1990

Late tertiary synorogenic sedimentation in the northern Livermore Basin, California

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**Late Tertiary synorogenic sedimentation in the northern
Livermore Basin, California**

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San Jose State University, 1990

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LATE TERTIARY SYNOROGENIC SEDIMENTATION IN
THE NORTHERN LIVERMORE BASIN, CALIFORNIA

A Thesis

Presented to

The Faculty of the Department of Geology
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Masters of Science

By

Kathleen A. Isaacson

December, 1990

APPROVED FOR THE DEPARTMENT OF GEOLOGY

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ABSTRACT

The fluvial Sycamore Formation, consisting of gravel, sand, and fine-grained sediment, was deposited in the northern Livermore basin located east of San Francisco Bay. The gravels of the formation are important because they provide evidence for the evolution of the basin between about 8.5 Ma and 2.5 Ma.

The majority of the formation was deposited by braided streams. Thick sequences of amalgamated packages of horizontally-stratified sand with minor gravel and homogeneous, red silty clay may have been deposited by ephemeral, proximal braided streams. Clast-supported gravel beds, which fill incised channels and are overlain by sandy deposits, are common in the upper part of the formation. Grain-size distribution indicates an upward-coarsening trend, with the youngest sediment of the formation ranging up to boulder-size.

Three distinct petrofacies have been identified in the Sycamore Formation, based on the composition of the gravel. The Finley Road petrofacies is composed of rocks derived from a Franciscan source in the California Coast Ranges. The sandy Blackhawk petrofacies is dominated by andesitic material. The Roundhill petrofacies is composed of clasts of Tertiary sedimentary rocks.

Miocene and Pliocene tuffs and late Clarendonian fossils, identified within the formation, provide time constraints for deposition of each of the petrofacies and allow for correlation of events recorded in the Sycamore Formation with more regional trends.

The three petrofacies indicate successive changes in provenance for the sediment of the Sycamore Formation. The Finley Road petrofacies, contained near the base of the formation, records the change from deposition of Sierran-derived Miocene volcanic material in the underlying Neroly Formation to a local Franciscan source. The uplift at the south end of the Livermore basin in the central Diablo range provided the Franciscan material at the north end of the basin by about 7.5 Ma. Uplift of the Altamont Hills to the northeast of the basin provided a source of reworked andesitic detritus. The Neroly Formation, which was overlying the Altamont Hills, was eroded and redeposited as the sandy Blackhawk petrofacies, starting about 7 Ma. Uplift to the northeast of the basin continued, and by 4.5 Ma, the coarse gravel of the Roundhill petrofacies became dominant, as the entire section of older Tertiary rocks was eroded and redeposited.

Uplift at the south end of the Livermore basin and subsequent uplift northward along the east side of the basin were in response to changes in regional stresses, which

resulted from passage of the Mendocino triple junction through the area. The Sycamore Formation was folded after 2.5 Ma, which corresponds with the shift to a compressional regime. This shift records the change in relative plate motion between the Pacific and North American plates. Final uplift of Mount Diablo, today the dominant edifice at the north end of the Livermore basin, occurred after deposition of the Sycamore Formation, as no evidence of detritus from the Franciscan core of Mount Diablo is found in the formation.

INTRODUCTION

A record of the late Cenozoic history of the continental margin of northern California has been partially preserved in numerous Neogene basins, which evolved as the tectonic regime changed from a convergent to a transform plate boundary. Sediment in these basins records both the development of regional trends and local events that are specific to an individual basin.

One of these Neogene basins, the Livermore basin (fig. 1), is located in the California Coast Ranges on the eastern edge of a broad zone of deformed rocks bounded to the west by the San Andreas fault system. The Livermore basin is bounded by the Calaveras fault to the west and by the Greenville fault to the northeast (fig. 1). The Diablo Range bounds the basin to the south, and the Altamont Hills and Mount Diablo bound the basin to the northeast (fig. 1).

The nonmarine gravel, sandstone and fine-grained rocks of the Sycamore Formation, deposited in the northern Livermore basin from the late Miocene into the Pliocene, record the changes in depositional environments and source areas during that time. The Livermore basin was initiated as part of a large forearc basin system, when subduction was active and before the passage of the Mendocino triple junction at the latitude of San Francisco Bay, at about 10 Ma (Dickinson and Snyder, 1979a). The offshore Eel River

Figure 1. San Francisco Bay region with location of study area (modified from Jennings, 1977).

basin, north of the present location of the Mendocino triple junction, probably is a remnant of the larger forearc system that included the Livermore basin (Nilsen and Clarke, 1989).

The adjoining Contra Costa basin (fig. 1), west of the Calaveras fault, was also part of the forearc basin. Changes in the configuration of the Contra Costa basin and associated changes in depositional environments and sediment sources have been documented by Graham and others (1984). At about 12 Ma, a topographic high was well established along the present-day trend of the Hayward fault, west of the Contra Costa basin (fig. 1). Fluvial sediments shed to the east disrupted forearc sedimentary patterns. At that time, material was also deposited westward from the last Sierran volcanoes, across the Sacramento and Livermore basins and was preserved in the Miocene Mehrten and Neroly formations (Lerbekmo, 1956). The sedimentary record in the Contra Costa basin reflects a shallowing of the marine environment and a transition to estuarine, fluvial, and lacustrine environments.

Time-equivalent events east of the Calaveras fault in the Livermore basin are not well understood, and this has precluded detailed interpretation of the history of the basin (Graham and others, 1984; Nilsen and Clarke, 1989). The lack of information is due in part to confusion about stratigraphic relationships within the Sycamore Formation.

Local structural complexity and lack of exposures have hampered studies that could resolve the stratigraphy of the formation and relate it to the evolution of the basin.

The area of this study is located in the northern Livermore basin where the Sycamore Formation and the underlying Tertiary section are exposed on the southwest flank of Mount Diablo. Beds commonly are vertical to overturned. Natural exposures generally are limited to stream-cut valleys that trend across strike and to rare outcrops of more resistant units. Road cuts and recent major housing developments have provided valuable temporary exposures.

The purpose of this thesis is 1) to better define the stratigraphy of the Sycamore Formation, 2) to identify petrofacies that possibly are mappable throughout the basin, even where structure is complicated, 3) to determine the provenance of the gravels in the Sycamore Formation, and 4) to integrate these data with other studies to establish a more complete understanding of the evolution of the Livermore basin in relationship to regional tectonics.

GEOLOGIC SETTING

The northwest-trending Livermore basin is both a structural and depositional basin. The south end of the basin is the current center of deposition and represents a remnant of a larger Neogene basin which covered about 450 km².

Tectonic Setting

The Livermore basin is bounded by the Calaveras fault to the west and the Greenville fault to the northeast (fig. 1). Both faults have historic activity and are right-lateral strike slip faults (Page, 1982; Wright and others, 1982). The Altamont Hills, which lie to the northeast and are part of the Diablo antiform and north Diablo Range, separate the Livermore basin from the San Joaquin Valley (fig. 1). The south side of the basin is bounded by the central Diablo Range, which includes Mount Hamilton (fig. 1).

On the north side of the basin, Mount Diablo stands as the dominant edifice. The steeply north-dipping Mount Diablo fault rings the structure on the south side (Dibblee and Darrow, 1981) and is to a great extent obscured by major landslide complexes. The mechanism of emplacement of Mount Diablo is not completely understood, but reverse slip on the

Mount Diablo fault has contributed to significant deformation of formerly overlying Tertiary units.

Beds in a thick sequence of Tertiary rocks are vertical to overturned on the south flank of Mount Diablo. Within the Livermore basin, the upper Tertiary rocks are deformed in a series of folds, and are locally cut by reverse faults (Dibblee, 1980a, 1980b).

Stratigraphic Setting

The upper Tertiary continental rocks, which are the focus of this thesis, overlie a sequence of older Neogene and Paleogene rocks. These in turn overlie rocks of the upper Mesozoic Franciscan Complex and Great Valley Group.

Franciscan Complex

The cores of the central Diablo Range to the south of the Livermore basin and of Mount Diablo north of the basin contain rocks of the Franciscan Complex that range in age from Jurassic to Cretaceous. Adjacent to the area of study, the Franciscan Complex of Mount Diablo is composed of greenstone, varicolored chert and shale, both metamorphosed and unmetamorphosed graywacke, argillite, serpentinite, and glaucophane schists (Dibblee, 1980c).

Great Valley Group

The Great Valley Group is exposed to the east of the area of study in the Altamont Hills, where it is represented by the Upper Cretaceous Moreno and Panoche formations. Rocks include massive and concretionary arkosic sandstone, graywacke, and shale (Dibblee, 1980d).

Tertiary Marine Rocks

The oldest Tertiary formations on the south side of Mount Diablo are the Eocene Capay and Domingine formations, which are composed of shale and arkosic sandstone. Miocene marine rocks unconformably overlies these older units.

The Miocene rocks are assigned to the Monterey and San Pablo groups. The Monterey Group is represented by the Sobrante Sandstone. The San Pablo Group includes the Briones, Cierbo, and Neroly formations. They include pebbly, fossiliferous and unfossiliferous arkosic and lithic sandstone, massive siltstone and claystone, and andesite-pebble conglomerate. The youngest unit in this group, the Neroly Formation, contains deposits of marine, non-marine and brackish-water origin (Kilmer, 1953).

PREVIOUS STUDIES

The upper Tertiary sandstones, conglomerates and associated fine-grained units of the Sycamore Formation formerly were divided into the Green Valley and Tassajara formations by Clark (1933, 1935, 1940). Clark (1933) used prominent tuff beds to separate the Green Valley and Tassajara formations. The main lithologic distinction was that the Tassajara Formation was generally described as finer-grained than the Green Valley Formation (Clark, 1933; Oestreich, 1958).

Clark initially grouped the rocks of the Green Valley Formation with the Orinda Formation (Clark, 1935), found to the west of the Calaveras fault, following the nomenclature proposed by Lawson (1914). He changed his nomenclature based on marine faunal ages within the Orinda Formation that are similar to those of the Neroly Formation (Clark, 1940), which underlies the Green Valley Formation.

Oestreich (1958) mapped the Tassajara quadrangle, using criteria for the upper Tertiary rocks established by Clark (1933, 1935, 1940). Oestreich separated the Green Valley and Tassajara formations at the stratigraphic level of a ridge-forming tuff ranging up to 14 m (45 ft) thick. Vitt (1936) had correlated this tuff with the Lawlor Tuff, which occurs on the north side of Mount Diablo. At that time, he incorrectly referred to it as the Pinole Tuff, which was a

correlation commonly used for massive tuffs in the area around Mount Diablo (S. Creely, 1990, written communication). Oestreich referred to abundant Franciscan debris in the Green Valley Formation, but he did not report any lithologic difference between the Green Valley and Tassajara formations, except that the Tassajara is finer. Oestreich suggested an average thickness of 850 m (2800 ft) for the Green Valley Formation and a maximum thickness of 550 m (1800 ft) for the Tassajara Formation.

The most comprehensive stratigraphic and structural mapping in the northern Livermore basin and surrounding areas was conducted by Dibblee (1980a, 1980b, 1980c, 1980d). He mapped upper Tertiary continental rocks as Tps and QTt. Tps has been widely used for Pliocene nonmarine sedimentary rocks distributed east and west of the Calaveras fault and includes the Orinda Formation. QTt refers to the Pliocene and/or Pleistocene nonmarine Tassajara Formation.

Sarna-Wojcicki (1976, 1979) used chemical and geochronologic data to correlate several tuffs within the Green Valley and Tassajara formations with tuffs on the north side of Mount Diablo and in the Sonoma Volcanic field, north of San Pablo Bay (fig. 1). His work indicated that tuffs of different ages are distributed throughout both formations. It demonstrated that folds and faults greatly complicated stratigraphic correlations that were based

solely on the field characteristics of the tuffs. The work of Sarna-Wojcicki (1979) indicates that Oestreich's map (1958) was oversimplified.

Wagner (1978) introduced the term Sycamore Formation to replace the Green Valley and Tassajara nomenclature and suggested a total thickness of 2400 m (7800 ft) for the formation. He argued, based in part on the work of Sarna-Wojcicki (1976), that prior criteria for separation of the units were tenuous. Wagner's nomenclature has not been formalized, but the term Sycamore Formation is used for this study. Wagner (1978) inferred a Franciscan source for the conglomerate of the Sycamore Formation. Based on sparse paleocurrent data derived from cross-bedding, Wagner (1978) suggested that the eastern part of the formation had a source in the central Diablo Range to the south and that the western part was derived from sedimentary rocks west of the Calaveras fault.

STRATIGRAPHY

Stratigraphic Sections

Three stratigraphic sections were chosen for this study in locations that provide the most continuous stratigraphic sequences with the least structural complications (fig. 2). The Blackhawk section is located north of Tassajara Road within sections 29 and 32, T1S, R1E, in the Diablo 7.5' quadrangle. The Roundhill section is located north of Stone Valley Road within section 8, T1S, R1W, in the Diablo 7.5' quadrangle. The Whitecliff section lies adjacent to Whitecliff Road in T1N and T1S, R1W, in the southeast quarter of the Walnut Creek 7.5' quadrangle. Natural exposures are scarce but local drainages and road cuts commonly trend across strike. Many of the exposures for the Blackhawk section were temporary, provided by a major construction grading operation. The majority of the sampling localities in the Blackhawk section no longer are accessible.

The base of each of the three sections is at the contact between the Sycamore and the Neroly formations. The sections differ in thickness, in part due to local structure and in part because the upper part is covered. The sections were not measured in the traditional sense, because discontinuous exposures made description of every bed

Figure 2. Locations of stratigraphic sections and fossil and tuff localities within area of study.

impossible. The goals of the study could be met if the stratigraphic position of the samples is known, so the thickness of each section was determined by map distance. The dip of the beds generally varies little from vertical, and calculated corrections for thickness with change in dip resulted in a change in total thickness of less than 5 percent. The sections, as presented, remain uncorrected, but provide close approximations to true thickness.

The Blackhawk section (fig. 3) is about 2.3 km thick. The base is the contact between the Neroly Formation and the overlying Sycamore Formation as mapped by Kilmer (1953). The lowest sample collected during this study is from 400 m above the base of the section. The top of the section is near the axis of the Tassajara syncline, as mapped by Dibblee (1980b).

The Roundhill section (fig. 4) is about 1.2 km thick. The base is at the contact of the Sycamore Formation with the underlying Neroly Formation as mapped by Kilmer (1953), although the contact is obscured here by large recent landslides. The top of the section is the location of the highest accessible exposures. The rest of the formation, in the axis of the syncline mapped by Dibblee (1980b), is covered.

The base of the Whitecliff section (fig. 5) is the contact between the Sycamore Formation and the Neroly

Figure 3. Blackhawk Section of the Sycamore Formation with gravel, sandstone and tuff sample locations, lithofacies designations by number, and maximum grain size.

Figure 4. Roundhill Section of the Sycamore Formation with gravel, sandstone and tuff sample locations, lithofacies designations by number, and maximum grain size.

Figure 5. Whitecliff Section of the Sycamore Formation with gravel, sandstone and tuff sample locations, lithofacies designations by number, and maximum grain size.

Formation as mapped by Kilmer (1953). The lowest 200 m of the section are covered. The section studied is 1.1 km thick. The top of the Whitecliff section is at the limit of accessible exposures, which are about 500 m from the synclinal axis as mapped by Dibblee (1980a).

Lithofacies

To understand the transport of material into the evolving Livermore basin, each section was examined for depositional patterns. Seven lithofacies were recognized and interpreted to represent distinct depositional environments. These lithofacies are widespread in the northern Livermore basin, and some occur in all of the sections studied.

Lithofacies 1: Light-bluish-gray Sand

This lithofacies consists of light-bluish-gray, medium- and fine-grained sand and silty sand generally organized in repeated upward-fining sequences. In a typical sequence, the basal 1 to 2 m of medium sand is horizontally laminated to trough cross-bedded or appears structureless. The sand grades upward into ripple-laminated fine sand, consisting of up to 1 m of stacked, 2- to 3-cm sets.

Lithofacies 2: Well Homogenized Sandy Silt and Silty Clay

This lithofacies is composed of burrowed, moderate-reddish-brown sandy silt, clayey silt and silty clay. The well homogenized, structureless beds range in thickness from less than 5 cm to more than 1 m. The contact at the bottom of the bed is either gradational or abrupt. The top of the clay is a sharp erosional surface.

