LITHOFACIES OF THE PLEISTOCENE TO RECENT SEDIMENTS IN WESTERN KERN COUNTY, CALIFORNIA

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ABSTRACT

The Pleistocene to Recent sediments in western Kern County are mapped as the Tulare Formation and Alluvium. The Tulare and Alluvium have traditionally been described as unconsolidated sands, silts, and clays of continental origin which are difficult to map as separate units in the subsurface. However, within areas of adequate subsurface control, as in the westside oil fields, the Tulare and Alluvium can be subdivided into lithofacies based on texture, mineralogy and electric log expression. The lithofacies which have been mapped are: (1) sandy alluvial plain/alluvial fan, (2) silty alluvial plain/alluvial fan, (3) deltaic, (4) lacustrine silts and clays. The textures of these lithofacies correspond to the sediment sources and reflect the history of erosion of the Temblor Range.

Introduction

The Pleistocene to Recent sediments in San Joaquin Valley, California, have not been subjected to intense study until recent years, although outcrops are abundant (Figure 1) and correlation into the subsurface is possible in a very precise manner in many places, especially on the westside of the basin.

In the late 1970's, when the price of oil enabled oil companies to exploit the Pleistocene Tulare heavy oil deposits, there was an economic incentive to understand the nature of the trap and the controlling parameters of the reservoir sands. The general relationship of depositional environment to trapping and reservoir was summarized by Lennon in 1976. He divided the Tulare into alluvial, deltaic, and lacustrine facies based on lithology and electric log expression.

In the 1980's, Pleistocene to Recent sediments also became the focus of renewed attention because in some areas they contain useable groundwater and in other areas they are used as water disposal zones. One must understand these sediments more fully than they have been understood in the past in order to provide the necessary geotechnical framework for the proper management of the groundwater resources in the San Joaquin Valley.

Page, 1986, summarized and described the lithologies of the Pleistocene to Recent sediments. Page also recognized the same depositional environments identified by Lennon, 1976, but did not discuss the criteria for recognition of lithofacies in

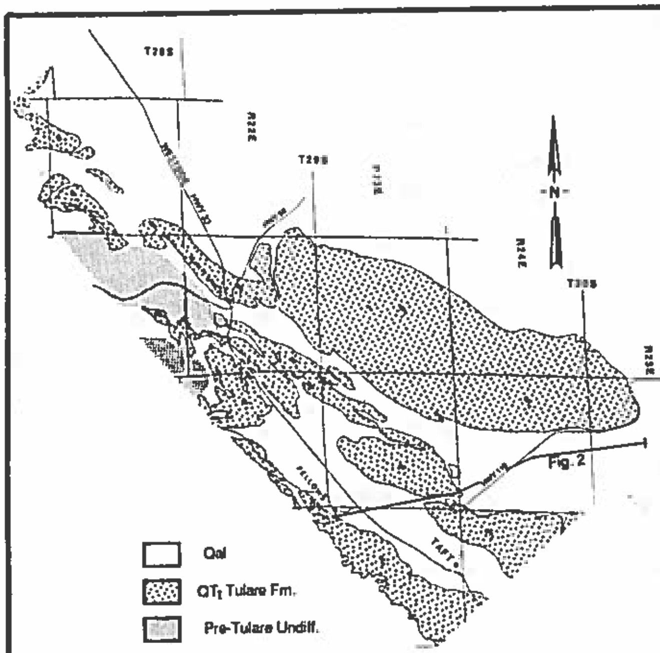


Figure 1 : Index map of Western Kern County, Ca. Shown are surface exposures of Pleistocene to Recent sediments and the location of regional cross section presented in Figure 2. Map adapted from Dibblee, 1973.

the subsurface. He relied on texture maps to aid in his discussion of the different depositional environments. Texture maps are essentially net sand isopach maps, presented as a percentage of the total thickness, without regard to other factors which enable a more precise subdivision of the sediments into various lithofacies. Lettis (1982, 1988) also described the different depositional environments in a regional framework in northern San Joaquin Valley, subdividing lithofacies by composition and texture.

The use of electric logs to complement texture and composition analyses provide a more integrated approach in subsurface studies. Subsurface lithofacies descrption of the Pleistocene to Recent sediments, including the electric log characteristics as Lennon (1976) first recognized are herein discussed based on ongoing studies in western Kern County (Figure 1). Within the lithofacies definitions, the Pleistocene and Recent sediments have been subdivided into meaningful units on the westside of San Joaquin Valley. This approach has resulted in a paleogeographic reconstruction of the Pleistocene to Recent sediments which describe the interplay between the limited source area of the Temblor Range and depositional patterns through time in this restricted basin.

