DEEP-WATER SEDIMENTS OF UPPER CRETACEOUS PIGEON POINT FORMATION, SAN MATEO COUNTY, CALIFORNIA

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ABSTRACT

The well-exposed Upper Cretaceous Pigeon Point Formation along the Pacific coast in San Mateo County, California, provides a good example of an ancient deep-water depositional system. The formation is exposed along 18 km of coastline from Pescadero Beach to Año Nuevo Point, but this study focuses on the area from Pescadero Point to Pebble Beach. The Pigeon Point Formation is part of the Salinian Terrane, which is thought to have provided sediments to the study area during Late Cretaceous time. The formation includes sandstone, mudstone and locally conglomerate along with other lithologies intermediate between these units. Fossils are rare but the formation has sedimentary structures, both syn-depositional (planar lamination, cross bedding, ripples) and post-depositional (soft sediment deformation). The formation has been addressed in a number of studies but the detailed stratigraphy, process sedimentology and the depositional environment of the formation remain unknown and need to be studied in detail.

INTRODUCTION

This study will focus on the deep-water sediments of Upper Cretaceous Pigeon Point Formation, which is exposed along Pacific Coast in San Mateo County for nearly 18 km starting from Pescadero Point to Pebble Beach (Fig. 1). Terraces and sea cliffs provide a spectacular exposure of the formation. The formation is within Salinian Block and was thought to be fed by this block during Late Cretaceous. The thickness of the formation is estimated to be ~ 3300 m (Lopez-Gamundi, 1993). The strata dip with steep angles ranging from 65 to 89 degrees. The formation mainly has three lithofacies, which are thick-bedded sandstone, thin-bedded sandstone and mudstone, and mudstone. There is also conglomerate observed in the study area, however it will be included in the thick-bedded sandstone lithofacies in this report.

Although the area has been studied previously by several authors (Hall, C. A., Jones, D. L., and Brooks, S. A., 1959; Tyler, J. H., 1972; Lowe, D. R., 1979; Howell, D. G., and Joyce, J.

E., 1981; Elder, W. P., 1993; Lopez-Gamundi, O. R., 1993; Paterson S. R., and Tobisch O. T., 1993), the depositional environment, the process sedimentology and stratigraphy of the formation will be studied in detail.

GEOLOGIC BACKGROUND

The Pigeon Point Formation crops out along the Pacific Coast in San Mateo County, California, over ~18 km between Pescadero Point and Año Nuevo (Fig. 2). Mollusks put the age at Campanian or Maastrichtian (Hall et al., 1959). The formation is within the Salinian Block, which is composed of granitic and metamorphic rocks and bounded to the NE by the San Andreas Fault (Fig. 3). The Pigeon Point Formation also lies to the SW of another major strike-slip fault of the San Andreas system, the San Gregorio-Hosgri Fault that lies along or just offshore along much of the central California coast. Pigeon Point Formation lies immediately west of this fault. The western boundary of the formation and the nature of the basement to the formation remain uncertain (Fig. 2).

Due to its proximity to a major strike-slip fault, the Pigeon Point Formation is intensely disrupted by joints and fractures, small and intermediate-scale faults, and some folds. The Pigeon Point Formation includes a range of lithofacies including thick-bedded sandstone, inter-bedded sandstone and mudstone beds, and mudstone. Previous studies have generally interpreted the Pigeon Point Formation as having been deposited by a combination of grain flow, turbidity flow and fluidized flow (Howell and Joyce, 1981). The generalized stratigraphic section of the area reveals that the depositional environment is submarine canyon/fan complex (Lopez-Gamundi, 1993). The thin-bedded sandstone bodies show complete or partial parts of the Bouma sequence (Bouma, 1962).

METHODS

This study will use outcrop analysis to understand the sedimentary processes, stratigraphy and the depositional environment of the Pigeon Point Formation. 380 m of stratigraphic section have been measured in detail in the study area. Graphic sections were drawn in the field at centimeter scale, highlighting sedimentary structures, grain size, and depositional units. A few ripple orientations were measured to identify the paleocurrent direction, and hand samples were collected to analyze the minerals under the microscope to get a better understanding in terms of

petrography. Google Earth™ images were used to aid in correlations of the rock units across strike-slip fault offsets.

