

KECK GEOLOGY CONSORTIUM

21ST KECK RESEARCH SYMPOSIUM IN GEOLOGY SHORT CONTRIBUTIONS

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Franklin & Marshall College

Keck Geology Consortium
Franklin & Marshall College
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2007-2008 PROJECTS:

Tectonic and Climatic Forcing of the Swiss Alps

John Garver (Union College), Mark Brandon (Yale University), Alison Anders (University of Illinois),
Jeff Rahl (Washington and Lee University), Devin McPhillips (Yale University)
Students: William Barnhart, Kat Compton, Rosalba Queirolo, Lindsay Rathnow,
Scott Reynhout, Libby Ritz, Jessica Stanley, Michael Werner, Elizabeth Wong

Geologic Controls on Viticulture in the Walla Walla Valley, Washington

Kevin Pogue (Whitman College) and Chris Oze (Bryn Mawr College)
Students: Ruth Indrick, Karl Lang, Season Martin, Anna Mazzariello, John Nowinski, Anna Weber

The Árnes central volcano, Northwestern Iceland

Brennan Jordan (University of South Dakota), Bob Wiebe (Franklin & Marshall College), Paul Olin (Washington State U.)
Students: Michael Bernstein, Elizabeth Drewes, Kamilla Fella, Daniel Hadley, Caitlyn Perlman, Lynne Stewart

Origin of big garnets in amphibolites during high-grade metamorphism, Adirondacks, NY

Kurt Hollocher (Union College)
Students: Denny Alden, Erica Emerson, Kathryn Stack

Carbonate Depositional Systems of St. Croix, US Virgin Islands

Dennis Hubbard and Karla Parsons-Hubbard (Oberlin College), Karl Wirth (Macalester College)
Students: Monica Arienzo, Ashley Burkett, Alexander Burpee, Sarah Chamlee, Timmons Erickson
Andrew Estep, Dana Fisco, Matthew Klinman, Caitlin Tems, Selina Tirtajana

Sedimentary Environments and Paleoecology of Proterozoic and Cambrian "Avalonian" Strata in the United States

Mark McMenamin (Mount Holyoke College) and Jack Beuthin (U of Pittsburgh, Johnstown)
Students: Evan Anderson, Anna Lavarreda, Ken O'Donnell, Walter Persons, Jessica Williams

Development and Analysis of Millennial-Scale Tree Ring Records from Glacier Bay National Park and Preserve, Alaska (Glacier Bay)

Greg Wiles (The College of Wooster)
Students: Erica Erlanger, Alex Trutko, Adam Plourde

The Biogeochemistry and Environmental History of Bioluminescent Bays, Vieques, Puerto Rico

Tim Ku (Wesleyan University) Suzanne O'Connell (Wesleyan University), Anna Martini (Amherst College)
Students: Erin Algeo, Jennifer Bourdeau, Justin Clark, Margaret Selzer, Ulyanna Sorokopoud, Sarah Tracy

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INTRODUCTION

Coral reefs are often referred to as the “Rainforests” of the marine environment. Like their terrestrial counterparts, reefs harbor incredible diversity. They also maintain a delicate balance by fiercely recycling limited resources within the boundaries of the ecosystem. This allows efficient transfer of material throughout the system at a low cost, but it also leaves the system susceptible to perturbation as a result of even small stresses. In seeming contradiction, reefs have remained surprisingly stable until recently, despite significant degradation of the reef fishery, starting as early as 1900, and ever increasing exploitation since WWII. The recent decline in coral reefs worldwide is likewise paradoxical inasmuch as it seems disproportionate to the increases in known stresses over the past two decades. This argues for a non-linearity in the relationship between stress and the response of the reef system.

Reefs have endured for three billion years. The earliest examples built largely without skeletonization. As an increasingly oxygenated atmosphere encouraged the evolution of higher metazoans, an “arms race” began between organisms building reefs and others trying to chew them out of existence. An increase in the types and efficiency of grazers and borers saw the advent of strategies like photo-symbiosis that could support rapid calcification. A uniformitarian approach gets progressively simpler as we move closer to the present, and all the main players on modern reefs have been with us for at least a few million years.