GENERAL STRATIGRAPHY

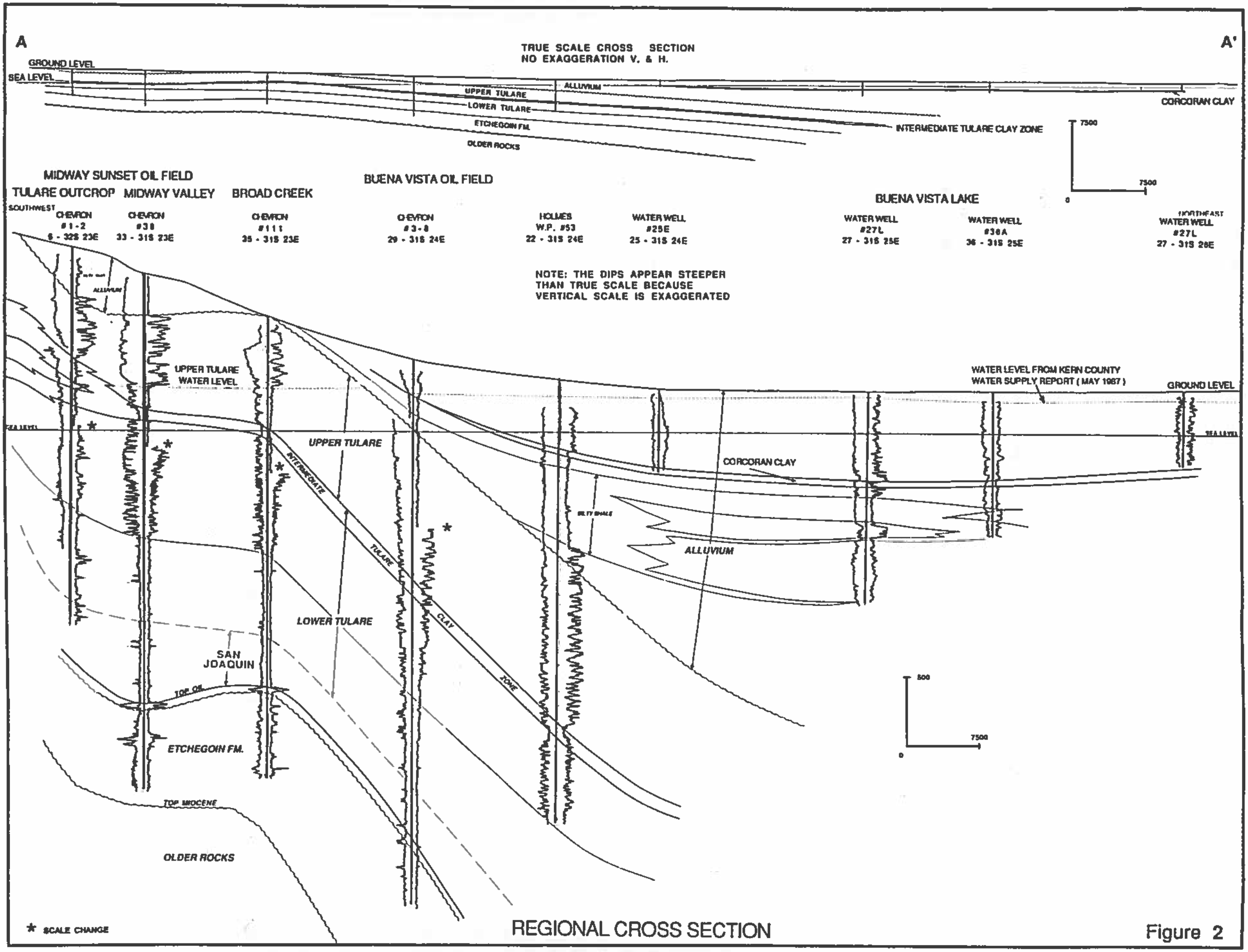
The Pleistocene to Recent sediments in San Joaquin Valley comprise the non-marine fill of the basin. In different regions of the basin the sediments have been given different formation names. In western Kern County, the units are referred to as Tulare Formation and Alluvium. Detailed studies done for Valley Waste Disposal Company (Wilson et al, 1988) documented the stratigraphic relationships of the Pleistocene to Recent units south of Elk Hills. One cross section from that effort is presented in Figure 2.