LITHOFACIES

The sediments in the studied section of the Pigeon Point Formation include three main lithofacies: thick-bedded sandstone, thin-bedded sandstone and mudstone, and mudstone. Thin units of conglomerate occur within the thick-bedded sandstone lithofacies in the southern part of the study area, at Pebble Beach, but, because the beds are thin and the section dominated by thick-bedded sandstone, these conglomerate layers are included within the thick-bedded sandstone lithofacies in this analysis.

Thick-bedded sandstone

Thick-bedded sandstone characterizes two and perhaps three 10-50-m-thick units in the studied part of the Pigeon Point Formation. They are mostly coarse to medium-grained. The thick-bedded sandstones lithofacies consists of amalgamated sedimentation units that range in thickness from 30 cm to 7 meters. Most of these sandstone bodies are structureless, but a few toward the top shows dish structures (Fig. 4). They generally show a fining upward trend, although a few of them show coarsening upward. Amalgamation surfaces, scour surfaces and flame structures are present along the contacts between individual beds. Some of these beds also contain mudstone chips or mudstone clasts (Fig. 5), which indicate that the mudstone beds were disrupted by high-density flows and this thick-bedded sandstone lithofacies had been deposited in a slope/canyon environment. Dish structures and related water-escape structures also show that the sandstone beds were disturbed after the deposition by water escape (Lowe, 1975) (Fig. 4). These thick-bedded sandstone bodies are interpreted as the S_3 division of Lowe, 1982, deposited through suspended sedimentation from high-density turbidity currents.

Inter-bedded sandstone and mudstone

Bouma divisions T_b and T_c (Bouma, 1962) are mostly found on top of the thick-bedded sandstone beds, which show that the energy of the high-density turbidity currents decreased and fine sediments started being deposited (Fig. 6). The lithofacies are generally followed by T_e divisions (Fig. 7). Sandstone bed thicknesses generally range from 0.08 m to 0.45 m, and the

thickness of mudstone beds range from 0.01 m to 23 m. The bases of the beds are mostly flat and scoured surfaces are absent. Beds show cyclicity, with an upward decrease in cycle thickness (Fig. 8). Thick-bedded and thin-bedded sandstone beds are generally overlain by this inter-bedded lithofacies. Being inter-bedded indicates that the change in the energy of the flow happened during the time of deposition. What changed the character of the flow is currently unknown.

Mudstone

Mudstone beds are one of the most common lithofacies in the Upper Cretaceous Pigeon Point Formation. All the mudstones are medium to dark gray in color and their thicknesses range from a few centimeters to several tens of meters. This facies is mostly massive, locally bioturbated. Most mudstone beds are exposed below sea level, and even during low tide, they are visible only at some locations and mostly covered by vegetation. Locally, there are folded mudstone beds, which are intensely deformed. The lithofacies indicate the action of low energy turbidity currents during the time of deposition.

DEPOSITIONAL SETTING

The thick-bedded sandstone lithofacies characterizing at least two and possibly three major units in the studies section of the Pigeon Point Formation indicate the high-energy flow existence during the deposition time. They are thought to be close to the proximal part of the deposition. Numerous beds are amalgamated with neighboring sand bodies. It is mostly composed of coarse to medium grained. Mudstone chips and clasts are observed within this lithofacies. The beds are normally-graded, however locally there is a few reversely graded beds. According to this information, the depositional site can be canyon or large submarine channel.

Overlying these thick sandstone bodies, there are thin-bedded sandstone beds inter-bedded with mudstone suggesting the waning energy of high-density turbidity currents. The fine grain size represents that the depositional site is not a confined channel or canyon. This facies can be interpreted as lobes or fans on basin floor.

Although conglomerate is not one of the main facies in the formation, it is observed at Pebble Beach and it either represents a proximal part of sediment accumulation or bypassing of coarse grain sediments to the deep ocean via distributary channels.

According to Tyler (1972), the inter-bedded mudstone and fine sandstone were deposited in tidal flat environment. The mudstone beds are interpreted as being deposited in shelf or lagoonal environment (Tyler, 1972). However, these interpretations are problematic in view of the predominance of turbidity current and related sediment-gravity-flow-dominated sedimentation and have not been widely accepted.