As we increasingly face the problems with environmental decline, reefs become not only a record of the distant past, but perhaps a window to help

us understand what might happen in the future as human population pressure increases. In the words of Wendell Berry, “We cannot know what we are doing until we know what nature would be doing if we were doing nothing”. Fossil reefs, and particularly those from the very recent past, say only 15,000 years, provide unique opportunities to understand the scope of natural change when “we were doing nothing”, or at least precious little to alter our planet. The Keck-St. Croix project was designed to address these questions on several spatial and temporal scales. In each case, the intent was to compare a present-day depositional system to one that existed in the past. The time scale of the comparison varied from tens of years to thousands of years, and the projects looked both back in time and into the future.

GEOLOGIC SETTING

St. Croix (Fig. 1) is the largest of the US Virgin Islands. Unlike St. Thomas and St. John to the north, St. Croix is underpinned by Cretaceous volcanoclastic sedimentary rocks that were deposited in the Pacific before the formation of the present-day Caribbean. St. Croix sits on the Caribbean Plate, against the fault system that separates it from the largely igneous islands on the North American Plate. The rocks on St. Croix and Buck Island are identical and probably represent a continuous section nearly 20,000 ft thick (Whetten, 1966; Hubbard, 1989).

Tague Bay Reef (Fig. 1c) sits ca 0.65 km north of St. Croix and extends from the eastern end of the island. It formed ca. 7,000 years ago as sea-level rise was slowing. Burke et al. (1989) proposed that it started as a series of patch reefs that coalesced over