Lithofacies 3: Ripple-laminated and Mottled Silt and Fine Sand

This lithofacies is characterized by light-bluish-gray silt and fine sand, which are ripple-laminated or burrowed and mottled. The ripple-laminated silt and fine sand are organized in 2- to 3-cm-thick sets, which are stacked to a maximum observed thickness of 1.5 m. Preservation of structure is variable due in part to vertical burrows. The mottled silt and fine sand contain irregular-shaped, lighter, bluish-gray patches, which do not branch downward. This facies commonly is part of an upward-fining sequence, which includes a horizontally-laminated, basal, medium sand (lithofacies 1) below it, ranging up to 0.5 m thick and a moderate-reddish-brown clay (lithofacies 2) overlying it. Sharp boundaries separate sequences, and bed-form transitions are gradational within a sequence.

4Lithofacies 4: Moderate-reddish-brown and Gray Sand and Gravel

Moderate-reddish-brown and gray sand and moderate-reddish-brown and gray pebble to cobble gravel are unique to lithofacies 4. Unstructured to sub-horizontally bedded, pebble to cobble gravel, ranging up to 1.5 m thick, forms the basal beds of this facies. The gravel grades into amalgamated horizontally and tabular planar cross-bedded sand and gravel. Individual beds are up to 15 cm thick. Moderate-reddish-brown stains color most of the sand. Sub-rounded to rounded clasts of dark-reddish-brown clay ranging up to cobble size occur within the beds. Similar clay occurs as drapes on some of the foresets of the cross-bedded units.

Lithofacies 5: Sand and Sandy Gravel

Gray, light-grayish-blue, and light-brownish-gray sand and small amounts of sandy pebble gravel occur in this lithofacies. The sediment is primarily horizontally bedded. Trough cross-bedding, in sets up to 10 cm thick, rarely occurs in the coarser material. Individual beds are not always distinguishable, but rather the units, up to 5 m thick, appear to be composed of amalgamated beds.

Commonly, the sand beds grade into a well-homogenized, pale-reddish-brown sandy silt or silty clay of facies 2.

Interbedded, very thin, dark reddish-brown clay beds are rare in facies 5. Where it overlies facies 2, the sandy sequence of facies 5 has a sharp horizontal base.

A variation of this facies includes small-pebble conglomerate ranging up to about 3 cm thick at the base of a package ranging up to 0.5 m thick. These packages commonly are interbedded with very thin, laminated clay beds. Clast orientation indicates some b-axis imbrication, with the long-axes of clasts perpendicular to flow. Horizontal bedding is dominant.

Lithofacies 6: Clast-supported Gravel

Clast-supported gravel and moderately lithified conglomerate characterize this lithofacies. Large clasts are common and range in size up to boulders. These gravels and conglomerates, in beds ranging up to 1.5 m thick, are basal units of upward-fining sequences in which deposits of facies 5 overlie facies 6. These sequences are associated with an irregular erosional surface that commonly is deeply incised into the underlying unit. The conglomerate exhibits little or no imbrication, and it commonly contains sandy lenses, ranging up to 0.5 m in width. Lithofacies 6 grades into facies 5 for a combined total thickness of 2 to 5 m.

Included in facies 6 is a poorly sorted gravel that contains clasts ranging up to boulder size. This gravel

lacks internal organization and has a flat, non-erosive base. Packages of this type of conglomerate ranging up to 2.5 m thick may be composed of amalgamated thinner beds.

Lithofacies 7: Well Homogenized, Dark Silty Clay

This lithofacies is composed of well homogenized, dark-reddish-brown or grayish-black silty clay. The dark-reddish-brown silty clay, ranging up to 1 m thick, contains a few unidentified small shell fragments, but generally is unfossiliferous. The grayish-black silty clay occurs in beds ranging up to 0.5 m thick. In both cases, the beds have sharp bases and grade upward into coarser-grained material of facies 3 or 5.

Interpretation of Depositional Environments

The horizontally to cross-bedded sand overlain by a succession of ripple-laminated sand of lithofacies 1 and well homogenized silt and silty clay of lithofacies 2 resemble deposits of a point bar in a meandering stream system (Cant, 1982). The repetition of upward-fining sequences is inferred to represent stacked point bars.

Lithofacies 2 and 3, which are interbedded with lithofacies 1, are inferred to represent floodplain and overbank deposits, respectively. The stacked sets of

ripple-laminated fine sand and silt of facies 3 overlying slightly coarser, horizontally bedded sand of facies 1 are interpreted as levee and crevasse splay deposits (Cant, 1982). The closely related, well homogenized, mottled fine-grained material of facies 2 supports the interpretation that this is a fluvial system.

In lithofacies 4, the cobble-size conglomerate and the dominance of horizontally stratified sand and gravel interbedded with tabular cross-bedded gravelly sand in amalgamated sequences are indicative of longitudinal bars and in-channel braided stream deposits (Miall, 1977, 1978; Rust, 1978). Lithofacies 5 is related to facies 4, but is sand-dominated. Although average grain size is not much greater than that of facies 1, the organization of beds is completely different. The abundance of horizontal stratification and small amount of gravel suggests deposition in a setting similar to that described by Miall (1977, 1978) for Bijou Creek, Colorado. The meter-thick, amalgamated, horizontally stratified and less commonly low-angle cross-bedded sand and sandy-pebble conglomerate represent in-channel deposits. The well homogenized, reddish silty clay beds of facies 2 at the top of each package are either interchannel or channel-fill deposits. Thinness of individual beds, rare low-angle cross-bedding, and little or no scour at the base of each unit, fit the

Bijou Creek model of Miall (1978) for an ephemeral, proximal, sandy braided stream. These features are consistent with high-energy flow conditions associated with flash floods.

Lithofacies 6 is the coarsest of the braided-stream deposits. The clast-supported conglomerate in beds with irregular erosive bases is typical of channel deposits (Miall, 1977, 1978; Rust, 1978). The unsorted conglomerate, with a flat base resembles debris-flow deposits (Miall 1978; Rust 1978).

Lithofacies 7 is associated with both facies 1, 3, and 5 and the very dark, well homogenized silty clay, is interpreted as a pond deposit (R. Sullivan, 1986, oral communication).

Lithofacies Associations

Figures 3, 4, and 5 illustrate the general distribution of lithofacies types throughout the three sections. These lithofacies associations provide an overview of the internal organization of each section. The figures also show the distribution of maximum grain size for the sections, along with sample and tuff localities.

Blackhawk Section

From 400 to 740 m above the base of the Blackhawk section (fig. 3), the Sycamore Formation is dominated by silt and sand and is composed of interbedded units of facies 1, 2, 3, and 7. Lithofacies 1 and 3 dominate and are organized in upward-fining sequences ranging up to several meters in thickness. Lithofacies 7, the dark-reddish-brown, well homogenized silty clay and clay, occurs most commonly at the base of this part of the section. The associated lithofacies suggest a well developed, meandering stream system during deposition of the lower part of the Sycamore Formation.

A typical 3.5-m-thick sequence containing facies 7 has a 1-m-thick, homogenized, dark-reddish-brown clay at the base, which grades upward into a 15-cm-thick, ripple-laminated, fine, light-gray sand of facies 3. A thin bed of clay, overlying the sand, is succeeded by another fine-sand unit, which is organized into 2- to 3-cm-thick, well laminated beds, which total 20 cm. This clay and sand package is again repeated, with a final clay bed at the top of the exposed sequence.

Approximately 740 m above the base of the section, the maximum clast size increases abruptly to about 13 cm. The cobble-size clasts are contained in poorly sorted beds, which are designated as part of facies 4. Lithofacies 4

here is approximately 50 m thick and is overlain by a small amount of facies 3, which in turn is succeeded by a thick section of sediment of facies 5. Individual or amalgamated beds of facies 5 commonly grade upward into the well homogenized silty clay of facies 2.

Lithofacies 5 and 2 dominate the rest of the Blackhawk section between 0.8 and 1.8 km above the base of the section, indicating that braided stream systems persisted as the predominant depositional environment. Clasts greater than sand size occur throughout this part of the section, but they are not abundant and comprise only about 5 percent of the material.

About 1.8 km above the base of the section, the average grain size decreases markedly, with the silt and particularly the clay components becoming more significant. Field observations supplemented by field maps from 1986 by Engeo, Inc. indicate that the rest of the section is dominated by facies 7 in association with facies 5 and 2. Grayish-black, well homogenized silty clay up to 0.5 m thick is interbedded with uncommon, thin units of sand and gravel.

Roundhill Section

The basal 300 m of this section is covered (fig. 4). The lowest exposures are composed of facies 5 with very small amounts of gravel. About 400 m above the base of the

section, the abundance of gravel and the size of the largest clasts increases. Cobbles ranging up to about 13 cm in diameter are contained in units of gravel about 25 cm thick. At about 600 m, maximum clast size again increases. Boulder-size clasts are contained in the clast-supported gravel of facies 6. The rest of the section, up to about 1.2 km above the base, is composed of upward-fining sequences of alternating facies 6, 5, and 2. Packages typically are 2 m thick, but these may represent amalgamated smaller packages of facies 5 on top of facies 6. The base of facies 6 commonly is incised into the finer-grained upper portion of the underlying unit, consisting of either facies 5 or 2. Lithofacies 6 grades upward into facies 5, which commonly grades upward into facies 2. The Roundhill section exhibits an overall upward-coarsening trend that is dominated by braided stream deposits.

Where the coarsest gravel occurs, the base of the unit commonly is smoother, lacking the deep incision found in other parts of the section. The clast size varies greatly within the gravel and there is no apparent internal organization. These features are characteristic of debris flows. Large clasts are as likely to occur at the top or bottom of an individual bed, which may be up to about 2 m thick.

Whitecliff Section

The Whitecliff section consists of alternating facies 5 and 6 with facies 2 commonly overlying facies 5 (fig 5). Gravel is less abundant than at Roundhill, although the maximum clast size is as great as 30 cm. Much of the section is covered and may include finer sediments of facies 2.

GRAVEL AND SANDSTONE PROVENANCE

Clast composition of fluvial gravel can be a sensitive indicator of provenance. In this study, gravel beds were sampled along the three sections and the proportions of different clast types were determined for each sample. Two samples (5-85 and 6-85) from the Finley Road quarry (fig. 2), located to the east of the Blackhawk section, are included with counts for samples from the Blackhawk section. Where gravel is absent, thin sections of sandstone samples provided additional information for provenance.

Methods

Samples were counted either in the field or in the laboratory. Separate counts were made for clast sizes of 4 to 16 mm, 16 to 64 mm, and greater than 64 mm.

Samples for laboratory study were collected by marking a portion of a gravel bed and totally removing all material into a plastic bag. In the laboratory, the poorly lithified gravel was easily sieved. Each sieved fraction was counted with the aid of a binocular microscope.

In the field, a portion of a gravel bed was marked and all clasts were counted. Clasts were marked or removed from the outcrop as counted to avoid repetition and to ensure that the actual clast size was determined.

Figures 3, 4, and 5 indicate the localities of samples taken from each section. Each locality number is represented by both 4-16 mm and 16-64 mm clast-size samples. Some localities also have clasts greater than 64 mm.

Composition of Clasts

Clasts of gravel were categorized primarily based upon lithology. Degree of induration was also a criterion. The categories counted are groupings of related types of clasts. Raw data for clast counts for each section are included in Appendix I.

Tertiary Sedimentary Rocks

The category of Tertiary sedimentary rocks includes a variety of clast types. The majority are friable to well indurated, light-colored sandstone of several distinctive lithologies described in detail below. In general, sandstones range from well lithified and indurated, light-colored arkosic rocks to poorly lithified, friable volcanoclastic rocks. Siltstone and claystone also occur in various colors and degrees of cementation. Marine invertebrate fossils occur both as separate clasts and within sandstone clasts.

Chert

Chert has been segregated by color. Red, reddish-brown and brown chert have been grouped as red chert. Green chert includes grayish-green chert. Black chert may also include other dark, siliceous clasts not easily distinguished in hand specimen in the 4 to 16 mm range.

Volcanic Rocks

Most of the pitted, well rounded volcanic clasts are andesite and basalt. The andesite clasts are characterized by their pinkish to gray color and distinctive plagioclase and pyroxene phenocrysts. Rhyolite clasts are present but rare.

Quartzite

Quartzite is primarily of light color and fine grained and includes coarse-grained clasts. Some clasts are well rounded and this category may include some recrystallized cherts.

Vein Quartz

The vein-quartz category includes both white and colored types. Clasts range from sub-angular to well rounded. The white quartz clasts generally are well rounded. The sub-

angular to sub-rounded, very light-gray to gray quartz clasts may include other dark, vein-forming minerals.

Graywacke

These are dark, moderately to well indurated, immature sandstones. The rocks generally contain more than 10 percent lithic fragments and more than 5 percent feldspar with an interstitial matrix of grayish-green, microcrystalline phyllosilicates. Most clasts are well rounded and commonly exhibit slight foliation expressed by elongate clasts and aligned grains. Elongate finer-grained fragments, previously siltstone or claystone contained within the graywacke clast, also define foliation.

Metamorphic Rocks

Blueschist. Clasts are identified by their distinctive blue color and marked foliation.

Metavolcanic Rocks. These clasts are easily distinguished from the Tertiary volcanic clasts. The meta-volcanic clasts are extremely hard, dark and silicified, and the plagioclase laths appear as vague ghosts. Greenstone is included in this category.

Other Metamorphic Rocks. These clasts include phyllites and other clasts that exhibit some metamorphic features such as preferred orientation or elongation of grains.

Miscellaneous

Those few clasts that cannot be identified because they are too small or would require petrographic examination were included in this general category. In most cases these are clasts that are siliceous and quite durable.

Provenance

Not all clast types are useful as indicators of provenance. Tables 1, 2 and 3 are modified versions of the raw data presented in Appendix I. The clast types that have been eliminated are those that may have originated in any of several regions or are minor in occurrence. These include chert and related siliceous rocks, vein quartz and quartzite, which are extremely durable clasts and may have been reworked and concentrated over time. The clast types retained are grouped into three distinctive categories.

TABLE 1.
Relative Percentages of Each of the Three Categories of Clast in Conglomerate
from the Blackhawk Section

SAMPLES	C-3 # clasts %	91A # clasts %	5-85 # clasts %	6-85 # clasts %	C-4 # clasts %	100A # clasts %
Tertiary Sedi- mentary Rock					4 13	5 11
Andesitic Rocks					24 77	41 89
Coast Range Rocks	47 100	193 100	117 100	84 100	3 10	
Total	47	193	117	84	31	46

SAMPLES	C-2 # clasts %	37 # clasts %	39 # clasts %	38 # clasts %	40 # clasts %
Tertiary Sedi- mentary Rock	11 33	132 55	53 66	93 74	165 72
Andesitic Rocks	22 67	106 45	27 34	29 23	65 28
Coast Range Rocks				4 3	
Total	33	238	80	126	230

TABLE 2.
Relative Percentages of Each of the Three Categories of Clast in Conglomerate
from the Roundhill Section

SAMPLES	C-5 # clasts %	C-11 # clasts %	C-12 # clasts %	C-13 # clasts %	C-14 # clasts %
Tertiary Sedi- mentary Rock	95 75	79 84	89 82	36 78	48 81
Volcanic Rocks	22 17	6 6	17 16	2 5	10 17
Coast Range Rocks	10 8	9 10	2 2	8 17	1 2
Total	127	94	108	46	59

SAMPLES	C-6 # clasts %	C-31 # clasts %
Tertiary Sedi- mentary Rock	104 72	135 81
Volcanic Rocks	37 26	23 14
Coast Range Rocks	4 2	9 5
Total	145	167

TABLE 3.
Relative Percentages of Each of the Three Categories of Clast in Conglomerate
from the Whitecliff Section

SAMPLES	C-10 # clasts	%	128 # clasts	%	C-9 # clasts	%	C-20 # clasts	%	C-7 # clasts	%	C-8 # clasts	%
Tertiary Sedi- mentary Rock	39	91	150	94	52	79	86	98	90	85	132	96
Volcanic Rocks	2	4.5	9	6	8	12	2	2	6	6	6	4
Coast Range Rocks	2	4.5			6	9			10	9		
Total	43		159		66		88		106		138	

Tertiary Sedimentary Clasts

Clasts are assigned to this category based on condition and type of sandstone and fossil content. The Tertiary category includes a broad range of clast types whose source for the most part can be identified in the Tertiary section below the Sycamore Formation. It also includes those sandstones and finer-grained rocks that may be intraformational to the Sycamore Formation.