The Alluvium mapped by Dibblee (1942, 1966, 1971) widely conforms with work done all along the west side (Woodring, 1940; Maher, et al, 1975). In the subsurface this unit can be traced easterly towards Buena Vista Lake. It includes an interval identified as Tulare by Frink and Kues (1954), in their "type description" of the Corcoran Clay, subsequently widely adopted in groundwater studies of the San Joaquin Valley (see Page, 1986 for review of these studies). However, Frink and Kues did not correlate back to the surface, thus setting the stage for decades of water resources work which does not recognize the mappable delineation in the surface and subsurface between the aquifer containing the fresh groundwater sources in the San Joaquin Valley and the older rocks.

There is a disagreement as to the name of the formation which contains Corcoran Clay. A formal proposal to resolve the problem is not presented here, however, major mappable units correlated in our work are delineated and characterized based on relationships in Figure 3.

LITHOFACIES DESCRIPTIONS

The Tulare and Alluvium can be subdivided into lithofacies based on well log responses and petrographic data. Figure 4 illustrates the typical well log responses. This is a typical well in the Midway-Sunset and Buena Vista Oil Fields, where: (1) the Alluvium is predominantly silty to clayey alluvial fan/alluvial plain; (2) the Upper Tulare is dominantly sandy alluvial fan/alluvial plain with some deltaic lithofacies; and (3) the Lower Tulare is lacustrine to deltaic. In other areas, the Alluvium, Upper Tulare and Lower Tulare do not necessarily have these same lithofacies. There are a number of pitfalls in using electric log characteristics to distinguish lithofacies. One is that the typical well log characteristics of the various lithofacies are dependent upon what is filling the pore space (air, fresh water, salt water, or oil). This difficulty can be overcome by utilizing the density/neutron log in combination with the resistivities and core information. When air is in the pore space (due to the "gas effect") the apparent neutron porosity is much lower than the apparent density



