DR2015257

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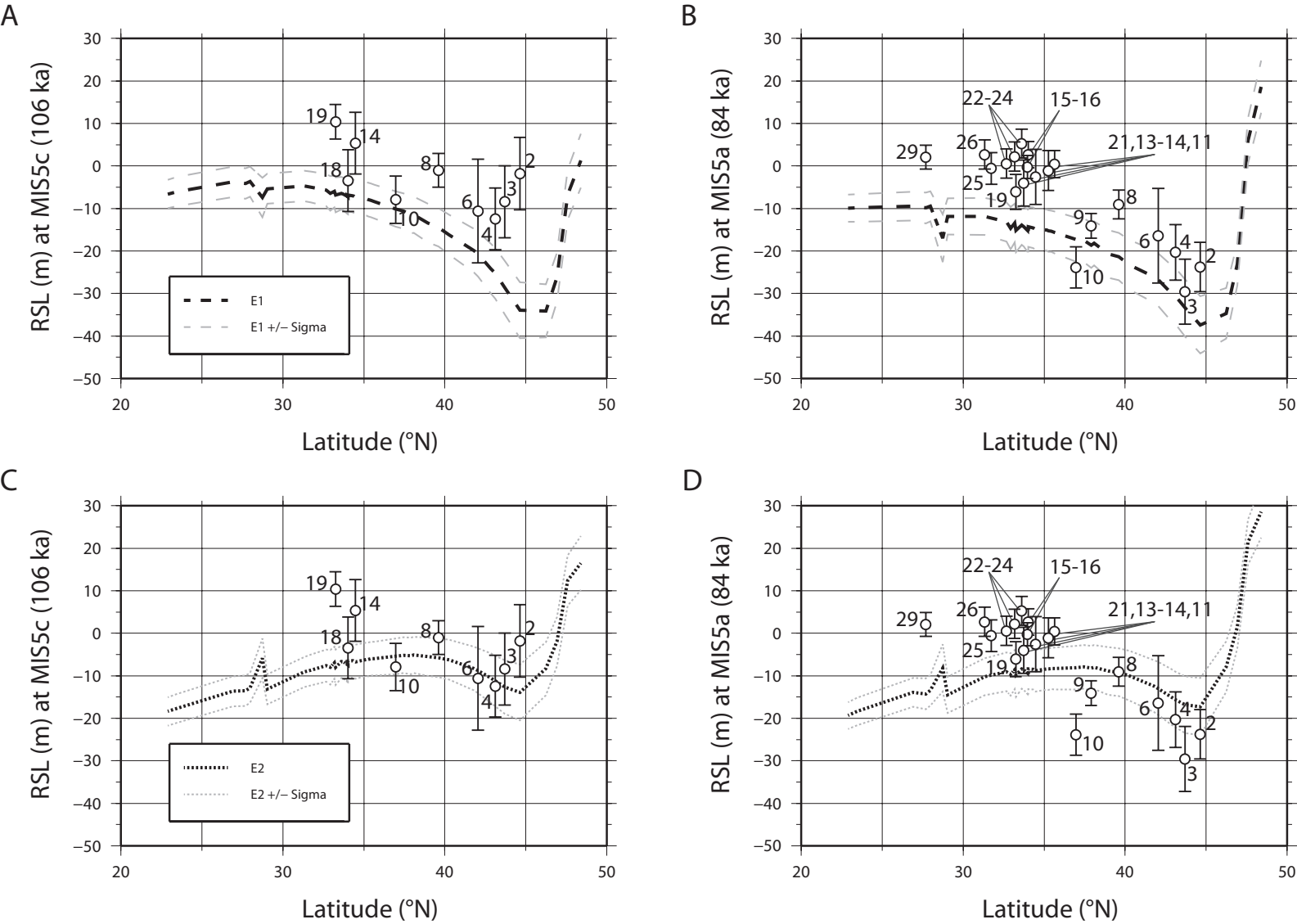
Table S1. Different scenarios of terrace ages and their resultant predicted MIS 5c and MIS 5a sea-level elevations at Santa Cruz, California.

Figure S1. Predictions of GIA adjusted sea levels for (A, C) MIS 5c and (B, D) MIS 5a using earth models *E*1 (A, B) and *E2* (C, D), compared with observed elevations of marine terrace shoreline angles corrected for tectonic uplift rates based on the elevation of equivalent MIS 5e terraces. See Figure 1 for locations.

Supplementary Text. Discussion of the ages and elevations of marine terraces across the Pacific Coast of North America presented in Table 1.