Tertiary sandstone clasts vary in composition and degree of induration and are similar to sandstone in the Tertiary section below the Sycamore Formation. Clasts of arkosic sandstone inferred to be derived from the Domengine Formation (Eocene) generally are well indurated and commonly contain the gastropod Turitella. The Domengine sandstone bearing the Turitella is only exposed on the south flank of Mount Diablo (J. W. Durham, 1986, oral communication). The Neroly Formation, which contains brownish- and bluish-gray sandstone (Lerbekmo, 1956), is the probable source of distinctive moderately to well cemented, bluish clasts. A brown lithic tuff, the marker unit between the Diablo and Neroly formations as described by Kilmer (1953), has been identified as clasts within the Sycamore Formation. Poorly to moderately cemented clasts include micaceous, very light-gray to light-yellowish-brown sandstones, medium-gray sandstone with abundant quartz and dark grains, and quartz-

rich sandstones with colored chert grains. These clasts could all have their source in the Tertiary section underlying the Sycamore Formation, given the wide variety of rock types available from those formations (Dibblee, 1980a, 1980b).

Some poorly lithified sandstone clasts resemble the matrix sandstone in which they are found and these may be intraformational clasts.

Clasts of marine invertebrate fossils are common within the Sycamore Formation. Several specimens have been identified by J. W. Durham of the University of California (1986, oral communication) as fragments of Astrodapsis major or A. tumidus and as Ostrea bourgeoisii or O. titan. These marine fossils are indicative of sources in the Neroly Formation and underlying Cierbo Formation, because they commonly occur in those formations.

Clasts of fine-grained rocks include siltstone and mudstone that vary in their degree of lithification and color. Soft, irregularly shaped, green and red clasts are common and some may be intraformational. Rounded and lithified gray, light-brown or reddish-brown clasts are inferred to be from the Tertiary section. Several clasts of leaf-bearing mudstone were identified and probably have their source in the leaf-bearing shale of Condit (1938) within the Neroly Formation.

Miocene Volcanic Rocks

The relatively fresh appearance of the andesite clasts suggests that they are derived from the abundant Miocene volcanic rocks in California. Both the Mehrten Formation of the Sierran foothills and the Neroly Formation near the Livermore basin contain clasts derived from Miocene volcanoes in the area of the present-day Sierra Nevada (Lerbekmo, 1956). These clasts form the category Miocene volcanic rocks, and they are inferred to have been derived from the Sierra Nevada or reworked from the Neroly Formation. A few basalt clasts have been included.

Coast Range Rocks

The graywacke, blueschist, metavolcanic rocks and other metamorphic clasts are combined into the category of Coast Range rocks. These clast types commonly occur together in the California Coast Ranges, where rocks of the Franciscan Complex and Great Valley Group are exposed. Possible Coast Range sources now occur on all sides of the area of study.

Petrofacies

Distinctive assemblages of types of clasts in gravel are here used to define petrofacies for stratigraphic correlation within the Sycamore Formation. The three

categories described above define the poles of the ternary diagram presented as figure 6. All of the samples are plotted on the ternary diagram. Samples were first plotted according to the two grain-size fractions of 4 to 16 mm and 16 to 64 mm, but no significant difference in distribution patterns on the ternary diagrams was observed. Because the ternary diagrams for the fractions were similar, the clast types for each fraction were added together as presented in Tables 1, 2 and 3, and the relative proportion of each group was plotted to establish the petrofacies.

Generally the samples plot near one of the three poles. This allows a grouping of the samples into three petrofacies. The petrofacies names are taken from localities that provide distinctive examples.

Finley Road Petrofacies

This petrofacies contains samples that are almost entirely composed of clasts derived from Franciscan or Great Valley rocks of the Coast Ranges. These samples occur near the base of the Blackhawk section and at the Finley Road quarry (fig. 2) southeast of the section.

Blackhawk Petrofacies

Samples containing 45 percent to 90 percent Miocene volcanic clasts, with the balance made up primarily of

Figure 6. Relative proportion of Coast Range rocks, Miocene volcanic rocks and Tertiary sedimentary rocks in gravel samples from the Sycamore Formation.

Tertiary sedimentary clasts, are included in the Blackhawk petrofacies. Samples from about 800 m to 1250 m above the base of the Blackhawk section are composed of this petrofacies. One sample with only 45 percent Miocene volcanic clasts is included in this petrofacies, but it evidently represents a transition to the overlying petrofacies.

Roundhill Petrofacies

This petrofacies is dominated by Tertiary sedimentary clasts with Miocene volcanic rocks and Coast Range rocks contributing up to 34 percent of the total. Samples from the Roundhill section, from the upper half of the Blackhawk section, and from all of the Whitecliff section are composed of this assemblage.

Sand and Sandstone

Several samples of sand and poorly lithified, friable sandstone were examined in thin section. Sand and sandstone samples from the Neroly Formation and two other localities in the Sycamore Formation within the Livermore basin also were examined. Because the sandstone was not the focus of the study, quantitative counts of samples were not done, but the samples were evaluated qualitatively. The goals were to

determine major differences in assemblages of grain types at different stratigraphic levels and, where possible, to determine how the sandstone composition reflects variation in associated gravel composition.

Neroly Sandstone

Three samples of the Neroly Formation were examined. Sample 18 was collected in the upper portion of the formation just below the Roundhill section; sample 55 was collected lower in the Neroly below the Whitecliff section; and, sample 73 was collected at the top of the Neroly below the Black Hawk Ranch quarry (fig. 2).

Sample 18 is a medium- to coarse-grained, well sorted sandstone dominated by about 75 percent volcanic lithic fragments. Grains are subrounded to rounded and most have a distinctive thin clay coating that imparts a bluish color to the sand in hand specimen (Lerbekmo, 1956). The volcanic grains range from basaltic to andesitic in composition with the andesitic types in the majority. Many of these grains are porphyritic. The groundmass is either intergranular or intersertal. Microlites are common. Other clasts include chert, polycrystalline quartz, monocrystalline quartz, minor amounts of plagioclase and clinopyroxene, and rare hornblende. Most of the plagioclase, clinopyroxene and

hornblende, however, are contained within volcanic rock fragments.

Sample 55 is a fine- to medium-grained, well sorted sandstone containing more than 50 percent volcanic lithic grains. Grains are subangular to subrounded and lack the clay coats observed in sample 18. The general composition of grains is similar to that in sample 18. Monocrystalline grains of clinopyroxene, primarily augite, plagioclase, and quartz are common in this sample. Chert and polycrystalline quartz occur in amounts similar to those in sample 18.

Sample 73 is a fine-grained, well sorted sandstone that strongly resembles sample 18. Volcanic lithic fragments are more than 75 percent of the rock.

Sycamore Formation Sandstone

Blackhawk Section. Gravel was not observed between 400 m and 700 m above the base of the Blackhawk section, but sandstone was collected (fig. 3). These samples provide information about the transition in composition between the Neroly and the Sycamore formations and the provenance for the oldest part of the Sycamore Formation.

Sample 90, collected 400 m above the base of the section, is a fine-grained, moderately sorted, lithic sandstone with abundant metamorphic clasts and polycrystalline quartz. The grains are angular to

subrounded, and volcanic lithic fragments make up less than 10 percent of the rock. The volcanic clasts and plagioclase grains are strongly sericitized. Numerous other grains appear to be of shale. Chert and polycrystalline quartz, occasionally occurring as elongate grains, make up at least 25 percent, whereas monocrystalline quartz is less than 10 percent of the rock. Metamorphic fragments, which include phyllitic and schistose grains, make up more than 50 percent of the rock. The sandstone contains minor glaucophane and other distinctive metamorphic grains. Minor amounts of calcite are also present.

Sample 95, 500 m above the base of the section, is similar in composition to sample 90, but the amounts of chert and of polycrystalline and monocrystalline quartz are greater. A minor amount of glaucophane and more abundant foliated fragments are present.

Calcite cement makes up more than 25 percent of sample 79, collected about 600 m above the base of the Blackhawk section. Angular to subrounded grains appear to be floating in the cement. Numerous fragments with ragged edges and embayments filled with calcite indicate that the calcite cement possibly replaced or has partially replaced other grains. Volcanic lithic fragments make up more than 25 percent of the rock. Plagioclase also is abundant. Chert and metamorphic grains make up about 20 percent of the rock.

Sample 78 was collected 750 m above the base of the Blackhawk section and at the same stratigraphic level as the lowest gravel samples, which belong to the Finley Road petrofacies (figs. 3,7). The sample has a composition similar to that of Sample 90, except that the volcanic fragments make up less than 1 percent of the rock. Clasts are primarily chert, strained and unstrained polycrystalline quartz, strongly foliated metamorphic fragments, and siltstone and claystone.

Sample 74 was collected about 800 m above the base of the Blackhawk section and just below the stratigraphic level of the conglomerate samples of the Blackhawk petrofacies (fig. 3). The sandstone is fine to medium grained and poorly to moderately sorted. Grains are subangular to rounded, and many of the former appear to be previously well rounded grains that have been broken. Volcanic lithic fragments make up more than 60 percent of the rock. Chert and monocrystalline quartz total about 10 to 15 percent of the sandstone. Other grains appear to be siltstones. Metamorphic fragments are minor constituents.

Sample 76, collected 1000 m above the base of the Blackhawk section, is very similar in composition to sample 74. The chert and monocrystalline quartz appear to make up a slightly larger portion of the rock than in sample 74.

Sample 105a was collected between gravel samples 38 and 40 in the uppermost third of the Blackhawk section (fig. 3). The sand is extremely immature with poorly sorted, angular to subrounded grains. Altered to somewhat fresh-looking volcanic fragments make up more than 40 percent of the rock. Also present are about 5 to 10 percent total chert and polycrystalline quartz, about 15 percent monocrystalline quartz, and about 5 percent plagioclase. Many grains contain sericite, and clay cement is abundant. Siltstone is a minor component, as are biotite, hornblende and green glauconite.

Roundhill Section. Sample 81, collected at about 750 m above the base of the Roundhill section (fig. 4), has abundant volcanic rock fragments. The sample is similar in appearance to sample 105a, although the percentage of volcanic fragments is somewhat less. Siltstone grains are more common.

Whitecliff Section. Sample 127 collected in the lower part of the Whitecliff section (fig. 5) is the most immature of all the samples. The grains are poorly sorted and are angular to subrounded. Volcanic fragments are present, but represent a smaller fraction of the clasts than in the Roundhill sample.

Black Hawk Ranch Quarry. Sample 71 from the Black Hawk Ranch quarry (fig. 2), located to the east of the Blackhawk section, appears to be similar in composition to the sandstone collected from near the base of the Blackhawk section. Altered volcanic fragments make up less than 25 percent of the rock. Chert and polycrystalline quartz make up about 50 percent of the rock. The remaining 25 percent consist of strained and unstrained quartz, siltstone, and metamorphic fragments including quartzite and strongly foliated grains, glaucophane, and possible actinolite.

Collier Canyon Quarry. Sample 51 from the Collier Canyon quarry (fig.2) contains abundant siltstone and metamorphic clasts. The latter include strongly foliated grains and platy minerals, and rare glaucophane, biotite and muscovite. Chert, quartzite and polycrystalline quartz also are common.

Discussion

On figure 7, stratigraphic levels are designated by the petrofacies to which they belong. The trends in gravel

Figure 7. Distribution of petrofacies in the Sycamore Formation.

composition are strongly supported by the sand composition.

Sand between 400 m and 750 m above the base of the Blackhawk section, where gravel is absent, records the transition from the Miocene volcanic clasts of the Neroly Formation to the Finley Road petrofacies. This represent an influx of Coast Range material which mixed with Miocene volcanic detritus. Sandstone sample 71 from the Black Hawk Ranch quarry indicates that the Sycamore Formation, near its contact with the underlying Neroly Formation, records a significant contribution from a Franciscan source.

The Finley Road petrofacies, occurring between about 750 m and 800 m above the base of the section, records a complete shift in provenance to a Franciscan or Great Valley source. The complete absence of Miocene volcanic clasts and the shift to a Coast Range source also is reflected in the sand-size fraction from that part of the section. Sandstone sample 51 from the Collier Canyon quarry appears to be closely related to sand of the Finley Road petrofacies. Clasts of graywacke, quartzite, vein quartz, chert of varying color, and greenstone are prominent in the gravels of the Collier Canyon quarry.

The overlying Blackhawk petrofacies, between about 800 m and 1250 m above the base of the Blackhawk section, provides evidence of a shift back to a Miocene volcanic source. Sand collected just above the Finley Road petrofacies shows that

the change in provenance was abrupt. In the sand sample, the volcanic fraction of the Blackhawk petrofacies does not represent as great a proportion of the rock as it does in the Neroly sandstone. The sandstone lacks the textural maturity of the Neroly sandstone. Broken rounded clasts suggest that the material may be reworked from the Neroly Formation.

Gravel and sand from 850 m above the base of the Blackhawk section to the top of the section and all of the Roundhill and Whitecliff sections belong to the Roundhill petrofacies. Clasts ranging up to boulder size are rocks from the Tertiary section below the Sycamore Formation that can easily be identified, particularly in the Roundhill section. Representative sand of the Roundhill petrofacies from each of the three sections contains a smaller fraction of volcanic fragments and exhibits an upward increase in textural immaturity relative to the lower petrofacies. The large proportion of angular to subangular grains and poor sorting indicate a possible proximal source. Sericitization and clay cements are prominent. The source area does not appear to have contained many metamorphic rocks, but evidently was quite diverse in the type of grains that were contributed. The sand reflects the composition of the gravels that indicate a provenance from the entire Tertiary section below the Sycamore Formation.

These results indicate that the petrographic makeup of the Sycamore Formation is much more complex than previously determined. Clasts of the Franciscan Complex described by Oestreich (1958) and Wagner (1978) represent the composition of only a small portion of the Sycamore Formation near the base, here assigned to the Finley Road petrofacies. Two additional succeeding changes are recorded in the Blackhawk petrofacies and the overlying Roundhill petrofacies. These three petrofacies indicate that the provenance for the Sycamore Formation changed over time.

AGE

To understand how depositional systems and sediment provenance changed with time, age control within the Sycamore Formation is necessary. Age constraints for the Sycamore Formation have been obtained from the numerous tuff units distributed throughout the formation and from the sparse fossil record contained within it.

Fossil Record

In general, the fossil record is poor within the Sycamore Formation. The majority of invertebrate fossils identified were derived from the underlying Tertiary formations, primarily the Miocene Neroly and Cierbo formations (J. W. Durham, 1986, oral communication). Vertebrate localities also are rare, but have been more useful in constraining the age of the Sycamore Formation.

Previous Studies

The Black Hawk Ranch quarry locality (University of California V-3310) is within the Sycamore Formation to the west of the Blackhawk section, and stratigraphically just above the Neroly Formation (fig. 2). A diverse suite of late Clarendonian fauna (late Miocene) was identified by Richey (1948) and MacDonald (1948) and named the Black Hawk

Ranch fauna. The accompanying flora were described by Condit (1938) and Axelrod (1944) and interpreted as species found in mesic flood-plain and woodland-chaparral environments. A summary of both fauna and flora is contained in Appendix II.

Savage (1955) identified a Megalonychid ground sloth (V-5053) of Hemphillian age (late Miocene-early Pliocene) up section from the Black Hawk Ranch quarry and about 1300 m (4500 ft) above the base of the Sycamore Formation.

Other fossils have been found throughout the northern Livermore basin and are catalogued in the University of California Museum of Vertebrate Paleontology. Reexamination of these specimens by C. Swischer (1986, oral communication) of the University of California indicated that the ages assigned to these fossils are tenuous. The age assignments generally were Blancan (Pliocene-early Pleistocene) and younger. In all cases, the poor condition of a particular fossil or its occurrence over a broad stratigraphic range precluded precise dating.

Present Study

Two vertebrate fossil specimens were identified during this study. A fossil found at the Roundhill section just below the contact of the Neroly and Sycamore formations (fig. 2) was identified as part of a late Clarendonian

juvenile mastodont jaw (C. Swischer, 1986, oral communication). A late Clarendonian hipparion horse foot bone (C. Swischer, 1986, personal communication) was found down section from the Finley Road quarry (fig. 2), east of the Blackhawk section. Both specimens are now catalogued in the University of California Museum of Vertebrate Paleontology.

Tuffs

The abundant tuffs, which occur throughout the Sycamore Formation, have provided an opportunity to better understand the age relationships of the sections examined during this study.

