td></td>
<td>Lower “White Ss” or Ione Member</td>
</tr>
<tr>
<td></td>
<td>“Shaly” Member</td>
</tr>
<tr>
<td></td>
<td>U. Sandstone Unit</td>
</tr>
<tr>
<td></td>
<td>White Sandstone</td>
</tr>
<tr>
<td></td>
<td>Black Diamond Vein</td>
</tr>
<tr>
<td></td>
<td>Basal Unit</td>
</tr>
<tr>
<td></td>
<td>Capay Shale</td>
</tr>
<tr>
<td></td>
<td>Meganos “E” Shale</td>
</tr>
<tr>
<td>Lower Eocene</td>
<td>Hamilton Sandstone</td>
</tr>
<tr>
<td></td>
<td>Meganos “D” Sandstone</td>
</tr>
<tr>
<td></td>
<td>Meganos “C” Shale</td>
</tr>
<tr>
<td></td>
<td>Meganos “B” Sandstone</td>
</tr>
<tr>
<td></td>
<td>Meganos “A” Conglom/ Sand</td>
</tr>
<tr>
<td>Paleocene</td>
<td>Martinez Formation</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Deer Valley Formation</td>
</tr>
</tbody>
</table>

Terminology after Fulmer (1956), Bodden (1981), Cherven (1983b) and others
<table>
<thead>
<tr>
<th>M. YEARS</th>
<th>SERIES</th>
<th>STAGES</th>
<th>PLANKTONIC FORAM. ZONES</th>
<th>NANNOFOSIL BIOCHRON ZONES</th>
<th>RELATIVE CHANGE OF COASTAL ONLAP</th>
<th>BLACK DIAMOND</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>MIDDLE</td>
<td>BARTONIAN</td>
<td>P14</td>
<td>CP14B</td>
<td>40.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P13</td>
<td>CP14A</td>
<td>42.5</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>LUTETIAN</td>
<td>P12</td>
<td>CP13C</td>
<td>44.0</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>NARIZIAN</td>
<td>P11</td>
<td>CP13B</td>
<td>46.5</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>EOCENE</td>
<td>LUTETIAN</td>
<td>P10</td>
<td>CP13A</td>
<td>Nortonville Shale U. Markley Mbr</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>LOWER</td>
<td>YPRESIAN</td>
<td>P9</td>
<td>CP12A</td>
<td>Domengine Fm 48.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ULETISIAN</td>
<td>P8</td>
<td>CP11</td>
<td>Capay Shale 49.5</td>
<td></td>
</tr>
</tbody>
</table>

FIG. 4 CHRONOSTRATIGRAPHIC INTERPRETATION OF THE EOCENE SUCCESSION OF BLACK DIAMOND MINES REGIONAL PRESERVE
**Within Each Parasequence:**

- Sandstone Bedsets and Beds Thin Upward
- Sandstone/Mudstone Ratio Decreases Upward
- Grain Size Decreases Upward
- Bioturbation Increases Upward to the Parasequence Boundary

**Parasequence Boundary Marked By:**
- Abrupt Change in Lithology from Mudstone or Coal Below the Boundary to Sandstone above the Boundary
- Abrupt Increase in Bed Thickness
- Truncation (Several 10's of Feet or Less) of Underlying Strata
- Abrupt Deepening in Depositional Environment Across the Boundary

- **Marine Sandstone**
- **Coal**
- **Trough-Cross Beds**
- **Flaser Beds**
- **Lenticular to Wavy Beds**
- **Marine Mudstone**
- **Nonmarine Mudstone**
- **Sigmoidal-Cross Beds**
- **Burrows**
- **Roots**

SBT = Subtidal; INT = Intertidal; SRT = Supratidal

Fig. 5. Stratal characteristics of two upward-fining parasequences. These types of parasequences are interpreted to form in a subtidal to tidal flat environment on a muddy, tide-dominated coastline. The parasequence in the "White Sandstone" Member of the Domengine Formation are similar but subtidal units dominate. (From Van Wagoner et al. 1990, Siliciclastic Sequence Stratigraphy in Well Logs, Cores and Outcrops: Concepts for High-Resolution Correlation of Time and Facies. AAPG Methods in Exploration, Series No. 7.)
The lower Domengine Member is about 183 meters (600 feet) in thickness and forms the chaparral covered sandstone ridges above the old coal mining settlements. Bodden (1981) gave the informal name “White Sandstone” Member to this unit and Cherven (1983b) called it the Ione Member (fig.6). The member is composed of a thin basal fluvial unit, between 1 to 16 meters (0 to 50 feet) thick, which grades up into estuarine sandstones that total about 170 meters (550 feet) in thickness. The basal fluvial unit is a gravel lag that fills in the incised valleys at the base of the middle Eocene succession. Clasts in the conglomerate are mainly well rounded black chert, quartzites and volcanic pebbles which indicate a provenance in the Sierra Nevada. The unit grades upward into sandstones and siltstones rich in plant fossils. At the top of the basal fluvial unit is the Black Diamond Vein which is the most widespread of the coal beds in the lower part of the Domengine Formation and was mined extensively throughout the region. Cherven (1983b) believes that this basal fluvial unit may be equivalent to the upper part of the Holt Member in the subsurface.

The lower Domengine Member above the fluvial basal unit is made up predominantly of stacked units of upward-fining estuarine parasequences. A typical parasequence is made up of sub-tidal sandstones that grade upwards into inter-tidal siltstones and thin supra-tidal carbonaceous mudstone (fig.5). Sandstones increase in importance upwards within the succession and the upper part of White Sandstone is mainly composed of stacked, upward-coarsening, tidal bar units. Sandstones are well sorted, fine to medium grained, quartz-rich sediments often displaying massive to sigmoidal cross bedding. Channel bases are frequently marked by an erosional surface and pebbly lags. In the underground mine workings, fresh surfaces of the sandstone units reveal mud drapes on many of the foreset cross beds and thin interbedded rippled mudstones. The estuarine sandstones also include highly bioturbated units rich in Ophiomorpha as well as occasional sea anemone burrows. Bioturbation is most intensely developed in the overlying inter-tidal siltstones. Macrofossils are extremely rare but sandstones have yielded shallow marine dinocysts; while coals have produced a fairly rich assemblage of spores and pollens from subtropical plants (Kimyai, 1993). The age of the lower Domengine Member can be constrained as mid Eocene (CP12b) by the presence of dinocysts including Kisselovia coleothrypta, Rhombodinium ? sp., Wetzeliiella articulata, Spiniferites ramosus and other forms (Denison 1991, pers. comm.). The most extensive coal in the upper part of the succession is the Clark Vein near the top of this unit. The location of the Clark Vein in the surface outcrops is often marked by a recessive bench within the prominent ridge formed by the massive sandstones. The upper sandstone units have been extensively mined for glass sand throughout the Preserve.

The overlying upper Domengine Member was named the “Brown Sandstone” by Bodden (1981) and the Somersville Member by Cherven (1983b). It forms a series of oak grassland hills down slope from the more rugged chaparral covered ridges developed in the “White Sandstone”. There is an abrupt contact between the lower and upper members of the Domengine Formation. The surface represents the regional marine flooding event at the base of a transgressive systems tract. It is a planar surface with little or no relief and the top of the “White Sandstone” is often extensively burrowed. The retrogradational stacking pattern of the upper Domengine Member is indicative of deposition during the transgressive systems tract when accommodation is typically highest. The upper Domengine is about 46 meters (150 feet) thick in the area and can be subdivided into a lower mud-rich unit or “Shaly Member” of Bodden (1981) and a sandstone unit above.
DOMENGINE FORMATION
MOUNT DIABLO COALFIELD,
CALIFORNIA

Fig. 6 Generalized stratigraphic section of the Domengine Formation (after Bodden, 1981).
The mud-rich lower unit is rarely exposed but can be seen in a prospect tunnel south of Stewartville (Stop 10) and in the Nortonville area (Stop 4). It is made up of laminated mudstones, shales and siltstones with occasional and thin lenticular sandstones. Small scale cross-bedding is common together with ripples, flame structures and convolute bedding. Sandstones are often bioturbated and many of the bedding planes are filled with horizontal burrows. Numerous specimens of the trace fossil *Bergaueria*, an actinian anemone, can be found in the "Shaly Member" and *Thalassanoides* in the overlying sandstones at Nortonville. Bodden (1981) has interpreted the environment of deposition as an offshore muddy shelf. Arenaceous benthic foraminiferal assemblages have been recovered from the lower unit and were identified by McDougal (1991, pers. comm.). The assemblages are dominated by *Bathysiphon eocenicus*, *Haplophragmoides* spp., *Cyclammina* spp., *Eggerella subconica*, *Ammobaculites* sp. and *Globobulimina pyrula* and it was suggested that deposition was at bathyal depths. However, Tom Dignes (1991, pers. comm.) pointed out that work by Lagoe (1988) in the Tejon Formation of Central California favored an outer shelf or shelf-edge environments for this benthic foraminiferal biofacies.

The "Shaly Member" is overlain by a more sand-prone interval comprised of hummocky cross-stratified lower shoreface sandstones. The lithic sandstones in this upper unit are predominantly composed of quartz, feldspar, biotite and glauconite clasts. This unit also contains a diverse coral-molluscan fauna reflecting marine conditions. Bioturbation is also common in some beds. Berry (1964) published a list of benthonic foraminifera from "near the base of the Brown Sand" and Bodden (1981) reported that it was a shallow water marine assemblage. This part of the middle Eocene succession, therefore, records the change from a tide dominated environment of the lower Domengine to wave dominated depositional conditions seen in the upper Domengine Member.

**Nortonville Shale**

The aggradational shales, mudstones and sandstones of the overlying mid Eocene Nortonville Formation are interpreted as the highstand deposits associated with the Domengine lowstand and transgressive strata.

The Nortonville Shale is easily eroded and forms a valley between resistant sandstone formations. This formation is about 125 meters (405 feet) in thickness and is divided into lower and upper parts by a sandstone unit developed in the middle of the section. The lowest shale unit is well displayed in a large landslide on the west side of Nortonville Pass but elsewhere exposures are rare and deeply weathered. Samples from the lower Nortonville Shales processed for this study were barren of microfossils except for palynomorphs which may indicate restricted marine conditions. Rich assemblages of foraminifers, radiolarians and diatoms have been reported from the upper Nortonville Shale by Fulmer (1956) and others. A quartz sandstone in the middle of the section can be traced throughout the Preserve. Flute markings and thin shelled marine clams are present in this unit on Stewartville Pass. The environment of deposition of the Nortonville Shale is thought to be on a western sloping shelf that may have reached bathyal depths (Cherven and Bodden, 1983).
Markley Formation

The Markley Formation of mid Eocene age abruptly overlies the Nortonville Shale and the contact is interpreted as marking the boundary of the next sequence. Matthews (1963) and Crane (1994) indicated an unconformity at the base of the Markley Formation based on the sudden facies change with the introduction of thick clastic units into the section. Further work is needed on this critical part of the section in order to complete the depositional history of the early Tertiary. Unfortunately exposures are poor but additional stratigraphic information will be forth coming from well log data and cores from this formation in monitoring wells located in the Keller Canyon Landfill site. The Markley Formation is about 1075 meters (3500 feet) in thickness and forms a prominent series of ridges that dominate the northern part of the Preserve. It has been divided into three member by the development of siliceous shale and mudstone units in the section.