A
B
C
D
RSL (m) at MIS5c (106 ka)
RSL (m) at MIS5a (84 ka)
Latitude (°N)
E1
E1 +/– Sigma
E2
E2 +/– Sigma
22-24
15-16
21,13-14,11
30
20
10
0
−10
−20
−30
−40
−50
20
30
40
50

Supplementary Discussion on the Ages of Marine Terraces

Many studies have mapped and provided approximate age constraints on the terraces in Oregon via AAR and warm-water versus cool-water mollusk assemblages (Kennedy et al., 1982; Muhs et al., 1990), U-series dating of individual corals (Muhs et al., 1990), and soil development (Bockheim et al., 1992; Kelsey and Bockheim, 1994; Kelsey et al., 1996). Locations in which paired LIG and MIS5a or MIS5c terraces have been identified include Newport (OR) (Kennedy et al., 1982; Kelsey et al., 1996), Cape Arago (Adams, 1984; McInelly and Kelsey, 1990), Coquille Point (Muhs et al., 1990; McInelly and Kelsey, 1990), Cape Blanco (Adams, 1984; Muhs et al., 1990; and Kelsey, 1990), and Brookings, Oregon (Bockheim et al., 1992; Kelsey and Bockheim, 1994). Based on faunal assemblages and AAR ratios, Kennedy et al. (1982) assign a LIG age for the Yachats terrace at Newport. Kennedy et al. (1982) likewise assign the younger terraces, the Newport and Wakonda terraces to MIS5a and MIS5c, respectively and a study of soil development by Kelsey et al. (1996) supports these age assignments. Farther south along the Oregon Coast near Coquille Point and Cape Blanco MIS5a and MIS5c terraces were identified and successfully dated (Muhs et al., 1990; Klein et al., 1997). At Coquille Point, the MIS5a terrace locally referred to as the Wiskey Run terrace, was dated using oxygen isotope stratigraphy to 80-85 ka (Klein et al., 1997). Muhs et al. (1990) likewise arrived at an age of ~80 ka based on AAR ratios. These authors also obtained similar AAR age constraints on the equivalent marine terrace at Cape Blanco, locally known as the Cape Blanco Terrace, as well as the higher and older Pioneer Terrace that they assign to MIS5c. No absolute ages are available for the MIS5e terrace at Coquille Point or Cape Blanco. In addition, no absolute ages from any terrace are available for Cape Arago or Brookings, although the flights of terraces are easily correlated to Coquille Point and Cape Blanco where age assignments are available (Adams, 1984; McInelly and Kelsey, 1990; Muhs et al., 1990; Bockheim et al., 1992; Kelsey and Bockheim, 1994). Although included in our compilation, we did not include terraces from Cape Blanco in our analysis because of a large active synclinorium alligned parallel to the shoreline that complicates the

interpretations of relative elevation differences between the LIG, MIS5c, and MIS5a terraces (Kelsey, 1990).

The two sites in California north of San Francisco Bay include Bruhel Point and Point Reyes. The chronology of the terraces at Bruhel Point is based on a single AAR age (Merrits and Bull, 1989) but the relative ages are well constrained based on soil development of the area (Merrits et al., 1991) and the terrace sequences are readily correlated across the region. The MIS3 and MIS5a terraces of Point Reyes were dated using a combination of optically stimulated luminescence (OSL), thermoluminescence (TL), and optically-stimulated infrared luminescence (IRSL) (Grove et al., 2010). Most of the ages from the three techniques are in broad agreement with each other. No confirmation of the age of the reported LIG terrace at this site is available, although the flights of terraces are correlated widely throughout the general region (Grove et al., 2010).

The marine terraces at Santa Cruz in north-central California have a long history of study (Bradley, 1956). Studies by Bradley and Griggs (1976) focused on the genesis and form of the marine terraces with the first attempt at radiocarbon dating of the lowest terrace yielding an infinite age (<37,000; Broecker et al., 1956; Bradley, 1956). Subsequently Bradley and Addicott (1968) obtained ages of 68-100 ka based on U-Th dating of mollusks from the first emergent marine terrace. Perg et al. (2001) used the cosmogenic inventory method of the isotopes ^{10}Be and ^{26}Al to obtain ages of the first four emergent terraces including the first terrace dated in the earlier studies. They obtained ages of 65 ka, 91 ka, 137 ka, and 138 ka and interpreted these terraces to represent MIS3, MIS5a, MIS5c, and LIG terraces, respectively. The numerical ages and MIS attributions are younger than the traditional age and MIS assignments for the terraces.