Previous Studies

Several tuffs were previously identified in the northern Livermore basin and chemically correlated with tuffs of widespread distribution in the central Coast Ranges of California and the southern Cascade Range of California (Sarna-Wojcicki, 1976, 1979). These include the Wilson Grove Tuff, the Pinole Tuff, and the Lawlor Tuff. Other tuffs have been identified within the basin that do not correlate with presently known tuffs in other areas.

Sarna-Wojcicki (1976) utilized X-ray fluorescence spectrophotometric analysis for trace and minor elements supported by mafic mineral petrology, stratigraphic position and potassium/argon (K/Ar) dating to correlate tuffs. Data were processed graphically as binary and ternary diagrams, by calculation of similarity coefficients and by cluster analysis.

The Wilson Grove Tuff, which has its type locality in the Wilson Grove Formation near Sonoma, has also been correlated with a tuff north of San Pablo Bay, and has its most southerly determined extent in the northern Livermore basin (fig. 2). This tuff has been dated at 6.0 ± 0.1 Ma (Bartow and others, 1973) and 5.7 ± 0.5 Ma (Sarna-Wojcicki, 1976) at its type locality.

The Pinole Group, a 275-m-thick sequence of tuffs northwest of Mount Diablo, generally has been correlated with the lower part of the Sonoma volcanic field east of Sonoma and with a sequence of tuffs in the northern Livermore basin (fig. 2). A date of 5.2 ± 0.1 Ma was obtained for the tuff at the Pinole locality northwest of Mount Diablo (Evernden and others, 1964), and an age of 5.4 ± 0.2 Ma was obtained for the tuff east of Sonoma (G.H. Curtis, oral communication, 1971, in Sarna-Wojcicki, 1976).

The Lawlor Tuff, with an age of 3.96 ± 0.1 Ma at its type locality north of Mount Diablo, has been correlated with a

tuff located east of Sonoma. It also has been correlated with two tuffs south of Mount Diablo. The tuff in the northern Livermore basin (fig. 2) has been dated at 4.0 ± 1.0 Ma, and a correlative tuff in the Livermore Gravels south of the city of Livermore has been dated at 4.46 ± 0.45 Ma. The Megalonychid ground sloth of Hemphillian age was found by Savage (1955) adjacent to an exposure of the Lawlor Tuff up section from the Black Hawk Ranch quarry.

Other tuffs in the northern Livermore basin have been analyzed, but they do not have known correlatives (A. Sarna-Wojcicki, 1986, oral communication). Their relative ages have been determined by stratigraphic relationship with tuffs of known age.

Present Study

Several additional tuffs have been located in the northern Livermore basin during this study. They have been analyzed and correlated by A. Sarna-Wojcicki (1986, oral communication) utilizing the methods described above.

Appendix III contains the raw microprobe data for each tuff correlated. The fifty best matches, which are based on relative proportions of major elements for each tuff compared, are included.

Tuff A (Simp-3; T126-10 of Sarna-Wojcicki), collected near the base of the Roundhill section (fig. 2), has been

correlated with a tuff for which there is no known correlative outside of the Livermore basin. Extreme alteration, stratigraphic position near the top of the Neroly Formation, and correlation with other tuffs of ages greater than 5 to 6 Ma within the basin (A. Sarna-Wojcicki, 1986, oral communication) suggest an age as old as 7 to 9 Ma.

Tuff B (SCFLD-1; T126-1 of Sarna-Wojcicki), stratigraphically above the Black Hawk Ranch quarry (fig. 2), has been tentatively included in the Pinole Group, and assigned an age of about 5 Ma (Sarna-Wojcicki, oral communication, 1986).

Tuff C (WC-2B2; T117-8 of Sarna-Wojcicki) lies at the base of the Whitecliff section (fig. 5) and has been correlated with the Huitchica Tuff of the Huitchica Formation (Sarna-Wojcicki, oral communication, 1986). The latter tuff previously has been identified above the Lawlor Tuff within the Livermore Gravels, south of Livermore (A. Sarna-Wojcicki, 1986, oral communication). It has been dated at 4.09 ± 0.19 Ma at the type locality east of Sonoma (Fox and others, 1985).

Tuff D (T-1-85; T110-11 of Sarna-Wojcicki) is located 900 m above the base of the Roundhill section (fig. 4), and tuff E (WC-2B1; T117-7 of Sarna-Wojcicki) is located a few meters above tuff C, the 4 Ma Huitchica Tuff, at the base of

the Whitecliff section (fig. 5). Tuffs D and E strongly match with each other. Both tuffs D and E are similar to two other tuffs of differing ages of 3.3 Ma and 6.0 Ma (A. Sarna-Wojcicki, 1986, oral communication). The occurrence of tuff E stratigraphically above the 4 Ma Huitchica Tuff (fig. 5) indicates correlation with the Putah Tuff which has an age of 3.3 ± 0.1 Ma (Sarna-Wojcicki, 1979). Therefore, tuff D in the Roundhill section is also correlated with the Putah Tuff (Sarna-Wojcicki, oral communication, 1986).

Tuff F (T-4-86-KI; T126-12 of Sarna-Wojcicki) is located a short distance east of the Roundhill section (fig. 4). It has been correlated with the 3.3 Ma Nomlaki Tuff, which is exposed near the base of the Tehama Formation in the northern Sacramento Valley (A. Sarna-Wojcicki, 1986, oral communication). The source for the Nomlaki Tuff is the southern Cascade Range of California (fig. 1).

Several additional tuffs were observed within the Blackhawk section. A sequence of highly altered tuffs, designated G (fig. 3), is located between about 900 m and 950 m above the base of the section. Other tuffs, designated H, I and J (fig. 3), are at 1050 m, 1200 m and 1700 m, respectively, above the base of the section. The Lawlor Tuff, tentatively identified by Sarna-Wojcicki at this locality by stratigraphic correlation with nearby dated exposures, occurs about 2.2 km above the base. Except for

the 4 Ma Lawlor Tuff, an absolute age cannot be assigned to any of these tuffs in the Blackhawk section.

Conclusions

Fossil and tuff data place age constraints on the Sycamore Formation. Figure 8 presents the stratigraphic relationships for each section on an absolute time scale, and indicates the distribution of petrofacies and lithofacies associations over time. Where missing time has been identified, correlation by petrofacies between sections has been utilized to determine approximately what amount of time is missing.

Neroly-Sycamore Formation Contact

The age of the Neroly Formation is generally considered to be Clarendonian (Miocene), and the top of the formation is youngest south of Mount Diablo (Kilmer, 1953). In its entire extent, the ages for both the top and bottom of the formation vary. The late Clarendonian Black Hawk Ranch fauna, located within the Sycamore Formation approximately 60 m (200 ft) above the contact with the Neroly Formation, suggests a late Clarendonian age for the top of the latter in the area of study. Evidence from radiometric dating

Figure 8. Distribution of petrofacies of the Sycamore Formation relative to absolute time with lithofacies designated by numbers.

related to microtine rodents indicates that the Hemphillian-Clarendonian faunal change took place at about 9 Ma (Repenning, 1987). West of the Calaveras fault, the 150-m-thick Lafayette Tuff conformably overlies the Neroly Formation (Wagner, 1978). The lowest part of the tuff sequence is dated at 8.2 ± 1.5 Ma (Wagner, 1978). Current information thus suggests that the Neroly-Sycamore formation contact formed between about 9.0 Ma and 8.5 Ma.

Absolute Ages within the Sycamore Formation

Where absolute ages for the tuffs are not known, age assignments have been made based on the stratigraphic relationship with other tuffs in the region. These tuffs may have age ranges designated to emphasize the uncertainty associated with them.

The tuffs at 900 to 950 m or at 1050 m above the base of the Blackhawk section correlate stratigraphically with the tuff above the Black Hawk Ranch quarry, assigned to the approximately 5 Ma Pinole Group. The oldest tuff of the section could also correlate with the approximately 6 Ma Wilson Grove tuff, identified by Sarna-Wojcicki (1979) just below the Pinole Group in the areas of Tassajara, Highland and Collier Canyon roads (fig. 2). Tentative age assignments for the tuffs have been made based on these relationships. From the Blackhawk section northwestward,

the thickness of sections appears to decrease along strike. Tuffs higher in the Blackhawk section at 1200 m and 1700 m above the base cannot be ruled out as belonging to the Pinole Group.

When placed on the absolute time scale, it is apparent that the Blackhawk section provides the most continuous record of deposition between 8.5 Ma and 4 Ma. Absence of the Finley Road and Blackhawk petrofacies at Roundhill suggests that the time between about 8.5 Ma and 5 Ma is not represented in that section. Earliest deposition of the Sycamore Formation at Whitecliff may be only 4.5 Ma. The time between about 4 Ma and 3.3 Ma is represented by only a few meters of strata in the Whitecliff section. Therefore, time missing at the top of the Blackhawk section after about 3.5 Ma is present in the other two sections. The youngest sediments of the Sycamore Formation are at the top of the Whitecliff section, where over 1 km of section is present above the 3.3 Ma Putah Tuff. This suggests that the top of the section may represent deposition at about 2.5 Ma.

Summary

The fossil record and the tuff correlations have provided the framework to place time constraints on the Sycamore Formation. Although only tentative ages have been

assigned to some of the tuffs, age constraints have been placed on those portions of the formation where they occur, which allows for correlation between the three different sections. The Blackhawk section represents a time period between about 8.5 Ma and 4 Ma, whereas the bases of the Roundhill and Whitecliff sections are significantly younger than 8 Ma. The age control and the provenance determination for each petrofacies provide the tools to better understand the evolution of the Livermore basin during the last 10 Ma.

GEOLOGIC HISTORY

Resolution of the provenance of gravel within the Sycamore Formation and of time constraints on the deposition of the gravel allows construction of paleogeographic maps at distinct times. Figures 9, 10, 11, and 12 present time-slices at 9.5 Ma, 7.0 Ma, 6.0 Ma, and 3.5 Ma, respectively. The maps are non-palinspastic. The paleogeographic reconstructions utilize the work of Wagner (1978), Graham and others (1984), and Barlock (1989) in an effort to integrate this study with their data for tectonic events at the south end of the basin and west of the Calaveras fault.

Events Prior to 8.5 Ma

Significant tectonic changes in the northern Livermore basin appear to have been predated by a tectonic reorganization in the Contra Costa basin to the west, which was established by 12 Ma. In the Contra Costa basin, the fluvial Orinda Formation consists of clasts of subduction-complex material containing up to 20 percent blueschist-facies rocks that were shed from uplands along the future trend of the Hayward fault (Graham and others, 1984). To the east in the Livermore basin, however, andesitic detritus reflecting the last stages of Sierran volcanism continued to be deposited as the shallow-marine Neroly Formation.

Figure 9. Generalized paleogeographic reconstruction of the Livermore basin region at about 9.5 Ma. Map is nonpalinspastic.

Figure 10. Generalized paleogeographic reconstruction of the Livermore basin region at about 7 Ma. Map is nonpalinspastic.

Figure 11. Generalized paleogeographic reconstruction of the Livermore basin at 6 Ma. Map is nonpalinspastic.

Figure 12. Generalized paleogeographic reconstruction of the Livermore basin region at about 3.5 Ma. Map is nonpalinspastic.

Neroly deposition transgressed westward into the Contra Costa basin by about 9.5 Ma (fig. 9), while Franciscan sediments continued to be shed eastward. In the Livermore basin, depositional environments of the Neroly Formation varied from shallow marine to fluvial.

At that time the Mendocino triple junction was moving northward and was just south of, or at the latitude of, San Francisco Bay (Dickinson and Snyder, 1979a). Between 9.5 Ma and 8.5 Ma the Hayward fault became active as did the more local Moraga thrust fault, between the Hayward fault and the present-day trend of the Calaveras fault to the east (Graham and others, 1984; Wagner, 1978). Eastward transport of sediment across the Contra Costa basin was locally disrupted by the evolving fault systems. Neroly sediment was no longer deposited in the evolving Contra Costa basin (Graham and others, 1984).

Events from 8.5 to 7 Ma

At approximately 8.5 Ma, the sand near the base of the Sycamore Formation at the Blackhawk section records an increasing contribution of sediments derived from Franciscan sources in the Coast Ranges. The change in composition of sand from Sierran-derived andesitic material to more locally

derived Franciscan detritus was not abrupt, but may have spanned a period of 1 to 2 million years.

To the west in the Contra Costa basin, the Mullholand Formation was deposited between 8 Ma and 7 Ma and is composed of estuarine, lacustrine and fluvial sediments (Liniecki-Laporte and Andersen, 1988). The presence of estuarine ostracodes and the lack of Sierran-derived material in the basal member of the formation indicate that this area was near sea level and that a topographic barrier existed to the east.

The mixed-provenance material at the base of the Blackhawk section of the Sycamore Formation was deposited in meandering stream systems. The late Clarendonian flora and fauna identified at the Black Hawk Ranch quarry at an equivalent stratigraphic level suggest well developed grassland and riparian habitats. The final shift to continental environments coincides with a world-wide drop in sea level (Vail and Hardenbol, 1979) and infilling of the last remnants of the marine embayment, which previously covered the area.

Deposited between about 7.5 Ma and 7 Ma, the Finley Road petrofacies was wholly derived from a Franciscan source (fig. 10). The dramatic increase in grain size and shift to braided streams suggests that the relief in the source area had increased. The Finley Road petrofacies lacks the

blueschist clasts seen in the Orinda Formation and was not derived from a blueschist-rich Franciscan terrain to the west of the Hayward fault. Similarly, the marked absence of red chert from the gravel suggests that neither the chert-rich terrane of Mount Diablo to the north of the basin nor the Franciscan rocks of the Marin Headlands, directly north of San Francisco, was the source. Instead, the likely source for the graywacke-rich Franciscan material was to the south of the basin in the evolving central Diablo Range in the area presently occupied by Mount Hamilton (fig. 1). Uplift of the central Diablo Range, possibly as early as 10 Ma, is recorded in an unroofing sequence of Tertiary and Franciscan rocks deposited in the Carbone Formation near the city of Tracy, on the east side of the range (Bartow, 1987).

The distinctive Franciscan material of the Finley Road petrofacies has been identified in the Blackhawk section, at the Finley Road quarry, and to the south at the Rasmussen quarry and Collier Canyon Road quarry (fig. 2). At the latter two locations, the average grain size is even greater than at the outcrops to the north. A coarsening of material to the south provides additional evidence for a southern source. Rocks of this age and composition are not preserved in the Livermore Gravels on the south side of the Livermore basin, where younger rocks of the lower Livermore Gravels rest unconformably on older Tertiary and Cretaceous rocks

(Barlock, 1989). The base of the Livermore Gravels near the town of Livermore evidently is between 5 Ma and 4 Ma (Barlock, 1989). The absence of this unit in the Livermore Gravels suggests that sediment from the south bypassed the southern part of the basin before 5 Ma.

Events from 7 to 5 Ma

The relatively abrupt change from deposition of the Finley Road petrofacies to deposition of the Blackhawk petrofacies indicates a marked change of source area (fig. 11). The sand and gravel in the Blackhawk petrofacies are dominated by andesite clasts. Though the braided stream environment persisted, the average grain size decreased to sand, with only minor amounts of gravel. This change in provenance also is recorded in sand associated with the 5 Ma Pinole Tuff above the stratigraphic level of the Collier Canyon Road quarry farther to the south in the basin (A. Sarna-Wojcicki, 1986, oral communication).

Primary andesitic material may not have been transported into the Livermore basin from a Sierran source since at least 7.5 Ma and had been shut off at an earlier time in the Contra Costa basin to the west (Graham and others, 1984; Linieki-Laporte and Andersen, 1988). A high may have been evolving along the trend of the Calaveras fault to the west

of the Livermore basin (Wagner, 1978) and provided a sediment barrier. It is more likely that the barrier and the source of the andesitic detritus was the high evolving in the area of the present day Altamont Hills, as the unconsolidated portions of the Neroly Formation were gradually unroofed and reworked. The unroofing may have started as early as 8.5 Ma, and andesitic material deposited at the base of the Sycamore Formation may not have been from a primary Sierran source. Because andesitic detritus was mixing with Franciscan source material, it would be difficult to distinguish primary from reworked andesitic detritus. Barlock (1989) reported that by 5 Ma andesitic detritus, derived from a source to the northeast, was being deposited in the lower Livermore Gravels on the south side of the basin. Primary Sierran andesitic material did continue to be transported to the south into the San Joaquin basin as recorded in the Miocene/Pliocene Etchegoin Formation (Perkins, 1987).