REGIONAL CROSS SECTION

Figure 2

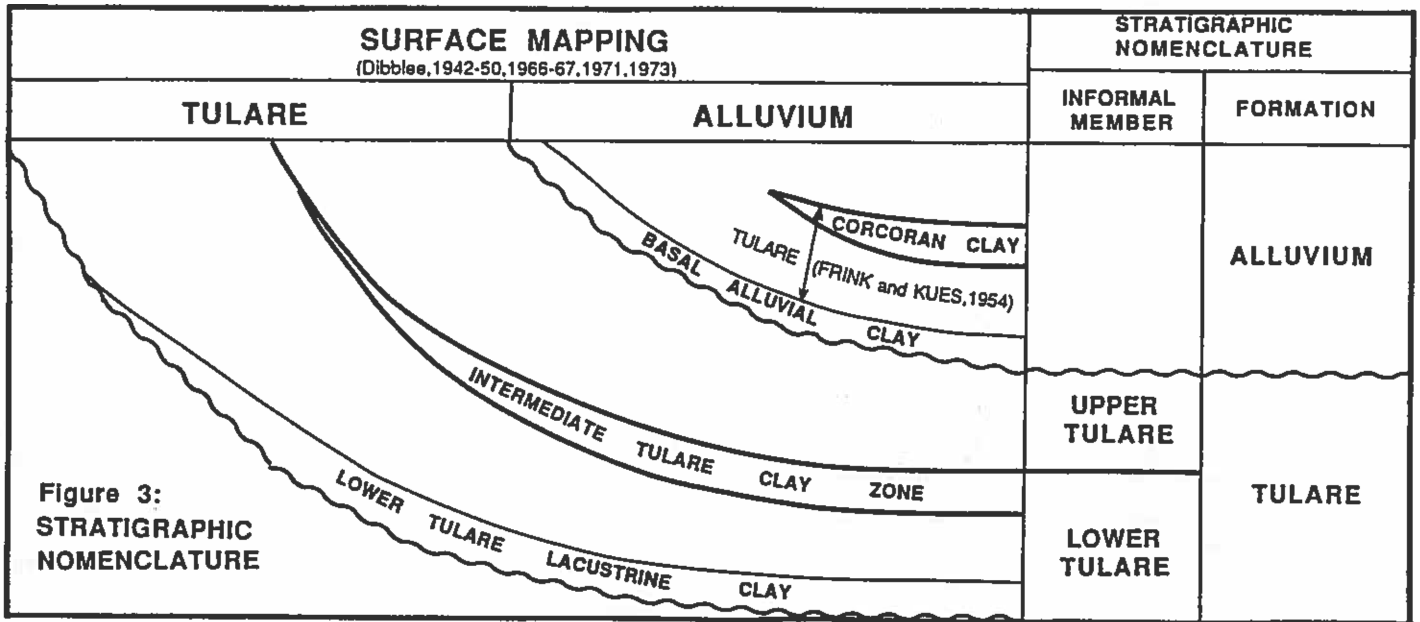


Figure 3: STRATIGRAPHIC NOMENCLATURE

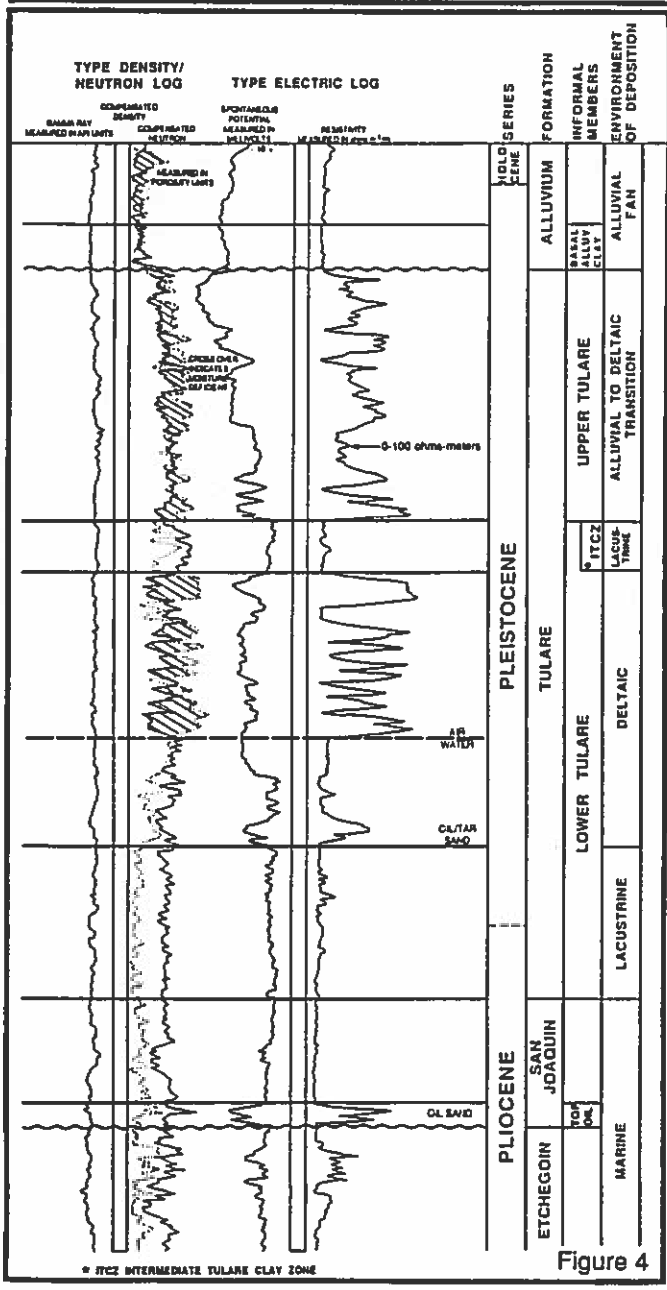


Figure 4

porosity, resulting in a "cross-over" of these two porosity curves. However, when the sands are fluid-saturated, the density and neutron porosities tend to have similar apparent porosities. Fresh water and oil/tar sands are highly resistive, whereas saline water sands have low resistivities. Because of this, the resistivity contrast between moisture-deficient sands and saline water sands, coupled with neutron/density log gas effects allows for an accurate determination of the water table elevation. Examples of this determination are shown in the Lower Tulare portion of Figure 4, and on cross section A-A' (Figure 2).

1. Alluvial fan/alluvial plain

   a. Sandy alluvial fan/alluvial plain:

This sand-dominated facies (Figure 4) is characterized by thick massive sands and conglomerates (20 to 60 feet thick) with interbedded silts and mudstones (5 to 10 feet thick). The sands are generally poorly sorted and range from fine-grained and silty to very coarse-grained with occasional discontinuous conglomeratic lenses. The clasts, cobbles, and boulders have a diverse composition including granite, diatomite, chert quartzite, rhyolite, and basalt. The silts and mudstones are green to brown with planar to convolute bedding.