The Lower Markley Member is 740 meters (2400 feet) in thickness and is composed of Ta and Tb sand-rich turbidites that grade upwards into mudstones. Fulmer (1956) has described in some detail the stratigraphy and petrology. Units are massively bedded, fine grained, arkosic lithic sandstones. They are poorly sorted with a mud rich matrix. Some horizons have abundant mud rip-up clasts. Wood fragments are common in the section but other fossils are rare except for turrettlled snails and thin shelled clams that are occasionally found in calcareous concretions. The formation weathers very readily and exposures are rare. A small prospect tunnel, located in a steep ravine on the east side of the old railroad embankment midway between Sidney Flat and Somersville, provides the only fresh exposures of this formation in the Preserve. The section is made up of massive sandstone beds that fine upwards into siltstones and mudstones. Large mud rip-up clasts occur at several horizons. The overall lithological association would suggest that the Markley Formation in this area is made up of lowstand submarine canyon-fill facies. Abundant calcareous nannofossils from the Lower Markley in the prospect tunnel suggests deposition at bathyal depths and a mid Eocene, CP13 age. Nannofossil assemblages include Coccolithus pelagicus, Pemmma serratum, P. basquense, P. basquense crassum, Helicopontosphaera lophota, H. seminulum, Lanternithus minusus, Neococcolithes dubius, Campylosphaera dela, Ericsonia formosa, Sphenolithus furcatolithoides, S. springer, Pseudotriquetrorhabdulus inversus, and Discoaster bifax (Steinkraus 1991, pers. comm.).

Overlying the Lower Markley is the Sidney Flat Shale which is about 185 meters (600 feet) in thickness. It can be divided into lower and upper units. The contact with the Lower Markley is drawn at the point where the sand-rich turbidites give way to more distal units. Siltstones, mudstones and shales make up the lower unit of the Sidney Flat. Nannofossils and Foraminifera are common in calcareous nodules in some of the shales and a CP 13c age has been assigned to this part of the section. Nannofossils include Nannotettrina fulgens, Rhabdosphaera gladius, Helicopontosphaera dinesenii, H. seminulum, Sphenolithus furcatolithoides, Pseudotriquetrorhabdulus inversus, Pemmma basquensis, P. serratum, Campylosphaera dela, and Discoaster bifax (Steinkraus 1991, pers. comm.).

The upper part of the Sidney Flat Member is a prominent siliceous diatomaceous shale unit with interbedded mudstones. The member is very fossiliferous and contains thin shelled clams, gastropods, fish, as well as assemblages of radiolarians, diatoms and forams. The
microfossil assemblages have been described in detail by Almgren and McDougall (1975), Blueford and Brunner (1984) and Jeffries (1983). Diatoms were recovered from this unit included _Triceratium inconspicuum_ var. trilobata, _Pyxilla gracilis_, _Pterotheca aculeifera_, _P. gracillima_, _Protheca sp._ and _Hemiaulus sp._ (Steinkraus 1991, pers. comm.). The paleontological evidence points to bathyal, cold water, oxygen deficient conditions. When traced westward across the Kirker Pass fault the diatomaceous shales thin and grade laterally into mudstones.

The overlying Upper Markley Member is about 140-150 meters (450-500 feet) in thickness and is composed predominantly of brown-weathering mudstones, rich in carbonaceous debris with thin interbedded siltstones and fine grained lithic sandstones. A resistant calcareous cemented lithic sandstone bed in the middle of the member can be traced over the area. Sparse foraminiferal assemblages from this member suggest marine deposition at middle to outer neritic depths. The stratigraphic relationships described by Fulmer (1965) in Markley Canyon have been complicated by landsliding. The unusually thick section of sandstones assigned to the Upper Markley, exposed in road cuts on the east side of the canyon is due, in part, to a landslide block which places the Kirker Formation in juxtaposition with the Upper Markley (Dibblee 1980a).

Dibblee (1980a and 1980b) in his mapping of the area found that the three fold division of the Markley Formation became difficult to define when these members are traced westward from the type section in Markley Canyon. This was due in part to facies changes in the section and major stratigraphic changes that takes place across the Kirker Pass fault. The present study, however, shows that Sidney Flat Shale can be traced across the area and an attenuated section of these siliceous shales is present in outcrops and monitoring wells at the Keller Canyon Landfill site. The Upper Markley, however, can only be recognized in western outcrops as far as the Kirker Pass fault and is then cut out by erosional unconformity (fig. 7).

**OLIGOCENE-MIOCENE STRATIGRAPHY**

The base of the Oligocene and Miocene succession is marked by a regional unconformity across which a major basinal shift in facies is observed. At the unconformity, volcanic-rich estuarine sandstones that are considered to be Oligocene age overlie mid Eocene bathyal shales and shelfal sandstones. The Oligocene to Miocene strata can be divided into three depositional sequences that correspond to the Kirker, Cierbo and Neroly formations. Each sequence consists of lowstand/transgressive systems tract, but the associated hightstand deposits do not appear to be preserved.

**Kirker Formation**

Unconformably overlying the Markley Formation is the Kirker Formation that has been assigned to the Oligocene (Primmer, 1960). The contact defines a major stratigraphic change and it marks the appearance of abundant volcanic detritus into the section. In its thickest development at the type section, a few miles to the west of the Preserve, the formation is 95 meters (310 feet) with a poorly cemented conglomerate at its base. The conglomerate is about 9 meters (30 feet) thick at its maximum and the cobble sized clasts
FIG. 7. WEST TO EAST STRATIGRAPHIC RELATIONSHIPS OF THE KIRKER AND CIERBO FORMATIONS

KELLER CANYON
23-T2N-R1W

KIRKER CREEK WEST
30-T2N-R1E

THOMAS RANCH
33-T2N-R1E

MARKLEY CANYON
33-T2N-R1E

MARKLEY CANYON EAST
34-T2N-R1E

KIRKER PASS FAULT

SIDNEY FLAT SHALE

cgc m ft sc

Tree Trunk

cgc m ft sc

NEROLY FM

Oysters

Ash Marker

Clams

Clams

Plants

Vertebrates bone

Bedded sandstone

Pebby sandstone

Bioturbated sandstone

Cross-bedded sandstone

Siltstone - mudstone

Channelized Sandstone

Tuffaceous siltstone/sandstone
FIG. 8  STOP 1 DEVIL'S MOUNTAIN RANCH QUARRY EXPOSURE
WEST SIDE OF MARKLEY CANYON IN SEC. 33 T. 2 N, R. 1 E

KEY

- Conglomerate
- Channelized sandstone
- Pebbly sandstone
- Bedded sandstone
- Bioturbated sandstone
- Cross bedded sandstone
- Concretionary sandstone
- Carbonaceous Shale
- Siltstone - mudstone

NEROLY Fm

450

400

300

250

200

150

100

50

0

FEET

CERBO FORMATION

Olesea Tuff Bed

Marker Bed

Clams

Tuff Unit

Acila

Convolute bedding

Plants

Base of Quarry Section

KIRKER FORMATION

OLIGOCENE?

cg cm tf st cc

Base of section exposed along creek bed in Markley Canyon is covered by landslides.
include a wide variety of pebbles of black chert, quartzite, and volcanic rocks derived from the Sierra Nevada. In the vicinity of the type section in Kirker Creek, a shell layer is present at the top of the conglomerate and contains clams, gastropods and occasional vertebrate remains. The conglomerate represents an incised valley fill at the base of a lowstand systems tract and, as a result, it is very variable in thickness across the region. Since the conglomerate is weakly cemented, it is not well exposed but can be seen in occasional stream gullies. The remainder of the section of the Kirker Formation at the type section was divided by Primmer (1960) into a lower sandstone some 43 meters (140 feet) thick and an upper fine grained volcanic tuff that is 48 meters (175 feet) in thickness (fig. 7). Numerous fossil clams and gastropods have been described from these units in this area. When the formation is traced a short distance westward, it is found to be absent in the section on the west side of the Kirker Pass fault. This is possibly due to uplift and erosion in Miocene times associated with renewed activity along the fault.

When traced eastward from the type section to Markley Canyon, the Kirker Formation gradually thins to 70 meters (240 feet). The best exposures of the basal conglomerate in the vicinity of Black Diamond are in the gullies in section 34, T.2N R.1E to the east of Sidney Flat. The formation is well displayed in the quarry on the west side of the canyon and is made up predominantly of tuffaceous shallow marine and estuarine sandstones which are often cross-bedded and highly bioturbated (fig. 8). Interbedded mudstone units in the succession contain abundant plant debris as well as spore and pollen assemblages. The upper volcanic tuff unit, which is well developed in the type section, is only thinly represented in the canyon by 9 meters (30 feet) of tuffaceous siltstones, interbedded sandstones and conglomerates. This change in facies is due to the section becoming less marine eastwards and increasing amounts of sandstone appear in the succession. It may also be due, in part, to erosion below the unconformity at the base of the Cierbo Formation. This facies trend continues and a few miles to the east from Markley Canyon, in the eastern part of section 34 T.2N. R.1E., the Kirker Formation is predominantly made up of fluvial sandstones and gravels.

Sarna-Wojcicki (1993, pers. comm.) did a detailed chemical analysis of the volcanic tuff from the upper part of the Kirker Formation in the Thomas Ranch section immediately west of Markley Canyon. His study concluded that the Kirker tuff is very similar to late Tertiary and Quaternary tephra layers from Snake River Plain-Yellowstone area of Idaho and western Wyoming. Among the close matches are tephra layers from the Carbona Formation west of the town of Newman on Interstate 5. They correlate, in turn, with tephra layers found in the Valley Springs Formation on the east side of the Great Valley.

**Cierbo Formation**

The Cierbo Formation of Miocene age unconformably overlies the Kirker Formation. The Cierbo Formation reaches its maximum thickness of 120 meters (390 feet) immediately east of the Kirker Pass fault. The formation can be divided into a lower unit, which is made up of brown sandstones and conglomerates approximately 57 meters (185 feet) in thickness, and an upper gray channel, cross bedded, tuffaceous sandstone unit 63 meters (205 feet) thick. Clasts in the section includes black argillites, black cherts, white quartzites, and volcanic rocks that indicate an origin in the Sierra Nevada. A cross- bedded, white weathering, pumiceous sandstone bed in the basal part of the upper unit is an excellent marker.
WEST TO EAST SECTION OF THE NEROLY FORMATION

KELLER CANYON
Sec. 23, 24 T2N R1W

KEY

- Rhyolitic breccia
- Conglomerate
- Pebbly sandstone
- Cross-bedded sandstone
- Bedded sandstone
- Bioturbated sandstone
- Siltstone - mudstone
- Tuffaceous siltstone/sandstone

Resistant Unit
Iron concretions
Clams
Marker Bed

100
50
0
FEET

500
400
300
200
100
0
FEET

NEROLY FORMATION

CERBO FM

KIRKER CREEK WEST
Sec. 25 T2N R1E

MARKLEY CANYON
Sec. 33 T2N R1E

LAWLOR TUFF
Recessive unit
Top of ridge Clams
Petrified wood
Iron concretions
Clams
Resistant Unit
Cross-bedded sandstone
Bedded sandstone
Siltstone - mudstone
Tuffaceous siltstone/sandstone
Bioturbated sandstone
Iron concretions
Clams
Resistant Unit
Cross-bedded sandstone
Bedded sandstone
Siltstone - mudstone
Tuffaceous siltstone/sandstone
Bioturbated sandstone
Rhyolitic breccia
within the Cierbo Formation (fig. 9). The Cierbo Formation, also, contains an abundant and rich assemblage of clams, gastropods and sand dollars and indicates a shallow marine environment of deposition. Estuarine channel tuffaceous sandstones become increasingly important in the upper part of the formation, particularly in the Kirker Creek area, where they form massive cross bedded channelized units. The Cierbo Formation thins eastwards to about 48 to 65 meters (175-210 feet) in the Markley Canyon section.