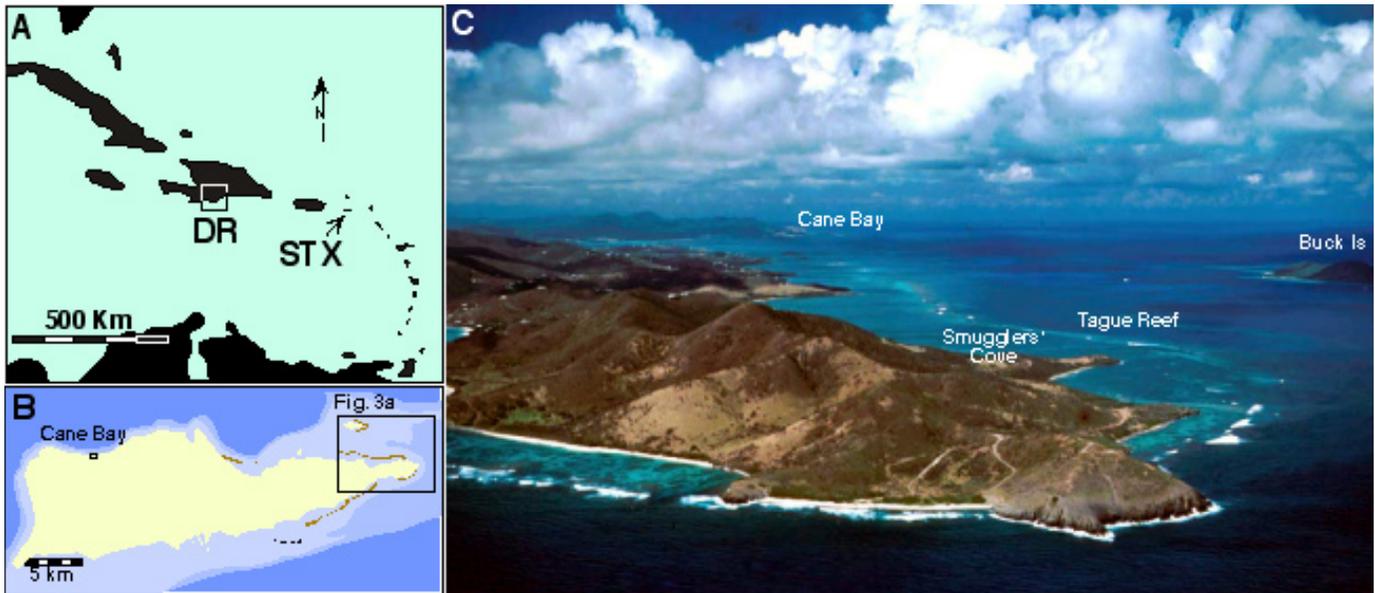


Figure 1. A) Map of the Caribbean showing the locations of St. Croix (STX) and the Dominican Republic fossil-reef site (DR). B) Map of St. Croix showing the locations of the field projects. The box shows the location of Figure 3a. C) View looking to the northwest across St. Croix. The core study was conducted in Smugglers' Cove. Reef and fish surveys were conducted on the Tague Bay and Buck Island forereefs. Cane Bay is around the point of land in the far background.

time. The reef that protects eastern Buck Island has a similar depositional history and reflects a reef catching up with rising sea level (Hubbard et al., 2005; Arienzo, this volume).

STUDENT PROJECTS

Student research projects generally fell into three groups: Three students collected quantitative data on reef-community structure (corals, grazing organisms, and their predators) along the Tague Bay forereef and the southern Buck Island reef front (Fig. 2a,b). Five students compared the present and past depositional system in Smugglers' Cove lagoon using both surface samples from each major sedimentary environment, as well as thirteen cores that generally spanned the entire Holocene lagoon sequence down to the underlying Pleistocene surface (Fig. 2 c,d). Two students sampled dead corals at Cane Bay and Tague Reef to characterize post-mortem alterations in the corals (bioerosion) along depth gradients, and compared the general bioeroder community on these modern reefs to those from a fossil Holocene reef in the Dominican Republic (Fig. 2 d,e).

BENTHIC-MARINE SURVEYS

Buck Island has been largely protected by the federal government since 1961, when John F. Kennedy created the first Underwater National Monument in the US. Fishing and other extractive activities (except for research) have been banned for the past four decades. In contrast, fishing has been allowed all around St. Croix. In addition to higher fishing pressure, Tague Reef is closer to St. Croix and other sources of anthropogenic pressure (e.g., runoff from land clearing for coastal development). The close proximity of the two areas under different levels of protection provides an opportunity to assess the effectiveness of marine protected areas in a time of increasing anthropogenic stress. Monica Arienzo and Dana Fisco found similarly degraded reefs at both sites, based on three 20-m reef transects at each of 9 sites on the two reefs (Fig 3a; they surveyed transects at 3, 6 and 9m at each site). While macroalgae are denser on Tague reef, owing to higher nutrient input from land, both reefs suffer from low coral abundance and poor post-storm recovery after Hurricane Hugo. Arienzo further concludes that cores through the two reefs reflect a community structure that is a better match to reefs three decades