Along the central California coast south of Santa Cruz, terraces with age constraints are found at San Simeon Point, Point Buchon, and Gaviota. The ages of the marine terraces at San Simeon Point

were determined by Hanson et al. (1992) and Berger and Hanson (1992). Hanson et al. (1992) mapped the five lowest terraces in the San Simeon Area. A MIS3 terrace with a U-Series age of 46+/-2 ka is only found in an area adjacent to an active fault where rates of tectonic uplift exceed 2 mm/yr (Hanson et al., 1992). The next two lowest marine terraces found throughout the San Simeon Point area were interpreted to represent MIS5a (San Simeon Terrace) and LIG (Tripod Terrace) terraces. An infinite radiocarbon age and an OSL age of 95+/-13 ka were obtained from the San Simeon Terrace (Hanson et al., 1992; Berger and Hanson, 1992). No absolute ages are available for the Tripod terrace but its location in the landscape is consistent with a LIG terrace. The ages of marine terraces at Point Buchon are based on U-series dating of coral specimens (Hansen et al., 1992). These ages are also corroborated by AAR ratios from mollusks on neighboring terraces that have been well mapped throughout the central California coast (Hansen et al., 1992) where other well-dated terraces (e.g. Cayucos; Muhs et al., 2002) have been identified. At Cayucos, a prominent marine terrace has been dated with twenty-one U-series dates on corals by Muhs et al. (2002). The ages vary from 110.1 to 136.1 ka and agree well with a MIS5e interpretation although Muhs et al. (2002) suggest that they are also consistent with a MIS5c interpretation. Due to only having one terrace, Cayucos was not included in our analysis. The ages of the terraces west of Gaviota are based on a combination of U-series dating of bones, molluscan assemblages, and AAR dating (Rockwell et al., 1992). The lowest terrace was found to be older than ~68 ka based on a U-series date on bone material in an overlying unit as well as one U-series age of 87 ka from the deposit itself. In addition, the molluscan faunal assemblage is that of cooler water – indicative of a glacial period (Rockwell et al., 1992). Preliminary AAR dating also suggests the age of the lowest terrace is MIS5a (Rockwell et al., 1992).

In the greater Los Angeles area, terraces are preserved in Malibu, the Palo Verdes Hills and the San Joaquin Hills. Three prominent marine terrace levels were mapped in the Malibu region by Birkeland (1972). U-series dating of corals from the lowest of the terraces, the Dume terrace, by Szabo

and Rosholt (1969) gives an average age of 104+/-5 ka and is interpreted to represent a MIS5c terrace. The next higher terrace, the Corral terrace, was also dated using U-series by Szabo and Rosholt (1969) and resulted in an average age of 131+/-15 ka and is interpreted as a MIS5e terrace. The highest terrace, the Malibu terrace, has not been dated. Six terraces were mapped in the Palo Verdes Hills by Woodring et al. (1946) the lower two of which, based on correlation with nearby U-series dated terraces and AAR ratios (Muhs et al., 1992b), represent MIS5a and MIS5c marine terraces. The San Joaquin hills terraces south of Los Angeles, California have been dated using U-series of solitary corals (Grant et al., 1999). Six ages were obtained from the second emergent terrace of which only three had initial $\delta^{234}U$ values that indicated little diagenetic alteration, yielding ages ranging from 120.4 to 124.1 ka and consistent with a LIG age (Grant et al., 1999). One age of 106 ka was obtained from a coral on the lowest terrace although Grant et al. (1999) - based largely on the earlier work of Barrie et al. (1991) - interpreted this to be reworked and suggested a MIS5a age for it.

Ages from marine terraces on the northern Channel Islands have been obtained from Santa Cruz Island (Pinter et al., 1998), San Miguel Island (Muhs et al., 2014), and Santa Rosa Island (Muhs et al., 2014). Pinter et al. (1998) obtained three U-series dates from the lowest terrace on Santa Cruz Island. These ages ranged from 123.4-137.5 ka and are interpreted to represent MIS5e. Two prominent lower terraces are found on Santa Rosa and San Miguel Islands. Muhs et al. (2014) obtained one U-series age of a coral from the higher of these two terraces on Santa Rosa Island with a result of 125.5+/-0.8 ka. Muhs et al. (2014) also obtained five U-series coral ages on the second terrace on San Miguel Island with ages ranging from 113.1-121.7 ka. Amino acid ratios of the lower terraces on both San Miguel and Santa Rosa Island are consistent with a MIS5a age and amino acid ratios of the second terrace on Santa Rosa Island are consistent with a MIS5e age (Muhs et al., 2014). Thus Muhs et al. (2014) interpret the lowest terrace on both Santa Rosa and San Miguel Islands as a MIS5a feature and the second terrace on both islands as a MIS5e feature.

San Nicolas Island, along with its neighbor San Clemente Island (Muhs et al., 2002), have arguably the best dated series of marine terraces along the Pacific Coast. Only San Nicholas Island was included in our analysis because San Clemente Island included ages for the LIG terrace only. At San Nicholas Island, Muhs et al. (2012) obtained six U-series ages from Terrace 1 that ranged in age from 78.6 to 82.7 ka. They interpreted Terrace 1 to represent a MIS5a marine terrace. Terraces 2a and 2b formed within just a few meters of each other and returned ages ranging from 116.1-165.3 ka and 95.7 and 152.5 ka, respectively, with a majority clustered around 120 ka. Eight U-series ages of solitary corals were obtained from Terrace 2a and fifty-one U-series ages were obtained from Terrace 2b and were attributed to the LIG and MIS5c, respectively (Muhs et al., 2012). At San Clemente Island, Muhs et al. (2002) obtained twenty-nine U-series ages from corals on the Eel point terrace. The ages range from 114.5 to 153.7 ka, although most closed-system ages range between 114 and 128 ka (Muhs et al., 2002). They interpret this terrace to have formed during the LIG. A lower undated terrace is found on San Clemente Island.