Neroly Formation

The Neroly Formation unconformably overlies the Cierbo Formation. The formation is a very prominent ridge forming unit at the northern end of the Preserve. It is composed of dark gray, often poorly sorted, volcanioclastic sandstone and mudstone units of predominantly fluvial origin. The Neroly Formation reaches a maximum thickness of about 168 meters (550 feet) in the section immediately east of the Kirker Pass fault and thins abruptly westward across the fault to about 98 meters (320 feet) in the Keller Canyon Landfill (fig. 9).

At the base is a green tuffaceous mudstone bed about two feet in thickness which locally serves to mark the base of the formation. It separates the predominantly estuarine/shallow water marine units of the Cierbo Formation from the fluvial/non-marine deposits of the Neroly Formation. Dark brown iron concretionary beds are developed in the sandstone beds above the contact. East of Markley Canyon there is a marked discordance between the Neroly and the underlying Cierbo Formation. The Neroly Formation is rich in fossil leaves and petrified wood. The volcanioclastic sandstones are about 92 meters (300 feet) thick in Markley Canyon and are overlain by a recessive non-marine volcanic clay unit with interbedded sandstones. This unit is about 62 meters (200 feet) in thickness in Markley Canyon and can be mapped eastward to Contra Loma Reservoir and westward to Kirker Pass. A thin marine bed is present near the top of the formation in the section east of the Kirker Pass fault and in the middle of the formation in Markley Canyon.

Pliocene Stratigraphy

The Lawlor Tuff (4.5 Ma) unconformably overlies the Neroly Formation. In Markley Canyon a multisourced conglomerate occurs at the base of the Lawlor Tuff. The basal conglomerate includes large boulders of vesicular basalt, red and black chert, tan quartzite, and porphyritic volcanic rocks. The overlying beds are made up of light brown colored rhyolitic breccia and pumiceous tuffs which attain a thickness of about 52 meters (170 feet) in sections west of Black Diamond Mines Regional Preserve. The unconformity at the base of the Lawlor Tuff is well displayed in outcrops immediately east of the Kirker Pass fault where the tuffs can be seen cutting downwards into beds of the underlying Neroly Formation. Overlying the Lawlor Tuff is a thick succession of non-marine clays, silts and sands that have been assigned to the Wolfskill Formation.

Basaltic lava of Pliocene age has been found in scattered surface outcrops to the west of the Black Diamond Mines Regional Preserve in the Keller Canyon Landfill Site and the Concord Naval Weapon Station. The basalts show a very distinct flow banding and many of the flows have vesicular tops. Studies by USGS have a date of 4.8 Ma for those lavas in
the Concord Naval Weapon Station where they rest on the Markley Formation of Eocene age. A younger age is suggested, however, since identical basaltic flows overlie Lawlor Tuff (4.5 Ma) in the Keller Canyon Landfill a few miles to the northwest. Preliminary studies indicate that the basalts in the Naval Weapon Station occur as flows along old drainage channels. The basaltic lavas in this area have been step faulted up the hills on the east side to a height of 1100 feet. Basaltic lava has also been reported by Hoffman (1992) at the base of the Wolfskill Formation of Pliocene age in wells in the Los Medanos gas field.

CONCLUSION

The Tertiary succession in the Black Diamond Mines Regional Preserve is one of the most complete sections of this time interval in the Coastal Ranges. The area is the type location for many of the classical Tertiary stratigraphic units including the Nortonville Shales, Sidney Flat Shales, Markley Formation, Kirker Formation and Lawlor Tuff. The succession records the geological history of deposition in an active subduction-trench arc system of the early Tertiary to a predominantly transform setting in late Tertiary time. Major stratigraphic changes are recorded at the base of the Domengine Formation, Kirker Formation and Lawlor Tuff. The overall pattern of deposition is the filling of a large and deep forearc basin that today forms the Great Valley of California and the Coast Ranges. The succession and its biota also records the gradual change from the subtropical warm and moist climate of Eocene time to the cooler and drier climates of later times.
FIELD TRIP: THE BLACK DIAMOND MINES REGIONAL PRESERVE, CONTRA COSTA COUNTY, CALIFORNIA.

Black Diamond Mines is a 4000-acre natural and historic preserve, one of 61 parks and Regional Trails administered by the East Bay Regional Park District. As a natural preserve, Black Diamond provides an environment that supports a wide variety of plants and animals, including rare and endangered species. The Preserve is also an ideal location for the study of the classical geology of the northern Mount Diablo Range, making it a popular field trip and research site for educational, governmental and professional groups.

Black Diamond Mines Regional Preserve is reached by taking Highway 4 to the Somersville Road exit and continuing south to the park entrance in Markley Canyon.

STOP 1. PRESERVE HEADQUARTERS SIDNEY FLAT

The headquarters are located at Sidney Flat, a mile north of the mine workings. The earliest coalfield settlement was established here because of the availability of potable water. Following the building of a railroad in 1866, water could be transported to the mine sites. Sidney Flat residents moved to the new town of Somersville, which was centered around the workings, and Sidney Flat became a "red light district".

Five mining towns were eventually established on the coalfield. Somersville and Nortonville were the largest settlements and prospered to become the most populous in the county (fig. 11). When the mines closed, the towns quickly died and many of the structures were relocated to nearby communities. To preserve the architectural heritage of the mining era, six structures, including four believed to be original to the coal towns, were moved to Sidney Flat and renovated for use as Preserve Headquarters.

The strike valley in which the headquarters are located is developed in the Sidney Flat Shale Member of the Markley Formation (Plate 1). The beds are dipping about 35 degrees northward and striking to the WNW. Exposures of Sidney Flat Shale and Upper Markley members can be observed in the creek bed on the west side of the road. Landslides are frequently developed in the strike valleys of the Preserve and several examples can be seen at Sidney Flat. Distal turbidites and shales in the lower part of the Sidney Flat Member are exposed in the southern end of the creek. Carbonate concretions in the shales yield a rich microfossil assemblage and forams are visible through a hand lens. White siliceous shales of the upper part of this member crop out in the creek a few hundred yards downstream. These more resistant siliceous rocks form a strike ridge in the middle of the valley on either side of the highway. The brown mudstones of the Upper Markley Member abruptly overlie the Sidney Flat Shale at the northern end of this exposure. Details of the biostratigraphy of this part of the section has been described by Jeffries (1983). The overlying Kirker, Cierbo, Neroly formations can be seen in road cuts in Markley Canyon at the northern boundary of the Preserve and in the quarry on Devil's Mountain Ranch (Plate 2). Landslides at the head of the narrow canyon complicate the succession. The succession is, however, particularly well exposed on the west side in the quarry on Devil's Mountain Ranch outside of the boundary of the Preserve (fig. 8 and Plate 2).
Fig. 10  Shell Ginochio #1 was drilled in 1963 south of Sidney Flat to a depth of 10,026 feet.
PLATE 1

UPPER PHOTOGRAPH

View looking southeast across the old town site of Somersville which in its boom days had a population of about 900 people. Oxidized refuse dumps mark the location of the old coal mining operations. The sites of former residences can still be identified by the exotic trees that are scattered along the valley floor. The valley in which the town is situated is developed in Nortonville Shale. The valley follows the strike of the beds and the overlying sandstone units in the Lower Markley form the resistant ridge to the northeast (left). Exposures are poor but a change from clay-rich adobe to a sandy soil enables the contact to be drawn at the base of the ridge. The junction with the underlying Domengine Formation is drawn along the base of the brush covered hills to the southwest (right). The trail extends south-east along the valley and gradually climbs to Stewartville Pass where it provides a spectacular view of the southern parts of the Preserve.

LOWER PHOTOGRAPH

View looking northeast across the old town site of Sidney Flat and the present day location of the headquarters of the Preserve. On the east side of the valley, adjacent to the highway, can be seen the old railroad bed that connected the mines at Somersville to the dock facilities on the San Joaquin River to the north. The valley in which the headquarters are located is developed in the Sidney Flat Shale. The more resistant diatomaceous shales are the upper unit of this member and they form a minor ridge in the valley. The trail eastward from the headquarters follows this ridge and provides access to the eastern limits of the Preserve. The contact between the Sidney Flat and overlying Upper Markley members can be seen in the creek bed west of the headquarters. The main ridge overlooking the headquarters to the north contains the stratigraphic units that overlie the Eocene succession. Exposures are once again poor but occasional outcrops on the ridge enable a correlation with the well exposed section in Markley Canyon. The main part of the ridge is made up of Upper Markley at the base and Kirker and Cierbo formations above. The Neroly Formation appears as the top most cap rock for the ridge but the main part of this unit forms the next ridge to the north. The best exposures of Neroly Formation are on the westward continuation of this ridge on the other side of the canyon.
Field Trip Stop No. 2
Somersville Sand Mines
CONTRA COSTA COUNTY, CALIFORNIA
DOMENGINE FORMATION -
IONE MEMBER (UPPER "WHITE SANDSTONE")

Map based on Brunton & tape survey
by John Waters, East Bay Regional Park District
PLATE 2

UPPER PHOTOGRAPH

This view of Markley Canyon shows the outcrops of the upper Tertiary stratigraphic units along the west side of the creek. The Kirker Formation at the base of the section is well displayed in a small quarry at the extreme south (left) of the photograph. The Cierbo Formation unconformably overlies the Kirker Formation and can be divided into a lower brown weathering sandstone and conglomerate unit and an overlying gray tuffaceous channel sandstone unit. Fossils are fairly common in the Cierbo Formation which includes specimens of the large oyster Ostrea bourgeoisi. The junction between the Cierbo and Neroly formations is located at the appearance of dark gray, volcaniclastic fluvial sandstones in the succession. Fossil leaves and wood are common in the fine grained tuffaceous mudstone and siltstone units within the Neroly Formation. A marine unit in the upper part of the Neroly occurs at the top of the ridge in the upper right of the photograph. Several small north-south vertical faults displace the section along the westward continuation of this ridge.

