OFFSET FLUVIAL AND NEAR-SHORE SEDIMENTS ALONG THE SAN ANDREAS FAULT, NORTHERN CALIFORNIA

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INTRODUCTION

Uplift along the San Andreas Fault has raised multiple marine terraces above sea level along a crescent-shaped area of the California coast between Point Arena and Point Delgada in northern California (Jennings, 1977). The northwest-striking San Andreas Fault extends offshore at Point Arena and continues northward offshore for approximately 100 km before returning to land near Point Delgada. (see Figure 1 in Merritts and Gardner, this volume). Smaller strands and splays of the main SAF cut and deform marine terraces along the coast to the east of the fault.

One effect of the subsidiary faults is the horizontal displacement of westward-flowing fluvial channels that are incised into the terraces and backfilled with sediment. Two of these large (~100 m by 10 m and 90m by 30m) channel deposits were discovered near the small town of Westport. We interpret the source of the sediment as Wages Creek. The southernmost deposit is located approximately 450 m north of the mouth of Wages Creek, and the northernmost approximately 750 m north of Wages Creek (Figure 1). Both deposits have been translated northward with respect to Wages Creek along a zone of right-lateral strike slip faults, and the northernmost fluvial deposit is almost juxtaposed with the mouth of DeHaven Creek.

The timing of the formation and backfilling of these channels can be used to correlate and date marine terraces in the area, an ultimate goal of the project. Determining the age and depositional environment of these two channel deposits was performed through extensive field surveying, sedimentological analysis, and aerial photo analysis.

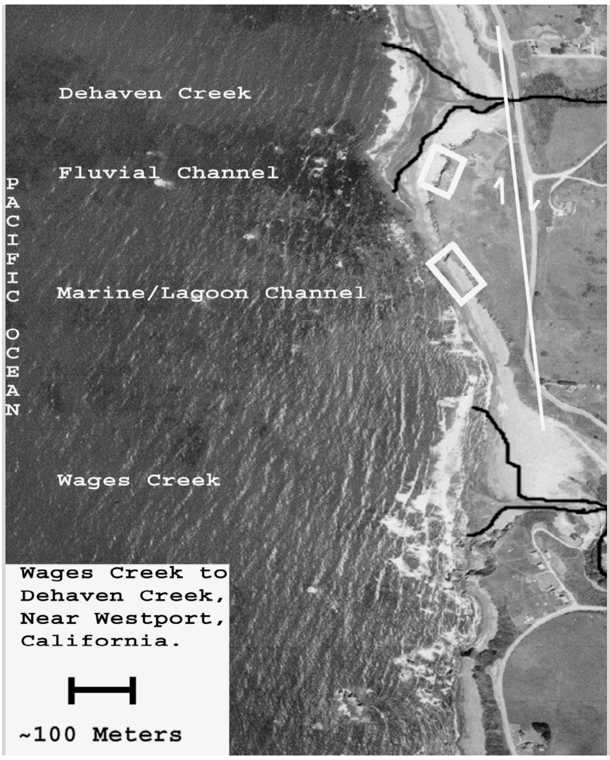


Figure 1. Aerial photograph of study site. Estimated fault location detailed by white line. Boxes display location of sedimentary deposits investigated in this study.

Methods

During the field season, we used a Sokkia Set 3 Total Geodetic Station to survey sedimentary beds, faults, and sample sites in the two large sections of sedimentary deposits. Suitable sample locations were identified, carefully sampled, and then marked. Finally, an examination of several strike-slip and thrust faults was carried out. The orientation and dip of these faults was determined using aerial photos and field mapping. Extensive digital photo analysis was performed to document both stratigraphic sections and to locate samples within each section.

After returning to the laboratory, the sediment samples were placed in a warm oven to dry, then sieved using methods prescribed in Folk (1974). Cumulative percent curves were prepared for grain size analysis and comparison. Sorting and skewness also were determined using guidelines outlined in Prothero and Schwab (1996). A binocular microscope was used to perform microanalysis of the samples, allowing for determination of the minerals present. Samples of small (<1 mm) white crystals, found growing in the pore spaces at the southern sedimentary deposit, were analyzed in an SEM for elemental composition.

Large photo mosaics were created using Adobe PhotoShop's image merge feature to merge the images that were photographed in the field. This allowed for little distortion and high resolution. Total Station data was then projected to a north-south axis, along which the sections are generally trending. This data was then placed as a digital overlay onto the mosaics using Adobe Illustrator.