The well log characteristics of this lithofacies is typical of a sand-shale sequence. The resistivity of the sands can be over 50 ohm-meters when they are saturated with oil and over 100 ohm-meters when they are moisture deficient ("air" sands).

b. Silty Alluvial Fan/Alluvial Plain:

This lithofacies is comprised of silt and clays with minor lenticular fine-grained sands. The typical well log character (Figure 4) is very different from the sandy alluvial fan/alluvial plain facies. The resistivities are low (less than 11 ohm-meters) and often decrease with depth (possibly suggesting an increase in shaliness and/or compaction effects). The spontaneous potential has only minor deflections. Due to the shallow depth and the inherently high porosities of this fine-grained sediment, the apparent density/neutron porosities are very high and often the neutron porosity is lower than the density porosity, exhibiting a "gas effect". The cross-over in this silty facies is different from the sandy alluvial facies because the density and neutron curves tend to parallel each other. Sometimes the cross over is almost eliminated in shaley facies. In the moisture-deficient sands there is a more classic gas effect with the density and neutron porosities opposing each other in an "hour-glass" effect.

2. Deltaic:

The deltaic lithofacies consists of thinly interbedded sands, siltstones, shales, and conglomerates. The sands are 5 to 10 feet thick and are interbedded with 2 to 10 feet thick shales and siltstones. The lithology and well log responses of the deltaic lithofacies are similar to that of the alluvial fan/alluvial plain lithofacies. The main mineralogic and textural difference between these two lithofacies are that the deltaic has an overall higher clay content and finer grain size.

The well log responses of the deltaic lithofacies are similar to the sandy alluvial lithofacies, being most dependent upon the pore-filling material. There are two overall differences between these two lithofacies. First, the well log character of the deltaic lithofacies is very cyclic due to the nearly equal thicknesses of the interbedded sands, shales and siltstones. Secondly, the overall resistivities and spontaneous potential deflections are generally lower in the deltaic facies. The lowered resistivities are due to a combination of effects which include more saline formation water and thin bed effects. The spontaneous potential tends to have less deflection due to the overall finer-grained nature of the deltaic sediments, lower permeabilities, and thin bed effects.

3. Lacustrine:

The lacustrine lithofacies consists of blue-green to brown clays, siltstones, and shales. This fine-grained dominated facies is at the opposite extreme from the sandy alluvial fan facies.

The well log character of this lithofacies (Figure 4) is similar to that of the silty alluvial fan/alluvial plain. It has low resistivities and spontaneous potential deflections. Since the lacustrine facies is normally deeper in this section than the silty alluvial facies, the density log response reflects the additional compaction with lower porosities. The high water content of these fine grained sediments cause the apparent neutron porosity to be anomalously high.

Because the well log response of a marine clay/siltstone can not normally be distinguished from a lacustrine clay/siltstone, it is difficult to distinguish the base of the lacustrine portion of the Tulare from the fine-grained marine sediments of the San Joaquin formation.

PALEOGEOGRAPHY

There are a number of obvious factors to keep in mind when discussing paleogeography of the