LOWER PHOTOGRAPH

This is a close up of the basal part of the section illustrated in the previous photograph. It shows the contact between the Kirker and Cierbo formations in the small quarry on the west side of Markley Canyon. The quarry is located outside of the park boundary on the property of Devil's Mountain Ranch. The upper part of the Kirker Formation is seen in the photograph. The tuffaceous sandstones to the left of the talus are highly bioturbated and contain poorly preserved clam molds including specimens of Acila. Overlying these beds, above the talus, is the white volcanic tuff unit with interbeds of lenticular conglomerate and sandstone beds at the top of the Kirker Formation. There is an erosional unconformity at the base of the overlying Cierbo Formation.
STOP 2. SOMERSVILLE

From the headquarters, the road follows the floor of Markley Canyon and occasional exposures on the hills on either side are in massive turbidite sandstone units of the Lower Markley Formation. A prospect tunnel in the hills on the east of the road is located within this part of the section. The valley in which Somersville was situated is developed in Nortonville Shale. The contact of Markley Sandstone and Nortonville Shale is at the base of the ridge that rims the north side of the valley (Plate 1). Exposures are poor, but the change from a sandy to clay-rich adobe soil provides a means for mapping the contact. The railroad bed that connected the Somersville mines to the coal docks on the San Joaquin River is visible on the east side of the valley.

Little remains of the former town of Somersville which in its boom days had a population of about 900 people. The Union, Manhattan, Eureka, Independent and Pittsburg Mines were located here. The latter three were eventually consolidated under the Pittsburg Mine Company, one of the two largest operations on the coalfield. The town grew around the mines, which can be identified by oxidized waste dumps. Building sites can be identified by exotic trees such as black locust, almond, eucalyptus, pepper tree, Chinese tree of heaven and Italian cypress. Somersville is a good central point for trails to all parts of the Preserve (fig. 11).

**Lower Chaparral Loop Trail**

This trail climbs up from the valley floor following the north-south canyon system that dissect the ridge of Domengine Sandstone. Calcareous sandstone and shale of the “Brown Sandstone” is exposed as the trail enters the mouth of the canyon. The western loop follows along the strike of these beds until the Greathouse Portal is reached. At this point the trail turns into a steep sided canyon with excellent dip sections of the upper part of the “White Sandstone” to the crest of the ridge. The Clark Vein within the “White Sandstone” was worked in the canyon and a refuse dump is present at the entrance to this mine. The canyon opens at its head with less resistant sandstone units in the lower “White Sandstone”.

The trail loop descends into the canyon containing the Hazel-Atlas Portal. As the canyon narrows, massive cross-bedded, light-colored, quartzose sandstones of the upper part of this sequence are again displayed along the trail. Some of the sandstone units are bioturbated as evidenced by numerous iron stained burrows. These quartz-rich, well-sorted sandstones were mined and quarried for foundry and glass sand in the area, and they are best displayed in the underground mine walk. The Clark Vein is poorly exposed on the ridges on either side of the canyon.

**Underground Mine Walk**

Silica sand mining began in the early 1920s. The original operation in Somersville was at the Greathouse Portal, off the Chaparral loop. Mining was later expanded by the Hazel-Atlas Company to this site. The Somersville mine produced glass making sand, while the Nortonville mine was developed as a source of foundry sand. Mining operations are described by Waters (1978) and Sullivan and Waters (1980). Sand mining operations ceased
PLATE 3

UPPER PHOTOGRAPH

View looking west from Nortonville road of exposures in the canyon south of the town site of Nortonville (Stop 4). The Eocene formations are dipping northward (right). The "White Sandstone" ridge is on the extreme south (left) of the photograph and is covered with chaparral. The grass covered slopes above is formed by the "Brown Sandstone" and the dip slope at the top of the unit is easily recognized by its cover of oak trees. The last ridge on the north side (right) is formed by a sandstone in the middle of the Nortonville Shales.

LOWER PHOTOGRAPH

View looking south along Markley Canyon and the valley of Sidney Flat beyond (Stop 1). The Tertiary formations are dipping northwards (down the canyon) and the canyon is cut into the resistant sandstones of the Kirker, Cierbo and Neroly formations. Above Somersville road is a trail that leads north from the Preserve Headquarters at Sidney Flat. The trail can be seen descending the canyon and meets the old railroad bed near the lower left corner of the photograph. The railroad from the coal mines at Somersville entered above the head of the canyon in a short tunnel that has now been closed and filled. The rocks along the east side of the canyon are mainly tuffaceous brown sandstone of the Kirker Formation. The section, however, is complicated by landslides and better exposures are in the quarry on the west side in Devil's Mountain Ranch.
PLATE 4

UPPER PHOTOGRAPH

Photograph taken in the Hazel Atlas Portal (Stop 2) of cross beds in the upper part of the "White Sandstone". Organic rich mud drapes are common on foreset laminae. Unidirectional reactivation surfaces are present between cross beds. Numerous Ophiomorpha nodosa pelletal lined burrows can be seen in the sandstone beds. Ophiomorpha represents the dwelling burrows of decapod crustaceans, including numerous species of thalassinidean shrimp. It is commonly associated with the Skolithus ichnofacies which are found in marine shoreface, estuarine and tidal shoal environments.

LOWER PHOTOGRAPH

Fault is in the upper part of the "White Sandstone" in the Hazel Atlas Portal (Stop 2). This is one of a series of small N-S faults that cut through the Domengine section in this area. The photograph shows highly sheared shales in the fault zone. Sandstone units are also highly veined, fractured and mineralized in the vicinity of the fault. These small near vertical faults caused problems during coal mining operations and also limited the work of the glass sand. This fault can be trace through some parts of the underground workings. The highly fractured sandstones at the end of the Greathouse room on the A level of the mine is probably the result of the nearby location of this fault.
in 1945 with an estimated total production of 500,000 tons. Since about 1973, East Bay Regional Park District has been developing these workings as an underground mining museum.

The Hazel-Atlas Portal is located stratigraphically near the top of the "White Sandstone". The beds are striking approximately east-west and dipping 35-40 degrees northwards. The main haulage level trends southward into the hills and for the first 75 meters (250 feet) it follows the dip of the beds, exposing older units along its length (fig. 13). About 30 meters (100 feet) into the mine, the gangway cuts across a thin coal seam and carbonaceous shale of the Clark Vein in the upper "White Sandstone". This part of the old coal workings was mined about a century ago. The coal was accessed by a gangway from the Eureka Slope, an incline driven from the surface in the next canyon to the west. The old wooden supports have collapsed under the weight of overlying sandstone causing the rock mass to settle and close the space.

The main haulage level turns west about 90 meters (200 feet) from the entrance to follow the strike of the beds (fig. 12). Sandstones exposed in the haulage level are typically cross-bedded and well-sorted while other beds are highly burrowed (fig. 13 and Plate 4). A unit containing oscillation ripple marks is exposed in the roof of the haulage tunnel. Numerous plant fossils and burrows are preserved in the associated shales.

About 90 meters (300 feet) along the western end of this part of the haulage level, the gangway narrows and the sequence is disturbed by a north-south trending, high angle fault. This fault may be observed at the surface on the Chaparral Loop Trail near the Hazel Atlas Portal. Highly sheared shale is present in the fault zone and mining operations avoided the disturbed section (Plate 4).

The room and pillar method of mining can be seen in the workings west of the fault. Extraction of the sand was highly mechanized and dynamite was used to break out large sections of rock. A slusher (winch) in an upper machinery drift or gangway operated a slusher bucket (scraper) to drag sand down the incline to a haulage drift. At the drift, sand was loaded into cars and hauled to the surface. This method of mining created huge underground caverns 9 to 12 meters (30 to 40 feet) in dimension. The largest of these rooms is 245 meters (800 feet) in length. Massive pillars of undisturbed sandstone were left for support. Miners regularly sound test exposed surfaces for weak and loose sections which are sealed off for safety.

The remainder of the mine beyond this point is still in the developmental phase. A replica of the old coal mine is planned for the lower level which will be accessible by the wooden stair case seen below. This lower haulage level trends northward and exists at the Greathouse Portal. The gangway parallels the dip of the beds and two coal seams are present in the upper "White Sandstone" near the southern end of the gangway (fig. 14). The stratigraphically lowest of these is a one foot seam overlain by five feet of carbonaceous shales. The tunnel roof is unstable at this location due to the break up of shale and seepage of groundwater along this impervious unit. About 40 feet stratigraphically above this seam is another coal seam that has been identified as the Clark Vein. A side passage midway along the level leads to the Eureka Slope and old mine workings. High levels of carbon dioxide and
FIG. 13
Section of the upper part of Domengine Formation exposed in the adit of the Hazel-Atlas sand mine, Somersville, Sec.9 and Sec.4, T1N, R1E.
STOP 2 SECTION EXPOSED IN THE GREATHOUSE PORTAL
AND NEAR BY CANYON

Fig. 14
Section measured in the adit of the Greathouse Portal and along trail on NW side of ravine, Somersville in Sec.4 and Sec.9, T1N, R1E.
(After Bodden, 1981)
other gases sometimes are encountered rising from below. A short distance toward the mine entrance, another side excursion views the original sand operations of the 1920's in the "Greathouse room". This large cavern was named after Marvin Greathouse who was the mine owner and operator at that time. A visitor center is planned for this site. Blackened roof and walls of this room are evidence that, before the inclusion of these mines into the East Bay Regional Park District, local teenagers once freely roamed these dangerous tunnels. The "Shaly Member" is encountered near the entrance and from this point to the surface the tunnel is lined with timber to prevent caving of the shale.

STOP 3. NORTONVILLE PASS

The Nortonville Trail can be followed westward and climbs the grade to Nortonville Pass. Many business establishments were located on the south side of the road. The road in the lower part follows close to the contact of "Brown Sandstone" and Nortonville Shale. "Brown Sandstone" outcrops on the hillside to the south and a bed near the top of the formation is rich in fossils including corals, bivalves and gastropods. Nortonville Shale is exposed in the sharp bend in the road below Rose Hill Cemetery.

Rose Hill Cemetery

The Protestant burial ground of Rose Hill Cemetery is located between the settlements of Somersville and Nortonville. About 200 miners and their families were buried on this site during the latter part of the last century. A large number of the graves belong to Welsh settlers who left their homeland to start a new life in California. Many of their children died from diseases such as smallpox, diphtheria, typhoid and scarlet fever that were widespread in these coal mining towns. Gravestones also reveal that many workers died in mining accidents. The majestic Italian cypress trees are believed to have been planted during the coal mining era.

Summit of Pass

The Pass provides an overview of the coalfield. Looking eastward, the town site of Somersville can be located in the valley below by the refuse dumps around the old mines (Plate 1). A change in strike of the beds can be demonstrated as the valley formed in Nortonville Shale curves southeastwards beyond the town and rises to Stewartville Pass (Stop 8). The rugged brush covered hills to the southeast are formed in the "White Sandstone" of the Domengine Formation. The steep grass covered dip slopes above, with scattered oak trees, are developed in the overlying "Brown Sandstone". The contact of the Nortonville Shale and the ridge-forming Markley Formation can be traced at the base of hills that border the north side of the valley.

The town of Nortonville is in the valley to the west. The head of a recent landslide exposes an almost complete section of the lower unit of the Nortonville Shale. It is overlain by light-colored quartz-rich, sandstone in the middle of the formation that is exposed immediately below the Pass. The upper shale unit is mainly covered by slides on the north side of the valley. Nortonville Shale can be followed beyond the town site where the middle sandstone unit forms a prominent ridge (Plate 3).
FIG. 15  SECTIONS OF DOMENGINE FORMATION AT SOMERSVILLE AND NORTONVILLE
After Bodden (1981)
STOP 4 COAL CANYON, NORTONVILLE

Section exposed in Nortonville Sec.5, T.1N., R.1E.
At Nortonville Pass, the Black Diamond Trail leads off to the more remote western areas of the Preserve. The trailhead is situated near the contact of the Nortonville Shale and "Brown Sandstone" Member. The trail provides access to good exposures of the various units within the Domengine Formation including sections of the Black Diamond Vein. Meganos "C" is present below the unconformity at the base of the Domengine Formation. The field trip will return to Nortonville Pass on this trail after visiting the western exposures of Stops 5, 6 and 7.