RESULTS AND DISCUSSION

It was determined that the two sedimentological sections had two separate origins, the northernmost section being fluvial, and the southernmost being marine/lagoonal. These different origins are the result of changes in sea level that both constructed marine terraces and changed the mechanics of the channels due to their relative proximity to sea level and the near-shore beach environment.

The northernmost channel is fluvial in nature. This was determined in several different ways, but the largest indicator is the nature and orientation of sediment within the section. The sediment was generally moderately sorted, imbricated in a landward to seaward direction, and was largely made up of local Franciscan lithology in graded bedding sequences. When compared to sediment from the marine/lagoonal sequence, this fluvial sediment generally was finer-grained and better sorted (Figures 2 and 3).

Another indicator of a fluvial origin was the presence of large woody debris and stumps within approximately one meter of the bedrock valley wall exposed along the northern margin of the deposit. A stump in growth position was located along part of a point bar or the bank of a paleo-channel. This wood was returned to the laboratory and examined under a Scanning Electron Microscope. If this wood could be found to be Brewer Spruce, a species that thrives within narrow climatological ranges, an estimate of the age of the channel backfill could be determined by correlation with paleo-climatological data. These samples were sent to the Center for Wood Anatomy Research, run by the USDA, but although identification was narrowed to family (spruce) level, the species level could not be determined due to the decay of the samples.

The southernmost channel, closest to Wages Creek, is inferred to be younger than the northern channel, and of marine/lagoonal origin (Figure 3). Several findings, including the presence of abundant zircon, pyroxene, and gypsum in the sediments, of alternating oxidized and unoxidized zones within the deposit, and of a similarity to modern beach facies near the mouth of a river indicate a fluvio-marine origin. The sediment in this area can be classified in two ways. It was interpreted that this is due to seasonal patterns. In the winter, sediment, including large pebbles, was deposited in the lagoon as a result of severe storm action and high stream flows. In the summertime there were fewer severe storms and stream flow was low, thus the sediment that was deposited was of a finer nature.

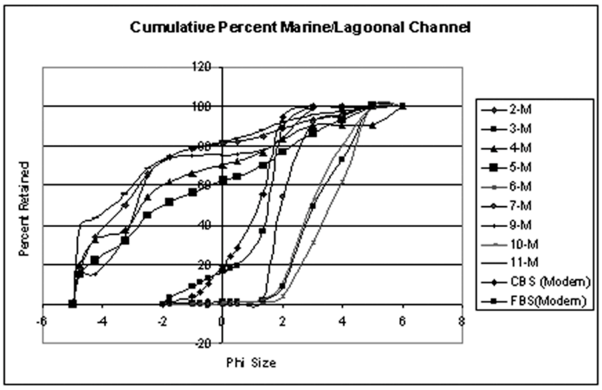
Volcanigenic lithologies that might contribute zircon and pyroxene are not abundant in the local Franciscan rocks. A possible source of fine-grained volcanigenic sediments exists to the north, in the Klamath mountain area (an accreted volcanic arc). It is interpreted that longshore drift, coming from north to south, brought with it the zircon and pyroxene, as well as other ferromagnesian minerals, and deposited them in the beach environment.

Gypsum is also present in the sediments just north of Wages Creek, as indicated by X-Ray Defractometer technology. This indicates that salt must have been present in large quantities during deposition, providing for a marine origin hypothesis (Murray, 1964).

In the present landscape, lagoonal environments are common at the mouths of streams along the beach, particularly because the coastal California climate is Mediterranean, and streams have high winter flows and very low summer flows. It is assumed that these lagoonal environments are the origin of the southernmost sedimentary section. Salt water and marine sediment would have been washed into these lagoons, providing a source for the gypsum and volcanigenic clasts. The oxidized and unoxidized beds would have been the result of winter storms and rain alternating with calmer, drier summer weather (Figure 2).

Comparison with samples from the southernmost section and the current beach environment led to very similar conclusions. Samples 6-M and samples of present day beach sands are very similar, both having sorting averages of 0.96.