The lower part of the Sycamore Formation in the Blackhawk section was deposited between about 8.5 Ma and 5 Ma. Deposits of this age are not present in the other sections to the northwest, suggesting that the Neogene Livermore basin had not reached its maximum size at that time.

Events after 5 Ma

The areal extent of deposition of the Sycamore Formation increased sometime between 4 Ma and 5 Ma. The Blackhawk section of the formation records a gradual increase in grain size and in the percent of clasts derived from the lower part of the underlying Tertiary section. The latter rocks were being unroofed on the northeast side of the basin. To the northwest, the Roundhill and Whitecliff sections of the Sycamore Formation record the unroofing of the evolving uplift, including the area presently occupied by Mount Diablo. The oldest rocks of the Tertiary section were being eroded and redeposited by about 4.5 to 4 Ma. The presence of boulders and debris-flow deposits in the part of the section that includes the 3.3 Ma Putah Tuff indicates that this part of the basin was proximal to the ongoing uplift at that time (fig. 12). To the southeast, sediment became finer in the Blackhawk section just prior to deposition of the 4 Ma Lawlor Tuff. Dark, well homogenized, clayey material indicates that ponding was occurring in this part of the basin. Ponding resulted from a shift in the location of active fluvial processes and the location of the basin axis during enlargement of the basin.

The time of onset of activity on the Calaveras fault is not clearly established, but has been placed at about 3.6 Ma

based on the radiometrically dated basalt located along the southern portion of the fault (Page, 1982). This age corresponds in general with the increased extent of deposition in the basin, suggesting that enlargement of the basin may have been tied to the evolution of the Calaveras fault during a continuing partly extensional tectonic regime that started at about 10 Ma (Harbert and Cox, 1989).

The sections of the Sycamore Formation examined in this study contain no record of erosion of the Franciscan core exposed at Mount Diablo. Graywacke, red chert, greenstone and serpentinite exposed today on the flanks of Mount Diablo are not abundant at any stratigraphic level. The thickness of the section at Roundhill and Whitecliff above the 3.3 Ma Putah Tuff suggests continued deposition until at least 2.5 Ma. Although uplift of the Altamont Hills commenced between about 8.5 Ma and 7 Ma, the exposure of the Franciscan core of Mount Diablo is a significantly younger event, that post-dates deposition of the Sycamore Formation. It is likely that additional deposition occurred after what is presently recorded, and that those deposits were eliminated prior to or during deformation of the Sycamore Formation sometime after 2.5 Ma. Deposition of the upper Livermore Gravels in the south part of the basin recorded uplift of Mount Hamilton at about 2.5 Ma and deposition of

the Livermore Gravels continued until about 450,000 year ago (Barlock, 1989).

Uplift of the area occupied by Mount Diablo today continued. The folding of the Sycamore Formation may be related to the uplift of Mount Diablo and activity along the Calaveras fault. This tectonism occurred under a partly compressional regime that commenced sometime between 2.4 Ma and 3.9 Ma, and resulted from the change in relative motion of the Pacific and North American plates (Harbert and Cox, 1989).

REGIONAL TECTONICS

The sedimentary record associated with the evolution of the Livermore basin in the last 10 Ma suggests that the onset of strike-slip activity on the Calaveras and associated faults occurred late in the history of the basin. Other mechanisms then need to be considered to account for the earlier uplift on the eastern edge of the basin and for subsidence of the basin. Early deformation likely results from more regional tectonic stresses related to the conversion of the plate margin from a convergent to transform boundary. This transition records the northward migration of the Mendocino triple junction (Dickinson and Snyder, 1979a).

The history of the area occupied by Mount Diablo today is complex. The sedimentary record indicates that the area was probably emergent during the Eocene (Bodden, 1983). The difference in depositional environments recorded in the Eocene units on the north and south sides of Mount Diablo can be accounted for by separation by a high (Bodden, 1983) possibly connected to the larger Stockton arch (fig.1). The area covered by deposition of the Neroly Formation and older units of the San Pablo Group in the Miocene was extensive, reaching into the Contra Costa basin. A high in the present location of Mount Diablo itself was not present during that time.

As the Mendocino triple junction approached the latitude of San Francisco Bay at about 12.5 Ma, highs developed to the west of the Livermore basin along the trend of the future Hayward fault. On the eastern edge of the Livermore basin, the early development of the Diablo antiform was not the antecedent of a major strike-slip system. Rather, the uplift of the central and north Diablo ranges which included the Altamont Hills may reflect crustal adjustments as subduction terminated. These crustal adjustments may have occurred to accommodate the unstable configuration of the Mendocino triple junction (Dickinson and Snyder, 1979b) or in response to lithospheric thinning and accompanying asthenospheric upwelling in the newly-formed slab window to the south of the triple junction (Dickinson and Snyder, 1979b).

Adjacent to the Livermore basin, warping may have been a result of the reactivation of features present in the Eocene. By 8 Ma the Mendocino triple junction was north of the Livermore basin. Uplift that had started earlier at the south end of the basin had progressed northward along the eastern edge of the basin. The warping coincided with a period of regional extension, tied to slightly divergent plate motion (Harbert and Cox, 1989). Increase in basin size until at least 3.5 Ma suggests that the period of extension continued until that time. Deposition of the

Sycamore Formation continued until about 2.5 Ma, but by then the Calaveras fault was already active, indicating that a slightly extensional regime was still active until at least that time.

Folds formed in the basin after 2.5 Ma may be directly attributed to displacement along the active Calaveras fault under a slightly compressional regime. A shift to a compressional regime may also account for the eventual uplift of Mount Diablo. The degree of folding and its extent may be tied to the final uplift of Mount Diablo. As Mount Diablo was uplifted and thrust to the south, folding was enhanced. The Mount Diablo massif and the adjoining Altamont Hills constrained the limits of the basin. They limited the extent of folding and provided considerable resistance, as folds evolved under the compressional regime, possibly accounting for eventual overturning of beds on the southwest flank of Mount Diablo.

CONCLUSIONS

The Finley Road, Blackhawk and Roundhill petrofacies record changes in provenance over approximately 6 million years of deposition in the Livermore basin of the fluvial Sycamore Formation, starting about 8.5 Ma. Prior to that time, the mixed marine and fluvial Miocene Neroly Formation, composed primarily of Sierran-derived andesitic material, was deposited in the last remnants of the former forearc basin.

The passage of the Mendocino triple junction through the area at the latitude of San Francisco Bay starting about 10 Ma and the slightly extensional regime imposed by divergent plate motion had a significant effect on the evolution of the basin. At about 9 Ma, the Hayward transform fault to the west in the adjoining basin was fully developed. To the east and south of the Livermore basin, uplift and erosion of the Franciscan core of the central Diablo Range may have started as early as 10 Ma. The results of these events are recorded in the Finley Road petrofacies at the north end of the basin at about 7.5 Ma.

As the Diablo antiform developed to the northeast of the basin, unconsolidated portions of the Neroly Formation were eroded and redeposited in the basin as the sandy Blackhawk petrofacies. Erosion of the Neroly Formation may have

started as early as 8.5 Ma, but redeposited sediment cannot be distinguished from primary Sierran detritus.

More pronounced uplift is recorded in the Roundhill petrofacies starting at about 4 to 5 Ma. The Roundhill petrofacies, consisting of clasts of the entire underlying Tertiary section, is the coarsest of the petrofacies. For the first time, well lithified clasts of the Neroly Formation were deposited, rather than the reworked andesitic sand and gravel observed in the Blackhawk petrofacies. There is no evidence of the Franciscan core of Mount Diablo in the sediments. Eastward migration of the limits of the transform fault system was accompanied by an enlargement of the basin as the Calaveras fault developed on the western edge of the basin.

Folds formed over a large area of the basin after 2.5 Ma, probably in response to changing stresses on the Calaveras fault. Overtaken folds only occur near the Mount Diablo uplift, particularly in the area of the northwest side of the basin, where the Calaveras fault and the Diablo antiform converge. The final uplift of the core of Mount Diablo is younger than 2.5 Ma and probably enhanced deformation of the basin.

The series of tectonic events recorded in the Sycamore Formation indicates that deformation along an evolving transform plate margin is complex. The passage of the

Mendocino triple junction through the Livermore basin and adjoining areas resulted in a variety of tectonic responses that were tied to the geometry of the triple junction, to plate motion, and to structures and materials unique to the area. Uplift and subsidence in the Livermore basin coincided with some of the early deformation far to the west of the basin, but the style of deformation on the eastern edge reflects a different response of the crust to termination of subduction. These parallel tectonic events to the east and west indicate that the wide zone of deformation present today, between the San Andreas fault and the eastern edge of the Livermore basin, attained its present width early in the evolution of the transform system.

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**APPENDIX I. CLAST COUNTS FOR THE 4-16 MM AND THE 16-64 MM
FRACTIONS OF SAMPLES**

APPENDIX I
BLACKHAWK SECTION

SAMPLE	C-3 4-16 (mm)	16-64 (mm)	Total clasts	91A 4-16 (mm)	16-64 (mm)	Total clasts	5-85 4-16 (mm)	16-64 (mm)	Total clasts	6-85 4-16 (mm)	16-64 (mm)	Total clasts
Clast diameter												
ROCK TYPE												
Tertiary Sand- stone/fossil/clay												
Chert												
red	4	2	6				7		7		1	1
green											3	3
black	3	1	4	10		10	5		4	8	2	10
Volcanic Rocks												
Quartzite												
Vein Quartz	5	17	22	24	12	36	15	11	26	43	4	47
Graywacke	10	20	30	112	12	124	72	19	91	63	2	65
Metamorphic Rocks												
blueshist		2	2									
metavolcanic							18	2	20	3	4	7
other	4	11	15	62	7	69	1	5	6	10	2	12
Miscellaneous												
Total	26	53	79	208	31	239	118	42	160	127	18	145

APPENDIX I
BLACKHAWK SECTION cont.

SAMPLE Clast diameter	C-4 4-16 (mm)	16-64 (mm)	Total clasts	100A 4-16 (mm)	16-64 (mm)	Total clasts	C-2 4-16 (mm)	16-64 (mm)	Total clasts	37 4-16 (mm)	16-64 (mm)	Total clasts
ROCK TYPE												
Tertiary Sand- stone/fossil/clay	2	2	4	5		5	7	4	11	116	15	132
Chert												
red	5	3	8	9	1	10	1		1	4		4
green	5	1	6	3		3	1		1			
black	4	8	12	20	4	24	13	13	26	16	3	19
Volcanic	12	12	24	30	11	41	3	19	22	92	14	106
Quartzite												
Vein Quartz	11	13	24	70		70	20	13	33	10	2	12
Graywacke		2	2								2	2
Metamorphic Rocks												
blueshist												
metavolcanic												
other		1	1				1	3	4			
Miscellaneous				10		10						
Total	39	42	81	147	16	163	46	52	98	238	35	273

APPENDIX I
BLACKHAWK SECTION cont.

SAMPLE Clast diameter	39 4-16 (mm)	16-64 (mm)	Total clasts	38 4-16 (mm)	16-64 (mm)	Total clasts	40 4-16 (mm)	16-64 (mm)	Total clasts
ROCK TYPE									
Tertiary Sand- stone/fossil/clay	40	13	53	82	11	93	142	23	165
Chert									
red	4		4				18	1	19
green							2	1	3
black	56	16	72	56	11	67	132	4	136
Volcanic Rocks	18	9	27	22	7	29	56	9	65
Quartzite		1	1						
Vein Quartz	30		30	24		24	44		44
Graywacke									
Metamorphic Rocks									
blueshist									
metavolcanic									
other				4		4			
Miscellaneous	18	3	21	14	3	17	20	3	23
Total	166	42	208	202	32	234	414	41	455

APPENDIX I
ROUNDHILL SECTION

SAMPLE	C-5 4-16 (mm)	16-64 (mm)	Total clasts	C-11 4-16 (mm)	16-64 (mm)	Total clasts	C-12 4-16 (mm)	16-64 (mm)	Total clasts	C-13 4-16 (mm)	16-64 (mm)	Total clasts
Clast diameter												
ROCK TYPE												
Tertiary Sand- stone/fossil/clay	37	58	95	57	22	79	73	16	89	10	26	36
Chert												
red	2		2	4		4	4		4	1	1	2
green	1		1	3		3				3	1	4
black	29	17	46	21	3	24	15		15	8	1	9
Volcanic Rocks	13	9	22	6		6	16	1	17		2	2
Quartzite	2	1	3	2		2	9		9		1	1
Vein Quartz	29	4	33	18		18	14	1	15	11	2	13
Graywacke				4		4				2	3	5
Metamorphic Rocks												
blueshist												
metavolcanic		3	3									
other	2	5	7	5		5		2	2		3	3
Miscellaneous	2	2	4		5	5	8	4	12	7	8	15
Total	117	99	216	120	30	150	139	24	163	42	48	90

APPENDIX I
ROUNDHILL SECTION cont.

SAMPLE		C-14		C-6		C-31	
Clast diameter		4-16 (mm)	16-64 (mm)	4-16 (mm)	16-64 (mm)	4-16 (mm)	16-64 (mm)
		Total clasts		Total clasts		Total clasts	
ROCK TYPE							
Tertiary Sand- stone/fossil/clay	17	31	48	59	45	104	76 135
Chert							
red	1		1	7		7	2 11
green	1		1	2		2	2
black	9		9	17	10	27	33 16 49
Volcanic Rocks	7	3	10	25	12	37	13 10 23
Quartzite							
Vein Quartz	10		10	4	3	7	4 2 6
Graywacke							
Metamorphic Rocks							
blueshist							
metavolcanic	1		1	2	2	4	1 3 5 8
other							
Miscellaneous	9	5	14	2		2	
Total	55	39	94	158	72	230	155 122 287

APPENDIX I
WHITECLIFF SECTION

SAMPLE Clast diameter	C-10 4-16 (mm)	16-64 (mm)	Total clasts	128 4-16 (mm)	16-64 (mm)	Total clasts	C-9 4-16 (mm)	16-64 (mm)	Total clasts	C-20 4-16 (mm)	16-64 (mm)	Total clasts
ROCK TYPE												
Tertiary Sand- stone/fossil/clay	16	23	39	130	20	150	49	3	52	64	22	86
Chert												
red				3		3	1		1	1		1
green							1		1			
black	3		3	9	3	12	5		5	8	1	9
Volcanic Rocks	1	1	2	6	3	9	7	1	8	2		2
Quartzite												
Vein Quartz	1	2	3	5	2	7	17		17	5	11	16
Graywacke							2		2			
Metamorphic Rocks												
blueshist												
metavolcanic		2	2				4		4			
other												
Miscellaneous				6	6	12	2		2	2	2	4
Total	21	28	49	159	34	193	88	4	92	82	36	118

APPENDIX I
WHITECLIFF SECTION cont.