STOP 4. TOWN SITE OF NORTONVILLE

The main mines operating at Nortonville were the Black Diamond, Mt. Hope and Cumberland which were eventually consolidated under a single ownership, the Black Diamond Company. A railroad, connecting the mines to the San Joaquin River, ran through the narrow canyon north of the town. Mining operation at Nortonville closed in 1885 and the company moved its coal operations to Washington Territory. The settlement, which at its peak had a population of about 1,400 residents, became a ghost town overnight.

This is the area of the type section of the Nortonville Shale. Coal Canyon south of the town site displays a complete succession of the Domengine Formation and the overlying Nortonville Shale (fig. 15). At the mouth of Coal Canyon is a section of "Brown Sandstone" which shows the coarsening upward sequence from the "Shaly Member" to the overlying sandstones. Hummocky cross bedding can be seen in some of the sandstone beds (fig. 16). The canyons steepens at the contact with the "White Sandstone". Mine workings and exposures of the Clark Vein are present near the mouth of the canyon. The trail climbs into Coal Canyon and crosses the lower part of the "White Sandstone". Mine workings in the Black Diamond Vein are near the head of the canyon.

STOP 5. BLACK DIAMOND WAY

Black Diamond Trail extends westward from Nortonville (fig. 11). The trail follows close to the base of the "Brown Sandstone" as it climbs up the valley. Eventually the trail intersects a paved road, Black Diamond Way, that services the radio towers on the hills south of the Preserve. A small quarry at the trail junction exposes the topmost beds of the "White Sandstone". Continue south on Black Diamond Way and, as the road winds up the hill, coal workings can be seen in the Black Diamond Vein. A stop will be made to observe the unconformable contact between the Meganos "C" Shale and the Domengine Formation (fig. 17). The contact is exposed in the gullies below the bend in the road and the base of the Domengine is marked by a thick fluvial channel conglomerate unit. The location of Black Diamond Vein can be located, once more, by old mine workings along the base of the hill. A section of lower "White Sandstone" is well exposed above the coal. Parasequences of channelized estuarine sandstones and carbonaceous shales are typical of this part of the succession. The upper "White Sandstone" forms a massive cliff above the valley and at the top of the ridge are working in the Clark Vein.
STOP 5

FIG. 17 SECTION OF DOMENGINE FORMATION EXPOSED IN THE WESTERN MARGINS OF BLACK DIAMOND MINES REGIONAL PRESERVE IN NW OF SECTION 8, T11N, R1E
STOP 6  

Fig. 18  SECTION ALONG BLACK DIAMOND TRAIL  
Sec.9 T.1N R.1E  

TOP OF RIDGE  

KEY  

- Conglomerate  
- Channelized sandstone  
- Pebbly sandstone  
- Bedded sandstone  
- Bioturbated sandstone  
- Cross bedded sandstone  
- Concretionary sandstone  
- Carbonaceous Shale  
- Coal  

FEET  

<table>
<thead>
<tr>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

CLARK VEIN?  
Cliff forming unit  
Iron concretions  
Covered by Talus  
Plants  
Iron Stained  
Petrified wood  
Black Diamond Vein  

UPPER WHITE SANDSTONE  
LOWER WHITE SANDSTONE  
DOMENECH FORMATION
STOP 6. BLACK DIAMOND TRAIL SECTION

The Black Diamond Trail will be followed eastward back to Nortonville Pass (fig. 11). The trail winds its way along the side of the valley and provides excellent views of massive cliffs of the "White Sandstone" that forms the ridge to the north. A stop will be made as the trail intersects this ridge about a mile from the turn off from Black Diamond Way. A short climb up the ridge on the north side of the trail provides access to one of the best sections of lower "White Sandstone" in the Preserve (fig. 18). This section can be correlated with the units seen at Stop 5. Once more, a basal conglomerate marks the base of the Domengine Formation and the Black Diamond Vein can be located by mine workings.

STOP 7. BLACK DIAMOND TRAIL VIEW POINT

Black Diamond Trail swings northwards from Stop 6 and cuts through the "White Sandstone" section as it climbs up to Nortonville Pass. A stop on a topographic bench developed on top of the "White Sandstone" provides an excellent panorama of Somersville and the hills to the north (fig. 19). Hummocky cross bedded sandstone units of "Brown Sandstone" are exposed on the north side of the trail.

STOP 8. STEWARTVILLE PASS

The field trip returns to Somersville and follows the Stewartville Trail to the southeastern part of the Preserve. The trail follows the Nortonville Shale valley to the head of the Pass.
The main residential district of Somersville was located on this side of the valley and the shade trees mark the former building sites. The land below the town was extensively mined.

There is a spectacular view from the Stewartville Pass across the valleys and hills in the south of the Preserve. This area was the location of the Meganos Canyon. The low hills on the south side of the valley are made up of the canyon fill facies of the Meganos Formation. The Hamilton Formation and the overlying Domengine Formation form the ridge on the north side.

The sudden change in topography, with the abrupt termination of the Nortonville Shale valley at the summit of the Pass, is an indication that a major east-west fault cuts the section at this point. The fault has been mapped as a detachment structure in the valley at the base of the Domengine ridge to the west. It then ramps up section in the narrow north-south gully below the Pass (fig. 20). The location of the fault can be determined by the offset of the formations on either side of the structure. The fault does not displace the overlying Markley Formation but reverts back to a detachment structure in the incompetent Nortonville Shale.

Several trails converge at Stewartville Pass. The Ridge Trail enters from the west following the "White Sandstone" and "Brown Sandstone" contact. It crosses the Pass and rises up the hill into the Markley Formation. The Miners Trail descends into Stewartville along the side of the Domengine ridge. Sandstones in the middle of the Nortonville Shale are exposed at the beginning of the trail and display flute marks on bedding plane surfaces.

STOP 9. STEWARTVILLE

From the Pass, the Stewartville Trail descends into the valley floored by shale units of the Meganos "C". The site of the Central Mine and the old settlement of Stewartville can be seen by the mine waste on the north side of the valley at the base of the strike ridge. The workings extended northward below the hills to reach the thin coal beds in the "White Sandstone". In addition to the Clark and Black Diamond veins, the Belshaw and Little veins, in the middle of the sequence, proved to be productive in the Central Mine. Faulting was a problem in these mines as it was elsewhere in the coal field, and small vertical faults are to be seen in the outcrops of the Domengine Formation above the town site.

The main drawback of the Central Mine was its isolation from railroad and docking facilities. The problem was initially solved by means of a 550 meter (1805 foot) tunnel driven north through this ridge that formed a barrier between Stewartville and the loading docks on the San Joaquin River, six miles away. In 1881, the Empire Railroad was extended to Stewartville, eliminating the need for wagon haulage. Mining activities ceased in 1897.

STOP 10. PROSPECT TUNNEL

Prospect Tunnel is located in the valley near the junction of the Stewartville and Star Mine trails. This tunnel was driven into the hills during the 1860's in search of commercial deposits of coal. It is about 122 meters (400 feet) in length and can be explored using a flash
light. About 60 meters (200 feet) into the adit a gate prevents access to the deepest part of the tunnel. The portal is mainly driven into the “Brown Sandstone” and a fault is encountered about 90 meters (300 feet) from the entrance. The fault in the mine brings upper “White Sandstone” against the “Shaly Member”. This fault can be traced to the surface and is best observed cutting the “White Sandstone” in the small quarry north of the Stewartville Trail. In its deepest section, the tunnel follows the strike of a thin lignitic bed in the upper “White Sandstone”. The “Shaly Member” is particularly well exposed in the tunnel and is made up of interbeds of shales, mudstones and thin bedded sandstones. Flaser, lenticular and cross bedded units are common and some beds have convolute bedding. The section coarsens upwards into more massive brown sandstones.

Prospect Tunnel area is a good location to explore trails into the southeastern corner of the Preserve (fig. 11).

**Star Mine Trail**

The Domengine Formation can be traced southeast from these exposures to West Hartley, the last of the coal settlements in the area. The Star Mine Trail leads to excellent exposures of upper “White Sandstone” in the Marchio Sand Quarry as described by Cherven and Bodden (1983).

**Oil Canyon Loop Trail**

Oil Canyon Loop Trail is accessible from the Stewartville trail in this area. The trail crosses the early Tertiary sequences below the Domengine Formation as described by Cherven and Fischer (1984). A panoramic view from the overlook at the crest of the hills displays the geology of Deer Valley and Stewartville Ridge.
SEQUENCE STRATIGRAPHY TERMS

The following definitions are from Van Wagoner et al. (1990) and Campion et al. (1994).

• **SEQUENCE STRATIGRAPHY** is the study of sedimentary rocks within a framework of chronostatigraphically defined significant surfaces. The sequence is composed of parasequences and parasequence sets. Sequences are interpreted to form in a single cycle of relative change in sea level. (see fig. 21)

• **SEQUENCE**: a relatively comfortable succession of genetically related strata bounded by unconformities or their correlative conformities.

• **UNCONFORMITY**: A surface separating younger from older strata along which there is evidence of subaerial-erosional truncation and, in some areas, correlative submarine erosion, a basinward shift in facies, onlap, truncation, or abnormal subaerial exposure, with a significant hiatus indicated. Local contemporaneous erosion and deposition associated with geological processes such as point-bar or eolian-dune migration are excluded from the definition of unconformity.

• **PARASEQUENCE**: Sequences are composed of parasequences which are defined as a relatively conformable succession of genetically related succession of beds or bedsets bounded by marine-flooding surfaces or their correlative surfaces.

Parasequences are typically composed of an upward shallowing succession of facies. In the deltaic and shoreface setting, for example, parasequences are coarsening upwards, whereas, in the tidal setting parasequences fine upwards. Parasequence boundaries are essentially time lines and parasequence correlation can be used to construct a very accurate chronostratigraphic framework.

• **PARASEQUENCE SET**: A succession of genetically related parasequences forming a distinctive stacking pattern, bounded by major marine-flooding surfaces and their correlative surfaces. Parasequence stacking patterns within parasequence sets are progradational, aggradational and retrogradational. (see fig. 22)

  • **Progradational**: Basinward building of the shoreline, occurring when the rate of sediment supply at the shoreline exceeds the relative rise in sea level.
  • **Retrogradational**: Landward stepping of the shoreline occurring when the overall rate of sediment supply at the shoreline is less than the overall rate of relative rise in sea level.
  • **Aggradational**: Successive parasequences build out to about the same shoreline position, indicating that the rate of sediment supply at the shoreline approximately equals the overall rate of relative sea level rise.