We correlate the northernmost sedimentary section with the 80 ka sea-level highstand (oxygen isotope stage 5a) and the preceding sea-level lowstand (Darter, 2000). This sedimentary section includes a 90-m wide bedrock walled valley that is back-filled with fluvial sediment that, in turn, is overlain by near-shore marine deposits. The marine deposits overlie a wave cut platform that extends both to the north and south of the paleo-river valley. Our interpretation of this section is that the river valley was cut into bedrock during a time of low sea level, then back-filled with sediment as sea level rose and drowned the mouth of the river (Wages Creek). During the ensuing sea-level highstand, a wave-cut platform was carved along the coast, and it was mantled with a veneer of marine sediment during the subsequent regression. This low marine terrace has been correlated with the 80-ka sea-level highstand by Kennedy et al (1982), so we tentatively postulate that the paleo-river was cut ~80-90 kyr ago by Wages Creek. If correct, the rate of slip along the fault that has offset this deposit by 750 m from Wages Creek is 9 mm/yr. For comparison, the slip rate on the San Andreas Fault at Point Arena is ~25-30 mm/yr (Prentice, 1989).



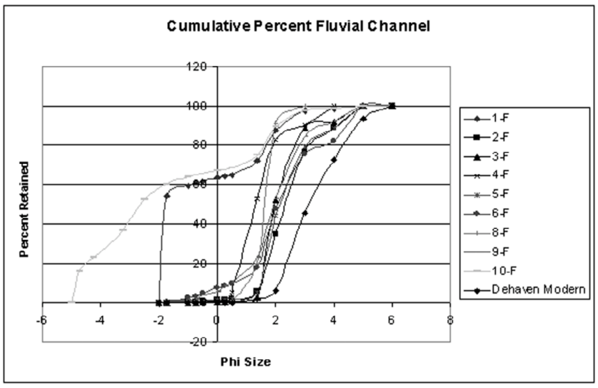


Figure 2. Cumulative percent curves of sediment samples taken from marine/lagoonal and fluvial sections.

It is our interpretation that the fluvial channel and lagoonal deposits 450 m north of the mouth of Wages Creek also originated during a time of low sea level. As sea level rose, transgressive facies were deposited across the continental shelf and the position of the seasonal lagoon at the mouth of Wages Creek shifted progressively landward, backfilling the stream channel mouth. Assuming that the uplifted beach/lagoonal sediment facies are from Wages Creek, and that the slip rate of the fault that has offset the deposit from its source is 9 mm/yr, the age of the deposit is about 50 kyr.

CONCLUSIONS

It is clear that there are two channels present in this very small section of the coastline. It is also clear that a fault has moved them from the place they were formed to the location that they currently occupy. We can assume that this process has been going on for significantly longer than 80kyr but that the record for this is destroyed by modern day DeHaven Creek, which erodes and discharges the sediment to the sea.

The northernmost section is of fluvial nature and was relocated ~ 750 meters to the north via a major strike-slip fault in the last 80 kyr. The southernmost section is of marine/lagoonal origin. A calculation of slip rate provides a value of 9mm per year.

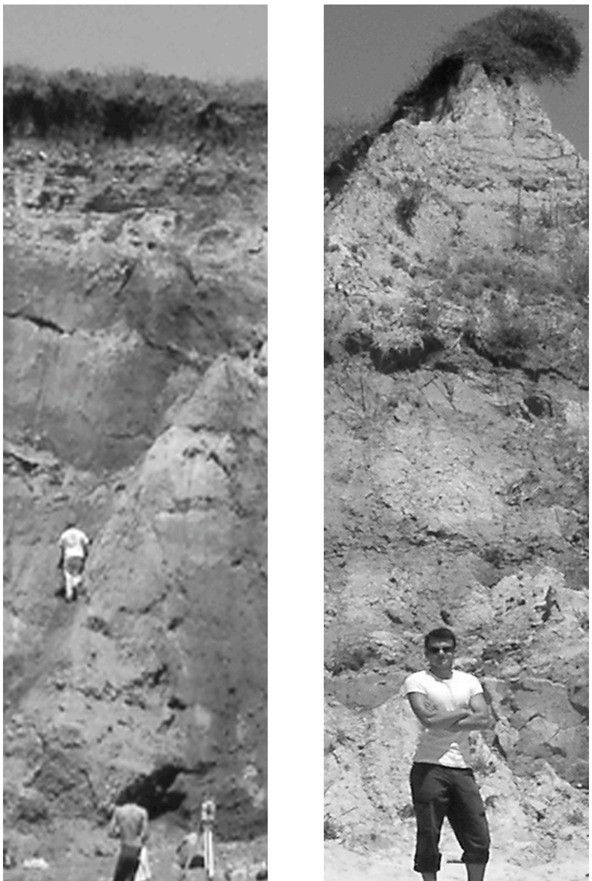


Figure 3. Photographs of sedimentary sequences. Note distinct bedding sequences in marine/lagoonal section on the right.

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