SAMPLE Clast diameter	C-7		C-8		Total clasts
	4-16 (mm)	16-64 (mm)	4-16 (mm)	16-64 (mm)	
ROCK TYPE					
Tertiary Sand- stone/fossil/clay	62	28	90		
Chert					
red	2	3	5	4	4
green		3	3		
black		1	1	44	44
Volcanic Rocks	2	4	6		6
Quartzite		2	2		
Vein Quartz	16		16	1	27
Graywacke		3	3		
Metamorphic Rocks					
blueshist					
metavolcanic		4	4		
other		3	3		
Miscellaneous		3	3	20	20
Total	82	54	136	228	233

APPENDIX II. BLACK HAWK RANCH FAUNA AND FLORA

BLACK HAWK RANCH FAUNA

Hypolagus--rabbits
Citellus--ground squirrels
Eucastor cf. *lecontei* (Merriam)--beavers
Vulpes cf. *vafer* (Leidy)--foxes
Aelurodon cf. *aphobus* (Merriam)--hyaenoid dogs
Osteoborus diabloensis Richy--hyaenoid dogs
Bassariscus parvus Hall--cacomistles
Procyoninae--raccoon-like animals
Mustelinae--weasels, martins, etc.
Pseudaelurus [?] *thinobates* MacDonald--early giant true cat
Machairodontinae--giant saber-toothed cats
Gomphotherium simpsoni (Stirton)--long-jawed mastodonts
Rhinocerotidae
Hipparion forcei Richey--medium-sized three-toed grazing horse
Plihippus cf. *leardi* Drescher--larger grazing horses
Prosthennops--peccaries
Ustatchoerus--large oreodonts
Procamelus?--camels
Pliauchenia?--camels
Paracamelus?--large camels
Capromeryx, new species--hornless? prongbucks

BLACK HAWK RANCH FLORA

Populus washoensis Brown--poplars
Salix hesperia (Knowlton)--willows
Quercus convexa Lesquereux--live oaks
Quercus lakevillensis Dorf--live oaks
Ulmus californica Lesquereux--elms
Plantanus dissecta Lesquereux--sycamores
Cercocarpus cuneatus Dorf--mountain mohoganies
Rhus moragensis Axelrod--evergreen sumacs

APPENDIX III. RAW MICROPROBE DATA FOR TUFFS WITH
THE FIFTY BEST MATCHES

Listing of 50 analyses used in the comparison of COMP. NO. 1557 SAMPLE NO. SCFLD-1 T126-13
 Very good correlation with T126-13. SCFLD-1 is probably better than SCFLD-13. Total: 0.98%
 C.No Sample Number Date S102 A1203 Fe203 MgO MnO CaO T102 Na2O K2O Total.R Sim. Co

C.No	Sample Number	Date	S102	A1203	Fe203	MgO	MnO	CaO	T102	Na2O	K2O	Total.R	Sim.	Co
1	1557 SCFLD-1 T126-13	7/17/85	75.00	15.22	3.64	0.11	0.10	1.25	0.26	2.58	1.85	100.01	1.0000	
2	1103 61384-31 ASH T82-4	10/11/84	72.93	13.54	3.71	0.05	0.08	1.48	0.25	2.52	3.63	100.00	0.9375	
3	489 758-363(1), T1-2, P	11/23/83	71.89	15.17	3.53	0.10	0.07	1.07	0.23	2.82	3.12	100.00	0.9331	
4	576 KT-2		73.31	13.72	3.21	0.04	0.05	1.19	0.22	4.44	3.60	100.02	0.9272	
5	490 758-363(2), T18-4		72.06	14.90	3.55	0.11	0.05	1.09	0.22	3.03	4.97	99.98	0.9266	
6	468 758-1788, T1-13, P		71.27	14.53	3.56	0.09	0.08	1.09	0.23	5.79	3.49	99.99	0.9261	
7	470 758-190A, T1-11, P		71.44	14.53	3.88	0.12	0.10	1.01	0.23	3.65	3.02	100.00	0.9230	
8	1326 BE-134 T105-3	8/29/85	71.27	14.74	3.41	0.11	0.09	1.04	0.24	3.54	3.56	100.00	0.9220	
9	491 758-368, T18-12		73.46	13.18	3.62	0.11	0.07	1.03	0.24	3.70	2.91	100.00	0.9174	
10	1653 AA-21 JOD	09/12/85	72.36	14.17	3.55	0.21	0.11	1.16	0.32	3.70	2.63	100.00	0.9113	
11	597 SH-ASH-33 (vase), T55-6	07/01/83	72.86	14.11	2.80	0.21	0.05	1.23	0.29	4.43	4.03	100.01	0.9077	
12	1580 ASH 61185-1 T128-10	8/18/86	74.24	12.64	3.30	0.03	0.08	1.17	0.22	4.04	4.26	100.00	0.9018	
13	1119 61484-48 ASH T83-7	10/12/84	73.55	13.05	3.20	0.03	0.09	1.15	0.22	4.62	4.07	100.00	0.8967	
14	1496 85-JB-07, T104-11	08/26/85	73.36	14.39	2.91	0.10	0.03	1.18	0.21	4.16	3.65	99.99	0.8949	
15	1501 85-JB-07 T104-recalc 6el odd	08/26/85	73.36	14.39	2.91	0.10	0.03	1.18	0.21	4.16	3.65	99.99	0.8949	
16	493 931A, T34-5		71.74	15.08	2.84	0.24	0.03	1.45	0.23	4.52	3.86	99.99	0.8948	
17	1555 T-2-86 KI LOW K FRACT T126-11	7/17/86	73.06	14.22	2.92	0.23	0.08	1.08	0.29	4.71	3.41	100.00	0.8942	
18	927 DR-35		71.68	14.64	3.02	0.28	0.08	1.22	0.35	3.92	2.81	100.00	0.8932	
19	1381 ASH-61085-23 T108-7	9/24/85	73.68	13.40	3.12	0.05	0.06	1.17	0.21	4.97	3.73	99.99	0.8927	
20	1643 AA-15 JOD	07/12/86	73.08	13.78	2.89	0.24	0.10	1.19	0.30	3.55	2.92	100.00	0.8921	
21	596 SH-ASH-33 (bubble wall), T56-6	07/01/83	72.77	14.25	2.78	0.21	0.04	1.17	0.31	4.63	3.83	100.00	0.8891	
22	915 DR-20		72.06	14.35	2.99	0.32	0.07	1.15	0.33	3.22	3.51	100.00	0.8866	
23	1657 AA-25 JOD	09/12/86	72.81	13.92	2.84	0.23	0.07	1.16	0.31	5.32	3.35	100.01	0.8865	
24	914 DR-19		71.83	14.43	3.00	0.33	0.07	1.15	0.34	3.32	3.51	100.00	0.8832	
25	979 DR-95		74.04	14.15	2.08	0.28	0.05	1.30	0.27	4.72	3.11	100.00	0.8826	
26	550 KRL71082-0, T50-7	02/01/83	70.78	15.71	2.13	0.19	0.06	1.22	0.28	4.47	3.18	100.00	0.8805	
27	670 JOD-7-7-82C	11/11/81	74.32	13.87	2.11	0.29	0.06	1.27	0.28	4.64	3.18	100.02	0.8789	
28	1533 HEADSBURO LOC. 3 T124-4	5/5/86	72.23	14.59	3.25	0.11	0.09	0.98	0.21	5.10	3.64	100.00	0.8786	
29	801 08-47		74.22	14.22	2.15	0.24	0.05	1.32	0.28	4.41	3.10	99.99	0.8780	
30	1075 61284-4-ASH OBSIDIAN CHIP T77-	7/30/84	74.25	13.76	1.85	0.29	0.04	1.27	0.23	5.21	4.29	99.98	0.8773	
31	920 DR-25		72.84	14.23	2.68	0.17	0.06	1.05	0.27	4.00	4.31	100.00	0.8766	
32	1076 61284-4-ASH OBSIDIAN CHIP T77-	7/30/84	74.02	13.97	1.86	0.28	0.04	1.25	0.26	3.92	4.37	100.00	0.8758	
33	1100 61284-19 ash obsidian	10/11/84	74.34	13.76	1.83	0.28	0.03	1.22	0.26	3.94	4.37	100.01	0.8748	
34	124 08-78-15, T15-12		74.60	13.09	3.28	0.08	0.05	1.35	0.21	3.20	3.49	100.00	0.8740	
35	629 TULELAKE-321, T61-10	08/17/83	70.96	14.71	3.37	0.35	0.07	1.37	0.42	3.25	3.49	99.99	0.8738	
36	980 DR-96		72.64	14.93	2.33	0.24	0.05	1.46	0.24	4.71	3.41	100.01	0.8738	
37	1384 ASH-61285-31 T108-10	9/24/85	74.12	13.92	1.86	0.28	0.04	1.24	0.27	4.04	4.24	100.01	0.8738	
38	765 08-4		73.48	14.53	2.22	0.24	0.05	1.37	0.29	2.81	3.01	100.00	0.8734	
39	422 MONO-2, T53-11		73.70	14.21	2.19	0.30	0.06	1.34	0.28	4.91	2.99	100.00	0.8731	
40	1254 BB-1 T56-13	5/29/85	74.10	14.05	1.77	0.26	0.04	1.21	0.26	4.01	4.30	100.00	0.8731	
41	689 TULE LAKE 1193, T73-14, 32.28	2/16/84	73.34	14.22	2.61	0.15	0.07	1.11	0.22	4.82	3.47	100.01	0.8727	
42	472 758-199, T1-15, P		72.15	14.63	3.23	0.09	0.08	0.93	0.21	5.36	3.32	100.00	0.8725	
43	903 DR-7		73.91	14.24	2.18	0.26	0.03	1.25	0.31	4.71	3.11	100.00	0.8717	
44	45 CARL-2(1), T8-3		74.41	14.59	1.84	0.28	0.05	1.28	0.24	4.91	2.40	100.00	0.8712	
45	46 CARL-2(2), T7-4, pd		73.95	15.00	1.87	0.26	0.06	1.38	0.27	4.88	2.33	100.00	0.8708	
46	1563 DST-2 T127-8		71.66	14.56	3.12	0.39	0.07	1.20	0.42	4.03	4.56	100.01	0.8697	
47	723 LD-76*	8/18/86	74.30	13.74	2.14	0.30	0.05	1.25	0.30	4.71	3.21	100.00	0.8696	
48	82 DSDP-16, T9-18		74.22	14.38	2.00	0.25	0.07	1.34	0.28	5.09	2.37	100.00	0.8691	
49	1072 CEM 61284-1 OBSIDIAN T77-1	7/30/84	74.00	13.89	1.91	0.29	0.04	1.24	0.28	4.02	4.32	99.99	0.8689	
50	1288 ASH-61385-320 T100-6	07/02/85	74.24	13.86	1.90	0.29	0.03	1.24	0.28	3.86	4.30	100.00	0.8686	

PDNUS CORP NO. 1356 DATE OF UPDATE: 10/01/86
 SAMPLE ID: T-4-86 KI T126-12
 ELEM. IN CALC. Al, Si, Ca, Ti, Fe

Listing of 50 analyses used in the comparison of COMP. NO. 1408 SAMPLE NO. T-1-85-KI (2) T110-11

MP-29 is Pub. L. Tuff. Co. 3.4M

C. No	Sample Number	Date	SiO2	Al2O3	Fe2O3	MgO	MnO	CaO	TiO2	Na2O	K2O	Total, R	Stm. Co
1	1408 T-1-85-KI (2) T110-11	9/24/85	75.30	13.36	1.77	0.09	0.01	0.73	0.13	3.86	4.75	99.99	1.0000
2	1018 MP-29 (597) T58-9	5/30/84	75.08	13.46	1.80	0.10	0.03	0.74	0.13	4.09	4.58	100.01	0.9919
3	1531 BPT OBSIDIAN (2) MICRO-FREE	5/5/85	75.42	13.54	1.79	0.10	0.07	0.69	0.13	4.80	4.46	100.00	0.9838
4	1059 SA-8 T76-7	7/28/84	75.50	13.50	1.76	0.02	0.03	0.66	0.13	4.72	3.69	100.01	0.9771
5	1369 T-1-85-KI T104-8	8/26/85	75.28	13.47	1.73	0.09	0.02	0.74	0.13	2.88	4.72	99.99	0.9768
6	133 6V-78-31, T16-6		76.77	12.82	1.86	0.04	0.02	0.75	0.13	2.88	4.72	100.00	0.9731
7	478 758-292, T7-17, P		74.90	13.92	1.76	0.09	0.03	0.72	0.14	4.06	4.36	99.98	0.9727
8	1475 MC-281 T117-7	3/6/86	75.18	13.47	1.74	0.09	0.04	0.77	0.14	3.68	4.91	100.02	0.9700
9	1409 ML 8-2A 22.0-22.5 CH RECALC T9	5/1/85	73.77	14.24	1.66	0.12	0.06	0.72	0.13	3.13	5.30	100.00	0.9684
10	81 DSDP-13, T9-19		73.02	13.49	1.84	0.01	0.03	0.70	0.13	3.31	5.30	100.00	0.9664
11	355 SH-ASH-09, T20-11		75.02	13.49	1.79	0.09	0.00	0.74	0.15	4.15	4.97	99.99	0.9657
12	316 CL-0519(200-323), T63-13	09/07/83	75.17	13.49	1.89	0.11	0.07	0.75	0.14	5.11	3.28	100.01	0.9654
13	1530 BPT OBSIDIAN (1) MICRO RICH	5/5/86	75.30	13.73	1.69	0.09	0.06	0.71	0.12	4.93	3.38	100.01	0.9647
14	660 BPT-1, T68-5	12/16/83	74.85	13.72	1.94	0.11	0.07	0.74	0.14	5.09	3.34	100.00	0.9590
15	475 758-287A, T1-10, P		74.50	13.81	1.82	0.10	0.03	0.74	0.15	4.31	4.94	100.00	0.9560
16	92 DSDP-36-1-5(88ca), T47-3		74.38	14.06	1.91	0.12	0.05	0.74	0.14	5.44	3.15	99.99	0.9560
17	1144 11-VI-84-5 T85-4	12/4/84	75.92	13.13	1.65	0.11	0.07	0.73	0.14	5.11	3.13	100.00	0.9547
18	91 DSDP-36-1-5(37ca), T47-4		74.21	14.07	1.98	0.12	0.06	0.73	0.14	5.42	3.27	100.00	0.9547
19	515 CL-0519(100-200), T60-9	08/16/83	76.32	12.45	1.76	0.12	0.07	0.75	0.14	5.05	3.18	100.02	0.9494
20	297 PICO-157(2), T46-1		76.05	12.91	1.78	0.02	0.03	0.60	0.13	3.71	4.93	99.99	0.9470
21	1642 AA-14 JOD	09/12/86	76.05	12.91	1.69	0.08	0.06	0.63	0.12	4.91	3.52	99.99	0.9449
22	61 CRANIEL ASH-1, T23-13		74.59	13.86	1.76	0.12	0.03	0.60	0.13	3.66	3.18	100.00	0.9444
23	102 FALOR-2, T41-7		76.24	12.93	1.72	0.02	0.04	0.60	0.13	4.07	4.37	100.00	0.9438
24	212 MANIX-6, T7-10		76.15	12.98	1.63	0.03	0.03	0.61	0.13	4.07	4.37	100.00	0.9438
25	986 RC-5		74.16	14.23	1.73	0.08	0.05	0.69	0.11	4.61	4.31	100.00	0.9419
26	93 DSDP-36-4-6, T47-3		76.33	12.46	1.73	0.03	0.06	0.59	0.13	3.61	5.05	99.99	0.9410
27	466 758-157, T1-1, P		74.43	13.77	1.79	0.10	0.04	0.58	0.13	4.23	4.70	100.00	0.9392
28	296 PICO-157(1), T47-7		76.61	12.25	1.73	0.03	0.04	0.59	0.13	3.72	4.89	99.99	0.9371
29	1013 TULE LAKE 786 T74-10	5/30/84	74.44	13.98	1.67	0.08	0.04	0.64	0.14	4.30	4.46	100.00	0.9371
30	453 264-1-9, T14-4		74.35	13.71	1.87	0.13	0.05	0.70	0.16	4.18	4.69	99.99	0.9365
31	987 RC-6		74.30	14.24	1.71	0.07	0.03	0.69	0.11	4.51	4.31	99.99	0.9365
32	1078 DSDP 36-1-6 T77-8	7/30/84	74.82	13.63	1.95	0.11	0.08	0.79	0.15	5.22	3.25	100.00	0.9344
33	373 TECO-2, T2-19		76.12	12.50	1.87	0.02	0.03	0.64	0.12	3.46	3.24	100.00	0.9342
34	1136 Tulelake 1894 (resamp. 749) T8	12/3/84	74.33	13.60	1.87	0.14	0.03	0.74	0.17	4.45	4.45	100.00	0.9340
35	378 TECO-1281, T47-6		76.30	12.36	1.75	0.03	0.03	0.61	0.14	3.46	3.29	99.99	0.9333
36	1458 126-2040 (AVO 3) T116-1	1/28/85	76.96	12.28	1.80	0.02	0.03	0.57	0.13	3.33	4.85	99.99	0.9323
37	637 68498(2), T34-14	06/11/83	75.94	12.57	1.75	0.02	0.04	0.63	0.11	3.66	3.26	100.00	0.9315
38	1343 68498(2), T34-14	01/06/83	75.94	12.57	1.75	0.02	0.04	0.63	0.11	3.66	3.26	100.00	0.9315
39	392 TECO-300, T17-14		76.75	12.66	1.72	0.03	0.03	0.55	0.13	2.78	5.36	100.01	0.9308
40	1447 126-2040 T116-1	1/27/85	77.08	12.30	1.75	0.02	0.03	0.56	0.13	3.33	4.77	99.99	0.9307
41	253 P3-23, T23-1		76.69	12.27	1.71	0.02	0.04	0.57	0.13	3.72	4.84	99.99	0.9294
42	166 JOD-31-8-82E, T32-15		76.16	12.50	1.75	0.03	0.04	0.59	0.13	3.72	4.84	99.99	0.9294
43	1499 0418V184-1 T80-3	7/20/84	74.85	13.72	1.98	0.13	0.07	0.80	0.15	4.77	3.53	100.00	0.9289
44	351 SH-ASH-04, T11-7		76.44	13.92	1.93	0.11	0.06	0.73	0.17	5.18	3.21	100.00	0.9282
45	1255 CCA-1 T96-14	5/29/85	76.44	13.92	1.75	0.01	0.04	0.59	0.12	3.55	3.13	100.00	0.9267
46	352 SH-ASH-05, T11-8		74.74	13.86	1.92	0.10	0.06	0.74	0.17	5.28	3.14	100.01	0.9259
47	1012 TULE LAKE 749 T74-9	5/30/84	74.29	13.92	1.86	0.13	0.05	0.77	0.17	4.32	4.47	100.00	0.9221
48	354 SH-ASH-08, T20-10		76.01	12.87	1.86	0.08	0.01	0.63	0.16	4.09	4.41	99.99	0.9214
49	1502 RC-63		72.88	14.63	1.82	0.10	0.07	0.83	0.15	4.41	5.11	100.00	0.9200
50	372 TECO-1, T1, N-ASH-73, P		76.51	11.92	1.93	0.03	0.03	0.64	0.14	2.85	3.95	100.00	0.9198