• **SYSTEM TRACTS**: Sequences can be subdivided into systems tracts based on stratal patterns, bounding surfaces and parasequence distribution. Three kinds of systems tracts have been described based on stratal geometries; lowstand systems tract, transgressive systems tract, and highstand systems tract. The parasequences commonly encountered within these systems tracts are described below.
The **lowstand systems tracts** consists of basin-floor fan, slope fan, and lowstand wedge. The basin-floor fan and slope fan have no shelfal equivalent. The lowstand wedge is made up of one or more parasequences that exhibit progradational to aggradational stacking patterns. The proximal part of the lowstand wedge consists of incised valley and associated lowstand shoreline. The incised valleys are cut by fluvial systems during a relative fall in sea level. The fill within the incised valley is variable, but commonly includes fluvial and tidal facies.

The **transgressive systems tract** is bounded below by the transgressive surface and bounded above by the downlap surface or maximum-flooding surface. Parasequences usually display retrogradational stacking patterns. Stratal surfaces exhibit progressive onlap onto the sequence boundary, and downlap terminations shift progressively landward. The systems tract progressively deepens upward as successively younger parasequences shift landward.

The **highstand systems tract** is bounded below by the downlap surface and above by the next sequence boundary. The early highstand usually exhibits aggradational parasequence stacking, whereas the late highstand is composed of progradational parasequences. Stratal surfaces exhibit onlap onto the underlying sequence boundary and exhibit downlap in a basinal direction. Typically, updip, stratal surfaces are truncated by overlying unconformities, making the highstand systems tract subject to low preservation potential.

**Application of sequence stratigraphy**

Wagoner et al. (1990) pointed out some of the important differences between the approach used in sequence stratigraphy compared to those used in conventional lithostratigraphy.

Lithostratigraphy relies on the formations as the basic stratigraphic analysis and typically, they are grouped into transgressive and regressive packages. In most cases, formations are defined as discrete rock units independent of any chronostratigraphic framework. The methods used to broadly date the formational stratigraphy include biostratigraphy, radiometric dating and magnetostratigraphy. It is not uncommon to find that formations have one or more unconformably defined sequences boundaries within them. These boundaries commonly have 10’s of feet of erosional relief and separate rocks that have no genetic relationship. As a result, facies and paleogeographic reconstructions are constructed without a genetic framework.

In contrast, each of the bounding surfaces within sequence stratigraphy (bed, bedset, parasequence, parasequence set and sequence boundaries) have chronostratigraphic significance. When recognized, these surfaces can be used as time lines and provide a chronostratigraphic framework to analyze the enclosed facies. These differences are reflected in different interpretations of the evolution of the sedimentary succession.
Stratal Patterns in a Typical Sequence

Highstand Systems Tract: Aggradational to Progradational Parasequence Set

Transgressive Systems Tract: Retrogradational Parasequence Set

Lowstand Systems Tract, Lowstand Wedge: Progradational Parasequence Set

Lowstand Systems Tract, Lowstand Fan

Highstand Systems Tract of Older Sequence

Fluvial or Estuarine Sands Within Incised Valleys

Coastal-Plain Sands and Mudstones

Shallow Marine Sands

Shelf and Slope Mudstones and Thin Sands

Submarine-Fan and Levee-Channel Sands

Type-1 Sequence Boundary

Log Response of Lowstand Wedge and Underlying Sequence Boundary: Abrupt Vertical Change in Facies Produced by a Basinward Shift in Facies

Log Response of a Parasequence: Normal Vertical Association of Facies

200 Feet

10 Miles

(From J.C. Van Wagoner et al., 1990)
Typical stacking patterns of parasequences; cross-section and well-log expression. The stacking pattern is controlled by the rate of sedimentation and the rate of accommodation, which is related to eustatic sea level change and subsidence. Sediment supply is assumed constant in the formation of three stacking patterns.  

(From J.C. Van Wagoner et al., 1990)
BIBLIOGRAPHY


Section AAPG, SEG, SEP San Francisco meeting p. 25-33.
Dibblee, T.W., Jr., 1980a, Preliminary geologic map of the Antioch South quadrangle, Contra Costa County, California: Open File Report 80-536, USGS.

Dibblee, T.W., Jr., 1980b, Preliminary geologic map of the Clayton quadrangle, Contra Costa County, California: Open File Report 80-547, USGS.


Lagoe, M. B., 1988, An Evaluation of Paleogene paleobathymetric models: Benthic foraminiferal distributions in the Metrella Member of the Tejon Formation, Central California. in Determining Paleobathymetry, Palaeo p. 523-536.


<table>
<thead>
<tr>
<th>EPOCH/SERIES</th>
<th>MIDDLE</th>
<th>LOWER</th>
<th>PALEOCENE</th>
<th>UPPER CRETACEOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NW-SE Stratigraphic table showing relationships across the Midland Fault</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Midland Fault

BYRON
- Kellogg Shale
- Nortonville Shale
- Domengine Formation
- Capay Shale
- Hamilton Sandstone
- Deer Valley Formation

BRENTWOOD
- Sidney Flat Shale
- Markley Formation
- Nortonville Shale
- Domengine Formation
- Capay Shale
- Hamilton Sandstone
- Meganos Formation (restricted)
- Martinez Formation
- Mokelumne River Fm.
WEST TO EAST STRATIGRAPHIC SECTIONS SHOWING CHANGES ACROSS THE REGION

WEST
Keller Canyon

Markley Canyon
NEROLY FORMATION
CIERBO FORMATION
KIRKER FORMATION
U. MARKLEY MEMBER
SIDNEY FLAT SHALE

L. MARKLEY MEMBER
NORTONVILLE SHALE
DOMENGINE FORMATION

EAST
Kellogg Creek

MIDLAND FAULT

Meter Feet

300 1000

0 500
Coal occurrences have been reported in 47 of the 58 counties in California (Hildegard, 1978). Significant quantities of coal, however, have been mined in only a few areas of California—on slopes of Mount Diablo in Contra Costa County, at Corral Hollow in Alameda County, Stone Canyon in Monterey County, Ione in Amador County, and Alberhill in Riverside County. These deposits are of subbituminous or lignitic coal of Tertiary age. The total recorded coal production for California to 1966 was 5,310,000 tons. California coal resources have been estimated to be more than 100 million tons, of which 50% is lignite, 40% is subbituminous coal, and 10% is bituminous coal.

**MOUNT DIABLO COALFIELD**

The largest known and most extensively mined coal deposit in the state is the Mount Diablo coalfield located 56 kilometers (35 miles) east of San Francisco. The coalfield extends for about 17 kilometers (10 miles) in a narrow curved belt on the north slopes of Mount Diablo (figure 1). For almost half a century, from the 1860s to the beginning of this century, the Mount Diablo coalfield supplied coal to the rapidly expanding urban and industrial centers of the San Francisco Bay area. The coal in the Mount Diablo coalfield is lignite (12th Report of the State Mineralogist). It is reported to have a bright black luster, to be brittle, and to crumble readily to small fragments and dust on exposure to the air. It is estimated that the total coal production of the field was approximately 4,000,000 tons, valued between $15 and $20 million (figure 2). The most productive area of the coalfield is now within the Black Diamond Mines Regional Preserve of the East Bay Regional Park District.

**Geological Evolution of the Coal Deposits**

The tectonic and paleogeologic framework of the Mount Diablo area in early Tertiary times was different in many respects to that of today (Clarke and others, 1975; Nilsen, 1977). At the present time...
Figure 2. Mount Diablo coalfield production, 1861–1914. After Goodyear, 1877 and Reports of State Mineralogists 1884–1914.

The succession of middle to upper Eocene rocks contains the coal deposits and represents one of these depositional cycles. The cycle commenced with a broad uplift of the region accompanied by widespread erosion. A shallow sea encroached the region, extending as far inland as the foothills of the Sierra Nevada. Rivers, flowing out of the uplands, brought large amounts of sediment to the shelf sea. The rivers formed a series of deltas that gradually expanded westward from the land. These neritic and delta sand deposits make up a large part of the Domengine Formation (Todd and Monroe, 1968). The sediments in which the coal beds occur were deposited in coastal marshes when the climate was warm, humid, and favorable for the development of swamp vegetation.

The next phase of the cycle was marked by rapid subsidence of the region and deposition of mud and sand in a deepwater (bathyal) sea. These deposits are represented by the Nortonville Shale, lower Markley Sandstone, Sydney Flat Shale and the upper Markley Sandstone. The shales in the succession are rich in microfossils including foraminifers, radiolarians and diatoms. The depositional cycle was brought to a conclusion by renewed tectonic activity and uplift of the region, leading to the formation of the present Diablo Range.

The major tectonic framework of the region is determined by the right-lateral transform movement along the San Andreas fault marking the junction of the North American and Pacific Plates (Nilsen, 1977). In early Cenozoic time, however, convergence of the Pacific and North American Plates formed a subduction zone and submarine trench in the vicinity of the present coastal ranges north of San Francisco.

The modern paleogeographic units were located eastward from their present position during the early Tertiary Period (Atwater, 1970), when the North American Plate was being thrust westward over the Pacific Plate. The ocean extended inland, to the foothills of the Sierra Nevada, which formed a rugged upland east of the coastline. The continental shelf extended offshore over a large part of the present day Great Valley. In the area of the present Sacramento Valley, several submarine canyons were cut into the continental shelf at various times during the early Tertiary Period (Almgren, 1978; figure 3). A large submarine canyon, the Meganos Canyon, existed in the Mount Diablo area during the Paleocene before the formation of the coal deposits. This canyon was about 80 kilometers (50 miles) long, 2 to 13 kilometers (1/4 to 8 miles) wide, and over 600 meters (1,969 feet) in maximum depth. It was later filled by marine sediments represented in the succession by the channel-fill facies of the Meganos Formation (Fischer, 1979; figure 4). The size and extent of this ancient submarine canyon was determined from core samples of oil wells drilled in the Mount Diablo area and the southern part of the Sacramento Valley.

The important controls on the formation of submarine canyons and the sedimentation pattern during Tertiary time appear to be tectonic movements along geologic structures on the west and south side of the Sacramento Valley. Tectonic movements, involving uplift and subsidence of the seafloor, produced a cyclic series of events that are clearly recorded in the Tertiary rocks of the region. Four cycles of marine deposition have been recognized by Almgren (1978) extending from the Paleocene to the Miocene (figure 5). The pattern of marine sedimentation is thought to have come to an end when right lateral plate boundary movement was initiated along the San Andreas fault in Miocene time.

Figure 3. Generalized location, Tertiary Period submarine canyons, southern Sacramento Valley. The submarine canyons were cut into continental shelf at various times during the Tertiary. The Meganos Canyon was located in the vicinity of Mount Diablo during the Paleocene before the formation of the coal deposits. After Almgren, 1978.

52 California Geology March 1980
Present Geological Setting

The terrain where coal was found is extremely rugged with bold hills and steep narrow valleys and ravines. The rocks of the area are highly faulted and steeply dipping sandstones and shales of late Mesozoic and early Cenozoic (Tertiary) ages. Exposures are commonly masked by alluvium in the valleys and landslide and slope wash deposits on the hillsides. The coal beds are present within the Domengene Formation, a predominantly sandstone unit. The beds dip approximately 30° to the north.

Coal Veins

Two main coal seams—the Clark Vein and Black Diamond Vein—crop out in the hills. The Clark Vein is located in the upper part of the Domengene Formation and varies in thickness between 46 and 137 centimeters (1½ and 4½ feet). The coal is of poorer quality than the Black Diamond Vein. The Clark Vein was the most extensively mined of the coal beds (figure 6).