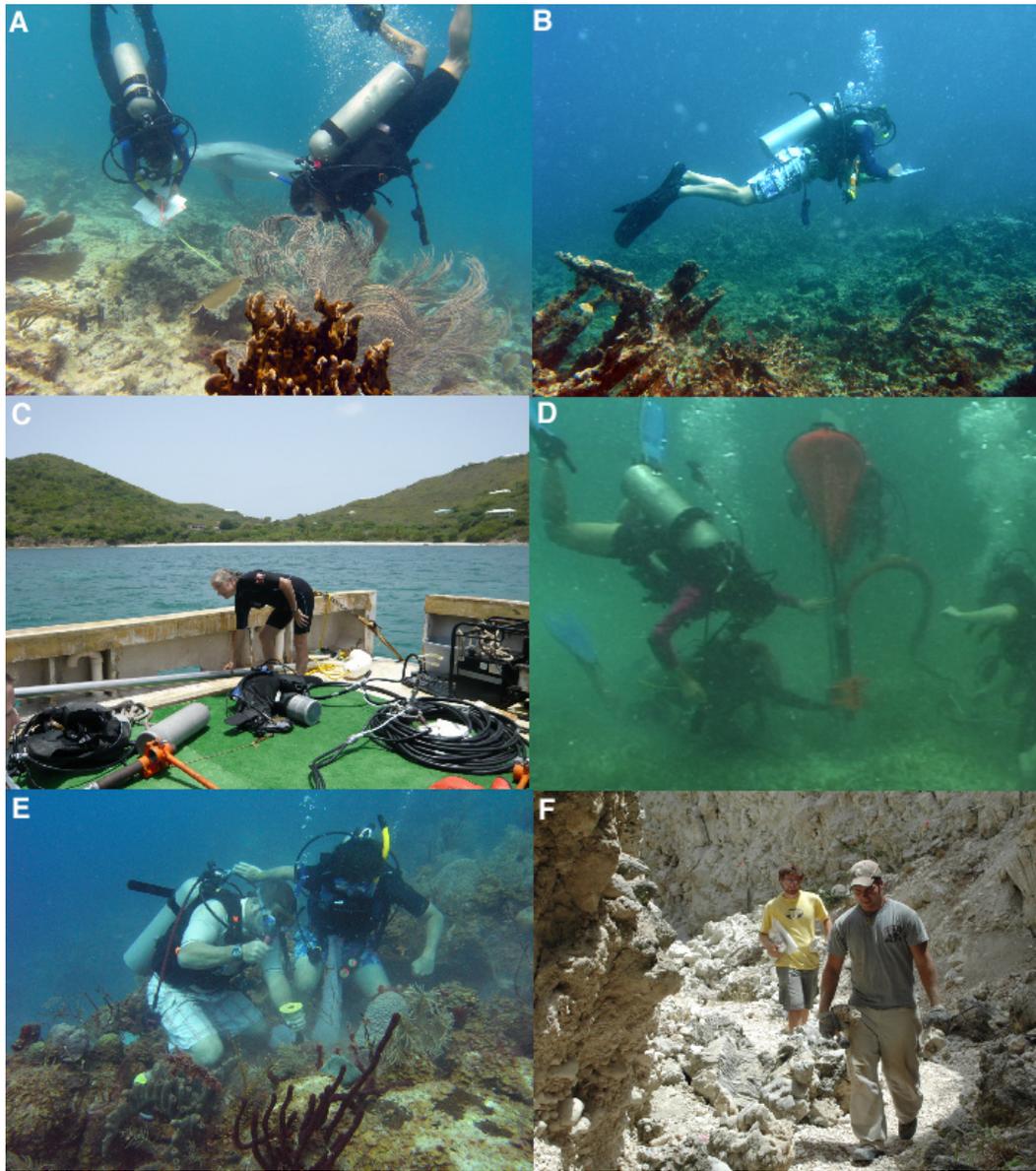


Figure 2. St. Croix student projects. A) Monica Arienzo and Dana Fisco survey the reef transect under the supervision of a local dolphin (A), while Alex Burpee characterizes general benthic cover and fish (B). The vibro-coring operation topside (C) and on the bottom (D). Timmons Erickson and Andy Estep sample dead corals from a modern reef at Cane Bay (E) and a fossil counterpart in the western Dominican Republic (F).

ago than those studied in 2007. A parallel study by Alex Burpee at the same sites shows a clear difference in both the predator and grazer populations on the two reefs. While grazing fish are significantly higher in the protected area, the population of grazing urchins is more robust on the unprotected reef. These findings have important implications to both present-day management issues and to understanding the relationship between carbonate production by corals and substrate destruction by grazers on both historic (century) and geologic scales (Holo-

cene and beyond).

HOLOCENE LAGOON EVOLUTION

Tague Bay sits along the NE corner of St. Croix (Fig. 1). The lagoon is protected by a barrier reef that sits ca. 0.7 km seaward of the beach. Based on the depth of the underlying Pleistocene surface, the lagoon would have flooded approximately 7,000 years ago. The major lagoon environments have included:

- 1) areas covered with seagrass (mostly *Thalassia*

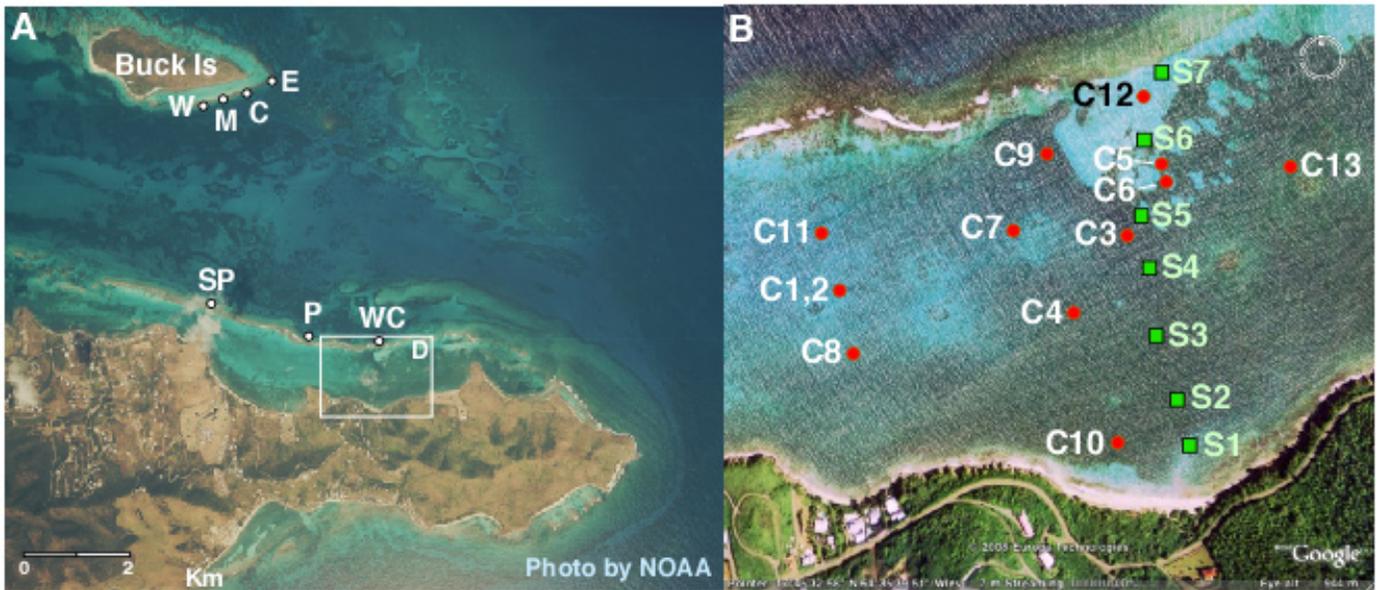


Figure 3. Vertical aerial photographs of eastern St. Croix (A) and Smugglers' Cove (B). The seven benthic- and fish survey sites on Tague Reef (SP, Pm WC) and Buck Island Reef (W, M, C, E) are shown in (A). Core locations (e.g., C8; red dots) and surface sediment samples (e.g., S3; green squares) in Smugglers' Cove are shown in (B). Photos from NOAA and Google.

testudinum and *Syringodium filiforme*), 2) areas dominated by bioturbation (the burrowing shrimp *Callinassa*), 3) unvegetated sand just behind the reef, and previously interpreted as “blow-outs” in the grassbeds, and 4) patch reefs. Where present, shrimp actively overturn the bottom to depths of up to two meters. In contrast, grassy areas are largely devoid of deep burrowers and are more stratigraphically stable. Five projects focused on the sedimentology and community structure of the lagoon over

the past 7,000 years and their relationship to reef development. They shared samples from thirteen vibrocores from Smugglers' Cove that generally fell along two transects (Fig. 3b), 4. Most of the cores penetrated through the entire Holocene sequence and bottomed out at the underlying Pleistocene surface. Matt Klinman and Sarah Chamlee characterized the surface environments based on bottom observations, granulometric analyses and point counting of sedimentary constituents. They then