POMCUS COMP NO. 1369 DATE OF UPDATE: 10/01/86

SAMPLE ID: T-1-85-KI T104-8

ELEM. IN CALC. Al, Si, Ca, Ti, Fe

Listing of 50 analyses used in the comparison of COMP. NO. 1356 SAMPLE NO. T-4-86 KI T126-12 MP-231758-328(2) is the youngest of the five bottle-bearing vitricuff while, ca. 30 m. from E of intersection of the 1st and 2nd Lanes. (see map on page 100)

C. No	Sample Number	Date	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	MnO	CaO	TiO ₂	Na ₂ O	K ₂ O	Total, R	Sim. Co
1	1556 T-4-86 KI T126-12	7/17/86	78.12	12.47	1.01	0.16	0.04	0.86	0.17	3.49	3.68	100.00	1.0000
2	1576 883-163 T128-6	8/18/86	76.58	12.72	1.01	0.12	0.06	0.87	0.17	3.29	5.22	100.00	0.9851
3	1175 ALT-3 T89-3	3/1/85	77.23	12.57	1.01	0.15	0.02	0.87	0.18	3.32	4.64	99.99	0.9827
4	528 JOD-S-83A(100-200), T67-2	11/18/83	78.03	12.67	0.99	0.18	0.03	0.86	0.17	3.60	3.57	100.01	0.9748
5	678 NP-23, T59-83	11/18/83	77.18	12.65	0.99	0.16	0.04	0.87	0.19	3.27	4.66	100.01	0.9674
6	1266 *TULE LAKE 2123 T94-2	5/28/85	77.99	12.50	0.85	0.16	0.02	0.85	0.17	3.94	3.52	100.00	0.9652
7	484 758-328(2), T15-2, low total		78.27	12.94	1.03	0.13	0.00	0.85	0.19	3.80	2.76	99.99	0.9651
8	356 SH-ASH-10, T20-12		77.35	12.48	0.98	0.13	0.02	0.82	0.19	3.33	4.67	99.99	0.9616
9	394 SH-ASH-278, T35-3		76.44	12.62	0.95	0.15	0.03	0.82	0.18	3.38	4.44	99.99	0.9610
10	325 RPT(L)15, pum. lt. bulk, T46-6		77.84	12.56	0.89	0.16	0.02	0.85	0.18	3.84	3.66	100.00	0.9607
11	415 DR-17		77.86	12.77	0.86	0.17	0.01	0.88	0.17	3.67	3.61	100.00	0.9604
12	432 ZEMORA-1, white, T38-7		77.68	12.73	0.89	0.19	0.04	0.86	0.18	3.91	3.51	99.99	0.9599
13	1134 T1403 (Tulalate) T84-4		76.85	12.63	0.86	0.16	0.03	0.84	0.17	3.85	3.63	99.02	0.9599
14	1132 T1245 (Tulalate) T84-7	V. hom 12/3/84	78.17	12.29	0.88	0.17	0.03	0.86	0.16	3.84	3.57	99.99	0.9595
15	358 SH-ASH-26C, T35-4	V. hom 12/3/84	78.14	12.36	0.87	0.17	0.04	0.86	0.16	3.89	3.51	100.00	0.9587
16	483 758-328(1), T7-18, pd		76.41	12.68	0.97	0.15	0.02	0.84	0.19	3.25	4.50	99.01	0.9587
17	430 TULELAKE-291(2), T62-11		78.21	12.43	0.87	0.17	0.04	0.85	0.16	4.04	2.31	100.00	0.9586
18	962 DR-75	08/25/83	77.76	12.73	0.89	0.17	0.02	0.85	0.16	3.80	3.47	100.00	0.9573
19	332 RMT-102-74, T1, N-ASH-62, P		78.54	11.95	0.91	0.15	0.02	0.85	0.16	3.81	3.61	100.00	0.9571
20	591 RPT(L)3, T62-12	11/11/83	77.99	12.49	0.86	0.18	0.03	0.85	0.16	3.66	3.73	100.00	0.9567
21	1328 BE-182 T105-5	8/27/85	74.94	13.84	1.00	0.16	0.08	0.85	0.15	3.76	3.59	100.01	0.9556
22	432 ZEMORA-1, tan, T38-6		76.70	12.72	0.84	0.15	0.03	0.84	0.17	3.56	3.32	100.00	0.9550
23	592 RRO-1, T62-13	08/25/83	78.02	12.49	0.85	0.19	0.04	0.85	0.16	3.77	3.90	99.02	0.9541
24	330 RRO-1, T9-1		77.73	12.77	0.86	0.16	0.03	0.85	0.18	3.81	3.59	100.00	0.9537
25	324 RPT(L)5, T2-5		77.53	12.76	0.91	0.18	0.03	0.85	0.16	3.88	3.53	100.00	0.9535
26	164 JOD-20-6-78A(1), LAN-3, T11-12		77.78	12.77	0.86	0.16	0.03	0.90	0.16	3.84	3.68	99.99	0.9535
27	244 OLD COM-3, T27-4		77.58	12.52	0.99	0.17	0.04	0.86	0.16	3.78	3.60	100.00	0.9530
28	326 RPT(L)15, pum. dt. bulk, T46-7		77.65	12.68	0.93	0.17	0.02	0.93	0.20	4.04	3.56	100.00	0.9529
29	990 RC-10		77.78	12.83	0.89	0.17	0.03	0.83	0.16	3.83	3.62	99.99	0.9529
30	224 RMC-2, T2-4		77.66	12.76	0.86	0.17	0.03	0.83	0.16	3.81	3.51	100.01	0.9510
31	241 OH-2A, T7-7		76.95	13.21	0.93	0.19	0.03	0.87	0.16	3.93	3.57	100.01	0.9503
32	190 LAMES CALCH-1, T33-1		77.65	12.74	0.97	0.16	0.02	0.82	0.18	3.53	4.19	99.99	0.9495
33	1265 *TULE LAKE 2122 T94-1	5/28/85	78.08	12.43	0.85	0.16	0.02	0.75	0.16	3.97	3.51	100.01	0.9488
34	16 BELL-60, T29-3		78.47	12.86	1.03	0.16	0.03	0.87	0.21	4.27	2.09	99.99	0.9488
35	718 LD-67		77.63	12.94	0.86	0.17	0.03	0.87	0.18	3.71	3.61	100.00	0.9484
36	328 RPT(M)7, T2, N-ASH-93		77.78	12.77	0.87	0.17	0.03	0.89	0.16	3.72	3.61	100.00	0.9484
37	200 LD-67, T3-4		77.62	12.96	0.86	0.17	0.03	0.87	0.18	3.67	3.64	100.00	0.9482
38	404 VINA-1, T8-1		77.93	12.70	0.86	0.18	0.02	0.89	0.16	3.61	3.65	100.00	0.9480
39	1042 JOD 19-7-83A, T78-2	07/18/84	77.92	12.57	0.88	0.17	0.02	0.85	0.15	3.86	3.65	100.00	0.9477
40	1371 76-CB-1624 T104-10	8/26/85	77.95	12.57	0.95	0.15	0.03	0.85	0.15	3.59	3.45	99.99	0.9474
41	347 SC-7, 22-May-81		78.13	12.64	0.87	0.16	0.07	0.86	0.15	3.57	3.53	99.99	0.9472
42	594 SC-5(2), T62-14		78.02	12.45	0.87	0.18	0.04	0.87	0.15	3.88	3.55	100.00	0.9460
43	11 AXL-301-160(2), T10-7	08/23/83	75.92	13.63	1.13	0.20	0.04	0.84	0.15	3.57	4.47	100.00	0.9459
44	331 RRO-2, T46-5		77.84	12.67	0.89	0.16	0.03	0.84	0.18	3.95	3.30	100.00	0.9450
45	988 RC-7		77.94	12.74	0.89	0.17	0.03	0.87	0.15	3.95	3.41	100.00	0.9442
46	172 KA-1, T2-3		77.63	12.82	0.90	0.16	0.03	0.87	0.15	4.00	3.43	99.99	0.9437
47	346 SC-6, 22-May-81		78.01	12.71	0.90	0.16	0.03	0.88	0.15	3.58	3.56	100.00	0.9434
48	327 RPT(M)6A, T1, N-ASH-92, P		77.71	12.71	0.93	0.17	0.03	0.90	0.15	3.61	3.76	100.00	0.9417
49	343 SAH-38, T33-4		77.34	12.89	0.91	0.20	0.01	0.90	0.15	3.77	3.62	99.99	0.9407
50	PDMAUS COMP NO. 1355												

DATE OF UPDATE: 10/01/86
SAMPLE ID: T-2-86 KI LOW K FRACT T126-11
ELEM. IN CALC. Al, Si, Ca, Ti, Fe

75B-339CR is slightly higher than 75B-339CR
 75B-339CR is slightly higher than 75B-339CR
 75B-339CR is slightly higher than 75B-339CR

Listing of 50 analyses used in the comparison of COMP. NO. 1954 SAMPLE NO. SIMP-3 T126-10

C.No	Sample Number	Date	S102	Al2O3	Fe2O3	MgO	MnO	CaO	TiO2	Na2O	K2O	Total R	Sim. Co
1	1954 SIMP-3 T126-10	7/17/86	77.19	13.50	1.59	0.17	0.04	0.85	0.20	3.19	3.26	99.99	1.0000
2	487 75B-339CR, T1-4, P		75.82	13.93	1.61	0.19	0.04	0.83	0.20	3.29	3.29	100.00	0.9831
3	853 LM-6		75.48	13.61	1.52	0.14	0.03	0.82	0.19	3.50	4.70	99.99	0.9681
4	472 75B-373, T18-2		74.92	13.58	1.51	0.15	0.00	0.82	0.19	3.59	5.24	100.00	0.9658
5	1411 14V185-3 T112-2	10/22/85	75.13	13.50	1.54	0.18	0.03	0.82	0.19	3.59	4.26	100.00	0.9613
6	299 PR, T23-3		74.53	13.86	1.53	0.16	0.07	0.81	0.19	4.11	4.64	100.00	0.9612
7	70 DSDP-3, T9-5		75.60	13.21	1.64	0.13	0.02	0.78	0.21	4.32	4.09	100.00	0.9595
8	614 TULELAKE-176(200-325), T61-2	08/17/83	75.80	13.37	1.50	0.14	0.03	0.83	0.17	4.31	3.83	100.00	0.9532
9	613 TULELAKE-175(200-325), T62-1	08/25/83	75.31	13.61	1.59	0.23	0.03	0.85	0.21	4.31	3.28	99.99	0.9507
10	1272 TULE LAKE 2438 T96-2	5/29/85	75.48	12.97	1.33	0.17	0.04	0.80	0.20	4.22	3.32	100.01	0.9466
11	611 TULELAKE-175, T60-13	08/16/83	75.76	13.71	1.59	0.21	0.06	0.86	0.22	4.45	3.30	100.01	0.9466
12	972 RC-13		75.28	13.63	1.31	0.17	0.04	0.85	0.19	3.71	4.81	100.00	0.9456
13	612 TULELAKE-175(1), T61-1(1)	09/01/83	75.91	13.31	1.59	0.20	0.05	0.97	0.23	4.47	3.27	100.00	0.9430
14	1082 TULELAKE-175, T61-1(1)	09/01/83	75.91	13.31	1.59	0.20	0.05	0.97	0.23	4.47	3.27	100.00	0.9430
15	163 JDD-18-10-81X, T44-3		75.74	13.42	1.56	0.19	0.04	0.96	0.23	4.51	3.34	99.99	0.9423
16	806 OS-51		75.77	13.63	1.59	0.20	0.03	1.04	0.22	4.41	3.11	100.00	0.9397
17	808 OS-53		75.65	13.55	1.58	0.20	0.03	1.04	0.22	4.41	3.11	100.00	0.9397
18	1084 TULELAKE-176(200-325), T62-2	08/25/83	75.44	13.62	1.53	0.21	0.06	1.02	0.22	4.33	3.36	99.99	0.9346
19	1274 CARL-1(1) T8-4	3/23/79	74.39	14.72	1.57	0.26	0.05	1.06	0.20	4.33	3.92	100.00	0.9346
20	1636 AA-08 JDD	09/12/86	75.70	13.29	1.64	0.20	0.03	1.03	0.22	4.32	3.34	99.99	0.9338
21	160 JDD-18-10-81L, T43-1		75.13	13.86	1.65	0.19	0.07	0.96	0.23	4.51	3.32	100.00	0.9332
22	829 OS-74		75.28	13.73	1.61	0.20	0.06	0.96	0.24	4.61	3.31	100.00	0.9330
23	767 OS-5		75.21	13.65	1.59	0.21	0.06	0.99	0.24	4.72	3.51	99.99	0.9327
24	1250 JY-84-27A T100-11	7/2/85	75.66	13.65	1.59	0.20	0.03	1.00	0.24	4.42	3.21	100.00	0.9303
25	603 TULELAKE-36, T69-36	12/xx/83	76.71	13.34	1.12	0.22	0.07	0.88	0.20	4.24	3.23	100.00	0.9304
26	247 ONT-1, T14-7		76.16	13.63	1.14	0.19	0.05	0.91	0.23	4.58	3.23	99.99	0.9294
27	1083 TULELAKE-175, T61-1(2)	08/17/83	75.27	13.66	1.65	0.22	0.03	1.03	0.22	4.63	3.27	100.02	0.9291
28	1626 RD-34 JDD	09/12/86	75.67	13.66	1.63	0.20	0.05	1.03	0.23	4.43	3.38	100.01	0.9289
29	921 DR-28		75.18	13.63	1.58	0.20	0.04	1.00	0.24	4.71	3.41	99.99	0.9283
30	10 AXL-301-160(1), T3.4	08/26/83	74.96	13.59	1.13	0.22	0.07	0.83	0.20	4.43	4.33	100.00	0.9281
31	634 TULELAKE-432, T61-11(2)		75.42	13.74	1.83	0.21	0.06	0.91	0.23	4.53	3.80	100.12	0.9274
32	965 DR-78		75.40	13.47	1.53	0.22	0.02	1.01	0.23	4.61	3.21	99.99	0.9256
33	1387 ASH-61285-33 T109-3	9/24/85	75.40	13.47	1.63	0.22	0.04	1.05	0.23	4.61	3.21	99.99	0.9256
34	43 BUT-1, T8-9		76.38	13.58	1.06	0.21	0.03	0.83	0.20	4.14	3.34	99.99	0.9258
35	368 SV-78-1(2), T29-4		75.52	13.41	1.57	0.20	0.03	1.02	0.24	4.64	3.37	100.00	0.9254
36	969 DR-83		75.63	13.64	1.48	0.17	0.03	0.96	0.24	4.51	3.31	99.99	0.9252
37	522 CL-06663, T56-1	07/01/83	75.45	13.60	1.26	0.15	0.03	0.94	0.19	3.54	4.84	100.00	0.9238
38	1958 WA 3-30 T127-1	7/18/86	76.48	13.28	1.20	0.20	0.03	0.92	0.21	4.06	3.60	100.00	0.9234
39	1382 ASH-61183-24 T108-8	9/24/85	74.30	14.07	1.72	0.13	0.04	0.89	0.16	4.30	4.40	100.01	0.9211
40	1130 T459 (Tulelake) t84-4 (rerun)	12/3/84	74.25	13.69	1.89	0.15	0.06	0.77	0.18	4.60	4.42	100.00	0.9203
41	698 LT-2		75.23	14.04	1.60	0.21	0.07	1.02	0.24	4.31	3.31	100.01	0.9196
42	210 LT-2, T3.4		75.25	14.04	1.60	0.21	0.07	1.02	0.24	4.31	3.31	100.01	0.9196
43	771 OS-10		75.83	13.74	1.62	0.20	0.06	0.96	0.26	4.61	3.31	99.99	0.9187
44	1623 RD-46 JDD	09/12/86	75.35	13.14	1.65	0.21	0.04	1.03	0.23	4.50	3.31	100.00	0.9186
45	908 DR-13		75.30	13.54	1.67	0.21	0.04	0.98	0.23	4.71	3.31	100.01	0.9184
46	316 RBN-79-1848A(2), T29-6		76.05	13.37	1.35	0.13	0.04	0.88	0.16	4.59	3.41	100.00	0.9181
47	807 OS-52		75.61	13.64	1.60	0.20	0.05	1.03	0.25	4.51	3.11	100.00	0.9177
48	315 RBN-79-1848A(1), T22-9		76.16	13.32	1.36	0.16	0.02	0.89	0.16	4.33	3.60	100.00	0.9167
49	485 75B-329, T7-19, pd, low total		75.70	14.65	2.18	0.10	0.03	0.85	0.19	4.01	2.29	100.00	0.9163