FUTURE WORK

During the next field season, a complete stratigraphic section of the Pigeon Point Formation from just south of Pescadero Point to Pebble Beach will be drawn and all sections will be digitized via Adobe Illustrator. Lateral changes in the units and bed thicknesses will also be noted and the correlation of the units both vertically and laterally will be documented with the aid of satellite imagery. The correlation will help to understand the story behind the deposition of the sediment during Late Cretaceous time. About 10 samples will be taken from different lithofacies for petrographic analysis. Paleocurrent measurements will be taken from sandstone bodies with ripples and cross beds. Paleocurrent direction will be useful to determine the direction of the flow and for the construction of the depositional environment. It is anticipated that the collection of data, analysis, and writing will culminate with completion of the MS project in June 2015.

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Figure 1. The location map of the Pigeon Point Formation shows the start and end points of the study area.

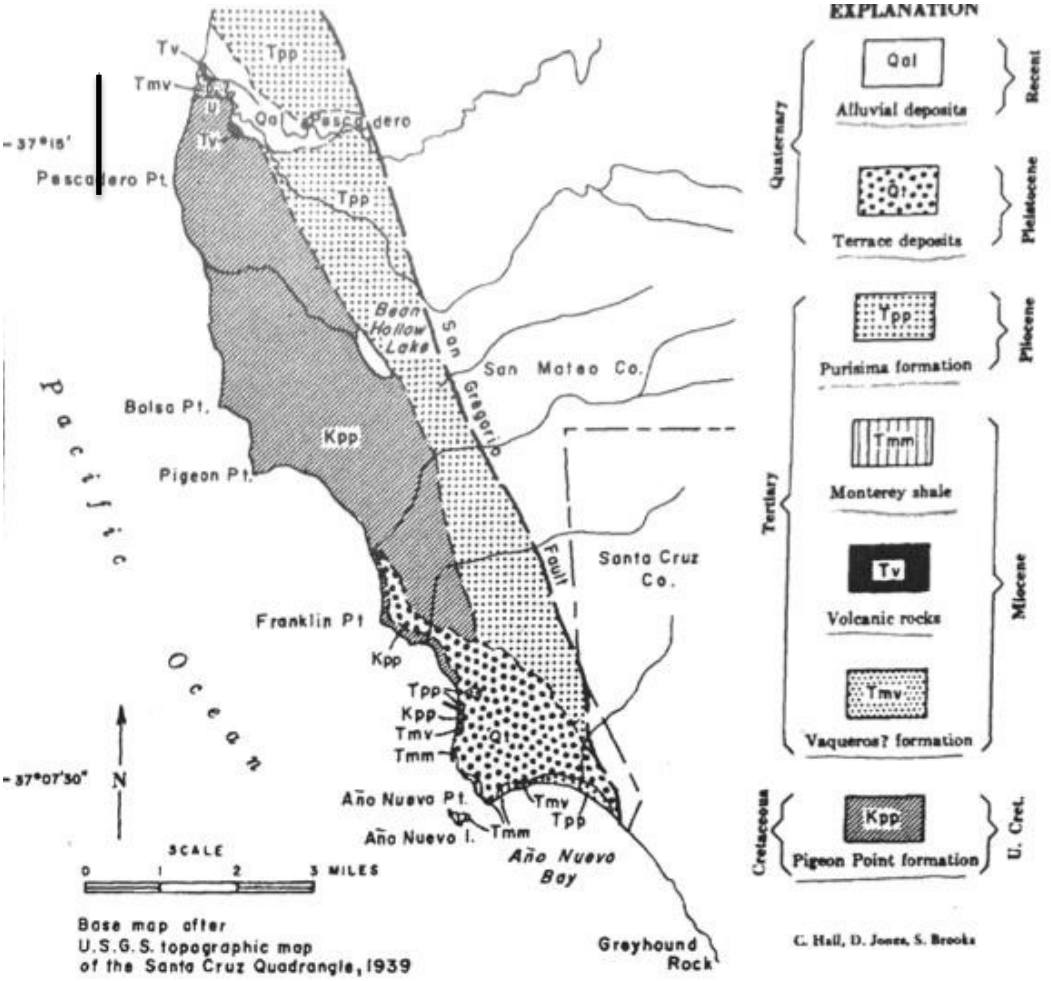

Figure 2. Geologic map of the Pigeon Point Area in San Mateo. The study area is within the black box. (modified from Hall et al., 1959).