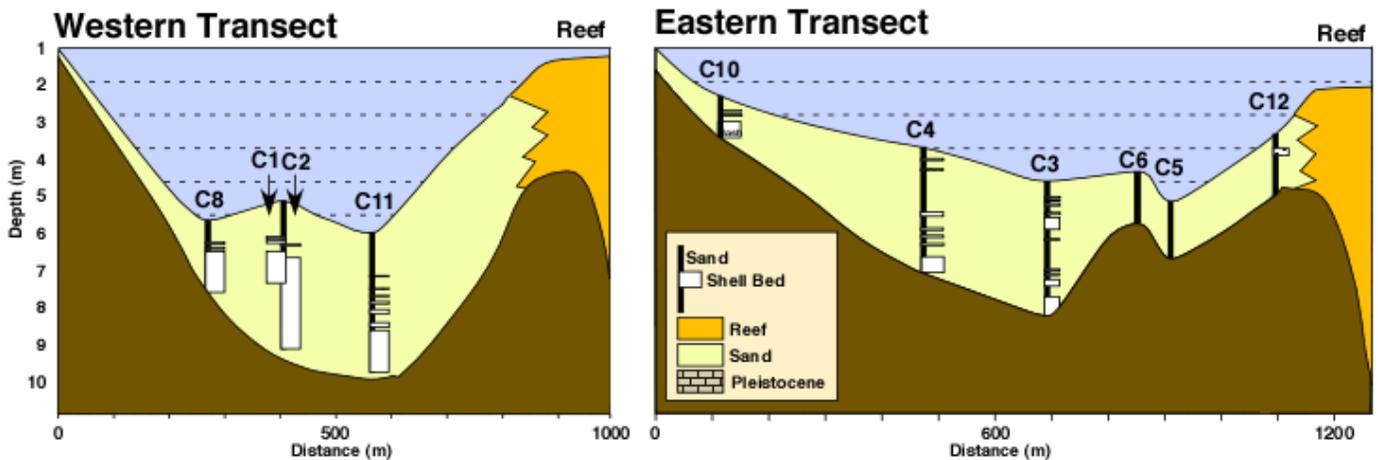


Figure 4. Generalized logs from the eastern and western cores in Smugglers' Cove (Fig. 3b). The inferred depth to the underlying Pleistocene is based on the depth of refusal for each core. The contact with Tague Reef is Based on Burke et al. (1989). In general, cores consist of an upper sandy interval (vertical black bar) with shell layers and basal shell lags (white boxes) beneath.

compared these to stratigraphic patterns based on samples taken every 20 cm in thirteen vibrocores. They carefully documented changes in sediment character, and their papers discuss whether these reflect either decreasing wave energy over time as Tague Reef developed, or increased trapping of fine-grained sediment associated with development of the grassbed community. Klinman also examined the viability of instrumental methods for determining the relative contribution of carbonate versus siliciclastic sediments into the system. Caitlin Tems and Ashley Burkett examined molluscan taxonomy and taphonomy (preservation) within the cores, while Selina Tirtajana examined vertical changes in the diatom community over the past ca. 1000 years using three cores from the major sedimentary environments. Collectively, the studies identified different sedimentological and biological regimes on the present-day surface relative to what existed early in the lagoon history. Their papers examine the alternatives of recent anthropogenic change, natural evolution of the lagoon, and changing rates of shell bio-accumulation as the lagoon developed.

CORAL BIOEROSION

As soon as a coral dies, its surface is invaded by filamentous algae, which attract grazing fish. At the same time, a variety of other organisms start to bore into the dead substrate to create protected galleries from which to feed. Collectively, these processes are referred to as bioerosion and reduce solid substrate to sediment at surprisingly high rates. While these processes have been recognized since the 17th century, depth-related patterns and the factors that control the abundance and types of bioeroders remain largely undocumented. Andrew Estep and Timmons Erickson collected dead coral samples along two depth gradients on the Tague Bay forereef and at Cane Bay to the west (Fig. 2 e,f). They compared their bioerosion data from these samples to data from corals they collected from Holocene fossil reefs in the western Dominican Republic using quantitative measurements from digital scans of their samples. Their work demonstrates a statistically significant difference in the bioeroder communities at the two sites, and a quantifiable depth-re-

lated pattern of bioerosion along depth gradients on both modern reefs and their Holocene counterparts. Their papers discuss possible causes of these differences and the significance of their findings to existing models of Quaternary coral-reef building.

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