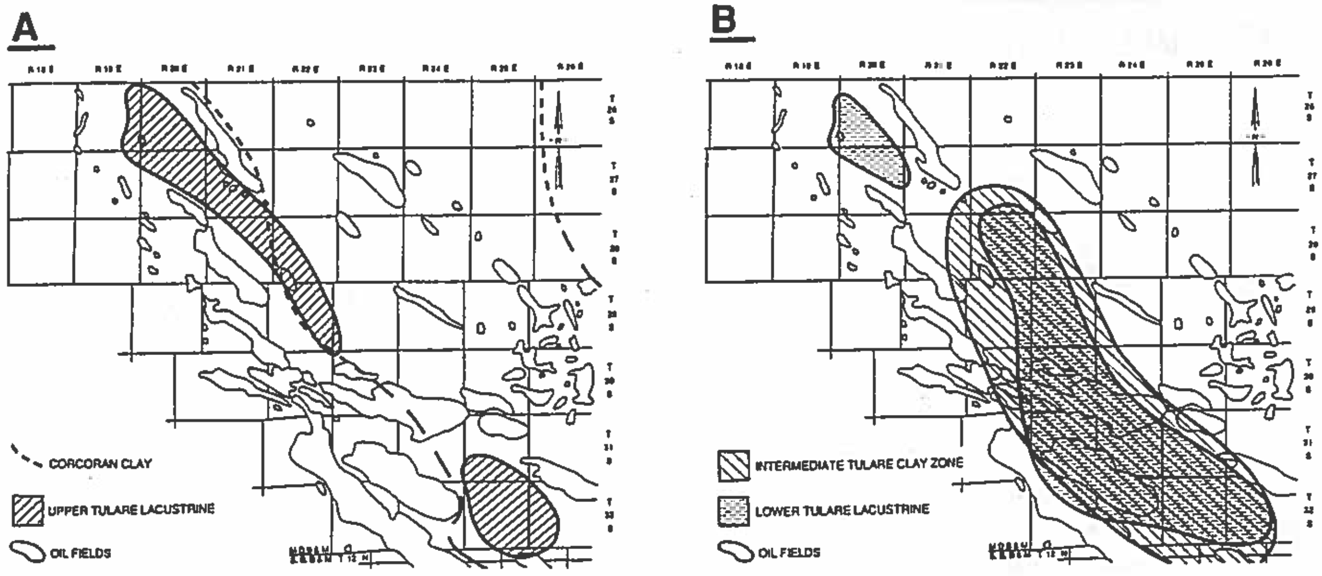


Figure 5: Lacustrine distribution:
A) Corcoran Clay and Upper Tulare
B) Intermediate Tulare Clay Zone and Lower Tulare

Pleistocene to Recent.

1. Pre-Pleistocene structures frequently influenced depositional patterns.

2. The systematic unroofing of pre-Pleistocene rocks of the rising Temblor Range resulted in areal differences in texture.

3. The sedimentation rate has generally exceeded the subsidence rate resulting in almost complete progradation of Recent alluvial deposits over the Pleistocene lake.

The proximity of the rising Temblor Ranges to the axial trough of the valley restricted the alluvial fan/plain deposits of the Lower Tulare to a narrow band on the westside. The distribution of deltaic sands was influenced by pre-existing highs which formed the shelves and bays into which the sands were deposited. During the emergence of the Temblors in the Pleistocene, there were several cycles of lacustrine transgression and regression. The approximate extent of four of these lacustrine transgressions in the southwestern San Joaquin Valley is shown in Figure 5.

The Lower Tulare and Upper Tulare lacustrine silts and clays are less areally extensive but relatively thick and coincide with the depositional axis of the basin. The distribution of these deposits was influenced by pre-Pleistocene structures and encroachment by the Kern River Fan to the east. The Intermediate Tulare Clay Zone (ITCZ) was deposited between the Upper and Lower Tulare. It is a relatively thin, 50 to 150 feet, widespread clay. The well known Corcoran Clay, which was deposited in the Recent sediments as defined in this paper, is comparable to the ITCZ in thickness and areal distribution.

The alluvial fan/alluvial plain deposits are characterized by poorly sorted sheet flow deposits which have been eroded and reworked by streams. The Alluvial fan/alluvial plain deposits encroached upon the lake as shown on the block diagram of Midway Valley in Figure 6 during Mid-Tulare and the Present. The deltaic sands are shoreline deposits fed by fluvial systems which interfinger with lacustrine silt and clay basinward.

The present day basin is characterized by extensive alluvial fan/alluvial plain deposits which have completely encroached