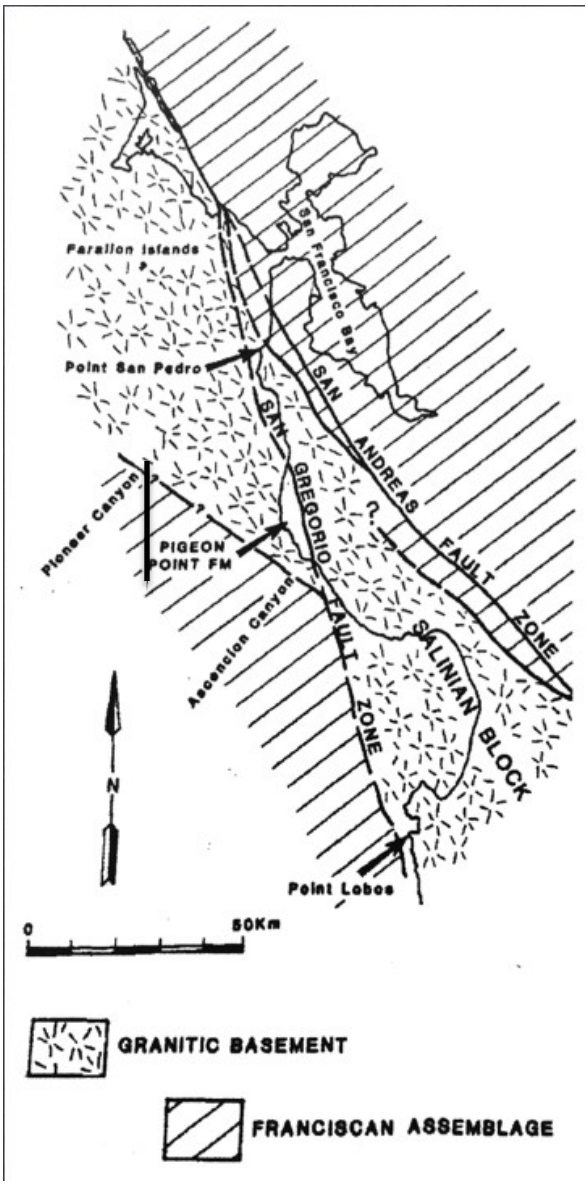

Figure 3. Pigeon Point Formation (in the black box) is within the Salinian Block and bounded by San Gregorio-Hasgri Fault on the East. The western boundary of the formation remains unknown. (derieved from Howell and Joyce, 1972).

Figure 4. Dish structures in a massive sandstone bed.

Figure 5. Massive sandstone bed with pebbles and mud clasts.

Figure 6. Thin-bedded sandstone and mudstone underlain by thick-bedded sandstone unit. (Black arrow indicates the stratigraphic up direction)

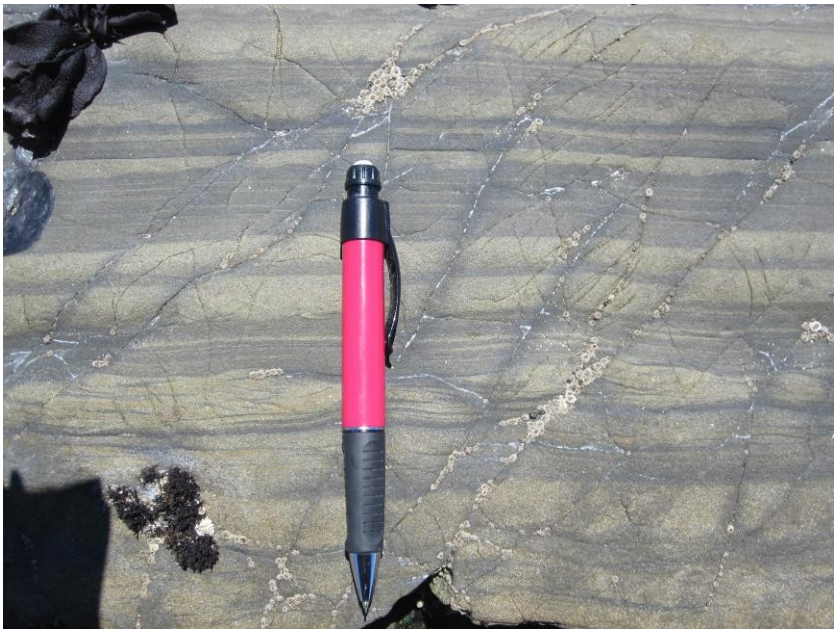

Figure 7. Thin-bedded sandstone and mudstone beds with Tb and Tc Bouma divisions (Bouma, 1962)

Figure 8. Thicknesses of the sandstone beds get thinner upwards. (Black arrow indicates the stratigraphic up direction)