PHOCUS COMP NO. 1408 DATE OF UPDATE: 10/01/86
 SAMPLE ID: T-1-85-KI (2) T110-11
 ELEM. IN CALC. Al, Si, Ca, Ti, Fe

Listing of 20 closest matches for COMP. NO. 1475 for elements: Na, Mg, Al, Si, S, Ca, Ti, Fe Date of Update: 05/15/90									
Case Sample Number									
Date	SI02	AL203	FeO	390	And	CaO	TiO2	Na2O	X20 Total, R Sim. Co
1 1465 MC-211 T117-7	75.13	13.47	1.74	0.79	0.04	0.77	0.14	3.68	4.91 100.02 1.0000
2 1359 T-1-25-K1 T114-3	75.23	13.47	1.73	0.78	0.02	0.74	0.14	3.61	4.92 99.99 0.9777
3 478 T-1-25-K1 T117-7, pd	74.90	13.92	1.73	0.80	0.03	0.72	0.14	4.06	4.36 99.98 0.9603
4 1703 T-1-33-K1 T110-11	74.37	13.34	1.54	0.77	0.05	0.73	0.14	4.03	5.10 100.00 0.9581
5 1018 W-29 (397) T108-3	75.39	13.36	1.77	0.98	0.01	0.73	0.13	3.86	4.75 99.99 0.9574
6 1018 W-29 (397) T108-3	75.03	13.46	1.69	0.90	0.03	0.74	0.13	4.09	4.58 100.01 0.9483
7 1045 CLV-20-AM T146-3	74.93	13.62	1.77	0.11	0.03	0.72	0.14	4.03	4.61 100.01 0.9468
8 305 J-1-33-K1 T110-11	75.02	13.49	1.73	0.03	0.00	0.74	0.15	4.15	4.57 99.99 0.9462
9 406 T58-137, T11-1, P	74.43	13.77	1.79	0.10	0.04	0.78	0.16	4.23	4.70 100.00 0.9412
10 475 T58-267A, T11-10, P	74.50	13.81	1.82	0.10	0.03	0.74	0.15	4.31	4.54 100.00 0.9369
11 2023 KAL-32842-D2 T148-7	73.58	14.10	1.62	0.09	0.05	0.73	0.12	4.39	5.29 100.00 0.9328
12 2174 KAL-32842-D2 T178-8	72.89	14.84	1.62	0.09	0.07	0.83	0.13	4.25	5.28 100.00 0.9325
13 2020 KAL-82892-D1 T169-4	73.68	14.11	1.62	0.09	0.05	0.73	0.12	4.33	5.26 99.99 0.9318
14 453 T34-1-7, T14-4	74.55	13.71	1.87	0.08	0.03	0.70	0.16	4.18	4.69 99.99 0.9266
15 1502 RC-63	72.88	14.63	1.92	0.10	0.07	0.83	0.15	4.41	5.11 100.00 0.9253
16 401 T59-141(2), T13-2	73.43	14.26	2.16	0.09	0.04	0.88	0.17	3.67	5.30 100.00 0.9186
17 1729 T4Y-2 T137-9	74.13	13.82	2.12	0.10	0.05	0.89	0.16	3.91	4.83 100.01 0.9183
18 1409 ML 8-2A 22-0-22.5 CH RECALL T9 5/1/35	73.77	14.24	1.66	0.12	0.05	0.72	0.13	4.16	5.13 99.99 0.9171
19 476 T58-267(1), T7-16, pd	75.92	13.16	1.74	0.09	0.03	0.61	0.19	3.91	3.91 99.99 0.9154
20 354 SM-AS4-03, T20-10	76.01	12.87	1.73	0.08	0.01	0.63	0.16	4.09	4.41 99.99 0.9148
21 459 T33-130, T19-1	73.57	14.27	2.14	0.08	0.04	0.88	0.14	4.30	4.46 100.00 0.9118
22 1013 TUL-LAKE T66 T74-10	74.44	13.93	1.67	0.13	0.06	0.84	0.10	4.30	4.46 100.00 0.9118
23 546 PICU-160, T9-1	75.23	13.69	1.60	0.05	0.04	0.90	0.14	3.79	4.63 100.00 0.9094
24 1103 T58-267 PUTAN T19-3	76.30	12.71	1.74	0.09	0.02	0.61	0.18	4.10	4.26 100.01 0.9080
25 1934 DW-373-2-1 T163-2	75.17	13.55	1.51	0.37	0.03	0.59	0.14	4.17	4.76 100.00 0.9071
26 2128 MC-344 T176-7	73.54	14.13	2.17	0.09	0.05	0.88	0.19	4.06	4.88 99.99 0.9057
27 621 TUL-LAKE-296, T61-6	75.70	13.47	1.21	0.09	0.04	0.56	0.14	4.16	4.63 100.00 0.9054
28 2186 MC-333 OK GLS T180-7	73.74	14.11	2.12	0.08	0.05	0.87	0.17	4.07	4.80 100.01 0.9044
29 504 CL-0172, T66-1	75.23	13.36	1.72	0.39	0.04	0.48	0.14	4.72	4.16 100.00 0.9036
30 1763 JO-ECQM-E1-54 CH T139-9	73.75	14.44	1.35	0.08	0.05	0.75	0.12	4.14	5.34 100.02 0.9023
31 2124 MC-343 (MAFIC) T175-14	73.28	14.57	2.05	0.09	0.04	0.92	0.18	4.14	4.73 100.01 0.9014
32 233 HP-8, T45-5	74.05	14.09	2.19	0.09	0.03	0.86	0.16	4.33	4.19 99.99 0.9011
33 1303 EXIF-2 T100-9	76.94	12.89	1.09	0.09	0.04	0.68	0.13	3.87	4.27 100.00 0.8991
34 2160 MC-333 T177-12	73.79	13.92	2.17	0.09	0.07	0.93	0.17	4.30	4.55 99.99 0.8981
35 1230 TUL-LAKE 2097 955.03M T90-15	76.61	12.72	1.23	0.09	0.05	0.54	0.15	3.87	4.74 100.00 0.8979
36 907 DA-12	76.27	13.53	0.73	0.09	0.03	0.81	0.12	3.61	4.81 100.00 0.8961
37 966 RC-5	74.16	14.23	1.76	0.08	0.05	0.69	0.11	4.61	4.31 100.00 0.8961
38 1530 OPT OBISIDIAN (1) MICRO RICW	75.30	13.73	1.69	0.09	0.05	0.71	0.12	4.93	3.38 100.01 0.8956
39 1931 3PT OBISIDIAN (2) MICRO-FREE	75.42	13.54	1.79	0.10	0.07	0.69	0.13	4.80	3.46 100.00 0.8950
40 43 CUMG T73-31, T26-1	74.93	13.60	1.54	0.07	0.03	0.59	0.15	4.36	4.74 100.01 0.8949
41 30 Q307-34-3-6, T48-1	75.04	13.61	1.49	0.07	0.03	0.60	0.14	4.45	4.57 100.00 0.8949
42 312 CL-492AC200-325, T63-11	76.88	12.79	1.05	0.08	0.02	0.77	0.15	3.07	5.20 100.01 0.8949
43 1231 ML 8-3A 50-52CM T92-14	73.99	14.14	1.66	0.07	0.05	0.74	0.09	4.08	5.17 99.99 0.8905
44 1382 A34-611A5-24 T108-8	74.30	14.07	1.72	0.13	0.04	0.89	0.16	4.30	4.40 100.01 0.8898
45 2253 T187-3 223-M	75.62	13.52	1.22	0.10	0.01	0.74	0.21	3.90	4.69 100.01 0.8898
46 1979 ML-5-7 (S1-83M) T164-7	75.54	13.66	0.98	0.07	0.05	0.68	0.14	4.01	4.87 100.00 0.8894
47 1169 TUL-LAKE 2036 (S3-14M) T90-3	76.13	13.05	1.22	0.10	0.03	0.61	0.15	4.11	4.59 99.99 0.8892
48 1966 ML-1-27 (S9-77M) T163-9	76.69	13.07	0.87	0.09	0.05	0.80	0.11	3.38	4.94 100.00 0.8889
49 5124 KAL-82832-02B T168-8	73.00	14.40	1.70	0.13	0.07	0.86	0.16	4.45	5.24 100.01 0.8888
50 026 CL-0519C200-325, T63-13	75.17	13.49	1.59	0.11	0.07	0.75	0.14	5.11	3.28 100.01 0.8874

Listing of Juvenile matches for COMP. NO. 1475 for elements: Mg, d7, Al, Si, K, Ca, Ti, Fe Date of Update: 05/15/90									
Case Sample Number	Date	SI02	AL203	MgO	CaO	TiO2	Mn2O	X20 Total, R	Sim. Co
1 1475 MC-24 T117-3	3/6/85	73.71	15.12	2.35	0.10	0.04	1.10	0.15	3.95
2 2123 MC-24 T117-11	12/7/93	73.63	14.07	2.26	0.08	0.05	1.10	0.16	4.09
3 1723 TAY-2 T137-9	4/23/87	74.13	13.02	2.12	0.10	0.03	0.89	0.16	3.91
4 2109 MC-23 T117-12	12/7/88	73.73	13.92	2.17	0.09	0.07	0.93	0.17	4.30
5 167 KT-(1), T4-3		74.01	13.49	2.22	0.10	0.04	0.94	0.17	4.77
6 425 T28-8, T1-12, P		73.35	14.47	2.27	0.10	0.05	1.09	0.18	4.83
7 223 MC-5, T4-5		73.35	14.47	2.27	0.10	0.05	1.09	0.18	4.83
8 145 JC0-1(1), T17-6		74.03	14.42	2.25	0.09	0.03	0.86	0.16	4.33
9 400 T53-14(1), T1-5, P		73.02	14.35	2.20	0.10	0.03	0.88	0.17	4.39
10 457 T58-86, T7-15		74.13	14.46	2.27	0.11	0.03	1.03	0.18	4.14
11 167 JC0-1(2), T1-4, N-ASH-17		73.55	14.92	2.14	0.08	0.03	1.02	0.17	4.06
12 530 MC-3(2), T12-2(2)	12/03/82	73.55	14.16	2.19	0.10	0.04	0.89	0.17	4.37
13 459 T58-130, T19-1		73.57	14.27	2.15	0.08	0.04	0.88	0.14	4.30
14 2123 MC-346 (SILICIC) T175-13	10/28/88	73.12	14.67	2.13	0.10	0.05	0.99	0.20	4.21
15 148 JC0-1(3), T19-7		73.83	14.35	2.16	0.07	0.04	1.03	0.16	4.50
16 475 T58-287A, T1-10, P		74.50	13.81	1.82	0.10	0.03	0.74	0.15	4.31
17 2124 MC-344 (CHALIC) T175-14	10/28/88	73.26	14.57	2.05	0.09	0.04	0.92	0.18	4.31
18 2128 MC-344 T175-7	10/27/83	73.54	14.13	2.17	0.09	0.05	0.88	0.19	4.06
19 138 M-1, T3-4		73.55	14.62	2.17	0.09	0.05	1.05	0.19	4.44
20 462 T58-141C, T19-3		72.35	14.81	2.13	0.10	0.03	0.87	0.17	4.76
21 2146 MC-333 OK GLS T180-7	12/22/88	73.43	14.26	2.15	0.10	0.04	0.88	0.17	4.67
22 461 T59-14(2), T19-2		73.74	14.11	2.12	0.08	0.03	0.83	0.16	4.23
23 466 T58-157, T1-1, P		74.43	14.77	1.79	0.10	0.04	0.78	0.16	4.23
24 1502 MC-83		72.84	14.63	1.82	0.10	0.07	0.83	0.15	4.41
25 231 MUNT-1, T9-2		73.22	14.43	2.17	0.09	0.05	0.90	0.18	4.93
26 222 MC-4, T12-4		73.55	14.04	2.17	0.10	0.03	0.88	0.19	4.62
27 465 T58-156A T19-5		73.53	14.31	2.14	0.09	0.03	0.91	0.18	4.65
28 581 MC-4(2), T12-4(2)	12/03/82	73.60	14.15	2.20	0.09	0.04	0.86	0.17	4.71
29 454 T58-156A, T19-4		73.56	14.27	2.17	0.09	0.04	0.86	0.17	4.71
30 2153 RFI-1 CHIFE RES 2 T179-7	12/21/88	74.25	13.96	2.15	0.09	0.07	0.91	0.21	4.19
31 186 KT-6, T6-2		74.30	13.59	2.24	0.09	0.05	0.89	0.18	4.61
32 188 KT-7(2), T5-2		73.65	14.30	2.15	0.09	0.04	0.91	0.18	4.69
33 473 T58-210C, T1-16, P		73.25	14.44	2.17	0.12	0.07	0.90	0.19	4.68
34 1018 MP-29 (597) T58-8	5/30/84	75.03	13.46	1.80	0.10	0.03	0.74	0.13	4.09
35 1496 T58-09-07, T104-11	08/26/85	73.35	14.39	2.91	0.10	0.03	1.18	0.21	4.16
36 1501 85-09-07 T104- recalc 681 odd	09/26/85	73.55	14.39	2.91	0.10	0.03	1.18	0.21	4.16
37 221 MC-3, T12-3		74.24	14.24	2.15	0.09	0.02	0.87	0.17	4.87
38 1845 FLV-20-W T146-8	8/25/87	74.93	13.62	1.77	0.11	0.03	0.72	0.14	4.03
39 478 T58-292, T7-17, pd		74.90	14.92	1.76	0.09	0.03	0.72	0.14	4.06
40 1362 ASM-61185-24 T108-8	9/24/85	74.32	14.07	1.72	0.13	0.04	0.89	0.16	4.30
41 355 SM-ASH-09, T20-11		75.02	13.49	1.73	0.08	0.00	0.74	0.15	4.15
42 1013 TUL- LAKE 795 T74-10	5/30/84	74.44	13.93	1.57	0.13	0.04	0.84	0.14	4.30
43 1475 MC-201 T117-7	3/5/86	75.18	13.47	1.74	0.09	0.04	0.77	0.14	4.30
44 453 T58-1-9, T13-5		74.55	13.71	1.87	0.08	0.05	0.70	0.16	4.18
45 1325 88-187 (?) T105-2	8/23/85	75.82	13.71	0.85	0.13	0.03	0.70	0.16	4.18
46 1706 OU-WMP-2-15 CN T139-6	5/29/87	74.37	13.94	1.54	0.09	0.05	0.73	0.14	4.03
47 140 HFN-1, T4-2		74.41	14.46	2.15	0.08	0.01	0.73	0.13	3.86
48 1403 T-1-85-KI (2) T110-11	9/24/85	75.30	13.36	1.77	0.08	0.01	0.73	0.13	3.86
49 2174 KRL-81982-W T179-8	12/6/93	72.89	14.84	1.62	0.09	0.07	0.83	0.13	4.25
50 1012 TUL- LAKE 749 T74-9	5/30/84	74.29	15.92	1.85	0.15	0.05	0.77	0.17	4.32