The Black Diamond Vein occurs 114 meters (375 feet) stratigraphically below the Clark Vein and is the thickest of the coal beds in the district, ranging between 2 and 5½ meters (6 and 18 feet) with interbedded shale and mudstone. Only the center part of the vein was of commercial value, however. Additional thin seams of commercially valuable coal are present locally in the succession. The most important of these is the Little Vein which occurs about midway, stratigraphically, between the Clark and Black Diamond Veins.

COAL DISCOVERY

General accounts of the presence of coal in the vicinity of Mount Diablo were circulated even before the gold discovery at Sutter's mill. A letter written in 1845 by Louis Gasquet, French Consul in Monterey, to French officials described abundant, good quality coal in the vicinity of San Pablo Bay. In 1848, when Charles Bennett stopped at Benicia while enroute to Monterey to secure for John Sutter the grant of land on which gold had been discovered in Coloma, he found the people of the town excited about a coal discovery near Mount Diablo.

The first well documented discovery of coal, however, was made in 1859 by William C. Israel at Horse Haven, about 10 kilometers (6 miles) south of Antioch. The discovery created some interest in the county, and other sites were soon found in the area. The prospecting was not done by coal miners but mainly by disillusioned gold seekers. They sampled and tested the coal and found the deposits to have commercial value.

COAL MINING TOWNS AND COMPANIES

Coal mining began in 1861. The main facilities of the mines were located in the valleys north of the coal outcrops and towns soon were established around the mines. The principal towns were Nortonville at the head of Kerker Pass, and Somersville in Markley Canyon. The smaller towns of Stewartville, west Hartley, and Judsonville, in Lone Tree Valley, were founded later in the southeastern portion of the coalfield (figure 7).

Nortonville (photos 1–3) was the largest town in the district and became the largest in the county at the peak of coal mining during the 1870s. Nortonville was near the Black Diamond, Cumberland, and Mount Hope mines and two short-lived operations of the Peacock and San Francisco companies. Eventually, the Cumberland and Mount Hope properties were purchased by the Black Diamond Company and they became the largest operation in the coalfield, accounting for more than a third of the entire production.

The town of Somersville was located in the broad basin at the head of Markley Canyon. Five main companies were located at Somersville—the Pittsburg, Manhattan, Union, Eureka, and Independent. The Pittsburg Company was the largest producer in the town and was second only to the Black Diamond Company in coal production. The Pittsburg mines were the last to close with major production ending in 1902 and final closure in 1907.

Details are not available for the number of men employed in the coal mines of Mount Diablo. Ballard (1933) reports...
made open cast mining impractical in the Mount Diablo coalfield and subsurface methods of mining were used to extract the coal (Goodyear, 1877; McMahon, 1882). The miners gained access to the coal seams by means of an adit (a nearly level tunnel), a slope (an inclined tunnel), or by a vertical shaft. The screening facilities and storage bunkers were located in the valleys near the townsites. The coal was hauled from the mines to docks on the San Joaquin River for transportation to San Francisco and other local markets.

Access

Adits, driven into the hillsides and intersecting the steeply dipping coal seams were used primarily in the early operations in the coalfield. Since most of the openings were driven in a southerly direction against the dip of the beds, mining commonly began on the Clark Vein and was extended later to the Little Vein and Black Diamond Vein (figure 8). The coal seam was developed along level gangways driven east and west from the adit following the strike of the coal beds. This method of mining had the advantage of requiring little mechanization, and therefore, a relatively small amount of energy was required to move the coal from the drawpoints, where it was loaded into the tram cars, and conveyed to the surface.

The Black Diamond Company’s first opening of the Black Diamond Vein was the upper Black Diamond Tunnel, a 129 meter (422 foot) adit (figure 8). It was located at a higher elevation than later adits in order to minimize its length to the

---

**MINING OPERATIONS**

Occurrence of the coal in steep terrain, along with the pronounced dip and massive overburden above the thin seams...
coal seam. Coal was hauled in trams to the portal and then moved down the hillsides by a surface inclined cable system (photo 1) over 275 meters (900 feet) in length, to screening and bunker facilities at Nortonville. Later, the Black Diamond Company extended their mining operations on both the Clark and Black Diamond Veins by driving another adit at a lower location near the townsite. This adit, the Clayton Tunnel (figure 8), had the advantage of having a portal situated close to the screening and bunker facilities.

The adit at the Central Mine at Stewartville was the longest on the coalfield and, unlike most openings, was driven in a northerly direction from beneath the line of the outcrops. The steep ridge between the mine and the coal distribution point on the San Joaquin River made haulage particularly expensive in the years before the railroads were constructed. To reduce transportation costs, this adit was driven 550 meters (1,805 feet) completely through the ridge, saving more than 3 kilometers (2 miles) of wagon haulage.

While adits were used in the early mining operations on the coalfield, the most common means of gaining access to the coal during most of the production period was by way of a slope, such as the Mount Hope Slope driven at Nortonville (figure 8). Slopes gained general use following the depletion of the coal deposits located in the hillsides above the townsite. The slopes enabled the mining operations to extend underground below the settlements, and had the advantage of reaching the coal in a shorter distance than by level adits. The disadvantage of the slopes, however, was that part of the mine’s coal production had to be used to fire the steam powered hoisting facilities needed to move the coal up the slopes to the surface. In the Eureka Mine, an early operation at Somerville, energy was minimized by utilizing a gravity cable system. The two skips that brought the coal up the Eureka Slope were connected so that the loaded skip hoisted up from the mine was partially counterbalanced by the descending empty one. The slopes were driven at a pitch of about 30°, and like the adits usually ran in to the south, first intersecting the Clark Vein. At the Central Mine at Stewartville, however, the longest slope on the coalfield was driven 366 meters (1,201 feet) in a northerly direction under and parallel to the Black Diamond Vein. Level tunnels were driven from four stations on the slope to provide access to the vein.

As coal above the slopes or adits was exhausted, counterslopes would be driven down along the dip of the coal from existing gangways, and lower gangways established. Underground hoisting machinery powered by steam plants on the surface would be placed at the head of these counterslopes, although in at least one mine, the Central, a horse-powered whim was at one time used for hoisting.

Adit and slope methods of mining were the most economical type to develop and operate. In the later stages of operations, when mining had reached to great depths underground, a vertical shaft from the surface was used as the most practical means of extending the workings.

The Independent Shaft was the first one sunk in the field and was considered notable for its poor planning and engineering procedures. When work on the shaft began in 1865, it was scheduled to reach the Clark Vein at 137 meters (450 feet) below the surface. A simple miscalculation of the dip of the beds had been made by the company. The Clark Vein at this site, at the northern end of Somerville, was in fact at a depth of 290 meters (951 feet). This was not realized until the shaft was abandoned at the 216 meter level (709 feet) without reaching the coal and instead, a level tunnel was driven 128 meters (420 feet) south where it encountered the Clark Vein. A large amount of coal was eventually removed from the Inde-
pendent Mine, but not enough to recover the estimated $150,000 expended in sinking the shaft.

The Black Diamond Shaft was sunk in Nortonville and by 1873 had reached the Lower Mount Hope Gangway on the Clark Vein. It was later extended toward the Black Diamond Vein, but the seam was not reached before the mine was closed in 1885. It was a three compartment shaft and was divided into a pumping compartment and two hoisting compartments, each fitted with a cage that carried two tons of coal.

Gangways

Once a coal seam had been reached by an adit, slope, or shaft, the mining method was essentially the same in all the operations on the field. Gangways were driven in both directions along the strike of the coal seams, either directly on or just below the coal. The longest of these gangways was the Black Diamond Gangway No. 1. It was driven on the Black Diamond Vein from the south end of the Clayton Tunnel for more than 1,200 meters (1/4 mile) to the west and east, for a total length of more than 2,400 meters (11/4 miles). These gangways required heavy timbering because they ran on or just under the unstable coal seams. On the Black Diamond Vein, an unstable clay shale, mudstone and slaty coal that the miners called "bone", formed the roof and floor of the gangway. In some places this material would swell when brought into contact with air and made it necessary to cut down the floor and retimber as often as every three months. Redwood and locally logged digger pine and oak were common timbering materials.

To minimize the effort and material used in driving these gangways, the dimensions were usually kept small with a clearance of as little as 1 1/2 x 1 1/2 meters (5 feet by 5 feet) inside the timbers. They were fitted with track that varied in type and gauge from mine to mine. Goodyear (1870) reported that early operations used strap rail exclusively, the gauge varying from 27 inches to 3 feet. By the mid-1870s, however, light "T" rail was coming into general use in gauges from 18 to 26 inches.

Ventilation

Part of the development of all the mines was the establishment of adequate ventilation through the workings. Since the amount of gas produced in most parts of the Mount Diablo mines was small and the dip of the coal beds steep, the process required only the running of vertical ventilator shafts from the gangways to the surface. This system allowed the difference in air temperatures inside and outside the mines to produce natural ventilating currents. At times it was necessary to keep coal fires burning at the base of the shafts to maintain a steady airflow because natural ventilation became insignificant when the outside temperature was close to that in the mine.

In spite of the relative ease of ventilating the mines in the Mount Diablo coalfield, the majority of serious accidents were caused by mine gases. Most of these accidents involved only one or two miners and the explosions resulted from the carelessness of an open flame. Explosions occurred when the miners entered a blind, unventilated tunnel where there was a buildup of methane gas in the workings. A few minor disasters, however, did occur in the coalfield. The largest of these was on July 24, 1876, when 11 miners were reported killed by a methane and coal dust explosion during the driving of a tunnel in the Black Diamond Mine.

Water in Mines

Water was also a nuisance underground, though only in the lower levels of the mines. Pumps or self-filling tanks, operated by hoisting machinery on the surface, handled the problem under normal conditions. During the winter months, or when an occasional underground spring was struck, the amount of water sometimes exceeded the capacity of the pumps and work would be suspended for days or weeks at a time. The large amounts of sulphates in the underground water made it too corrosive for use in the boilers, and its use for this purpose at the Independent Mine resulted in the boiler blowing up in 1873. Water for the mine plant and household use was normally brought in by railroad from the landings on the San Joaquin River. Eventually, the high cost
of pumping was a major factor in abandoning the mines.

Extraction Methods

When access from the surface had been completed, gangways driven on the coal seams, ventilation established, and pumping machinery put in place, the work of mining coal could proceed. The extraction of the coal was by a room and pillar method (12th Report of the State Mineralogist, 1893–94). The work was commonly done by a mining team consisting of an experienced miner and an assistant, usually a young boy, known as a nobber (figure 9). The team would dig openings about 1 meter (3 feet) square at intervals of about 9 meters (30 feet) along the gangways into the coal. The openings would be driven up and if a gangway had been established at a higher level, a connection made for ventilation. The miner would next enlarge the opening to provide access and working space and a low wood chute lined with sheet steel was installed from the gangway to the work area. Coal would then be removed from the walls of the opening for about 4½ meters (15 feet) on either side creating what was called a "room". These rooms extended as much as 180 meters (600 feet) to the next gangway above. This distance was known as a lift.

Next to the problem of gas explosions, being crushed by falling rock was the greatest danger to the miner. A pillar of coal was left next to the gangway to prevent its collapse, and other pillars were left at regular intervals throughout the work area to support the overlying rock. In addition to these pillars, the miner would install redwood props at whatever interval he felt was necessary to provide for his safety—often on 1 meter (3 feet) centers—and occasionally small redwood cribs were built for additional support. Coal would be mined in this fashion up to the next gangway above, or as high as the coal could be readily mined.