The marine terraces along the southern-most California mainland coast are nearly continuous for 70 km between Oceanside and Point Loma except where dissected by local canyons (Fig. 1). The two lowest terraces are the Bird Rock and Nestor Terraces, respectively, dated using U-series of solitary corals (Muhs et al., 2002) as well as AAR (Kern and Rockwell, 1992). Muhs et al. (2002) obtained U-series ages of the Bird Rock terrace at Point Loma of 87.7, 96.6, and 127.3 ka. Kern and Rockwell (1992) published nine AAR ratios on three different genera of mollusks and they an age of 80 ka for this terrace. Both authors interpreted this terrace to have formed during MIS5a. The Nestor terrace was dated with thirteen U-series ages on isolated corals by Muhs et al. (2002) and nine AAR ratios from five mollusk genera with ages varying from 98.5 to 149.5 ka (Kern and Rockwell, 1992). Both authors attributed a LIG age to the Nestor terrace although Muhs et al. (2002) suggested that it may be a composite MIS5c/LIG marine terrace.

In northern Mexico along the Baja California coastline, two prominent low elevation terraces are found at Punta Banda, the Lighthouse and Sea Cave terraces. Both sets of marine terraces were dated using U-series by Rockwell et al. (1989) and Muhs et al. (2002). The ages based on solitary corals on the Lighthouse terrace range from 78-89 ka and are attributed to MIS5a. Ages from the Sea Cave terrace range from 114.3 to 160 ka and are attributed to MIS5e. Farther south, two terraces were identified at Punta Cabras by Addicott and Emerson (1959). They surveyed the region and collected fauna from the marine terraces and preliminarily correlated the lowest terrace with the Nestor terrace of Point Loma. However, Mueller et al. (2009) assigned the lowest Punta Cabras terrace to MIS5a and the next higher terrace to the LIG. Two marine terraces were also identified by Emerson et al. (1981) at Turtle Bay. They noted that each of these terraces had a different faunal assemblage, with the higher terrace having a more warm-water assemblage and the lower terrace having a more cool-water assemblage. In addition, thirteen AAR ratios obtained from mollusk shells were generally consistent with a MIS5a and LIG interpretation for the younger and older marine terraces, respectively (Mueller et al., 2009).

Additional References:

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Bockheim, J. G., Kelsey, H. M., and Marshall, J. G., 1992, Soil development, relative dating and correlation of late Quaternary marine terraces in southwestern Oregon: Quaternary Research, v. 37, p. 60-74.

Broecker, W. S., Kulp, J. L., and Tucek, C. S., 1956, Lamont natural radiocarbon measurements III: Science, v. 124, p. 154-165.

Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., 1946, Geology and paleontology of Palos Verdes Hills, California: USGS Professional Paper, v. 207, p. 145.

Table S1. Santa Cruz Terrace Predictions

Scenario	MIS5e Terrace	MIS5c Terrace	MIS5a Terrace	MIS3 Terrace	Uplift Rate (m/yr)	Predicted MIS5c Sea Level (m)	Predicted MIS5a Sea Level (m)
Terrace Age Scenarios							
Using Elevation Observations of (*)							
S1	Blackrock	Wilder	Western	Santa Cruz	0.0013	-6.6	-23.9
S2	Wilder	Western	Santa Cruz	--	0.0010	-18.1	-53.1
S3	Western	Santa Cruz	--	--	0.0006	-34.4	
S4	Western	--	Santa Cruz	--	0.0006		-21.3
Using Elevation Observations of (†)							
S5	Quarry	Blackrock	Wilder	Western	0.0018	-20.6	-23.5
S6	Santa Cruz	Davenport	--	--	0.0001	2.9	
S7	Santa Cruz	--	Davenport	--	0.0001		5.9

Terrace Elevation Observations

Terrace	Elevation*	Terrace	Elevation†	GIA Prediction§	
Santa Cruz	31	Davenport	18	MIS5c	MIS5a
Western	87	Santa Cruz	30	3 m	-4 m
Wilder	132	Western	85	(+/- 6 m)	(+/-5 m)
Blackrock	170	Wilder	125		
		Blackrock	165		
		Quarry	225		

*Peng et al. (2001) †Bradley and Griggs (1976) §See Figure 6