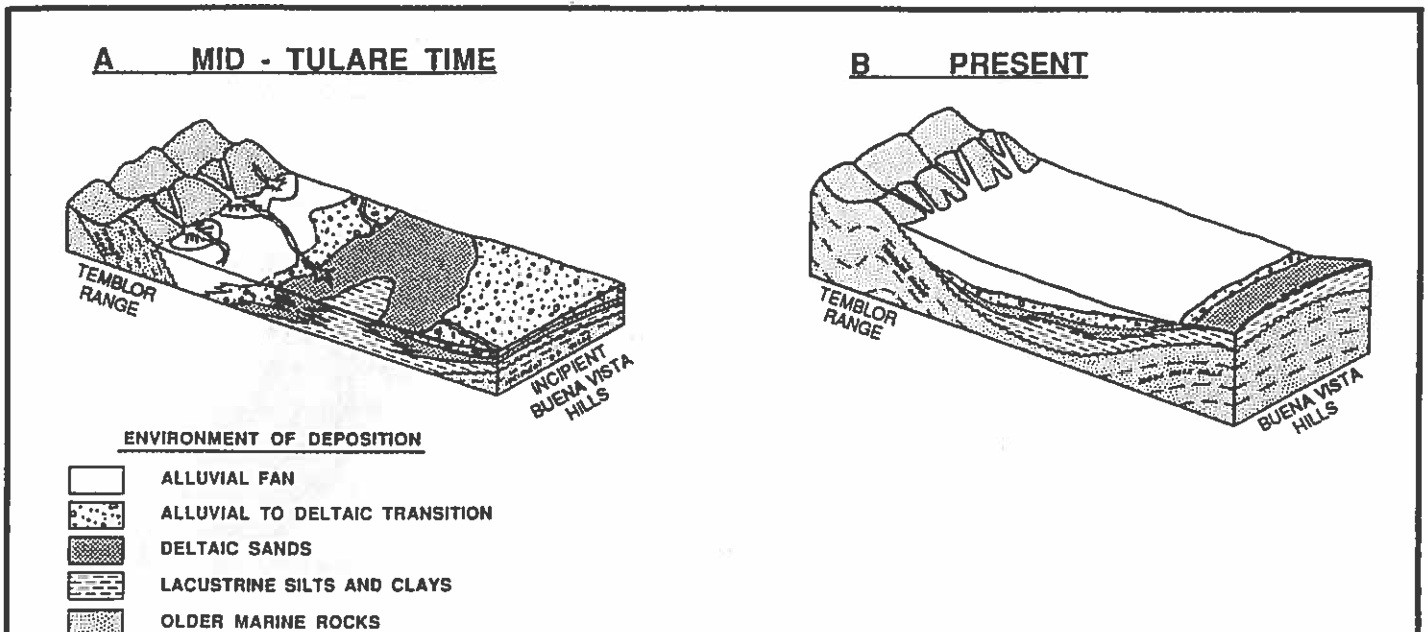


Figure 6

upon the lacustrine deposits. The texture of the Recent sediments directly corresponds to the texture of the adjacent outcropping formation as shown by the generalized texture map of the surface Alluvium (Figure 7). For example, the distribution of clayey alluvial fan deposits in the alluvium are adjacent to the Monterey shale outcrop and sandy alluvial fan deposits are adjacent to the Point of Rocks sandstone.

APPLICATIONS

The ability to subdivide and the recognition of the lithofacies in the Tulare and the Alluvium has important applications in petroleum exploration and reservoir evaluation; waste disposal and regulatory compliance; and water resources management practices.

1. As described by Lennon (1976), commercial steam soak projects in the Tulare are restricted to the deltaic lithofacies. Steam soak projects in the other lithofacies have not been successful.

2. The Alluvium and Tulare is commonly used for waste water disposal, therefore the relationship between wastewater disposal units and units containing drinking water must be understood.

3. Also, from the standpoint of managing the groundwater resources, the proper geologic framework in which to evaluate water use is necessary to properly identify sources of recharge, overdraft and pollution.

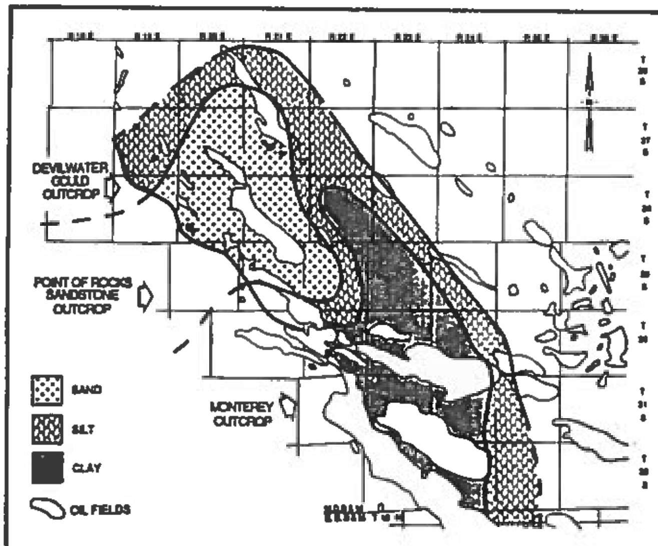


Figure 7: Generalized texture map of the surface alluvium.

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