Power for moving the coal cars was provided by horses and mules in the larger mines, by manpower in the smaller ones. Once on the surface, the coal was transferred to bunkers, which were always located at the townsites. There the coal was screened into two commercial sizes known as dump coal and screenings, or small coal. The slack, that passed through the finest screen, was either dumped or used to fire the boilers that powered the mine plants. The largest of these bunkers was at the Black Diamond Mine and held almost 1,800 tons. No coal breaking machinery was used, and in fact the tendency of the soft coal to break down during shipment was a problem for the companies.

TRANSPORTATION

The methods used to transport the coal from the mines to the distribution points on the San Joaquin River changed considerably over the course of mining operations. Initially, coal was hauled by heavy wagons such as those used at the Central Mine, which held about 15 tons, and were pulled by 6-horse teams. This method was very expensive, and impossible in the winter months when the roads were muddy. The Black Diamond Company made the first improvement when it built a wood rail tram road. Coal cars were hauled by mules from the mine to the storage bunker at New York Landing (later called Black Diamond Landing, now the city of Pittsburg).

By the mid-1860s when the volume of coal had increased with mine development and demand, railroads were built from Nortonville to Black Diamond Landing and from Somersville to Pittsburg Landing, about 3½ kilometers (2 miles) east of the present city of Pittsburg (figure 7). Much later a railroad was completed linking the mines at Stewartville with the dock facilities at Antioch. The Black Diamond railroad of Nortonville and the Pittsburg railroad of Somersville were each about 9 kilometers (5½ miles) long and of standard gauge. Over the first half of the distance from the landings to the mines the grade was moderate, and did not exceed 2%. As the railroad route climbed into the canyons, though, the grade rose to just over 5%. A series of trestles, the largest 93 meters (304 feet) long and 18 meters (60 feet) high, and a 107 meter (350 feet) tunnel on the Somersville side, were needed to traverse the rugged terrain. The steep grade made it unnecessary to actually pull the coal trains to the river. Instead, they were allowed to coast down from the mines with careful attention paid to braking. Often, a coal train would make the trip down without the engine, which would be sent later to retrieve it for the next day's run. In rainy weather the tracks were washed so that the speed of the trains could be kept within safe limits. The Black Diamond railroad was abandoned when the mine was closed in 1885, but the Pittsburg railroad continued operation until after the turn of the century.

The Empire Mine railroad ran from the Central Mine at Stewartville to Antioch, with spurs to Judsonville, West Hartley and various other mine sites (photos 4, 5). It was about 8 miles (13 kilometers) long, of narrow gauge, and was completed to Stewartville in 1881. The maximum grade was 2%, much less than the Nortonville and Somersville railroads, but some small up-grades existed on the trip from the mines to Antioch. This made it necessary to pull the trains both to and from the landing, adding to the transportation cost of the coal from the Lone Tree Valley mines. Operation of the railroad ended with the closing of the Central Mine in 1898.

Company owned operations ended at the landings on the San Joaquin River (photo 4) for all but the Black Diamond Company. This company operated its own boats to transport the coal to local markets, and also had retail outlets, located in San Francisco, for the sale and distribution of its product. The direct presence of the Black Diamond Company in the San Francisco coal market helped to maintain its position as the leading operation on the coalfield.

DECLINE OF COAL INDUSTRY

Increased mining costs as the mines went deeper, competition from higher quality Washington Territory coal and the advent of oil as an industrial power source led to closure of the mines in the Mount Diablo coalfield during the period 1885 to 1902. The cost of transportation, pumping, and the development and maintenance of mine plants had always been needlessly high. These costs were borne by each individual company, though it would have been more profitable had they cooperated and shared projects instead of duplicating facilities in each mine. Good-
year (1877) stated that the 6 mines of Nortonville and Somersville could have been most efficiently operated as a single mine, based in Somersville. He estimated that had this been the case, the savings up to 1877 would have been about $1/2 million dollars.

Even if the mines had been more efficiently run, however, it is doubtful that they would have continued operation since the cheap and easily mined coal near the surface was eventually exhausted. After two decades of operation the mines at both Somersville and Nortonville were down almost 213 meters (700 feet) below the surface. The energy required to lift the coal from the mine and pump out the ever-increasing quantities of water was a major factor in driving the cost of mining the coal above its market value. Even when the coal was extracted, competition with better quality, imported coal made it difficult to find a market.

Gerlach (1969) outlined the economic factors that contributed to the decline and final closure of the mines in the Mount Diablo coalfield. Mining, after a slow beginning in the early 1860s, steadily increased production as the rapidly expanding population of the Bay area required increasing amounts of fuel for homes and industries. Oil, gas, wood and electrical sources of energy were either not developed or technically impossible to produce on a large enough scale to meet the demands, while coal was available in large amounts in many parts of the world and was the main energy resource. Gerlach (1969) reported that in 1860, San Francisco imported 77,635 tons of coal, with the amount steadily increasing to 1,479,785 tons in 1893. This 19-fold increase in demand in a 33-year period was a reflection of industrial, rather than population, growth since the latter increased only 4-fold during this same period. During the decade 1864 to 1874, the Mount Diablo coalfield was the leading supplier of this coal, and in 1868 supplied about 47% of the coal received in San Francisco.

Because of the limited coal resources in California, large amounts were also imported from Pennsylvania, Great Britain, Australia, and Chile to meet the demand. While foreign coal was higher priced than the local product, this was partially offset by its better quality. The local coal was lignitic or subbituminous, while those imported were bituminous and ancharctic. The primary reason for the high price of the imported coal was extra shipping costs which for many years were increased by the lack of return cargo because the West Coast, at this time, had little to export. Ships leaving San Francisco were often forced to sail with ballast on the long voyage around the Horn to the ports of the East Coast, where they were again in the main stream of trade and could load cargo for the remainder of the homeward voyage.

Beginning in the early part of the 1870s, however, the situation changed as California began to produce large amounts of wheat for export, and vessels from abroad no longer had to return empty. This increased revenue made the price of the overseas coal more competitive with the poorer quality local product. At about the same time, Washington Territory began to supply another source of subbituminous coal, which had a marketing advantage over the Mount Diablo coal because it was of better quality and had more widespread industrial use. The Washington coal could also match the price of the local product, in spite of the longer transportation distance, because the Mount Diablo mines were now facing increased operating costs as the workings went deeper.

Several factors, however, enabled the Mount Diablo mines to survive for a time. The overseas coal supply was often unreliable, since the shipping distances were long and subject to delay by storms. The supplies also varied by the seasons, and depended upon the availability of wheat for export and the world demand for California grain. This fluctuating flow of overseas coals into the Bay area often produced fuel crises and the price and demand reflected these factors. The close proximity of the mines to the market enabled the local companies to respond quickly to the situation and modify price and production to meet the fluctuating demand.

In spite of these factors, after less than two decades of production the Mount Diablo coalfield began a marked decline, even though large deposits of coal remained underground. It is estimated that the reserves are still approximately 8 million tons. A report by engineer R. B. Symington (1917) to the Black Diamond Company, however, estimated the coal reserves in the 1,500 acres held by that company alone at 17 million tons.

Many adjustments were made by the companies to reflect the marketing situation and frequent closure of the mines produced hardships on the miners and their families. Some companies attempted to reduce production costs by bringing in Chinese laborers and lowering wages. This resulted in labor unrest and strikes. Several smaller companies soon went out of business, and the industry suffered a major setback with the closing of the Black Diamond Company operations in 1885. They removed the railroad and mining equipment from Nortonville and relocated their operation near Seattle in Washington Territory. The last mining in any significant scale came with the end of major operations at the Pittsburg Mine in 1902.

One other factor had limited significance in the decline of the Mount Diablo mines, but had a widespread effect on the coal industry worldwide. The 1860s saw the beginning of the natural gas and petroleum industry in California. The second oil well in the state was drilled in 1862 in Contra Costa County, 6½ kilometers (4 miles) southeast of San Pablo. As early as 1864 an oil well was drilled on the coalfield itself. Located near Somersville, it
was drilled to a depth of 61 meters (200 feet) and yielded several barrels of green-colored oil. The gradual entrance of oil and gas as a fuel on the world market first affected the low grade coal deposits such as those mined in the Mount Diablo coalfield, and this competition lowered coal prices to the point that many deposits became uneconomical to mine.

Several attempts were made to revive the coal industry at Mount Diablo. For a short time in 1905, the Nortonville mines supplied coal to a briquette plant in Los Medanos, but the plant burned and production again slowed to a trickle. A few hundred tons per year were also removed from the Black Diamond Mine on a contract basis until the end of World War I, and again during World War II. The most serious attempt to reopen the mine was the rehabilitation of the Clayton Tunnel in 1926. It was planned that mining operations would resume and that the coal would be used to power an on-site electrical generating plant. According to J. I. Ballard (personal communication), an engineer on the project, the plans were dropped when a natural gas pipeline from the newly discovered Kettleman Gas Field reached the Bay area, providing energy less expensively than could the Nortonville mines. All of these operations, then, failed to reestablish the coal mining industry, and instead the industry of sand mining came into the region in the 1920s.

THE MOUNT DIABLO COALFIELD TODAY

The towns of Nortonville, Somersville, Stewartville, West Harluy and Judsonville became ghost towns almost overnight when the mines closed. Several business ventures were attempted to ensure the survival of the larger towns, but they failed to prosper.

In the 1920s a new mining industry moved into the hills above the townships of Nortonville and Somersville. This development was too late to save the towns, however, because they had been long abandoned and most of the buildings removed or destroyed. In 1922, underground mining of silica sand began at the site of the old Pittsburg Mine in Somersville. Two massive sandstone units, 21 to 23 meters (67 to 75 feet) in thickness, in the upper part of the Domenigine Formation overlying the Clark Vein were mined. A similar sand deposit was also mined at Nortonville for the foundry of the Columbia Steel Company at Pittsburg. These deposits were mined until 1949 when operations ceased. It is estimated that 188,097 tons of glass sand valued at $3.5 million were extracted from the Somersville site and 367,543 tons valued at $1.3 million from Nortonville.

The hills and valleys are deserted today and are now part of the Black Diamond Mines Regional Preserve of the East Bay Regional Park District. Park naturalists conduct tours of the townsite, cemetery, and a small section of the underground workings.

The Park District has also begun work on a major underground facility (photo 6), the Black Diamond Mines Underground Mining Museum, in the mines near the Somersville townsite. This museum, when complete, will open more than 500 meters (½ mile) of underground workings to public view (Waters, 1978). The museum will be divided into two sections. The first section will be a reconstruction of a 20th century sand mining operation to be completed this year. The second section, approximately 10 meters below the first and connected by underground passageways, will be a reconstruction of a 19th-century coal mine.

REFERENCEs


ACKNOWLEDGMENTS

We wish to express our thanks to Charles Bohakel and Donald Wilson for the photographs used to illustrate this article. We also acknowledge the assistance of Gary Palmer and Judy Helsing, who drafted the figures; Peter Shields, who provided the information on the cross-section of the Black Diamond Mine, and Kerry Davis, who typed the manuscript.